NOTICE OF PROPOSED RULEMAKING TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT:

METAL HALIDE LAMP FIXTURES

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses supporting the information in the notice of proposed rulemaking (NOPR) for metal halide lamp fixtures (MHLF or "fixtures").

1.2 OVERVIEW OF THE APPLIANCES AND COMMERCIAL EQUIPMENT STANDARDS PROGRAM

Part B of title III of the Energy Policy and Conservation Act (EPCA) of 1975 (42 U.S.C. 6291–6309) established the Energy Conservation Program for Consumer Products Other than Automobiles, covering major household appliances. Additional amendments to EPCA have given the U.S. Department of Energy (DOE) the authority to regulate the energy efficiency of several products, including metal halide lamp fixtures, the equipment that is the focus of this document.

DOE designs any new or amended standard to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) To determine whether economic justification exists, DOE must review comments on the proposal and determine that the benefits of the proposed standard exceed its burdens to the greatest extent practicable, weighing the following seven factors:

(1) the economic impact of the standard on the manufacturers and consumers of the products subject to the standard;

(2) the savings in operating costs throughout the estimated average life of the products compared to any increases in the price, initial charges, or maintenance expenses for the products that are likely to result from the imposition of the standard;

(3) the total projected amount of energy savings likely to result directly from imposition of the standard;

(4) any lessening of the utility or the performance of the products likely to result from imposition of the standard;

(5) the impact of any lessening of competition, as determined in writing by the Attorney General, likely to result from imposition of the standard;

(6) the need for national energy conservation; and

(7) other factors the Secretary [of Energy] considers relevant.

(42 U.S.C. 6295(o)(2)(B)(i))

1.3 OVERVIEW OF METAL HALIDE LAMP FIXTURES STANDARDS

The following summarizes the pertinent legislative and regulatory history for metal halide lamp fixtures. DOE is conducting its first rulemaking cycle to review and consider amendments to the energy conservation standards in effect for metal halide lamp fixtures, as required under 42 U.S.C. 6295(hh)(2), which provides as follows:

> (2) Final rule by January 1, 2012. —
> (A) In general. —
> Not later than January 1, 2012, the Secretary shall publish a final rule to determine whether the standards established under paragraph (1) should be amended.
> (B) Administration. —
> The final rule shall—
> (i) contain any amended standard; and
> (ii) apply to products manufactured on or after January 1, 2015.

On December 19, 2007, the President signed the Energy Independence and Security Act of 2007 (EISA 2007), which made numerous amendments to EPCA and directed DOE to undertake several new rulemakings for appliance energy conservation standards. (Pub. L. 110-140) The MHLF provisions, section 324 of EISA 2007, amended EPCA by:

- inserting definitions pertaining to "metal halide ballast,"[a] "metal halide lamp,"[b] and "metal halide lamp fixtures"[c] (among others) into section 321 of EPCA (42 U.S.C. 6291(62),(63), and (64));
- amending section 323(b) of EPCA to direct DOE to develop a test procedure for metal halide (MH) ballasts based on the American National Standard Institute (ANSI) Standard C82.6-2005, *Ballasts for High-Intensity Discharge (HID) Lamps-Methods of Measurement* (42 U.S.C. 6293(b)(18));
- amending section 324(a)(2) of EPCA by directing the Federal Trade Commission (FTC) to conduct a labeling rulemaking for metal halide lamp fixtures (42 U.S.C. 6294(a)(2)(C)); and
- amending section 325 of EPCA by prescribing energy conservation standards for metal halide lamp fixtures, requiring that they contain ballasts that meet or exceed defined efficiency levels. Compliance with the EISA 2007-prescribed standards was required as of January 1, 2009. (42 U.S.C. 6295(hh)(1)) Additionally, the Secretary is directed to publish a final rule no later than January 1, 2012 to determine whether the energy conservation standards established by EISA 2007 for metal halide lamp fixtures should be amended. If such amendments to the standards are appropriate under the relevant statutory criteria, the final rule shall apply to products manufactured on or after January 1, 2015. (42 U.S.C. 6295(hh)(2)(B)) The Secretary is further directed to conduct a second

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[a] "Metal halide ballast" means "a ballast used to start and operate metal halide lamps." (42 U.S.C. 6291(62))

[b] "Metal halide lamp" means "a high intensity discharge lamp in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors." (42 U.S.C. 6291(63))

[c] "Metal halide lamp fixture" means "a light fixture for general lighting application designed to be operated with a metal halide lamp and a ballast for a metal halide lamp." (42 U.S.C. 6291(64))

rulemaking to review and amend the energy conservation standards for metal halide lamp fixtures then in effect, which requires publication of a final rule by January 1, 2019. (42 U.S.C. 6295(hh)(3))

The following statutory provisions are directly relevant to the energy conservation standards rulemaking for metal halide lamp fixtures. As amended by EISA 2007, EPCA regulates metal halide lamp fixtures designed to be operated with lamps rated greater than or equal to 150 watts (W), but less than or equal to 500 W, by prescribing performance requirements for the metal halide ballasts used in those metal halide lamp fixtures. Both metal halide lamps and ballasts are energy-using components of metal halide lamp fixtures. For this MH lamp wattage range, metal halide lamp fixtures must contain the following:

(i) a pulse-start metal halide ballast with a minimum ballast efficiency of 88 percent;
(ii) a magnetic probe-start ballast with a minimum ballast efficiency of 94 percent; or
(iii) a nonpulse-start electronic ballast with—
    (I) a minimum ballast efficiency of 92 percent for wattages greater than 250 watts; and
    (II) a minimum ballast efficiency of 90 percent for wattages less than or equal to 250 watts.

(U.S.C. 6295 (hh)(1)(A))

In addition to prescribing minimum efficiency requirements for the previously described metal halide ballasts contained in metal halide lamp fixtures, EISA 2007 amended EPCA to exclude the following types of metal halide lamp fixtures from the statutorily prescribed energy conservation standards:

(i) fixtures with regulated lag ballasts;
(ii) fixtures that use electronic ballasts that operate at 480 volts; or
(iii) fixtures that—
    (I) are rated only for 150 watt lamps;
    (II) are rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and
    (III) contain a ballast that is rated to operate at ambient air temperatures above 50 degrees Celsius, as specified by Underwriters Laboratories (UL)1029–2001 (“Standard for High-Intensity-Discharge Lamp Ballasts”).

(42 U.S.C. 6295 (hh)(1)(B))

This rulemaking also addresses 42 U.S.C. 6295(o), in which DOE is directed to incorporate standby mode and off mode energy use in any amended (or new) standard adopted after July 1, 2010. DOE continues to conclude that it cannot establish a separate standard that incorporates standby mode or off mode energy consumption.

The following statutory provisions (and associated rulemakings) are related to metal halide lamp fixtures but are separate from the current standards rulemaking:

- In conjunction with energy conservation standards for metal halide lamp fixtures, EPCA required DOE to undertake a determination to see if energy conservation standards for HID lamps (including MH lamps) would be technologically feasible and economically justified, and would result in significant energy savings. (42 U.S.C. 6317(a)(1)) DOE completed the HID lamps determination and published a final determination on July 1, 2010, concluding that energy conservation standards for certain HID lamps are technologically feasible and economically justified. 75 FR 67975. A notice of document availability announcing completion of a Framework document for HID lamps was published on February 28, 2012. 77 FR 18963. DOE then published an interim analysis for HID lamps on February 28, 2013. 78 FR 13566.
- DOE completed a test procedure rulemaking for metal halide ballasts, as required by EPCA through amendments from EISA 2007. (42 U.S.C. 6293(b)(18)) The final rule test procedure for metal halide ballasts was published in the *Federal Register* on March 10, 2010. 75 FR 10950.
- The FTC is directed to conduct a labeling rulemaking as part of the requirements set forth by EISA 2007 for metal halide lamp fixtures. (42 U.S.C. 6294(a)(2)(C)) To this end, the FTC published a final rule in the *Federal Register* on July 9, 2008, amending 16 CFR part 305, "Rule Concerning Disclosures Regarding Energy Consumption and Water Use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act ('Appliance Labeling Rule')." 73 FR 39221. On October 23, 2008, the FTC published in the *Federal Register* additional amendments to 16 CFR part 305 for metal halide lamp fixtures in the form of technical corrections. 73 FR 63066. Both final rules fulfilled the FTC's obligations under EISA 2007 pertaining to labeling requirements for metal halide lamp fixtures and metal halide ballasts.

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

DOE considers the participation of interested parties a very important part of the standards-setting process. DOE encourages the participation of all interested parties during the comment period of each rulemaking stage. Beginning with the rulemaking Framework document for metal halide lamp fixtures (hereafter "Framework document") and during subsequent comment periods, interactions among interested parties provide a balanced discussion of the information that is required for the standards rulemaking.

In conducting the energy conservation standard rulemaking, DOE involves interested parties through formal public notifications (*i.e.*, *Federal Register* notices). For this metal halide lamp fixture energy conservation standards rulemaking, DOE will employ the procedures set forth in DOE's Process Rule ("Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products," 61 FR 36974 (July 15, 1996), 10 CFR part 430, subpart C, appendix A) to the extent they are appropriate for developing energy conservation standards for the metal halide lamp fixtures covered under this rulemaking.

Before DOE determines whether to establish or amend energy conservation standards for metal halide lamp fixtures, it must first solicit comments on a proposed standard. (42 U.S.C.

6295(o)(2)(B)(i)) DOE must design each new or amended standard for these products to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in significant energy savings. (42 U.S.C. 6295(o)(2)(A) and (3)) To determine whether a proposed standard complies with these requirements, DOE must, after receiving comments on the proposed standard, determine whether the benefits of the standard exceed its burdens to the greatest extent practicable, weighing the seven factors described in section 1.2.

Subsequent to the publication of the Framework document, the standards rulemaking process involves preliminary analyses followed by two additional formal, major public notices, which are published in the *Federal Register*. The preliminary analyses are designed to publicly vet the models and tools used in the rulemaking and to facilitate public participation before the proposed rule stage. After the preliminary analyses are vetted, DOE issues the first major notice, the NOPR, which discusses the comments received in response to the preliminary analyses of the effects of standards on consumers, manufacturers, and the nation; DOE's weighing of the effects; and the proposed standards. The second notice is the final rule, which discusses the comments received in response to the NOPR; the revised analysis of the effects of standards; DOE's weighing of the effects; the standards adopted by DOE; and the effective dates of the standards.

Table 1.4.1 Analyses under the Process Rule

Preliminary Analysis	NOPR	Final Rule*
Market and technology assessment	Revised preliminary analyses	Revised analyses
Screening analysis	Life-cycle cost subgroup analysis	
Engineering analysis	Manufacturer impact analysis	
Energy use characterization	Utility impact analysis	
Product price determination	Employment impact analysis	
Life-cycle cost and payback period analysis	Environmental assessment	
Shipments analysis	Monetization of emissions reductions	
National impact analysis	Regulatory impact analysis	
Preliminary manufacturer impact analysis		

* During the final rule phase, DOE considers the comments submitted by the U.S. Department of Justice concerning the impact of any lessening of competition that is likely to result from the imposition of the standard. (42 U.S.C. 6295(o)(2)(B)(v))

In December 2009, DOE published a rulemaking Framework document for metal halide lamp fixtures that describes the procedural and analytical approaches DOE anticipated using to evaluate the establishment of energy conservation standards for metal halide lamp fixtures. A PDF copy of the Framework document is available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

DOE held a public meeting on January 26, 2010 (hereafter "Framework public meeting") to discuss procedural and analytical approaches to the rulemaking, and to inform and facilitate the involvement of interested parties in the rulemaking process. The analytical framework presented at the Framework public meeting described rulemaking analyses, such as the engineering analysis and the life-cycle cost (LCC) and payback period (PBP) analysis, the methods proposed for conducting them, and the relationships among the various analyses. See Table 1.4.1 for all the analyses discussed at the Framework public meeting to be undertaken in each of the formal public rulemaking documents. PDF copies of the slides and other material associated with the Framework public meeting are available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

During the Framework public meeting and the Framework document comment period, interested parties, including manufacturers, trade associations, environmental advocates, and others, submitted several comments about the MHLF rulemaking. The major issues discussed were: (1) the rulemaking's scope of coverage; (2) the development of equipment classes; (3) test procedures; (4) a system approach and ballast efficiency metric; (5) the methodology for the engineering analyses; (6) LCC analysis; (7) efficiency levels; and (8) energy savings. Interested party comments submitted during the Framework document comment period elaborated on the issues raised at the Framework public meeting. A detailed discussion of comments from interested parties is available in chapter 2 of the preliminary TSD, available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

As part of the information gathering and sharing process, DOE organized and held preliminary interviews with metal halide ballast manufacturers and MHLF manufacturers who operate in the U.S. MHLF market. DOE had five objectives for these interviews: (1) solicit feedback on the scope of coverage for the rulemaking; (2) solicit feedback on the engineering analysis (including methodology, prices, and ballast technologies); (3) solicit feedback on topics related to the preliminary manufacturer impact analysis; (4) provide an opportunity early in the rulemaking process to express specific concerns to DOE; and (5) foster cooperation between manufacturers and DOE. During the manufacturer interviews, DOE discussed these and other issues regarding market data, distribution channels, anticipated consumer responses to standards, production and product mix, conversion costs, and cumulative regulatory burden.

DOE published a notice announcing the availability of the preliminary analysis on April 1, 2011 (76 FR 18127), and held a public meeting on April 18, 2011. At this meeting, DOE presented the methodologies and results of the analyses set forth in the preliminary TSD. Interested parties discussed the following major issues at the public meeting: (1) expected changes to ANSI C82.6; (2) the planned amendment to the test procedure that would require multiple input voltage ballasts be tested at each input voltage; (3) the issue of standby mode and ballast designs that incorporate it; (4) the rationale for DOE's proposed scope; (5) the possible utilization of a system approach; (6) available technology options; (7) dimming; (8) considered equipment classes; (9) the screening analysis and the anticipated incremental costs and efficiency improvements from implementing these approved options; (10) the selection of representative wattages and fixtures for each equipment class; (11) the candidate standard levels considered; (12) the considered manufacturer production costs; (13) the use of normalized input power in DOE's analysis; (14) the approach taken to determine historical shipment data; (15) the trial standard levels considered; and (16) the identification of key issues and evaluation of the potential effect of standards on manufacturers. Written comments received since publication of the April 2011 notice, including those received at the April 2011 public meeting, have contributed to DOE's proposed resolution of the issues in this rulemaking. A detailed discussion of comments from interested parties is available in the NOPR *Federal Register* notice for this rulemaking.

Following the publication of the preliminary analysis and the preliminary analysis public meeting, DOE held additional meetings with manufacturers as part of the consultative process for the manufacturer impact analysis conducted during the NOPR phase. The interviews covered several key issues, including: (1) suitability of replacing magnetic ballasts with electronic ballasts in all applications; (2) high capital and conversion costs associated with fixture redesign; (3) appropriateness of investing in shrinking market; (4) diversion of resources from solid state lighting and controls; (5) electronic ballast field testing; and (6) compatibility between high-frequency ballasts and high efficacy lamps.

For the LCC, PBP, and national impact analyses (NIA), DOE developed spreadsheets using Microsoft Excel. The LCC and PBP spreadsheets calculate the economic impacts of replacing products with standards-compliant ones. The NIA spreadsheets calculate the national energy savings and national net present values at various energy efficiency levels and include a model that forecasts the effects of energy conservation standards at various levels on product shipments. These spreadsheets are available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

1.5 STRUCTURE OF THE DOCUMENT

This NOPR TSD outlines the analytical approaches used in this rulemaking. The TSD consists of 18 chapters and 9 appendices.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to the rulemaking for metal halide lamp fixtures, and outlines the structure of the document
Chapter 2	Analytical Framework: describes the rulemaking process, provides an overview of each analysis, and discusses comments received during the NOPR public meeting comment period
Chapter 3	Market and Technology Assessment: characterizes the MHLF market and the technologies available for increasing ballast efficiency and outlines equipment classes
Chapter 4	Screening Analysis: determines which technology design options are viable for consideration in the engineering analysis
Chapter 5	Engineering Analysis: describes DOE’s approach to the engineering analysis and discusses how manufacturer costs and selling prices relate to ballast efficiency
Chapter 6	Markups Analysis: discusses the methods DOE used for establishing markups from manufacturer selling price to installed customer prices
Chapter 7	Energy Use Analysis: discusses the sources and methods for developing energy use estimates for metal halide lamp fixtures

Chapter 8	Life-Cycle Cost and Payback Period Analysis: discusses the economic effects of standards and compares the LCC and PBP of metal halide lamp fixtures with and without higher energy conservation standards
Chapter 9	Trial Standard Levels: discusses the efficiency levels for each analyzed equipment class as they pertain to the trial standard levels chosen for metal halide lamp fixtures
Chapter 10	Shipments Analysis: discusses the methods used for forecasting shipments with and without higher energy conservation standards
Chapter 11	National Impact Analysis: describes the national forecast of energy consumption, efficiency of new metal halide lamp fixtures, and annual fixture sales in the absence or presence of new standards
Chapter 12	Life-Cycle Cost Subgroup Analysis: discusses the methods to be used to study the effects of standards on a subgroup of fixture consumers and compares the LCC and PBP of product with and without higher efficiency standards for these consumers
Chapter 13	Manufacturer Impact Analysis: discusses the methods to be used to study the effects of standards on the finances and profitability of metal halide lamp fixtures, and presents preliminary manufacturer impact analysis results
Chapter 14	Employment Impact Analysis: discusses the methods to be used to analyze the indirect effects of standards on national employment
Chapter 15	Utility Impact Analysis: discusses the methods to be used to study the effects of standards on electric utilities
Chapter 16	Emissions Analysis: discusses the effects of standards on emissions of carbon dioxide, nitrogen oxides, and mercury
Chapter 17	Monetization of Emission Reduction Benefits: discusses the basis for the estimated monetary values used for the reduced emissions of carbon dioxide and other pollutants that are expected to result from each of the trial standard levels considered
Chapter 18	Regulatory Impact Analysis: discusses the methods to be used to determine the impact of non-regulatory alternatives to energy conservation standards
Appendix 8A	User Instructions for Life-Cycle Cost and Payback Period Spreadsheet
Appendix 8B	Estimation of Potential Equipment Price Trends
Appendix 11A	User Instructions for Shipments and NIA Spreadsheet

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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Sections 6295(o)(2)(A) and (3) of Title 42 United States Code (42 U.S.C. 6295(o)(2)(A) and (3)) require that energy conservation standards set by the U.S. Department of Energy (DOE) be technologically feasible and economically justified, and achieve the maximum improvement in energy efficiency. This chapter describes the general analytical framework that DOE uses in developing such standards, and in particular, standards for metal halide lamp fixtures (MHLF or "fixtures"). The analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost (LCC); economic impact on manufacturers and users; national benefits; impacts, if any, on utility companies; and impacts, if any, from lessening competition among manufacturers. DOE will also solicit the views of the Department of Justice (DOJ) on any lessening of competition that is likely to result from the imposition of a proposed standard.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The central parts of this figure are the analyses contained in the boxes. The key inputs to the left and key outputs to the right show how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from interested parties or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Dotted lines connecting analyses show types of information that feed from one analysis to another. While Figure 2.1.1 summarizes the inputs, outputs, and analyses of a typical standards rulemaking, individual inputs and outputs may vary by rulemaking.

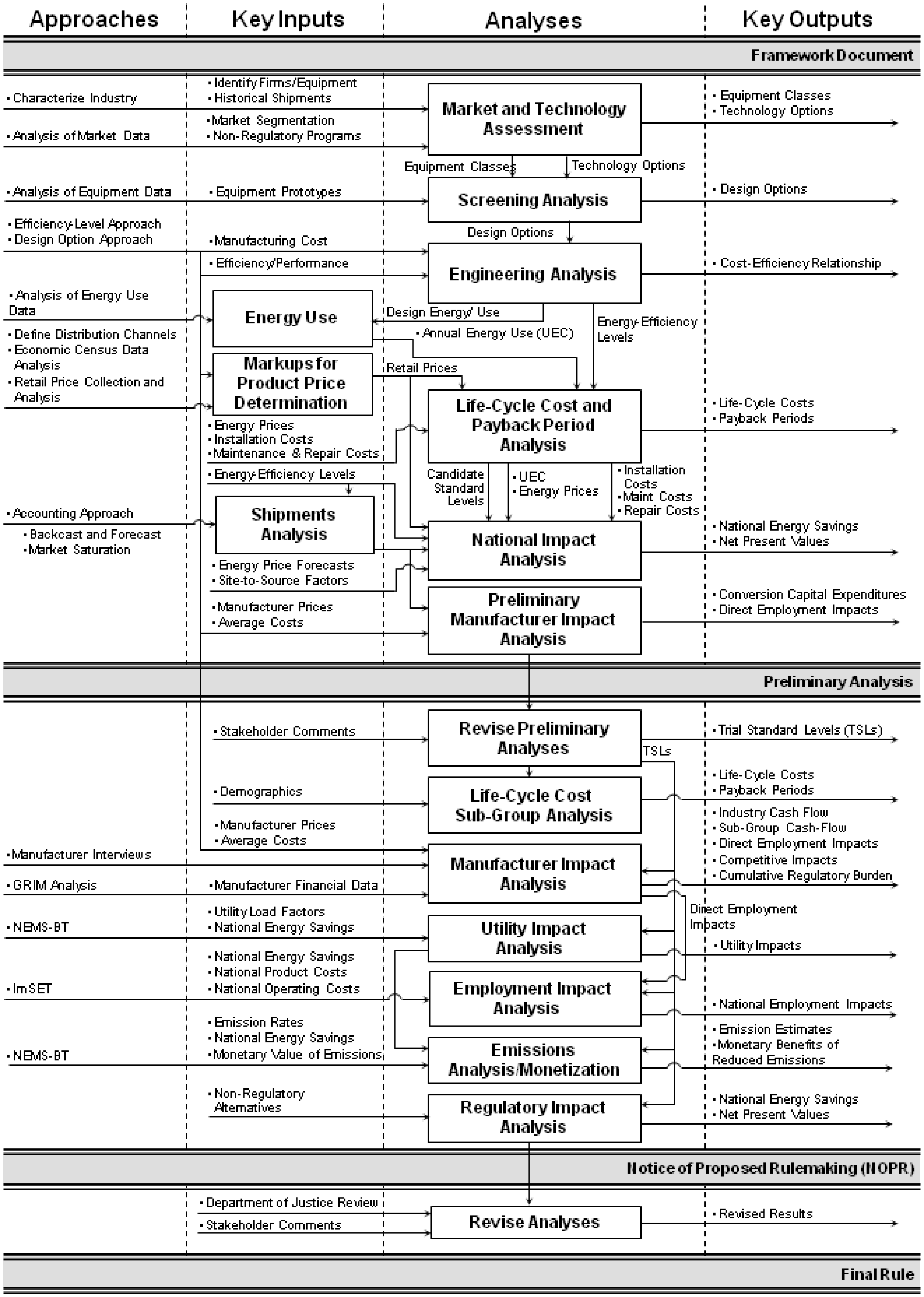

Figure 2.1.1 Flow Diagram of Analyses for the Metal Halide Lamp Fixture Rulemaking Process

The analyses performed in the notice of proposed rulemaking (NOPR) stage and reported in this technical support document (TSD) include:

- A market and technology assessment to characterize the MHLF market, identify technology options that improve efficiency, and develop equipment classes.
- A screening analysis to review each technology option and determine if it is technologically feasible; practical to manufacture, install, and service; would adversely affect fixture utility or fixture availability; or would have adverse impacts on health and safety.
- An engineering analysis to determine manufacturer selling prices (MSPs) associated with more efficient metal halide lamp fixtures by estimating the manufacturer production cost (MPC) and applying a manufacturer markup.
- A markups analysis that converts average MSPs to customer equipment prices.
- An energy use analysis to determine the annual energy consumption of metal halide lamp fixtures.
- An LCC analysis that calculates, at the customer level, the discounted savings in operating costs throughout the estimated average life of the fixture components, compared to any increase in the installed costs likely to result directly from imposition of the standard.
- A payback period (PBP) analysis to estimate the amount of time it takes customers to recover the (typically) higher purchase expense of fixtures with more energy efficient ballasts through lower operating costs.
- A shipments analysis to estimate yearly shipments of covered metal halide lamp fixtures over the analysis period.
- A national impact analysis (NIA) that assesses the aggregate impacts at the national level of potential energy conservation standards as measured by the net present value (NPV) of total customer economic impacts and national energy savings (NES).
- An LCC subgroup analysis that evaluates the economic impacts on identifiable groups of customers of metal halide lamp fixtures, including various categories of purchasers or owners who may experience disproportionate impacts from a national energy conservation standard.
- A manufacturer impact analysis (MIA) to calculate the financial impacts of energy conservation standards on manufacturers and to identify impacts on competition, employment at manufacturing plants, and manufacturing capacity.

- An employment impact analysis that estimates the indirect impacts of standards on net jobs eliminated or created in the general economy as a consequence of increased spending on the installed price of metal halide lamp fixtures and reduced customer spending on energy.

- A utility impact analysis that estimates the effects of proposed standards on the installed capacity and the generating base of electric utilities. An emissions analysis to provide estimates of the effects of amended energy conservation standards on emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg).

- A monetization of reduction of emission benefits from proposed standards.

- A regulatory impact analysis (RIA) that presents major alternatives to proposed standards that may achieve comparable energy savings at a reasonable cost.

In response to comments it receives on the NOPR, DOE may revise some of its analyses before publishing the final rule.

2.2 BACKGROUND

As described in chapter 1 of this NOPR TSD, in September 1995, DOE announced a formal effort to consider further improvements to the process used to develop appliance efficiency standards. DOE called on energy efficiency groups, manufacturers, trade associations, state agencies, utilities, and other interested parties to provide input to this effort. As a result of this combined effort, the DOE published "Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products" (the "Process Rule"), 10 CFR part 430, subpart C, appendix A. The Process Rule outlined the procedural improvements identified by the interested parties and included a review of the: (1) economic models; (2) analytic tools; (3) methodologies; (4) non-regulatory approaches; and (5) prioritization of future rules. The Process Rule recommended that DOE take into account uncertainty and variability by carrying out scenario or probability analysis.

DOE developed the analytical framework for the MHLF rulemaking under the Process Rule. DOE documented this analytical framework in the "Energy Conservation Standards Rulemaking Framework Document for Metal Halide Lamp Fixtures" (hereafter, "Framework document"), and presented the analytical approach to stakeholders during a public meeting held on January 26, 2010 (hereafter "Framework public meeting"). This document is available at www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/49. The following sections provide a general description of the different analytical components of the rulemaking framework.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant equipment markets and existing technology options, including prototype designs, and outlines equipment classes.

2.3.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the industry structure and market characteristics of the equipment concerned. This activity consists of both quantitative and qualitative efforts to assess the industry based on publicly available information. As such, DOE addresses: (1) industry structure and manufacturer market shares; (2) existing regulatory and non-regulatory efficiency improvement initiatives; and (3) trends in equipment characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE has used and will use the most reliable and accurate data available at the time of each analysis in this rulemaking. DOE welcomes and will consider any submissions of additional data.

2.3.2 Technology Assessment

DOE typically uses information relating to existing technology options to develop more efficient metal halide lamp ballast designs. DOE prepared a list of technologies for consideration that could improve the efficiency of this equipment. To develop this list, DOE reviewed manufacturer catalogs, recent trade publications, and technical journals, and consulted with technical experts.

2.3.3 Equipment Classes

DOE divides covered equipment into classes by: (a) the type of energy used; and (b) capacity of the product or any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) In general, DOE defined equipment classes using information obtained from manufacturers, trade association, and other interested parties.

For more detail on the market and technology assessment, see chapter 3 of the NOPR TSD.

2.4 SCREENING ANALYSIS

The screening analysis examines the technology options from the technology assessment as to whether they: (1) are technologically feasible; (2) are practical to manufacture, install, and service; (3) do not have an adverse impact on equipment utility or availability; and (4) do not have adverse impacts on health and safety. As described in section 2.3.2, DOE develops an initial list of technology options from the technologies identified in the technology assessment. Then, in consultation with interested parties, DOE reviews the list to determine if these technologies meet the screening criteria. In the engineering analysis, DOE only considers design options that meet all four of the screening criteria.

For more detail on the screening analysis, see chapter 4 of the NOPR TSD.

2.5 ENGINEERING ANALYSIS

DOE performed an engineering analysis to establish the relationship between the MPC and the energy efficiency of metal halide lamp ballasts. The relationship between the MPC and energy efficiency serves as the basis of the cost-benefit calculations for individual customers, manufacturers, and the Nation.

In the engineering analysis, DOE selects representative equipment classes to analyze. It then selects representative wattages within those representative equipment classes, and develops fixture designs that represent more efficient versions of the baseline fixtures. DOE then uses these fixture designs to develop efficiency levels and calculates price for each of these levels. The primary output of the engineering analysis is a set of cost-efficiency curves. In a subsequent LCC analysis (chapter 8 of the NOPR TSD), DOE used the cost-efficiency curves to determine customer prices for equipment by applying the appropriate distribution channel markups. The engineering analysis also develops system power ratings in which DOE uses to develop energy use in chapter 7 of the NOPR TSD.

2.5.1 Representative Equipment Classes

DOE reviewed covered metal halide lamp fixtures and the associated equipment classes. DOE identified and selected certain equipment classes as “representative” equipment classes and concentrated its analytical effort on these classes. DOE chose these representative equipment classes primarily because of their high market volumes.

2.5.2 Baseline Fixtures

DOE selected representative fixture types within each representative equipment class. For each representative equipment class, DOE selected a baseline model as a reference point against which to measure changes resulting from energy conservation standards. Typically, a baseline fixture is a unit that just meets current federal energy conservation standards and provides basic customer utility. To determine energy savings and changes in price, DOE compared each higher energy efficiency level with the baseline unit. DOE considered the ballast’s characteristics in choosing the most appropriate baseline ballast for each fixture type. These characteristics include the ballast’s starting method, input voltage, and electronic configuration (electronic vs. magnetic). For some of the representative equipment classes, DOE selected multiple baseline fixtures to ensure consideration of different high-volume fixtures and their associated customer economics.

2.5.3 More Efficient Ballast Designs

DOE selected more efficient ballasts for each of the baseline models considered for each representative equipment class. DOE only considered technologies that met all four criteria in the screening analysis. DOE considered these technologies either explicitly as design options or implicitly as design options incorporated into commercially available fixtures at the efficiency levels evaluated. In identifying the more efficient substitutes, DOE surveyed and tested many of the manufacturers’ equipment offerings for ballast efficiency to identify the efficiency levels corresponding to the highest number of models.

2.5.4 Efficiency Levels

Having identified the more efficient substitutes for each of the baseline fixtures, DOE developed efficiency levels based on the consideration of several factors including: (1) the design options associated with the specific ballasts being studied; (2) the maximum technologically feasible level.

For more detail on the engineering analysis, see chapter 5 of the NOPR TSD.

2.6 MARKUPS ANALYSIS

In this rulemaking, DOE performed teardown analyses and a manufacturer markup analysis to develop MSPs for representative equipment classes (chapter 5 of the NOPR TSD). DOE then applied distribution channel markups and sales tax to derive end-user prices (chapter 6 of the NOPR TSD). By combining the engineering analysis results and the distribution channel markups analysis, DOE derived typical inputs for use in the LCC analysis and the NIA.

For more detail on the markups analysis, see chapter 6 of the NOPR TSD.

2.7 ENERGY USE ANALYSIS

The energy use analysis provides estimates of annual energy use for representative metal halide lamp fixtures that DOE evaluates in the LCC and PBP analysis and the NIA. To develop annual energy use estimates, DOE multiplied annual usage (in hours per year) by the system input power (in watts). To derive annual energy usage, DOE used data published in the 2010 U.S. Lighting Market Characterization.[1]

For more detail on the energy use analysis, see chapter 7 of the NOPR TSD.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

Energy conservation standards on equipment usually reduce operating expenses and increase initial end-user prices. DOE analyzed the net effect of amended standards on end users by evaluating the net LCC using the cost-efficiency relationship derived in the engineering analysis, as well as the energy usage and costs derived from the energy use analysis. Inputs to the LCC calculation include the installed cost to the end user (purchase price plus installation cost); operating expenses (energy expenses and maintenance costs); the lifetime of the fixture, ballast, and lamp; and a discount rate. Chapter 8 of the NOPR TSD describes these inputs.

DOE estimated electricity prices for commercial and industrial customers by using Energy Information Administration (EIA) data. EIA's *Annual Energy Outlook* (*AEO2012*) was the default source of projections for future electricity prices.

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[1] U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. *Final Report: 2010 U.S. Lighting Market Characterization.* 2012. Washington, D.C. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf.

For more detail on the LCC and PBP analysis, see chapter 8 of the NOPR TSD.

2.9 TRIAL STANDARD LEVELS

Trial standard levels (TSLs) examine combinations of efficiency levels across the different equipment classes for maximum technological feasibility, maximum energy savings, maximum net present value (NPV), and other metrics.

For more detail on the TSLs, see chapter 9 of the NOPR TSD.

2.10 SHIPMENTS ANALYSIS

Shipments of metal halide lamp fixtures are key inputs to the NES and NPV calculations in the NIA model. Shipments are also a necessary input to the MIA. DOE followed a three-step process to project MHLF shipments. First, DOE used historical shipment data from the U.S. Census Bureau to estimate the total historical shipments of each fixture type analyzed. Second, DOE calculated an installed stock for each fixture type based on the average service lifetime of each fixture type. Third, by modeling fixture purchasing events, such as replacement and new construction, and applying growth rate, replacement rate, and emerging technologies penetration rate assumptions, DOE developed annual shipment projections.

2.10.1 Shipment Scenarios

To calculate shipments, DOE created several base-case and standards-case shipment scenarios. As rapidly emerging new lighting technologies (such as light-emitting diodes) and existing technologies (high-intensity fluorescent) could penetrate the MHLF market and significantly affect shipment projections, DOE creates two base-case shipment scenarios: low fixture shipments and high fixture shipments. The high shipments scenario assumes more limited penetration of other higher-efficiency equipment than the low shipments scenario.

To characterize customer behavior in the standards case, DOE developed a "roll-up" shipment scenario. The roll-up scenario represents a standards case in which all equipment in the base case that do not meet the standard would roll up to meet the new standard level. Customers who in the base case purchase fixtures above the standard level are not affected as they are assumed to continue to purchase the same base-case fixture in the roll-up scenario. The roll-up scenario characterizes customers primarily driven by the first-cost of the fixture.

2.11 NATIONAL IMPACT ANALYSIS

The NIA assesses the NPV of total end-user LCC and NES. DOE determined both the NPV and NES for the performance levels considered for the fixture equipment classes analyzed. To make the analysis more transparent to all interested parties, DOE prepared an NIA spreadsheet model to forecast energy savings and the national economic costs and savings resulting from amended standards. DOE assessed the aggregate economic impacts at the national level for this NOPR analysis. Chapter 11 of the NOPR TSD describes DOE's assessment of the aggregate economic impacts at the national level.

2.11.1 National Energy Savings Analysis

The inputs for determining NES are (1) annual energy consumption per unit; (2) shipments; (3) stock; (4) national energy consumption (calculated from consumption per unit and equipment stock); (5) site-to-source conversion factors; and (6) rebound rates. DOE calculated the national energy consumption by multiplying the number of units, or stock, of metal halide lamp fixtures (by vintage, which represents the age of the fixtures) by the unit energy consumption (also by vintage). Then, DOE calculated national annual energy savings from the difference between national energy consumption in the base case (without amended efficiency standards) and in each higher-efficiency standards case. DOE estimated energy consumption and savings based on site energy, and converted the electricity consumption and savings to source energy. DOE also examined potential rebound effects (an energy savings “take-back”) based on customer usage patterns. Cumulative energy savings are the sum of the annual NES, which DOE determined over specific time periods.

2.11.2 Net Present Value Analysis

DOE used five inputs to determine the NPV: (1) total annual installed cost; (2) total annual operating cost savings; (3) discount factor; (4) present value of costs; and (5) present value of savings. DOE calculates net savings each year as the difference between total operating cost savings and increases in total installed costs (including price and installation cost). DOE calculates savings over the life of the equipment, accounting for differences in yearly energy rates. DOE calculates NPV as the difference between the present value of operating cost savings and the present value of increased total installed costs. DOE discounts future costs and savings to the present with a discount factor.

DOE calculated increases in total installed costs as the product of the difference in the total installed cost between the base case, and standards case and the annual shipments in the standards case. Because purchase costs of the higher-efficiency equipment in the standards case are generally greater than the purchase costs of equipment in the base case, price increases appear as negative values in the NPV. DOE expressed operating cost savings as decreases in operating costs associated with the lower energy consumption of equipment in the standards case compared to the base efficiency case. Total operating cost savings are the product of savings per unit and the number of units of each vintage surviving in a particular year.

2.12 LIFE-CYCLE COST SUBGROUP ANALYSIS

A customer subgroup comprises a subset of the population that could, for one reason or another, be affected disproportionately by new or amended energy conservation standards. In this NOPR, DOE identified utilities, owners of transportation facilities, and warehouse owners as customers that could be disproportionately impacted by the proposed standards. The LCC subgroup analysis evaluates the effects on these customer subgroups by accounting for variations in key inputs to the LCC analysis.

For more detail on the LCC subgroup analysis, see chapter 12 of the NOPR TSD.

2.13 MANUFACTURER IMPACT ANALYSIS

DOE performed an MIA to estimate the financial impact of higher energy conservation standards on MHLF manufacturers, and to calculate the impact of such standards on domestic manufacturing employment and capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on two separate Government Regulatory Impact Models (GRIMs)—industry-cash-flow models customized for this rulemaking. The GRIM inputs are data characterizing the industry cost structure, shipments, and revenues. The key output is the industry NPV. Different sets of assumptions (scenarios) produce different results. The qualitative part of the MIA addresses factors such as equipment characteristics, characteristics of particular firms, and market and equipment trends, and includes an assessment of the impacts of standards on subgroups of manufacturers. The complete MIA is outlined in chapter 13 of the NOPR TSD.

DOE conducted the MIA in three phases. Phase 1, "Industry Profile," consisted of the preparation of an industry characterization. Phase 2, "Industry Cash Flow," focused on the industry as a whole. DOE used publicly available information developed in Phase 1 to adapt the GRIM structure to facilitate the analysis of amended ballast standards. In Phase 3, "Subgroup Impact Analysis," DOE conducted interviews with manufacturers representing the majority of domestic metal halide ballast and fixture sales. During these interviews, DOE discussed engineering, manufacturing, procurement, and financial topics specific to each company, and also obtained each manufacturer's view of the industry as a whole. The interviews provided valuable information DOE used to evaluate the impacts of an amended energy conservation standard on manufacturer cash flows, manufacturing capacities, and employment levels.

2.14 EMPLOYMENT IMPACT ANALYSIS

The imposition of standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the factories that produce the covered fixture types, along with the affiliated distribution and service companies, resulting from the imposition of new standards. DOE evaluates direct employment impacts in the MIA. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to the imposition of standards. The combined direct and indirect employment effects are investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model. The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis, and estimates the employment and income effects of energy-saving technologies in buildings, industry, and transportation. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

For more detail on the employment impact analysis, see chapter 14 of the NOPR TSD.

2.15 UTILITY IMPACT ANALYSIS

The utility impact analysis includes an analysis of the impact of higher energy conservation standards on the electric utility industries. DOE adapted the National Energy Modeling System (NEMS) produced by EIA for this analysis. NEMS is a large, multi-sector, general-equilibrium model of the U.S. energy sector that has been developed over the past decade by EIA, primarily for preparing DOE's *AEO*. In prior rulemakings, a variant of NEMS (currently termed "NEMS-BT," BT referring to the DOE's Building Technologies Program) was developed to better address the specific impacts of an equipment efficiency standard.

The NEMS produces a widely recognized baseline energy projection for the United States through the year 2035, and is available in the public domain. The typical NEMS outputs include projections of electricity sales, price, and avoided electric generating capacity.

DOE conducted the utility impact analysis as a scenario departing from the latest *AEO* reference case generated by NEMS-BT. In other words, the energy-saving impacts from amended energy conservation standards were modeled using NEMS-BT to generate forecasts that deviate from the *AEO* reference case. The utility impact analysis is discussed in more detail in chapter 15 of the NOPR TSD.

2.16 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector emissions of CO_2, SO_2, NO_x, and Hg using the NEMS-BT computer model. In the emissions analysis, NEMS-BT is run similarly to the *AEO* NEMS, except that MHLF energy use is reduced by the amount of energy saved (by fuel type) due to each considered standard level. The inputs of NES come from the NIA spreadsheet model, while the output is the forecasted physical emissions. The net benefit of each considered standard level is the difference between the forecasted emissions estimated by NEMS-BT at that level and the *AEO2012* Reference Case.

For more detail on the emissions analysis, see chapter 16 of the NOPR TSD.

2.16.1 Carbon Dioxide

In the absence of any federal emissions control regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emission reductions likely to result from a standard will be estimated using NEMS-BT and NES estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* reference case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results with broad coverage of all sectors and inclusion of interactive effects.

2.16.2 Sulfur Dioxide

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap-and-trade, and DOE has preliminarily determined that these programs create uncertainty about the potential standards' impact on SO_2 emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR, 70 Fed. Reg. 25162 (May 12, 2005)), which created an allowance-based trading program. Although CAIR was remanded to the U.S. Environmental Protection Agency (EPA) by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) (see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008)), it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (Aug. 8, 2011). (See www.epa.gov/crossstaterule/). On December 30, 2011, however, the D.C. Circuit stayed the new rules while a panel of judges reviews them, and told EPA to continue enforcing CAIR (see *EME Homer City Generation v. EPA*, No. 11-1302, Order at *2 (D.C. Cir. Dec. 30, 2011)). On August 21, 2012, the D.C. Circuit vacated CSAPR. See *EME Homer City Generation, LP v. EPA*, No. 11-1302, 2012 WL 3570721 at *24 (D.C. Cir. Aug. 21, 2012). The court required EPA to continue administering CAIR.

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO_2 as a result of standards.

Beginning in 2015, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants, which were announced by EPA on December 21, 2011. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO2012* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2015. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, NEMS shows a reduction in SO_2 emissions when electricity demand decreases (e.g., as a result of energy efficiency standards). Emissions will be far below the cap that would be established by CSAPR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO_2 emissions in 2015 and beyond.

2.16.3 Nitrogen Oxides

CSAPR established a cap on NO_x emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NO_x emissions in those States covered by CSAPR because excess NO_x emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_x emissions. However, standards would be expected to reduce NO_x emissions in the States not affected by the caps, so DOE estimated NO_x emissions reductions from the standards considered for these States.

2.16.4 Mercury

The MATS limit Hg emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reduction using NEMS-BT based on *AEO2012*, which incorporates the MATS.

2.16.5 Particulate Matter

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_x. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_x, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions.

2.17 MONETIZING CARBON DIOXIDE AND OTHER EMISSIONS REDUCTIONS

DOE plans to consider the estimated monetary benefits likely to result from the reduced emissions of CO_2 and NO_X that are expected to result from each of the standard levels considered.

In order to estimate the monetary value of benefits resulting from reduced emissions of CO_2, DOE plans to use the most current Social Cost of Carbon (SCC) values developed and/or agreed to by an interagency process. The SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But with full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

At the time of this notice, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions 2015 were \$6.2, \$25.7, \$41.5, and \$78.7 per metric ton avoided (values expressed in 2012\$). For emissions reductions that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE will give preference to consideration of the global benefits of reducing CO_2 emissions. To calculate a present value of the stream of monetary values, DOE will discount the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHG to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also intends to estimate the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. For NO_x emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from \$468 to \$4,805 per ton in 2012\$.[2] In accordance with U.S. Office of Management and Budget (OMB) guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[3]

DOE is evaluating appropriate monetization of Hg emissions in energy conservation standards rulemakings.

See chapter 17 of the NOPR TSD for more detail on the monetization of emissions reductions.

2.18 REGULATORY IMPACT ANALYSIS

DOE prepared an RIA pursuant to Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735, Oct. 4, 1993, which is subject to review under the Executive Order by the Office of Information and Regulatory Affairs at the OMB. The RIA addressed the potential for non-regulatory approaches to supplant or augment energy conservation standards to improve the energy efficiency of metal halide lamp fixtures on the market. The RIA is discussed in more detail in chapter 18 of the NOPR TSD.

2.19 DEPARTMENT OF JUSTICE REVIEW

Section 325(o)(2)(B)(i)(V) of the Energy Policy and Conservation Act states that, before the Secretary of Energy may prescribe a new or amended energy conservation standard, the Secretary shall ask the U.S. Attorney General to make a determination of "the impact of any lessening of competition…that is likely to result from the imposition of the standard." (42 U.S.C. 6295) Pursuant to this requirement, DOE will solicit the views of DOJ on any lessening of competition that is likely to result from the imposition of a proposed standard and will give the views provided full consideration in assessing economic justification of a proposed standard.

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[2] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, 2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities, Washington, DC.

[3] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter consists of three sections: the market assessment, the technology assessment, and the equipment classes. The market assessment provides an overall picture of the market for the equipment concerned, including the nature of the equipment, industry structure, and manufacturer market shares; regulatory and non-regulatory efficiency improvement programs; and market trends and quantities of equipment sold. The technology assessment identifies a preliminary list of technologies considered in the screening analysis. The equipment classes section discusses the equipment classes the U.S. Department of Energy (DOE) proposes using for this rulemaking and how they were developed.

The information DOE gathers from the market and technology assessment serves as resource material for use throughout the rulemaking. DOE considers both quantitative and qualitative information from publicly available sources and interested parties.

3.1.1 Definitions

The Energy Independence and Security Act of 2007 (Pub. L. 110-140; EISA 2007) added definitions to the Energy Policy and Conservation Act (42 U.S.C. 6311–6316; EPCA) for metal halide lamp fixture (MHLF or "fixture") and associated terms. DOE codified the statutory definitions and definitions of supplementary terms for metal halide lamp fixtures in the Code of Federal Regulations (CFR). 10 CFR 431.322. The following sections describe, in greater detail, EPCA definitions for metal halide lamp fixture, metal halide lamp, metal halide ballast, ballast, electronic ballast, probe-start metal halide ballast, pulse-start metal halide ballast, and ballast efficiency. These terms help define the scope of energy conservation standards for metal halide lamp fixtures.

3.1.1.1 Metal Halide Lamp Fixture

Section 321(64) of EPCA broadly defines metal halide lamp fixtures as: "light fixture for general lighting application designed to be operated with a metal halide lamp and a ballast for a metal halide lamp." (42 U.S.C. § 6291(64))

3.1.1.2 Metal Halide Lamp

Section 321(63) of EPCA defines metal halide lamp as: "a high intensity discharge lamp in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors." (42 U.S.C. § 6291(63))

3.1.1.3 Metal Halide Ballast

Section 321(62) of EPCA defines metal halide ballast as: "a ballast used to start and operate metal halide lamps." (42 U.S.C. § 6291(62))

3.1.1.4 Ballast and Electronic Ballast

Section 321 of EPCA defines ballast as: "a device used with an electric discharge lamp to obtain necessary circuit conditions (voltage, current, and waveform) for starting and operating." (42 U.S.C. § 6291(58)) Electronic ballast is defined as: "a device that uses semiconductors as the primary means to control lamp starting and operation." (42 U.S.C. § 6291(60))

3.1.1.5 Probe-Start Metal Halide Ballast

Sections 321(65)(A) and (B) of EPCA define probe-start metal halide ballast as: "a ballast that—

> (A) starts a probe-start metal halide lamp that contains a third starting electrode (probe) in the arc tube; and
> (B) does not generally contain an igniter but instead starts lamps with high ballast open circuit voltage."
>
> (42 U.S.C. 6291(65))

3.1.1.6 Pulse-Start Metal Halide Ballast

Sections 321(66)(A) and (B) of EPCA define pulse-start metal halide ballast as:

> "(A) In general.— The term "pulse-start metal halide ballast" means an electronic or electromagnetic ballast that starts a pulse-start metal halide lamp with high voltage pulses.
> (B) Starting process.— For the purpose of subparagraph (A)—
>> (i) lamps shall be started by first providing a high voltage pulse for ionization of the gas to produce a glow discharge; and
>> (ii) to complete the starting process, power shall be provided by the ballast to sustain the discharge through the glow-to-arc transition."
>
> (42 U.S.C. 6291(66))

3.1.1.7 Ballast Efficiency

Section 321(59)(A) of EPCA (42 U.S.C. § 6291(59)(A)) defines ballast efficiency (BE) as: "in the case of a high intensity discharge fixture, the efficiency of a lamp and ballast combination, expressed as a percentage, and calculated in accordance with the following formula: Efficiency = P_{out}/P_{in}."

Section 321(59)(B) of EPCA clarifies the definition of the calculations for ballast efficiency or P_{out}/P_{in} by defining the following:

“(i) P_{out} shall equal the measured operating lamp wattage;
(ii) P_{in} shall equal the measured operating input wattage”

(42 U.S.C. § 6291(59)(B))

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade association and domestic manufacturers of metal halide lamp fixtures and ballast; discusses manufacturer market share, regulatory programs, and non-regulatory initiatives; defines equipment classes; provides historical shipment data, shipment projections, and equipment lifetime estimates; and summarizes market performance data.

3.2.1 Trade Associations

The National Electrical Manufacturers Association (NEMA) is the trade association for metal halide lamp fixtures and ballasts. NEMA’s Lighting Systems Division is one of eight product divisions. The division’s 47 member companies compose 85 to 95 percent of the U.S. commercial and industrial market, as well as large portions of the institutional and educational markets.[1] In addition to metal halide lamp fixtures and ballasts, NEMA’s Lighting Systems Division also oversees products such as metal halide lamps, other high-intensity discharge (HID) equipment, fluorescent lamps and ballasts, solid-state lighting (SSL), emergency lighting technologies, lighting controls, and fixtures in general. NEMA provides an organization through which manufacturers of lighting equipment can work together on projects that affect their industry and business. NEMA’s activities relating to energy efficiency include:

- advising DOE and executive agencies on lighting research and market transformation needs;
- engaging in legislative work on energy and lighting issues;
- monitoring energy efficiency rulemakings and standards affecting lighting products by federal and state agencies;
- supporting adoption of 1999 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) 90.1 lighting provisions (hereafter ASHRAE/IESNA 90.1);
- working with market transformation and environmental groups to advance market use of energy efficient lighting technologies;
- advising DOE and the U.S. Environmental Protection Agency (EPA) on ENERGY STAR® Buildings and ENERGY STAR voluntary product labeling programs; and
- advocating market-based approaches to enhance the use and penetration of energy efficient technologies.[2]

3.2.2 Manufacturers and Market Share

The fixture market is composed of several domestic and international manufacturers. The following list contains the names of manufacturers that are part of the Luminaire Section of NEMA:

- Acuity Brands Lighting
- Arcalux Corporation
- Cooper Controls
- Cooper Lighting
- Emerson/EGS Electrical Group
- GE Consumer and Industrial of General Electric, Inc. (hereafter, “GE”)
- Genlyte Group/Lightolier/Gardco – Philips Lighting
- Holophane
- Hubbell Lighting
- Inter-Global, Inc.
- Juno Lighting Group
- Light One Inc.
- Lithonia Lighting
- National Cathode Corp
- OSRAM SYLVANIA of Siemens AG (hereafter “Osram Sylvania”)
- Ruud Lighting Inc.
- Technical Consumer Products, Inc.
- Thomas & Betts Corporation
- Philips
- Venture Lighting International

Several manufacturers are owned by parent companies that make up the majority of the market. For covered equipment, the majority of the MHLF market is held by NEMA members and non-members, which include:

- GE
- Osram Sylvania
- Philips Lighting
- Acuity Brands Lighting
- Cooper Lighting
- Hubbell Lighting
- Juno Lighting Group
- Venture Lighting International

Additional metal halide lamp fixtures manufacturers include:

- ABS Lighting
- Access Fixtures
- Acting Chile-Appleton Agency Southern Cone
- Arcalux
- Architectural Details, Inc.
- Architectural Lighting Works
- Atlantic Lighting, Inc.
- Atlas Lighting
- Rig-A-Lite
- Baero
- Bega
- Babican Architectural Products
- Barn Light Electric
- Better Designed Lighting
- C.W. Cole & Company
- CD Lighting
- CGF Design Inc.
- Con-Tech Lighting
- Custom Metalcraft
- Deco Lighting
- Deep Roof Lighting
- DMF Lighting Solutions
- Dynamic Lighting Solutions
- Amerlux Lighting Solutions
- G Lighting
- GSS Global Solutions
- Healthcare Lighting
- HessAmerica
- Hunza Lighting USA
- ICOF Inc.
- ICOF International
- Insight Lighting
- Intense Lighting
- K.J. Lighting Sales
- Kenall Manufacturing
- Kirling Company
- LDPI Inc.
- Legion Lighting Company
- LightGuard
- Lighting Nelson & Garrett
- Lighting Services
- Light Makers
- Litelab
- LITON
- LSI Industries
- Lumascape USA
- Lumca
- Lumenelle
- Lumenform Industries
- Lumenton Lighting
- Luminis
- Manning Lighting
- Neonlite Electronic & Lighting
- Paramount Industries
- Pauluhn
- Phoenix Products
- Pinnacle Architectural Lighting
- Prisma Architectural Lighting
- Qualite Sports Lighting
- Rambusch Lighting
- Reggiani Lighting
- Reyk Lighting
- Ruud Lighting Canada
- Satco Products
- Schreder Lighting USA
- Selux Corporation
- Sheed Lighting
- Sheedlight
- Sleeve Off Design
- Spectrum Lighting
- SPI Lighting
- Spot on Lighting
- Spring City Electrical Mfg Co
- Stanpro Lighting Systems
- Sternberg Lighting

- Eclipse Lighting
- EECOL Electric
- Elite Lighting
- Energie Lighting
- Energy Focus, Inc.
- Engineering Products Company
- Eureka Lighting
- EUTRAC Corp.
- Focal Point LLC
- Villa Lighting Supply
- Visa Lighting
- Vision3 Lighting
- Visionaire Lighting
- W2 Architectural Lighting
- WAC Lighting
- Welch Lighting
- Will-Burt
- Martin Professional
- Metalumen
- Meyda Custom Lighting
- Mohandesi Mahshid Sepahan
- Moutain States Lighting
- MP Lighting

Systems

- StressCrete Group
- Swivelier
- Tech Lighting
- Teddico
- The Lighting Quotient
- The Pennsylvania Globe Gaslight Company
- TPR Enterprises
- US Architectural Lighting

The following list contains the names of manufacturers that produce metal halide ballasts:

- Advance Transformer (Philips)
- AMF Lighting
- Etlin
- Fulham
- GE
- Hatch Transformer
- Howard Industries
- Lightec
- Metrolight
- Osram Sylvania
- Power Select
- Robertson Worldwide
- SOLA
- Sunpark
- Ultrasave Lighting Ltd.
- Universal Lighting Technologies
- Venture Lighting International
- Vossloh-Schwabe

Five manufacturers hold the majority of the domestic market share of metal halide ballasts:

- GE
- Osram Sylvania
- Advance Transformer of Philips Lighting (hereafter “Advance”)

- Universal Lighting Technologies
- Venture Lighting International

The lighting divisions of some of these companies also manufacture other products, such as fluorescent lamps and ballasts, light emitting diodes (LEDs), other HID lamp technologies, and compact fluorescent lamps (CFLs).

3.2.2.1 Small Businesses

Small businesses may be particularly affected by the promulgation of minimum energy conservation standards for metal halide lamp fixtures. The Small Business Administration (SBA) lists small business size standards that are matched to industries as they are described in the North American Industry Classification System (NAICS). A size standard is the largest that a for-profit concern can be and still qualify as a small business for Federal Government programs. These size standards are generally the average annual receipts or the average employment of a firm. For metal halide lamp fixtures, the size standard is matched to NAICS code 335122, *Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing*, which has a size standard of 500 employees or fewer.[3] For metal halide ballasts, the size standard is matched to NAICS code 335311, *Power, Distribution, & Specialty Transformer Manufacturing*, which has a size standard of 750 employees or fewer.[4]

DOE studies the potential impacts on these small businesses in detail as part of the manufacturer impact analysis, see technical support document (TSD) chapter 13.

3.2.3 Regulatory Programs

Several Federal and international regulatory programs affect the markets for metal halide lamp fixtures and ballasts. The following section summarizes U.S. and Canadian regulatory initiatives relevant to the fixtures and ballasts covered by this rulemaking. While the following discussion is not exhaustive in describing all regulatory action related to metal halide lamp fixtures and ballasts, it provides detail on some notable initiatives that characterize recent developments in the lighting market.

3.2.3.1 Federal Energy Conservation Standards

Title III of EPCA of 1975, Pub. L. 94-163, (42 United States Code (U.S.C.) 6291 *et seq*.) established an energy conservation program for major household appliances and industrial and commercial equipment. More specifically, Part A of Title III (42 U.S.C. 6291-6309) establishes the "Energy Conservation Program for Consumer Products Other Than Automobiles." Subsequent amendments to EPCA have given DOE the authority to regulate the energy efficiency of several additional kinds of equipment, including certain metal halide lamp fixtures.

On December 19, 2007, the President signed EISA 2007, which made numerous amendments to EPCA and directed DOE to undertake several new rulemakings for appliance energy conservation standards, including two cycles for metal halide lamp fixtures. DOE is initiating its first rulemaking cycle to review and consider amendments to the energy conservation standards in effect for metal halide lamp fixtures, as required under 42 U.S.C. 6295(hh)(2), which provides as follows:

(2) Final rule by January 1, 2012. —
  (A) In general. —
    Not later than January 1, 2012, the Secretary shall publish a final rule to determine whether the standards established under paragraph (1) should be amended.
  (B) Administration. —
    The final rule shall—
      (i) contain any amended standard; and
      (ii) apply to products manufactured on or after January 1, 2015.

As amended by EISA 2007, EPCA regulates metal halide lamp fixtures designed to be operated with lamps rated greater than or equal to 150 watts (W) but less than or equal to 500 W by prescribing performance requirements for the metal halide ballasts used in those metal halide lamp fixtures. Both metal halide lamps and ballasts are energy-consuming components of metal halide lamp fixtures. For this 150 to 500 W metal halide lamp wattage range, metal halide lamp fixtures must contain:

(i) a pulse-start metal halide ballast with a minimum ballast efficiency of 88 percent;
(ii) a magnetic probe-start ballast with a minimum ballast efficiency of 94 percent; or
(iii) a nonpulse-start electronic ballast with—
  (I) a minimum ballast efficiency of 92 percent for wattages greater than 250 W; and
  (II) a minimum ballast efficiency of 90 percent for wattages less than or equal to 250 W.

(U.S.C. § 6292 (hh)(1)(A))

In addition to prescribing minimum efficiency requirements for the previously described metal halide ballasts contained in metal halide lamp fixtures, EISA 2007 amended EPCA to exclude the following types of metal halide lamp fixtures from the statutorily prescribed energy conservation standards:

(i) fixtures with regulated lag ballasts;
(ii) fixtures that use electronic ballasts that operate at 480 volts; or
(iii) fixtures that—
  (I) are rated only for 150 watt lamps;
  (II) are rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and
  (III) contain a ballast that is rated to operate at ambient air temperatures above 50° C, as specified by UL [Underwriters Laboratories] 1029–2001 ["Standard for High-Intensity-Discharge Lamp Ballasts"].

(42 U.S.C. § 6292 (hh)(1)(B))

Pursuant to section 310 of EISA 2007, EPCA further directs DOE to incorporate standby mode and off mode energy use in any amended (or new) standard adopted after July 1, 2010. (42 U.S.C. § 6295(gg)(3)) Because this energy conservation standards rulemaking will be completed after that date, the requirement to incorporate standby mode and off mode energy use into the energy conservation standards analysis is applicable.

DOE published a final rule test procedure to comply with provisions from EISA 2007 that apply to metal halide ballasts included in metal halide lamp fixtures that are covered by this rulemaking. DOE found that while it is possible for metal halide ballasts to operate in active mode and standby mode, the off mode condition does not apply because it addresses a mode of energy use in which metal halide ballasts do not operate. 75 FR 10950, 10954-5 (March 9, 2010). One example of a metal halide ballast that operates in standby mode is a DALI[a]-enabled ballast. DALI-enabled ballasts exhibit standby power because they have internal circuitry that is integral to the design of the ballast that remains on and active, even when the ballast is not driving any lamps.

Pursuant to EPCA section 325(gg)(2)(A), 42 U.S.C. § 6295(gg)(2)(A), DOE has considered whether to incorporate standby mode into a single amended or new metric. DOE is not proposing to include standby mode standards in this rulemaking. For more information, see the notice of proposed rulemaking (NOPR) *Federal Register* notice.

3.2.3.2 California Energy Commission

Prior to the enactment of EISA 2007, the California Energy Commission (CEC) adopted regulations for metal halide lamp fixtures that took effect on January 1, 2006. California's MHLF energy conservation standards were amended in August 2009 with the adoption of CEC 2009 *Appliance Efficiency Regulation.* According to section 1605.3(n) of California Title 20, effective January 1, 2010, metal halide lamp fixtures manufactured and sold in the state of California may not be sold with probe-start ballasts, and in addition, must meet at least one of following requirements:

> 1) (a) contain ballasts with minimum ballast efficiency of 90 percent for fixtures designed to operate lamps rated 150-250 W, (b) contain ballasts with minimum ballast efficiency of 92 percent for fixtures designed to operate lamps rated 251-500 W; or
>
> 2) contain ballasts with minimum ballast efficiency of 88 percent and an occupant sensor that is an integral control, shipped with the factory default setting to automatically reduce lamp power through dimming by a minimum of 40 percent within 30 minutes or less after the area has been vacated; or
>
> 3) contain ballasts with minimum ballast efficiency of 88 percent and have an automatic daylight control that is an integral control, shipped with the factory default setting to automatically reduce lamp power through dimming by a minimum of 40 percent; or
>
> 4) contain ballasts with minimum ballast efficiency of 88 percent and a re-lamping rated wattage within one of the four wattage bins specified in the following subsections (a) through (d). The metal halide lamp fixture shall be able to operate lamps within only one of the four wattage bins and shall not be rated for any lamp wattage outside of that

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[a] DALI stands for Digital Addressable Lighting Interface, which is a system that enables communication between a central lighting controls system and the individual components, including the ballasts.

wattage bin. The metal halide lamp fixture shall have a permanent, pre-printed factory-installed label that states the re-lamping rated wattage.

(a) 150-160 W; or
(b) 200-215 W; or
(c) 290-335 W; or
(d) 336-500 W, provided that when a metal halide lamp fixture is able to operate 336 W to 500 W lamps, the fixture shall be prepackaged and sold together with at least one lamp per socket, having a minimum lamp mean efficacy of 80 lumens per watt (lm/W) based on published mean lumens and rated lamp power (in watts).

3.2.3.3 Canadian Energy Efficiency Standards

The Natural Resources Canada (NRCan) Office of Energy Efficiency regulates the energy efficiency of several consumer and industrial products in Canada. On May 10, 2010, NRCan published a bulletin on developing standards, stating NRCan's proposal to amend Canada's Energy Efficiency Regulations to include metal halide ballasts. Table 3.1 shows the proposed Canadian standards for metal halide ballasts.

Table 3.1 Proposed Canadian Standards for Metal Halide Ballasts

Ballast Type	Lamp Rated Wattage	Minimum Rated Ballast Efficiency (%)
Magnetic Probe-Start	150-500	94
Pulse-Start	150-500	88
Non-Pulse-Start Electronic	150-250	90
	251-500	92

NRCan proposed that listed standards apply to equipment manufactured on or after July 14, 2012.

3.2.4 Non-Regulatory Initiatives

DOE reviewed several national, regional, and local voluntary programs that promote the use of energy efficient lighting in the United States. These include the Federal Energy Management Program's (FEMP's) program for energy efficient lighting, the ENERGY STAR Program, and the Northeast Energy Efficiency Partnership (NEEP). The following section summarizes some of these programs for metal halide lamp fixtures and the ballasts contained in the fixtures covered by this rulemaking. While it is not an exhaustive list, the discussion provides detail on some notable initiatives that characterize recent developments in the lighting market.

3.2.4.1 Federal Energy Management Program

FEMP helps federal buyers identify and purchase energy efficient equipment including certain metal halide lamp fixtures. Section 161 of EPACT 1992 encourages energy efficient federal procurement. Section 104 of EPACT 2005 requires that each agency incorporate energy efficiency criteria consistent with ENERGY STAR and FEMP-designated products for "...all procurements involving energy consuming products and systems, including guides specifications, project specifications, and construction, renovation, and service contracts that include provision of energy-consuming products and systems, and into the factors for the evaluation of offers received for the procurement." Executive Order 13123 and Federal Acquisition Regulation (FAR) section 23.704 direct agencies to purchase products in the upper 25 percent of energy efficiency, including all models that qualify for the ENERGY STAR product labeling program. 64 FR 30851, 30854 (June 8, 1999). FEMP provides recommendations for how to buy energy efficient industrial fixtures, including the metal halide lamp fixtures shown in Table 3.2. FEMP offers buyers support tools such as efficiency guidelines, cost-effectiveness examples, and a cost calculator. FEMP also offers training, on-site audits, demonstrations, and design assistance.

Table 3.2 Federal Energy Management Program Efficiency Recommendation

Upward Efficiency*	**Lamp Wattage**	**Required Luminaire Efficacy Rating (LER)**	
		Lensed Fixture	**Open Fixture**
0%	150 - 399	50 or higher	49 or higher
	400 - 999	62 or higher	69 or higher
	≥1000	84 or higher	76 or higher
1% - 10%	150 - 399	68 or higher	49 or higher
	400 - 999	73 or higher	75 or higher
	≥1000	71 or higher	96 or higher
11% - 20%	150 - 399	70 or higher	55 or higher
	400 - 999	76 or higher	81 or higher
	≥1000	82 or higher	87 or higher

*Upward Efficiency is the portion of light directed up by the fixture. Both high bay and low bay HID fixtures are available with opaque reflectors, which direct all or most of the light downward, and with transparent refractors, which direct some light up.

3.2.4.2 ENERGY STAR

ENERGY STAR is a joint program of DOE and the Environmental Protection Agency (EPA) designed to protect the environment by promoting energy-efficient products and practices.[5] ENERGY STAR specifies criteria for residential lighting fixtures, which contain three parts: a lamp, a ballast, and the fixture that holds the lamp and ballast. Products that qualify for the ENERGY STAR label may not use magnetic ballasts in indoor fixtures. The ENERGY STAR specifications also define criteria for lamp start time, power factor, lamp current crest factor, ballast operating temperature, electromagnetic interference, frequency, transient protection, end of life protection, dimming, and safety.[6]

EPA is currently developing a new product specification for lamps which will replace existing CFL and integral light-emitting diode (LED) lamp specifications. EPA published a Draft 2 Version 1.0 Specification updating testing requirements, performance tiers, labeling requirements, and various other requirements, but did not specify performance characteristics of metal halide lamps.[7]

3.2.4.3 Northeast Energy Efficiency Partnerships

NEEP is a regional nonprofit organization that promotes energy efficiency in the Northeast. NEEP runs a Commercial Buildings and Technologies Initiative that “focus[es] on improved efficiency and energy performance that address the integration of technologies and best practices in building systems such as lighting system design.”[8] NEEP coordinates with multiple local and state governments, utilities, and other initiatives, such as Efficiency Vermont and the Long Island Power Authority, to promote efficient lighting products.

3.2.5 Alternative Fixture Efficiency Metrics

Although MHLF minimum performance requirements are measured by the ballast efficiency of the ballast included in the fixture, DOE and the fixture industry has researched alternative metrics for fixture efficiency. For the SSL ENERGY STAR Program, DOE has developed the FTE metric. NEMA, along with its luminaire division, has developed the Target Efficacy Rating (TER). DOE found that in general, overall fixture energy use depends on four areas of importance including: lamp efficacy, ballast efficiency, light absorption by the fixture, and usefulness of light emitted by the fixture (direction or light distribution pattern). FTE and TER metrics treat each area of importance more effectively in some ways than others. The following sections describe each metric and explain how they account for the four areas of importance.

3.2.5.1 Fitted Target Efficacy

DOE previously developed FTE[b] metric to quantify outdoor pole-mounted fixture performance for ENERGY STAR qualification purposes. In the FTE approach, fixture performance is measured by fitting a rectangle to the uniform “pool” of light specific to each fixture, multiplying the luminous flux (in lumens) landing in this pool by the percent coverage of the rectangular target, and then dividing by input power (in watts) to the fixture. The equation can be summarized as:

$$FTE = \frac{(\text{flux in uniform pool}) * (\text{percentage of rectangular target covered by uniform pool})}{(\text{flux in input power})}$$

The resulting calculation is measured against Illuminating Engineering Society (IES) recommended uniformity ratios. FTE addresses the four areas of importance as follows:

- Lamp Efficacy: FTE takes into consideration lamp efficacy by evaluating light delivered to the target. A source has to have a reasonably high efficacy to score a high FTE value.
- Ballast Efficiency: FTE incorporates ballast efficiency by incorporating total wattage of the fixture that is dependent on the ballast input watts. The more efficient the ballast, the closer to the lamp wattage the total wattage of the fixture will be.

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[b] The DOE introduction to FTE is available here: www.illinoislighting.org/resources/FTEoverview01Jul09.pdf.

- Light Absorption: FTE takes into account absorption of light by the fixture by evaluating light delivered to the target. A less efficient optical system yields a lower FTE value.

- Light Distribution: FTE only accounts for light hitting a specific rectangular target area.

Through using uniformity and rectangularity of distribution as the criteria for useful luminous flux, the same method of calculation can be applied to fixtures of all IES types (Types I through V), and no project-specific geometries or criteria are required. However, FTE only accounts for light hitting the specified target area and does not take into account other surfaces where the fixture is designed to light. ENERGY STAR has not yet adopted FTE for outdoor lighting and NEMA is working with EPA to develop a possible alternative to FTE.

3.2.5.2 Target Efficacy Rating

The TER[c] metric was developed by NEMA's luminaire division to succeed the previous metric of Luminaire Efficacy Rating (LER). TER calculates fixture efficacy by multiplying the light leaving the fixture by a value (the Coefficient of Utilization, or CU) that factors in the distribution of light. The CU calculates the percentage of rated lamp lumens reaching a fixture specific target. TER is calculated as follows:

$$TER = \mathrm{EEF} * \mathrm{TLL} * \frac{BF}{InputWatts}$$

Where:

TER = Target Efficacy Rating, expressed in rated lumens per watt,
EEF = Energy Effectiveness Factor, the percentage of lumens that fall upon a specified typical target area for a fixture. The method for calculating EEF is a function of fixture type,
TLL = Total initial lamp lumens, total number of lamps in the test fixture multiplied by the published rated initial lamp lumens,
BF = Ballast factor of test ballast or the average ballast factor of test ballasts used in the photometric test, and
INPUT WATTS = Total wattage of the fixture as measured during the photometric test, or calculated based on the ballast manufacturers' published data for that lamp/ballast combination if photometric test data is not available.

TER addresses the four areas of importance as follows:

- Lamp Efficacy: TER indirectly considers lamp efficacy by accounting for lumen output from the lamp. Lumen output for the lamp component is based on manufacturer published data only.

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[c] NEMA issued a revised version of the Target Efficacy Rating metric in 2009, LE 6-2009, available here: www.nema.org.

- Ballast Efficiency: TER incorporates ballast efficiency by using the total wattage of the fixture that is dependent on the ballast input watts. The more efficient the ballast, the closer to the lamp wattage the total wattage of the fixture will be.

- Light Absorption: TER accounts for thermal and optical losses by evaluating the portion of rated lamp lumens delivered to the target area.

- Light Distribution: TER builds upon LER. LER previously only looked how much light left the fixture versus in the input power. TER factors in the light distribution via CU. The light reaching the target is most important for a fixture. TER has different targets defined for different fixture types.

TER takes fixture general applications into consideration, allowing for different classifications (*e.g.,* indoor and exterior, subdivided into specific applications with both groups). However, TER has many different values for the different fixtures. Each fixture type has a different TER calculation method and value. Even though fixtures will generally fall within one of the different classifications for TER purposes, there are certain fixtures that can fall within multiple categories of fixture due to their designs.

3.2.6 Historical Shipments

Awareness of annual equipment shipment trends is an important aspect of the market assessment and the development of the standards rulemaking. For this rulemaking, DOE used publicly available HID lamp fixture shipments from the U.S. Census from 1993 to 2001,[9] lamp shipment data from the HID determination,[d] confidential lamp shipments from 2002 to 2008 from NEMA, and market trend information from manufacturers to develop historical shipment for metal halide lamp fixtures from 1993 to 2009.

DOE used this data for three main purposes. First, the shipment data and market trend information contributed to the shipments analysis and base-case forecast for metal halide lamp fixtures (chapter 10 of the NOPR TSD). By using historical shipment data and expert opinion on market trends and calibrating forecast assumptions with recent data, DOE believes it has based the shipments model and base-case forecasts on a sound dataset. Second, DOE used the data to select the representative equipment classes, wattages, units, and fixtures for analysis (chapter 5 of the NOPR TSD). Third, DOE used the data to develop the installed stock of fixtures for the national impact analysis (chapter 11 of the NOPR TSD). Based on its understanding of trends in the market, DOE estimated how the market would respond to various efficiency levels.

3.2.6.1 HID Lamp Fixtures Shipments

The U.S. Census historical shipment data for HID lamp fixtures is broken down into market sectors including commercial and institutional, industrial, and outdoor lighting. Within each market sector, the shipments are categorized by a variety of applications. Different

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[d] A final determination concerning the potential for energy conservation standards for HID Lamps was published in the Federal register on July 1, 2010. 75 FR 37975, The document in its entirety can be found at: www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/60.

applications under the commercial and institutional sector include surface or pendant, indirect lighting, recessed insulation contact, and recessed non-insulation contact. Under industrial, shipments are broken into applications including general lighting and hazardous lighting. For outdoor lighting, shipments are broken into street and highway lighting, general purpose floodlighting, HID sports lighting, and HID area and site lighting. Although the Census data includes metal halide lamp fixtures in the figures, it does not separate metal halide lamp fixtures from other sources such as high pressure sodium (HPS) or mercury vapor (MV) lamps.

Figure 3.2.1 depicts the HID lamp fixture market based on shipments reported to the U.S. Census in 2001.

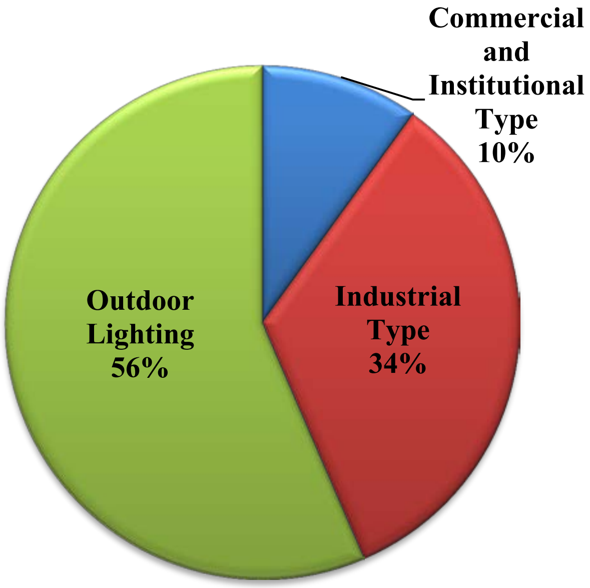


Figure 3.2.1 2001 HID Fixtures Market Share by Segment

Table 3.3 shows all of the HID lamp fixture shipments from the U.S. Census from 1993 to 2001.

Table 3.3 U.S. Census Shipments of HID Lamp Fixtures from 1993 to 2001

HID Fixtures Market Segments				**Shipments by Year (value in thousands)**								
				1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Electric Lighting fixtures, commercial and institutional type (except portable and spotlight)	HID	surface or pendant		191	167	128	163	-	-	-	-	-
		indirect lighting		81	88	53	43	281	214	246	274	289
		recessed non-insulation contact (3-inch minimum clearance from ceiling insulation)	open reflector	464	370	586	576	342	337	725	758	509
			enclosed	337	335	201	188	141	110	201	226	203
		recessed insulation contact (direct contact with ceiling insulation)	open reflector	-	-	-	-	-	-	-	-	-
			enclosed	20	15	13	8	7	3	16	27	33
Electric lighting fixtures, industrial type	General lighting (except portable)	HID including integrally mounted and remote ballasts	open reflector	928	1495	1691	1755	2319	2095	1878	2277	1879
			enclosed	900	902	1095	1240	1724	1587	1403	1531	1374
			parking garage lighting (fixtures designed specifically for this application)	104	136	120	111	151	123	149	360	247
Outdoor lighting equipment, excluding lamps	Street and highway lighting luminaries, including bridge and tunnel lighting	HID types, including low pressure sodium and integrally mounted and remote ballasts	open	503	528	476	546	605	613	2721	561	565
			enclosed	1266	1286	1361	1229	1382	805	1308	1376	1229
	Floodlighting, area, and site lighting fixtures	General purpose floodlighting	HID types, general, including low pressure sodium and integrally mounted and remote ballasts	1028	1103	1184	1363	1596	1371	1475	1390	1326
		HID sports lighting (fixtures designed specifically for this application)		148	160	174	181	231	251	267	252	252
		HID area and site lighting	site lighting (under 20-foot mounting)	1786	1935	1285	2668	2103	2131	1350	1452	1477
			bollards	33	39	50	58	81	80	94	97	97
			post-top	99	100	135	128	145	143	144	137	142
			large area lighting (20- to 60-foot mounting)	470	482	453	761	829	755	829	828	794
Totals				8,358	9,141	9,005	11,018	11,937	10,618	12,806	11,546	10,416

3.2.6.2 Estimated Historical Metal Halide Lamp Fixtures Shipments

To develop MHLF historical shipments from 1993 to 2001, DOE used the U.S. Census HID lamp fixture shipments and lamp shipments by type used in the HID determination. For each year, DOE received information on total metal halide lamps shipped and compared with total HID lamp shipments. DOE then applied the same percentage of metal halide lamps to the U.S. Census HID lamp fixture data to estimate total MHLF shipments from 1993 to 2001. The percentages and methodology are discussed in more detail in chapter 10 of the NOPR TSD. The table below shows the estimated historical shipments for metal halide lamp fixtures from 1993 to 2001.

Table 3.4 Estimated Historical Shipments of Metal Halide Lamp Fixtures from 1993 to 2001

Year	Estimated Total Metal Halide Lamp Fixture Shipments*
1993	2,701,000
1994	3,219,000
1995	3,885,000
1996	4,292,000
1997	4,884,000
1998	5,698,000
1999	6,697,000
2000	6,697,000
2001	6,771,000
* Shipments rounded to the nearest thousand	

DOE's estimates show that from 1993 to 2001, MHLF shipments have approximately doubled. In terms of growth, the market showed an average of 10 percent per year between 1993 and 2001. In comparison, HPS fixtures, a possible alternative to metal halide in certain applications, had an average market loss of 7 percent per year for the same time frame.

For 2002 to 2009, because U.S. Census data is not available for HID lamp fixtures, DOE used confidential lamp shipment information and estimated market shares of metal halide lamp fixtures to estimate total MHLF shipments per year. The estimated market shares of metal halide lamp fixtures are based on the historical U.S. Census data from previous years. Table 3.5 shows the estimated historical shipments for metal halide lamp fixtures from 2002 to 2009.

Table 3.5 Estimated Historical Shipments of Metal Halide Lamp Fixtures from 2002 to 2009

Year	Estimated Total Metal Halide Lamp Fixture Shipments*
2002	6,956,000
2003	7,102,000
2004	7,362,000
2005	7,866,000
2006	8,108,000
2007	8,157,000
2008	7,552,000
2009	7,741,000
* Shipments rounded to the nearest thousand	

In terms of growth, the market showed an average of 1.54 percent growth per year between 2002 and 2009. Due to overall market downturn, which was also expressed by manufacturers during interviews, DOE estimates shipments significantly decreased in 2008. Also, manufacturers in general estimate that alternative technologies such as fluorescent lamps and LEDs have captured significant market share. Fluorescent technology has improved and its lower cost has attracted consumers. Additionally, LED fixture costs have significantly decreased due to competition in the market along with increase in consumers' request for low maintenance and more-efficacious technologies. In general, manufacturers predict that HID applications will eventually be overtaken by LEDs, but will have to go through a transitional period. For a complete explanation on how DOE estimated historical shipments and additional information on shipments, see chapter 10 of the NOPR TSD.

3.3 TECHNOLOGY ASSESSMENT

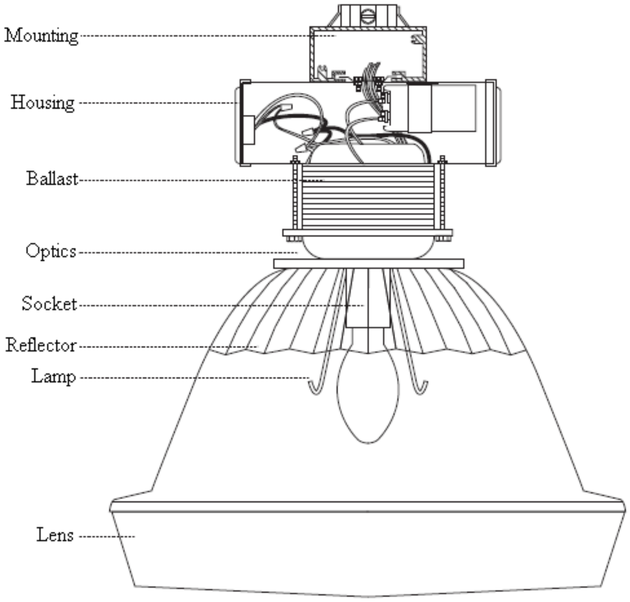
The purpose of the technology assessment is to develop a list of technologies that can be used to improve the efficiency of metal halide ballasts that are incorporated in metal halide lamp fixtures. The following assessment provides a description of the basic construction and operation of metal halide lamp fixtures, lamps, and ballasts, followed by technology options to improve efficiency of metal halide ballasts.

3.3.1 Metal Halide Lamp Fixtures Overview

Since the inception of metal halide lamps in the lighting market in the late 1960's, metal halide lamp fixtures have evolved from a few industrial applications to a vast array of uses such as residential applications, commercial retail, sports lighting, warehouses, hangars, airports, libraries, natatoriums, and several other industrial applications. Technology advances in both lamps and ballasts have significantly increased the energy efficiency of metal halide lamp fixtures. Also, manufacturers have made optional fixture components available, such as daylight sensors or occupancy sensors, which add both functionality and overall energy savings for the end user.

3.3.1.1 Basic Metal Halide Lamp Fixture Structure

The basic metal halide lamp fixture comprises a lamp, ballast, ballast housing or structure, optics, and wiring. Ballast housings are typically made of plastic, aluminum, or different types of steel. There is a variety of optics used, which are typically made of glass, acrylic, aluminum, or sheet metal. The shape and reflectivity of the optics are key factors in determining how effective the fixture distributes light to the desired target. Fixtures are commonly sold with lamps and ballasts. Manufacturers also offer additional components as options depending on the application. Figure 3.3.1 shows the basic structure of a typical metal halide lamp fixture.



Enterprise 22, *Source: Cooper Lighting - Lumark*
Figure 3.3.1 Metal Halide Lamp Fixture Structure

Fixtures generally fall within two basic categories: indoor and outdoor (see section 3.4.2). The following section discusses types of fixtures within each category. While it is not an exhaustive list, the discussion provides detail on different fixtures that are common within each category. Also discussed are additional options manufacturers offer in fixtures that reduce overall energy consumptions.

3.3.1.2 Indoor Fixtures

Downlight

Downlights are fixtures with light distribution directed downward onto a horizontal plane. Downlights usually incorporate a tight optical cut-off of 45° to 50°.[10] These fixtures may be recessed or surface-mounted. Construction includes aluminum or similar metal structure with optics, wiring, and either ballast housing or remote ballast. Typical applications include shopping mall or clothing stores, museums, or residential where the lighting fixture is recessed into a lower ceiling. Typical power ratings are 70 or 100 W. Similar to high and low bay fixtures, the ballast housing is more modular and an increase in ballast size would not likely require an entirely new fixture.

Lithonia LP6HN Open PAR, Source: Lithonia Lighting

Figure 3.3.2 Example of Recessed Downlight Metal Halide Lamp Fixture

High Bay

High bays provide general illumination to an area where the floor-to-ceiling height is greater than 25 feet. Most common construction includes aluminum or plastic ballast housing with wiring near the mounting location and optics attached below the ballast housing. An increase in ballast size might require a larger ballast housing (shown as the white box near the top of Figure 3.3.3), but would be unlikely to affect the optical portion of the fixture. The fixture is generally hung via chain or hook rather than mounted. Typical applications include hangars, retail stores or warehouses, or industrial applications with high ceilings. Manufacturers offer different ballast options, including both magnetic and electronic. Wattage range typically varies from 250 W to 1000 W.

Lithonia TPG High Bay, Source: Lithonia Lighting

Figure 3.3.3 Example of High Bay Metal Halide Lamp Fixture

Low Bay

In contrast to high bay, low bay fixtures provide general illumination to an area where the floor-to-ceiling height is less than 25 feet. Most common construction includes aluminum or plastic ballast housing with wiring near the mounting location and optics attached below the ballast housing. Because the wattage range is less than high bay, there is less thermal protection from the lamps to other components of the fixture. The fixture is generally hung via chain or hook rather than mounted. Typical applications include retail stores or warehouses, some parking garages, or industrial applications with low ceilings. Manufacturers offer different ballast options including both magnetic and electronic type. Wattage range varies from 70 W to 400 W.

Lithonia SX PA25D Low Bay; Source: Lithonia Lighting

Figure 3.3.4 Example of Low Bay Metal Halide Lamp Fixture

Uplight

In opposition to downlights, an uplight fixture has a light distribution directed upward onto a horizontal plane or vertical surface. Uplights usually incorporate a tight optical cut-off of 45° to 50°.[11] These fixtures may be recessed or surface-mounted. Construction includes aluminum or similar metal structure with optics, wiring, and either ballast housing or remote ballast. Typical applications include airports, double height spaces, museums, and natatoriums. Wattage range varies from 70 W to 1000 W.

3.3.1.3 Outdoor Fixtures

Area/Roadway (Streetlight)

Area/roadway fixtures are designed to produce reasonably uniform illuminance on streets, roadways, or parking areas. Most common construction includes wiring, optics, and ballasts enclosed by aluminum or steel housing. These fixtures are generally mounted on poles or vertical surfaces such as building walls. With improvements of weatherization and electrical design, manufacturers are beginning to offer ballast options, including electronic ballasts, beyond the common coil and core magnetic ballasts. Common wattage range varies from 70 W to 400 W.

Lithonia KSE, Source: Lithonia Lighting

Figure 3.3.5 Example of Area/Roadway Metal Halide Lamp Fixture

Bollard

Bollard fixtures are designed to be installed along pathways and in front of buildings. Bollards can be simple pathway post lights as well as robust posts used to provide a barrier and to keep vehicles from leaving roadways. Construction can be aluminum, steel, or even concrete for stronger applications. Optics are usually mounted near the top of the post structure and ballasts can be either remote or included in the fixture. Wattage range is commonly limited to 250 W.

Lithonia KBE, Source: Lithonia Lighting

Figure 3.3.6 Example of Bollard Metal Halide Lamp Fixture

Canopy

Canopy fixtures are designed to be installed under canopy structures. These fixtures may be recessed or surface-mounted. Construction includes aluminum or similar metal structure with acrylic optics, wiring, and ballast housing. Canopy fixtures are most commonly installed in gas stations and garages. Typical power ratings are 150 W or 250 W.

Lithonia KACM, Source: Lithonia Lighting

Figure 3.3.7 Example of Canopy Metal Halide Lamp Fixture

Cobrahead

Similar to area/roadway fixtures, cobraheads are designed to produce reasonably uniform illuminance on streets and roadways. These fixtures have been available in the market for more than 50 years but have gone through several changes, including the addition of metal halide technology and, most recently, LED. Mounting is usually done on a curbside pole, with an arm extending out over the roadway and the fixture at its end. Robust construction includes aluminum or similar metal structure with acrylic drop-bowl optics, wiring, and easily accessible ballast housing. Cobraheads are only used in roadways and street lighting applications. Wattage is commonly found in the 250 W range, but can be as high as 400 W.

Lithonia CHL, Source: Lithonia Lighting

Figure 3.3.8 Example of Cobrahead Metal Halide Lamp Fixture

Floodlight

Floodlights are multi-purpose fixtures designed to supplement other lighting or to provide illuminance to a wide area. Construction includes aluminum or similar metal structure with acrylic or glass optics, wiring, and either ballast housing or remote ballast. These fixtures are generally yoke-mounted on building surfaces or on the ground to supplement area/parking lot fixtures. Typical applications include parking lots, recreation areas, building facades, monuments, airports and docks. Wattage range varies from 70 W to 1000 W.

Lithonia TFL, Source: Lithonia Lighting

Figure 3.3.9 Example of Floodlight Metal Halide Lamp Fixture

Parking Garage

Parking Garage fixtures are designed to light ramps and parking areas of parking structures. Construction includes aluminum or similar metal structure with acrylic or glass optics, wiring, and ballast housing. These fixtures can be surface-mounted or slightly suspended. Due to parking structures' typical ceilings heights of less than 12 feet, these fixtures are limited to lamps rated at or less than 500 W.

Lithonia PGR, Source: Lithonia Lighting

Figure 3.3.10 Example of Parking Garage Metal Halide Lamp Fixture

Post-Top

Post-top fixtures are designed to be mounted directly on top of light posts and to provide general lighting. Unlike other fixtures that typically hang from ceilings or are installed on arms protruding from poles, post-top fixtures are installed directly on top of poles. Construction includes aluminum, sheet metal, or similar metal structure with acrylic or glass optics, wiring, and ballast housing. These fixtures have been associated with Dark Skies initiatives'[e] noncompliant fixtures because of their inherently poor fixture efficiency. Typical applications include streets, sidewalks, and parks.

Lithonia TCL, Source: Lithonia Lighting

Figure 3.3.11 Example of Post-Top Metal Halide Lamp Fixture

Sports Lighting

Sports lighting fixtures are designed to provide necessary lighting for sporting venues. For light-weight construction, these fixtures are made of either aluminum or light-weight sheet metal with acrylic optics. They include wiring and are typically remote ballasted. Because of the application, these fixtures are typically mounted in groups of 20 or more fixtures for maximum area coverage and light intensity. Additionally, because of the significant mounting heights and necessary light intensity, wattage is typically in the 1000 W range or higher.

Lithonia TSP, Source: Lithonia Lighting

Figure 3.3.12 Example of Sports Lighting Metal Halide Lamp Fixture

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[e] Initiatives following The International Dark-Sky Association's (IDA) movement to limit light pollution.

Wallpack

Wallpack fixtures are designed to be a self-contained fixture mounted to vertical wall surfaces. Construction includes aluminum, sheet metal, or similar metal structure with acrylic or glass optics, wiring, and ballast housing. With inherently poor fixture efficiency, wallpacks direct light downwards but most of the time end up spraying light out as glare. Typical applications include building walls lining parking lots, parking structures, or any other outdoor building walls were directional lighting is not necessary. Typical power rating is 150 W.

Lithonia TWP Wall Pack, Source Lithonia Lighting

Figure 3.3.13 Example of Wallpack Metal Halide Lamp Fixture

3.3.1.4 Energy Related Fixture Options

Lighting Controls

Generally, light sources are equipped with lighting controls for aesthetic or energy management control to comply with ASHRAE/IESNA 90.1 and other energy codes. MHLF lighting control technologies to conserve energy include: switching devices, timing and sensing devices, and dimming controllers.

Switching Devices: Switching decreases energy consumption by limiting the number of operating hours to only the times when light is needed. Although increasing switching frequency increases re-lamping costs, the energy savings associated with decreasing operation hours outweighs the new fixture costs. *Electric Power Research Institute* (*EPRI) Controls Pattern Book* analyzed the trade-offs between increased costs and amount of energy saved, and concluded that energy cost reductions surpasses the costs of re-lamping by six to more than 20 times.[f] Additionally, time delays, discussed later, can be incorporated into the system to optimizing the switching schedule.

Because metal halide lamps have extended warm-up periods and can take up to several minutes to restrike after having been extinguished, two-level systems (also called bi-level, stepped, or hi-lo systems) are used so that the lamp remains warm, ensuring quick transition from low to full light. Bi-level switching can lead up to 10 percent energy savings in retail

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[f] *EPRI Controls Pattern Book*, Rundquist, McDougal, et al, 1996.

applications. Specific fixtures with two-lamp tandem wired ballasts and circuit switch legs or multistep ballasts are capable of multilevel lighting controls.[12] Multistep ballasts are used to step down the lamps in a fixture, eliminating uneven appearance by reducing lumen output of all of the lamps without the need to switch any off. Multilevel ballasts provide the ability to be switched between two or more illuminances at a low cost, but do not provide controlled dimming. Multilevel ballasts that change illuminance in steps, and switching systems in general, are most practical in warehouses, parking garages, tunnels, and daylighting applications.

Timing and Sensing Devices: Timing and sensing devices are meant to control lighting in response to known or, as previously mentioned, scheduled sequences of events (*i.e.*, to turn off lights when they are not needed.) Time delays often work in conjunction with sensing devices to determine the interval between the last detected motion and the switching off of the fixtures. Some products have fixed settings, while most have adjustable time delay settings. Timing devices are also coupled with override functions to accommodate deviations from schedules and may be coupled with microprocessors that can control multiple events and lighting effects.[13]

Photosensors, a type of sensing device, use electronic components that transform visible radiation, or light, into an electrical signal that is then used to control another system or lamp. Photosensors are typically used to detect when an outdoor lamp should be turned on and off.[14] These sensors are either immune to or filtered from ultraviolet (UV) or infrared (IR) radiation. Photosensors are either in an open- or closed-loop system. An open-loop system is one in which the photocell responds only to daylight levels, but is still calibrated to the desired light level received elsewhere, such as on the floor of the warehouse. Most frequently, open-loop photosensors are used in warehouse high rack areas, where the lighting levels must be calibrated separately from photosensors in open areas.[15]

The alternative to photosensors is occupancy, or motion sensors. Occupancy sensors are meant to automatically switch off fixtures when spaces are unoccupied, and to switch fixtures on when they are occupied or light is needed. Electrical consumption is reduced by cutting the number of operating hours. These sensors take advantage of incomplete occupancy loads during periods of peak electric use. Occupancy can be sensed by audio, ultrasonic, passive infrared, or optical means. Most occupancy sensors used in commercial applications use passive IR or ultrasonic motion-sensing technologies. Passive IR occupancy sensors respond to the movement of IR sources using a pyroelectric detector located behind an IR-transmitting lens. Ultrasonic occupancy sensors transmit pressure waves at an inaudible frequency to detect motion within the space. Energy savings are earned when the sensitivity of the occupancy sensor and time delay are specifically calibrated to operate effectively for an area.

Dimming Controllers: Dimmers are resistors that rapidly shut the electrical circuit in a fixture on and off, ultimately reducing the wattage and lumen output of the lamps. Special magnetic or electronic dimming ballasts are required for metal halide lamp fixtures. These ballasts can be dimmed down to 10 or 20 percent of the maximum light output. However, unlike fluorescent dimming ballasts, metal halide dimming ballasts typically lose significant luminous efficacy after the lumen output drops to around 30 percent of maximum output.[g] Although the efficacy levels may depreciate after significant dimming, commercial dimming still offers

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[g] Heschong Mahone Group

significant lifetime savings over systems without dimming options. Average energy savings from dimming in typical 1200 W commercial loads can be up to 20 percent.[16] Additionally, certain dimming ballasts can be located away from the control panel by transmitting their individually coded identification number for special IR remotes or wall box controllers, leading to potential energy savings.

Emergency and Standby Circuitry

There are many regulations covering and defining emergency lighting; these specifications include UL standards, national safety requirements (such as The National Fire Protection Agency's Life Safety Code (NFPA 101) Articles 7.8 and 7.9, NFPA 70 (National Electrical Code; NEC), and Occupational Safety and Health Administration (OSHA) regulations) and building codes (such as the Uniform Building Code (UBC), the International Building Code (IBC), state, and local codes). While these regulations do not contain rules specifically for metal halide lamp fixtures, sometimes a fixture's added emergency lighting utility will be necessary to have its location meet standards. Metal halide lamp fixtures have options for emergency lighting, required standby systems, and optional standby systems that provide the needed illumination while limiting the use of backup energy.

Emergency Circuit Module: Some metal halide lamp fixtures incorporate an optional emergency circuit module (hereafter "ECM"). The ECM operates and controls an additional lamp that is part of the fixture, but not wired to the ballast. This backup lamp, typically incandescent or halogen, is wired by a separate circuit to the emergency power source of the application (*e.g.*, a building's backup generator). In the case of a power outage, the ECM turns on the extra lamp to provide illumination while using only a minimal amount of power (*e.g.*, backup lamps commonly use between 100 to 250 W).

Auxiliary Lamp Module: Some metal halide lamp fixtures incorporate an optional auxiliary lamp module (hereafter "ALM") to comply with optional standby lighting system regulation. The ALM operates and controls an additional lamp wired through a dedicated (usually 120 V) tap from the ballast. This backup lamp, typically incandescent or halogen, provides temporary low-level illumination in the event of a momentary power interruption until the metal halide lamp restrikes. Additionally, the ALM is activated in case of lamp failure.

3.3.2 Basic Structure of Metal Halide Lamps

A standard metal halide lamp comprises an arc tube, a bulb (or outer jacket), electrical connections, and a base. The arc tube, commonly made of quartz or sintered alumina, is the light-producing portion of the lamp. As in the older MV lamps, the metal halide arc tube is filled with a pressurized mixture of mercury vapor and noble gases (commonly argon). Unlike the MV lamps, metal halide lamps contain metal halide salts that radiate at different frequencies when ionized. The specific elements involved vary by application and type of light desired, and help produce a fuller spectrum and better coloring rendering relative to MV lamps.

The arc tube is surrounded by an outer bulb that protects the inner components, provides a structure for mounting them, and retains heat and ultraviolet radiation. In lamps rated for use in "open fixtures," the arc tube is surrounded by an additional glass shroud that protects the outer jacket in the event of an arc tube explosion. Lamps may be single-ended (*e.g.*, screw-type or bayonet-type lamps) or double-ended (*i.e.*, requiring electrical connection at both ends of the outer bulb).

Like other gas discharge lamps, metal halide lamps exhibit negative differential resistance. Because their resistance declines with increasing current, they are unable to regulate their own current and require ballasts to operate. When cold, however, the gas resistance is relatively high and the ballast's operating voltage is not usually enough to establish an arc. To overcome this problem, two primary starting methods are used: probe and pulse.

In a probe-start lamp, there is a third, starting electrode present in the arc tube. The starting electrode is closer to the opposite side of the lamp than the operating electrode and requires less voltage to overcome the cold gas's resistance. Once an arc is struck, a bimetal switch heats and removes the starting electrode from the circuit, allowing the operating electrode to take over. The addition of a third electrode and moving parts can make probe-start lamps less consistent over their lifetimes in color and lumen output than their pulse-start cousins, and the industry has begun to move away from probe-start lamps.

In a pulse-start lamp, there are only two electrodes. The pulse-start ballast strikes an arc by generating a high voltage pulse (typically several kilovolts (kV)) using a special circuit called an "igniter." This simpler, more reliable lamp comes at the cost of a more complex ballast. Some manufacturers advertise a third starting method called resonant start, which uses electronic controls to more gradually build up to ignition voltage. DOE's understanding is that this method is closely related to pulse-start in that both use two electrodes and accomplish their function through higher voltage instead of a shortened arc length. In principle, igniters allow pulse-start and resonant-start lamps to operate at higher fill pressures, which can reduce electrode sputtering and extend lamp life.

Arc tubes for probe-start lamps are made of fused quartz, while pulse-start lamps are typically made of either fused quartz or sintered alumina. Quartz tubes typically use a white coating at their ends to reduce thermal losses. Alumina arc tubes, often called "ceramic," are less permeable to certain metal halide ions and, consequently, are thought to offer better color stability, color rendering, and luminous efficacy. Studies done by manufacturers have shown that it is difficult to operate ceramic metal halide (CMH) lamps at high frequencies because higher fill pressures tend to move destructive resonant modes upwards in the spectrum. Particularly at smaller bulb sizes, the frequencies required to avoid those resonant modes are often on the order of a megahertz (MHz) and can therefore produce electromagnetic interference (EMI). All commercially available CMH lamps operate at low (sub-resonant) frequencies, between 0 and 400 Hz.

An elliptically shaped outer bulb or envelope, usually made of borosilicate glass, contains the arc tube. The bulb protects and buffers the arc tube and internal electrical connections from the environment. The outer envelope contains low-pressure inert gas (*e.g.*, nitrogen) or a vacuum, which not only helps minimize the oxidation of internal components, but also provides a margin of safety against threat of arc tube rupture (also known as non-passive failure). The outer envelope also provides additional thermal buffering for a more stable arc temperature. The glass itself absorbs the majority of ultraviolet radiation.

Inside the outer bulb are conductors to supply the arc tube with electricity, and structural metal components to support it. There might be other, minor components also within the outer bulb, including resistors, diodes, and small tabs called “getters” that help absorb impurities. Like other HID lamps, metal halide lamps often have bases resistant to corrosion.

3.3.3 Metal Halide Ballast Overview

Metal halide ballasts are “devices that, by means of resistance, inductance, capacitance, or electronic elements, singly or in combination, control the current, voltage, and waveform for proper lamp starting and operation.” (American National Standards Institute (ANSI) C82.9-1996). The following sections discuss basic ballast operation of both ballast types: electromagnetic (magnetic) and electronic.

A ballast has three primary functions:

1. To establish an electric arc through the lamp
2. To limit current through the lamp after ignition
3. To compensate for variations in line voltage and ensure consistent lumen output

Magnetic ballasts were the first technology used to operate lamps; electronic ballasts were developed later because of their higher efficiency. Section 3.3.4 provides additional discussion on these and other technology options that can be used to increase the efficiency of metal halide ballasts.

There are many performance parameters used to describe the operation of a metal halide ballast. These include ballast efficiency, starting method, power factor (PF), total harmonic distortion (THD), and EMI. These performance parameters are briefly discussed in the following sections.

3.3.3.1 Ballast Efficiency

Although the metal halide lamp test procedure requires a reference lamp for the test setup, metal halide ballast efficiency is a purely electrical metric and requires no photometric measurements. Ballast efficiency is measured in accordance with section 6.0 of ANSI C82.6, and equal to the ratio of lamp input power to ballast input power.

3.3.3.2 Starting Method

Metal halide ballasts can be categorized by the manner in which they operate the lamp, or more specifically, how the lamp is started. Metal halide lamps require a lower voltage to start than to operate. Before starting, the non-ionized lamp compounds present a relatively high impedance that the ballast must overcome. As the arc is struck, the lamp gases ionize to form a plasma whose impedance decreases with increasing current. As previously stated, ballasts commonly use two different starting methods: probe-start and pulse-start. Starting method can affect efficacy, color rendition, restrike time, and lumen depreciation.

Pulse-start lamps, as mentioned in section 3.3.2, have two electrodes that are used to both start and operate the lamp. The ballast alone is unable to supply a breakdown voltage and requires a separate component called an “igniter” to provide the arc-establishing voltage pulse. In magnetic ballasts, there is an obvious physical distinction between the igniter and the “run” section of the ballast; in electronic ballasts the separation is less evident. Furthermore, an igniter allows an extinguished lamp to be re-ignited well before the gas has cooled to temperatures at which a probe-start ballast could restrike the arc.

Probe-start ballasts overcome the cold gas’ breakdown voltage through use of a third, starting electrode. The starting electrode is longer and allows an arc to be struck with a lower voltage. As the lamp runs and heats, a bimetal switch disconnects the starting electrode, and the primary, running electrode takes over. Even with the starting electrode, however, probe-start lamps cannot be pressurized to the more efficient levels that pulse-start lamps are. The extra electrode introduces one more possible source of contamination, affecting lamp life and color rendition. EISA 2007 required probe-start ballasts to be 94 percent efficient, effectively relegating them to uncovered wattage ranges.

Resonant starting is exclusive to electronic ballasts. Although some resonant-start ballasts are designed to work in conjunction with specific lamps, most operate with ordinary pulse-start lamps. While pulse-starting strikes an arc using a high voltage pulse (or pulse train), resonant starting delivers alternating current at one of the lamp’s resonant modes, rapidly building voltage until gas breakdown occurs. In addition to potentially being gentler on the lamp, resonant starting might not require specialized, pulse-creating hardware. Resonant starting has its hazards, however, especially in hot restrike situations where the gas impedance is higher than usual. The arc is more difficult to strike, allowing voltage to build to the point where components of the system sustain damage. Resonant starting is less standardized than pulse-start and can be reliably employed only in certain lamp/ballast combinations.

Manufacturers have marketed pulse-starting as an energy-saving technology in metal halide lighting. DOE’s current understanding is that the primary advantage to pulse-starting comes in increased lamp efficacy, rather than better electrical efficiency in the ballast itself. Nonetheless, the ability to operate a more-efficacious pulse-start lamp is a feature that DOE believes could result in significant energy savings. As a result, DOE is considering a design standard that encourages pulse-starting, discussed in chapter 5 of the NOPR TSD.

3.3.3.3 Power Factor

PF is equal to the ratio of the active power to the apparent power. PF depends on the current’s wave shape as well as the phase angle between the current and the voltage. The power input is measured with a wattmeter capable of indicating the average power in watts. The ballast input voltage multiplied by the ballast input current is the ballast’s apparent power (ANSI C82.13-2002).

$$Power\ Factor = \frac{Power\ Input}{Ballast\ Input\ Voltage * Ballast\ Input\ Current}$$

Where:

$Power\ Factor$ = power factor

Power Input = input power in watts to ballast,
Ballast Input Voltage = voltage in volts to ballast, and
Ballast Input Current = input current in amps to ballast.

Power factors range between zero and one. A power factor of one indicates that the voltage and current waveforms are in phase; a power factor of zero indicates that voltage and current are 90 degrees out of phase and that no real power is being transferred. Metal halide ballasts can be characterized by two classes of power factor: high power factor (HPF) of 0.9 or greater and normal power factor (NPF) of 0.6 or greater. HPF ballasts use about one-half the current of NPF ballasts. For magnetic ballasts, the primary cause of low power factor is the inductance of the ballast transformers. It can be corrected with the addition of a suitable capacitance. In electronic ballasts, low power factor is due primarily to total harmonic distortion (defined in the following section 3.3.3.4) caused by a nonlinear load. According to ANSI C82.77-2002, commercial metal halide ballasts must have a HPF, while residential ballasts (with an input power less than 120 W) must have a power factor of 0.5 or greater.

3.3.3.4 Total Harmonic Distortion

Another important performance parameter is harmonic distortion. Line current harmonics are the components of the line current that oscillate at integer multiples of the fundamental frequency of the power supply (*e.g.*, 60 Hz, 120 Hz, 180 Hz). Harmonics of a fundamental frequency are an undesirable byproduct of any nonlinear system operation, generating noise and wasted power. Total harmonic distortion refers to the ratio of the root mean square (rms) values of the harmonic content and of the fundamental current, expressed as a percentage. It may also be called harmonic factor:

$$THD(fund) = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \dots}}{\sqrt{I_1^2}}$$

Where:

$THD =$ total harmonic distortion, and
$I_n =$ the rms current of harmonic *n*, where n=1 is the fundamental harmonic.

High THD values are not acceptable and are detrimental to many kinds of electronic devices connected to the power line. They are also considered a "pollutant" to the environment because of radio frequency noise. In related electronic fluorescent lamp ballast products, ANSI C82.11-2002 requires that the THD not exceed 32 percent. Metal halide ballast manufacturers also try to limit the THD of their products to reduce compatibility concerns with nearby devices.

3.3.3.5 Ballast Factor

In contrast with other forms of lighting, metal halide lighting is not usually understood in terms of ballast factor, a measure of relative light output.

3.3.3.6 Electromagnetic Interference

Many devices found in office environments, such as computers, photocopiers, facsimile machines, and HID lighting systems, can generate electromagnetic waves. The effects of these waves vary based on their strength and the susceptibility of nearby equipment. Alternating current (AC) in electronic devices produces a magnetic field, which in turn induces an AC voltage in a nearby electronic device. This process is considered EMI if it interferes with the operation of a device. EMI takes two forms: conducted or radiated. Conducted EMI occurs when electronic devices induce currents in the local power network that in turn negatively affect other devices on that network. Radiated EMI is associated with the electric and magnetic field inherent in electronic devices. EMI can be minimized with proper grounding and wiring techniques.[17] EMI limits for both consumer and non-consumer lighting products sold in the United States are listed in 47 CFR 18 subpart C. These regulations require that consumer/residential (Class B) ballasts have lower maximum EMI requirements than non-consumer (Class A) products. The International Committee on Radio Interference has more stringent regulations concerning EMI.

3.3.3.7 Transient Susceptibility

Metal halide lamp fixtures are frequently used in applications that have the potential for voltage spikes and surges caused by lightning strikes, switching contacts, and inductive loads. These transients pose a serious threat to ballast operation. While magnetic ballasts are somewhat rugged and can withstand 15 to 20 kV, electronic ballasts are more susceptible to drastic changes in voltage and generally cannot withstand a transient greater than 6 kV. In both cases, the ballasts can be protected by arrestors that either run the interference into the ground or absorb the excess flow of current. Such measures are incredibly important for electronic ballasts; the preferred arrestor technology to protect the ballast against transients is silicon oxide varistors (SOVs).[h] SOVs consist of a pair of metal electrodes separated by a silicon oxide compound. Under normal conditions, the silicon oxide is a good insulator so that no line current flows between the electrodes to ground. When an excessively high voltage occurs on the electrodes, the high energy electrical field ionizes the silicon oxide. Since the silicon ion is a good conductor, the high energy current is conducted to ground. When the voltage falls toward normal, the silicon and oxygen ions recombine, forming silicon oxide and shutting off the conduction. Electronic metal halide ballasts require approximately 10 kV surge suppressors in order to be installed safely in most outdoor applications.

3.3.3.8 Fitted Form

Magnetic and electronic ballasts come in a variety of form factors to accommodate different applications. Although electronic ballasts have been well miniaturized for low-wattage, indoor applications (*e.g.*, track lighting), thermal requirements make volume reduction difficult at higher wattages. While electronic ballasts tend to be monolithic, magnetic ballasts often have two or more pieces that can be arranged within a given fixture. Furthermore, electronic ballasts might require special mounting within a fixture for heat sinking. Nonetheless, some manufacturers have begun to market electronic ballasts that are “drop-in” replacements for magnetic units.

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[h] A similar function can be performed by metal oxide varistors (MOVs).

3.3.3.9 Dimming

Dimming, or the practice of intentionally operating a lamp at less than its rated output, holds enormous energy saving potential. In many lighting applications, it is important to have the ability to quickly summon full output, but less important to have it all the time. Examples of this might be roadways with infrequent traffic, daylight-harvesting buildings, untraveled warehouse aisles, and vacant parks. In certain applications, dimming may be a cost-effective path toward energy savings. A ballast dimmed to 50 percent input power half of the time would, mathematically, consume 25 percent less energy than that same ballast operated always at full output. Depending on the marginal cost of adding dimming capability, it might be far less expensive than purchasing a ballast that were natively 25 percent more efficient (if such a ballast were even available). Dimming has been successfully used to save energy in a variety of lighting technologies.

Dimming metal halide lamps, however, is not without its challenges. Lamps are designed to stabilize at a certain temperature, of which light color and lamp life are a function. As color temperature and color rendering index (CRI) are often reasons for choosing metal halide lighting over competing technologies, some applications will find color shift unacceptable. Furthermore, many lamp manufacturers recommend that their lamps be dimmed to not lower than 50 percent of rated power. While this may be a good step toward saving energy, it may be inadequate for aesthetic or “mood” lighting. Although electronic ballasts can usually dim continuously from full to minimum output and back, magnetic ballasts are usually constrained to stepped dimming, oftentimes only between full and half power. Finally, while the cost of a dimming ballast might not far exceed that of a non-dimming ballast, costs of hardware needed to regulate the dimming (*e.g.*, photosensors, radio receivers, relays, wiring) could be considerable.

Electronic and magnetic ballasts accomplished dimming in different, but analogous, ways. Because many electrical components have properties that vary with frequency, operating power transistors at higher or lower frequencies is a convenient way to limit power transfer to the lamp. Although magnetic ballasts have no ability to modulate frequency, they will change the electrical properties of their circuits in different ways. Constant-wattage autotransformer ballasts (discussed further in section 3.3.4.1) might use a bi-level capacitor, for example, switched by a relay between the two capacitances.

3.3.3.10 Magnetic Ballasts

Metal halide magnetic ballast technology is older than electronic ballast technology, and used today for its low cost and tolerance of harsh environments. The primary feature of a magnetic ballast is one or more coils of magnet wire around an iron core; because of this they are often called “core-and coil” ballasts. Apart from the igniter of pulse-start ballasts, magnetic ballasts contain no power electronics and are, therefore, better equipped to survive voltage transients and high temperatures.

The main components of a magnetic ballast are a magnetic choke to limit the current, a step-up transformer to obtain a high starting voltage, and a capacitor that corrects for the ballast’s low power factor. Magnetic ballasts operate at an input frequency of 60 Hz and operate the lamp(s) at the same frequency.

The main core and coil assembly consists of a capacitor and laminated transformer steel wound with copper or aluminum magnet wire. The assembly is infused with a potting material (*e.g.*, hot asphalt, epoxy) containing fiber such as silica and housed in a steel case. Figure 3.3.14 presents a view of a typical core and coil assembly.

Source: GE Lighting

Figure 3.3.14 Core and Coil Assembly of a Magnetic Ballast

The core and coil assembly functions as a voltage transformer and current limiter (choke). A capacitor enables the ballast to use energy from the alternating-current power line more efficiently; the ballast is then referred to as a HPF or PF corrected ballast. The purpose of the insulating material is to conduct heat away from the transformer coils and ensure tightness of the transformer coils to eliminate vibration noise.

Particularly at lower wattages, magnetic ballasts are less energy efficient than electronic ballasts. Magnetic ballasts fail to optimize lumen output for a given wattage. These ballasts also release energy not used to operate the lamp as heat in the transformer windings. In order of increasing cost and complexity, metal halide lamp magnetic ballasts have the following types of circuits: linear reactor (reactor), high-reactance autotransformer (HX-HPF), constant-wattage autotransformer (CWA), constant-wattage isolated (CWI), and magnetically regulated lag (mag-reg or regulated lag). In general, extra circuitry helps the ballast maintain a constant power output through variations in input voltage.

Linear Reactor

Reactor ballasts are the simplest, smallest, cheapest, and most efficient type of magnetic ballast. Though a capacitor is often employed for power factor correction (PFC), a reactor ballast can be as simple as a mere inductor in series with the load. A reactor ballast drops more voltage as current increases, stabilizing lamp current at the appropriate point. The major drawback of a reactor ballast is its susceptibility to line voltage variation; the commonly used ratio is a 5 percent voltage dip produces a greater than 10 percent power dip. Furthermore, the ballast has no ability to modify voltage, meaning the line voltage must be sufficient to run the lamp, often limiting reactor ballasts to 277 V applications.

High-Reactance Autotransformer

With high-reactance autotransformers, the addition of a capacitor to the primary circuit makes it possible for the ballast to provide a high power factor. The high power factor autotransformer is usually designed with an extra capacitor winding within its copper windings in order to provide a more economical and efficient system. The HX-HPF ballast's power factor can be increased to about 90 percent by combining the extended windings with the capacitor. The input current is reduced, as in the high power factor reactor. Lamp performance and regulation are also the same at plus or minus 5 percent. Currently, HX-HPF ballasts account for the majority of sales of magnetic ballasts rated at or less than 150 W.

Constant-Wattage Autotransformer

The CWA ballast type should be used where a stabilized light output is required. CWA is an HID ballast type that comes in a fairly small economical size, yet still provides a reasonable degree of regulation. The CWA ballast also offers the advantage of a high power factor, low line extinguishing voltage, and line starting currents that are lower than operating currents. The CWA type of ballast is the most commonly used ballast in North America today.

Unlike the HX-HPFs, which use a capacitor as a parallel component, the capacitor on a CWA ballast type is used in series with the lamp. This alignment provides the lamp with a more stable wattage when voltage on the branch circuit fluctuates. As the capacitor is performing an important ballasting function, it is referred to as a lead circuit. CWA is the most common ballast topology because of its ability to resist line voltage changes and for its lower starting current demands. Although some CWA units rated for lower than 150 W are sold, wattages higher than 150 W are firmly CWA territory.

Constant-Wattage Isolated Transformer

CWI ballasts are nearly identical to CWA ballasts in both structure and function, the primary difference being a conventional two-coil transformer in place of the single-coil autotransformer. At a very slight efficiency cost, CWI ballasts provide better protection against voltage transients, as the low and high sides of the ballast are coupled only magnetically. Though common in Canada, few CWI ballasts are sold in the United States.

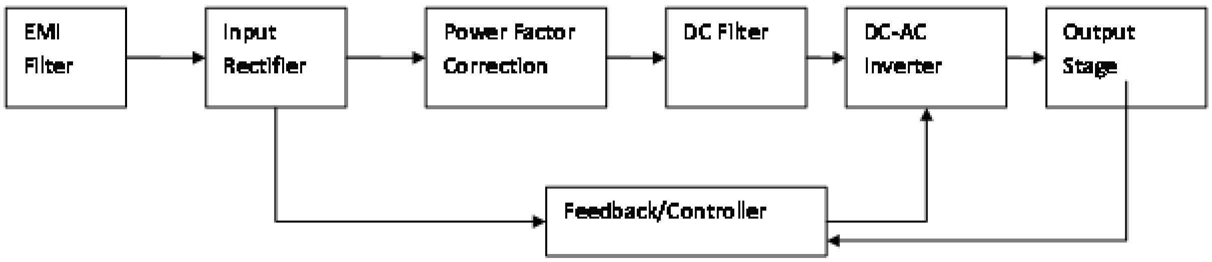
Magnetically Regulated Lag

Regulated lag ballasts are the largest, heaviest, and most expensive topology. Three distinct circuits collaborate to provide the greatest degree of resistance to voltage variation, and regulated lag ballasts may even sustain lamps through voltage drops of 30 percent. Regulated lag ballasts were exempted from standards in EISA 2007 and account for a very small (less than one percent) fraction of the North American ballast market. Due to their large size and high cost, regulated lag ballasts are unlikely to be substitutes for CWAs or other ballast types.

3.3.3.11 Electronic Ballasts

Depending on wattage, electronic ballasts might be between 2 and 20 percent more efficient than their magnetic counterparts. Electronic ballasts can be roughly divided into low-and high-frequency types that, respectively, operate lamps far below or above frequency ranges prone to acoustic resonance. Most low-frequency (LF) ballasts drive their lamps with a “square” wave, while high-frequency (HF) units usually produce sinusoids. Although HF units are thought by some to be more efficient because of smaller circuitry components and the elimination of a power processing stage from the ballast, metal halide efficiencies do not scale with frequency the same way fluorescent efficiencies do; high efficiency electronic ballasts can be found operating at both high- and low-frequencies.

Figure 3.3.15 presents a functional block diagram example of a fixed-light output electronic ballast. Auxiliary functions performed by a typical electronic ballast include EMI filtering to block ballast-generated noise, input rectification, PF correction for sinusoidal input current, a direct-current (DC) filter, a direct-current to alternating-current (DC-AC) inverter, a feedback/controller for high-frequency operation, and a final output stage to power the lamp.

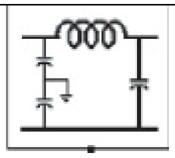
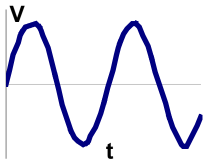


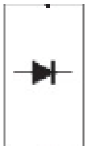
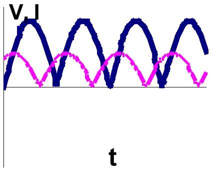
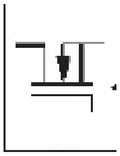
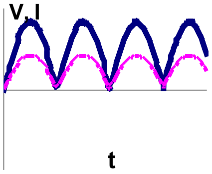
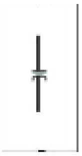
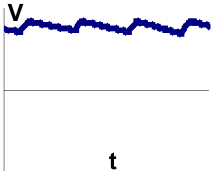
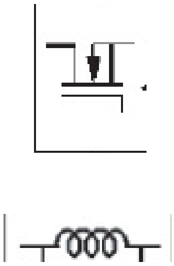
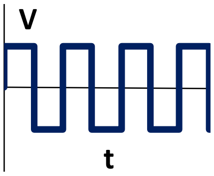
Source: T. Ribarich, A Systems Approach to Ballast IC Design*, El Segundo, CA, 1999, and Philips Semiconductor,* Power Semiconductor Applications*, 1994.*

Figure 3.3.15 Electronic Metal Halide Ballast Block Diagram

Figure 3.3.1 provides a description of each component in a typical electronic metal halide ballast, the efficiency impact of these components, and the waveform at each stage of the ballast circuit.

Table 3.6 Basic Building Blocks of a Metal Halide Ballast and Associated Characteristics

Circuit Stage	Function	Efficiency Impact	Waveform (not to scale)
 EMI Filter	Impedes EMI by providing a high impedance path to EMI and a low impedance path to the desired input. The circuit also protects against high voltage spikes.	Very Low	

 Input Rectifier	Begins to convert incoming AC to DC using diodes. A full-bridge rectifier, one type of input rectifier, is composed of four diodes, which "rectify" the full AC waveform as shown in the waveform on the right. The current is not in phase with the voltage.	Low	
 Power Factor Correction	Corrects the current so it is in phase with the voltage. Power factor correction can be achieved through a buck or boost-converter circuit topology.	Low-Medium	
 DC Filter	Reduces "ripple" of the DC current waveform using capacitors. The most common type of capacitor used is the electrolytic capacitor.	Low	
 DC-AC Inverter and Output Stage	Converts incoming DC to AC, sets the current to the lamp, and provides a high voltage pulse to start the lamp. The full-bridge (with integrated buck converter) circuit is one type of circuit topology that can be used to accomplish this task.	High	
Feedback/Controller	An integrated circuit (IC) that controls the frequency output of the DC-AC inverter. It can also protect against under voltage lockout and lamp faults.	Low	N/A

3.3.4 Metal Halide Ballast Technology Options

When analyzing equipment efficiency potential, DOE first identifies all of the different ways efficiency could be improved. These technology options are later evaluated on the basis of four statutorily prescribed criteria, after which the remaining selections are called design options. The following sections describe technology options for incrementally improving the efficiency of magnetic and electronic ballasts included in metal halide lamp fixtures.

3.3.4.1 Magnetic Ballasts

There are four main ways of reducing losses in magnetic ballasts: improving the core steel, using copper conductor, increasing the stack height, and increasing conductor cross-section.

Improved Core Steel

Electrical steel, placed in a time-variant magnetic field, loses energy in two ways. Eddy currents are small, unproductive currents that dissipate energy resistively, whereas hysteresis is a nonlinearity in the magnetization of a material in response to the magnetic field applied. Electrical steels are made in different grades that correspond to different losses. Inexpensive magnetic ballasts typically use non-oriented steel whose magnetic properties are isotropic. Higher grades of steel can be grain-oriented, where the microscopic structure of the material is optimized for a particular field direction, or amorphous, which has no grain structure at all and the most desirable magnetic properties.

Copper Conductor

Most inexpensive magnetic ballasts use aluminum conductor, which is more resistive than copper conductor of the same gauge. Because conductor losses vary in proportion to the resistance of the conductor, lowered resistance yields lower losses and higher ballast efficiency.

Increased Stack Height

Losses in electrical steel vary with magnetic flux density, with higher flux density yielding higher losses. For a given magnetic field, increasing core cross-section will lower flux density and, therefore, lower losses. Because steel laminations are said to be “stacked” to form a core, increasing core cross-section is ordinarily done by adding steel laminations, or increasing the stack height. However, adding steel also adds core losses in the form of eddy currents and hysteresis, and also requires a greater length of conductor, eventually offsetting decreased core losses from increased core cross-section.

Increased Conductor Cross-Section

The efficiency of a magnetic ballast could be increased with the use of increased conductor cross-sections in the windings of the magnetic choke and step-up transformer. This can be accomplished by both using larger wire gauges (*i.e.*, lower numeric values) and having multiple strands of wire operating in parallel. Using greater cross-sectional area in the magnetic component windings decreases the winding resistance and associated losses. Increased cross-sectional area in the windings could necessitate a longer core or additional layers of wire if the core length cannot be changed to maintain the same electromagnetic properties. This design option typically corresponds to an increase in manufacturing cost.

3.3.4.2 Electronic Ballasts

Electronic ballasts contain a wide variety of components and circuit types, leading to many paths to increased ballast efficiency. DOE organized these options into two categories, improved components and improved circuit designs. In addition, the use of electronic ballasts instead of magnetic ballasts is also a path to increased efficiency for many wattage ranges. Electronic ballasts use modern, solid-state components and circuits to perform the same function as magnetic ballasts with lower electrical losses.

Improved Components

A common way to increase the efficiency of electronic ballasts is to improve the quality of their components. Magnetics (transformers and inductors), diodes, capacitors, and transistors are the main components that affect efficiency.

Magnetics: In electronic ballasts, magnetics influence the efficiency of the EMI filtering, PFC, and output stage of the ballast. In magnetic ballasts, magnetic components influence the efficiency of the output stage and current-limiting portion of the ballast.

There are two loss mechanisms associated with magnetics: core losses and winding losses. Core losses involve the magnetic properties of the core material, which exhibits power losses in the form of hysteresis and eddy currents within the core itself. Winding losses come from the resistance in the winding, typically aluminum or copper. There are several technology options that can decrease magnetic component's core losses. These options include improved materials such as grain-orientated silicon steel and amorphous steel and increased core size. Litz wire can be used as a technology option to improve a magnetic component's winding losses.

Core losses in magnetic components can be decreased through four main methods. The material of the core can be varied. DOE has identified two types of core materials that ballasts can use: silicon steel (thinly laminated steel alloyed with silicon) and amorphous steel. Core performance of silicon steel can be enhanced by magnetically aligning the grain structure in the metal. To further increase the efficiency of the ballast using amorphous materials, one can create the core of the magnetic component from laminated sheets of amorphous steel, insulated from each other. However, this method can increase the size and weight of the ballast. Additionally, the magnetic component's core can be designed with a larger cross-section (increased stack height) to reduce core losses, though this method also increases the size and weight of the ballast.

Winding losses in magnetic components can be decreased via three main methods. Different materials have different resistive properties and can result in different winding losses. Aluminum is the most basic (least efficient) material currently used. Copper is more conductive, and with its gauge size optimized for wattage, voltage, and current specifications, and the number of windings increased, winding losses can decrease relative to aluminum. Litz wire has even lower losses as it consists of a number of individually insulated magnet wires twisted or braided into a uniform pattern. For high-frequency electronic ballasts, winding losses become more prominent through two additional loss mechanisms: skin effect and proximity effect. Skin effect refers to the tendency of AC current to flow through a conductor's surface or "skin" rather than a conductor's core. Proximity effect occurs when conductors are close together and the magnetic field of one conductor reduces the area that the current flows through in another conductor. Because litz wire increases the amount of surface area current can flow through, its use can reduce overall winding losses by decreasing the effective wire resistance. Winding losses can also be decreased within any material type by increasing the cross section of the wire used for the windings.

Diodes: In electronic ballasts, the input rectifier inverts the negative half of the AC sine wave and makes it positive. Several technology options can be used to improve the efficiency of this portion of the circuit. The power consumed by a diode is the product of the current flowing through the diode multiplied by the voltage drop across it. Conventional diodes have a voltage drop of about 0.6 V. Using Schottky diodes[i] could reduce the voltage drop across the diodes by about 0.3 V to 0.4 V.

Capacitors: In both magnetic and electronic ballasts, capacitors are used in the PFC and output stage of the circuit design. In electronic ballasts, capacitors are also used in the DC Filter stage of the electronic circuit. One way to improve the efficiency of each portion of the circuit is to use capacitors with low effective series resistance (ESR). Capacitors with a low ESR are also more reliable because they are cooler than capacitors with a higher ESR.

Transistors: In electronic ballasts, transistors are used in both the power factor correction and the DC-AC inverter portion of the circuit. The transistor dissipates energy due to its drain-to-source resistance (R_{DS_ON}) when the current flows through the transistor to the transformer. Using transistors with low R_{DS_ON} can reduce this loss. For example, the efficiency of electronic ballast's bipolar transistors can be improved by using metal-oxide-semiconductor field-effect transistors (MOSFETs), a transistor with a lower drain-to-source resistance. In addition, transistors with lower capacitance can reduce switching losses.

Improved Circuit Design

Another method of increasing the efficiency of electronic ballasts is to improve the ballast's circuit design. Examples of improved circuit design include integrated circuits (ICs) and improved starting method.

Integrated Circuits: In certain cases a ballast's efficiency can be improved by substituting ICs for discrete components. For example, some ballasts use bipolar transistors in a resonant half-bridge self-oscillating circuit to convert incoming DC to AC. The efficiency of this circuit can be improved by substituting the components in that circuit with an IC. Though the inclusion of ICs alone does not automatically increase efficiency, ICs allow for more advanced control of other components, which can lead to increased ballast efficiency.

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[i] A Schottky diode is a metal semiconductor diode with a smaller voltage drop than a conventional diode. Schottky diodes therefore consume less power.

3.4 EQUIPMENT CLASSES

When evaluating and establishing energy conservation standards, DOE divides the covered equipment into classes by the type of energy used, capacity, or other performance-related features that affect efficiency, as well as factors such as the utility of the equipment to users. (42 U.S.C. § 6295(q)) DOE then conducts its analysis and considers establishing or amending standards to provide separate standard levels for each equipment class. DOE applied the criteria of 42 U.S.C. § 6295(q) to metal halide lamp fixtures to develop equipment classes for this NOPR TSD. This section describes the equipment classes DOE proposed for this rulemaking.

In amending EPCA, EISA 2007 effectively set four equipment categories for metal halide lamp fixtures based upon the ballasts used and the wattage of the lamps in those fixtures. In prescribing initial energy conservation standards for metal halide lamp fixtures, the statute established minimum efficiency requirements for the metal halide ballasts contained in those fixtures. (42 U.S.C. § 6295(hh)(1)(A)) The current equipment categories for metal halide lamp fixtures are presented in Table 3.7.

Table 3.7 EPCA Equipment Categories Established by EISA 2007 for Metal Halide Lamp Fixtures (by Ballast Type and Lamp Wattage)

Ballast Type and Starting Method	Total Rated Lamp Watts
Pulse-Start	≥ 150 W and ≤ 500 W
Magnetic Probe-Start	≥ 150 W and ≤ 500 W
Non-Pulse-Start Electronic	≥ 150 W and ≤ 250 W
	> 250 W and ≤ 500 W

The equipment categories for metal halide lamp fixtures set forth in Table 3.7 are a composite of ballast type and lamp wattage. For pulse-start metal halide ballasts, EPCA does not distinguish by electronic configuration (magnetic or electronic), so fixtures with either type of pulse-start ballast would be subject to the statutory standards. Pulse-start, magnetic probe-start, and non-pulse-start electronic ballasts are considered separately, with two rated lamp wattage ranges identified for the latter, resulting in a total of four equipment categories. In addition, EISA 2007 exempts fixtures that contain certain ballasts, such as regulated lag ballasts and electronic ballasts that operate at only 480 volts.

In addition to the metal halide lamp fixtures identified in Table 3.7, the metal halide lamp fixture market includes fixtures that contain ballasts that operate low-wattage (*i.e.*, less than 150 W) and high-wattage (*i.e.*, greater than 500 W) lamps. DOE has also examined recent market trends. For example, pulse-start ballasts are gaining market share, whereas probe-start ballasts are becoming less popular and consequently, losing market share. This market shift accelerated in 2009. Based on review of catalog information of commercially available equipment, the standard levels (*i.e.*, the ballast efficiencies) established by EISA 2007 for metal halide lamp fixtures have essentially eliminated magnetic probe-start ballasts from the marketplace by requiring a ballast efficiency that is not currently attainable with electromagnetic ballast technology. Therefore, this trend is expected to continue. Due to market changes, and because

DOE is anticipating expanding its scope of energy conservation standards for metal halide lamp fixtures, DOE is considering amending the equipment classes for these fixtures and their associated ballasts. When determining equipment classes, DOE examines characteristics or features commonly found in commercially available equipment. For metal halide lamp fixtures, DOE examined several possible characteristics or features that could warrant separation into different equipment classes, including: (1) input voltage; (2) fixture application; (3) electronic configuration and circuit type; (4) lamp wattage; (5) number of lamps per ballasts; and (6) starting method. Each of the listed characteristics or features is discussed in the following sections.

3.4.1 Input Voltage

Through manufacturer interviews and further research of the market, DOE learned that the majority of available metal halide ballasts have the capability to operate at different voltages or have multiple voltage "taps" with different voltages for each tap. Multi-taps and multiple voltages benefit consumers and manufacturers by decreasing stock-keeping unit (SKU) count, allowing the operation of auxiliary equipment, and lowering costs by decreasing part counts and variations of ballasts. DOE's test results for ballast efficiency showed that although voltage can correlate weakly to efficiency, there is no prevailing relationship (*e.g.*, higher voltages are not always more efficient) across ballast designs. However, DOE did examine the > 300 V category (using 480 V ballasts as a proxy) to more fully understand this subgroup.

To study the impact of the ability to operate at 480 V, DOE first compared quad-input-voltage ballasts (ballasts able to operate at 120, 208, 240, and 277 V) and dedicated 480 V units. DOE found that the quad-input-voltage ballasts were, on average, 1.2 percent more efficient. DOE also compared quad- and quint-input-voltage ballasts (ballasts that are able to operate at 120, 208, 240, 277, and 480 V). DOE found that the quad-input-voltage ballasts were, on average, 0.4 percent more efficient.

Because dedicated 480 V ballasts have a distinct utility and a difference in efficiency relative to ballasts tested at 120 V and 277 V, DOE proposed separate equipment classes for ballasts tested at 480 V (in accordance with the test procedure). These would include dedicated 480 V ballasts and any ballasts which are capable of being operated at 480 V, but incapable of being operated at the input voltage specified by the test procedure (either 120 V or 277 V, depending on lamp wattage).

3.4.2 Fixture Application

DOE has preliminarily determined to set energy conservation standards based on a ballast efficiency metric. DOE's research has determined that the same efficiencies can be achieved in all applications (including outdoor and indoor) by the same or similar products. DOE also found that electronic ballasts have been successfully applied to a variety of both indoor and outdoor applications where temperature and other limiting conditions could hinder their implementation. DOE acknowledges, however, that there is currently a market reluctance to use electronic metal halide ballasts in outdoor applications, particularly due to concerns with the electronic ballast's ability to withstand voltage transients.

Regardless, DOE has found it is technologically feasible to address these concerns either with internal transient protection to the ballast using MOVs in conjunction with other inductors and capacitors or with an external surge protection device. DOE understands that this added protection also adds an incremental cost to the magnetic ballast or magnetically ballasted fixture, and has addressed these costs in chapter 5 of the NOPR TSD. DOE has determined that transient protection needed for outdoor applications and 120 V auxiliary power functionality needed for indoor applications leads to different overall fixture cost-efficiency relationships. Based on the difference in utility and the cost-efficiency relationship, DOE believes separate equipment classes are justified for indoor and outdoor fixtures. DOE proposes outdoor fixtures be defined as rated for use in wet locations and having 10 kV of transient voltage protection. DOE proposes to define the wet location rating as labeled for use in wet locations as specified by the National Electrical Code 2011, section 410.10(A)[j] or UL 1598 Wet Location Listed.[k] According to the ANSI C136.2-2004 standard for outdoor transient protection, outdoor fixtures must be rated to withstand a 10 kV pulse. DOE proposes to use this 10 kV voltage pulse withstand requirement from ANSI C136.2-2004 as a characteristic unique to outdoor fixtures. Thus, fixtures that do not meet both the NFPA 70 definition of rated for wet locations and the ANSI C136.2-2004 requirement of 10 kV voltage transient protection will be defined as indoor fixtures.

3.4.3 Electronic Configuration and Circuit Type

As previously discussed, metal halide ballasts have two distinct types of electronic configuration: electronic and magnetic. The more commonly used magnetic ballasts are typically composed of transformer-like copper windings on a steel or iron core. The newer and more efficient electronic ballasts rely on electronic filters, switches, and capacitors/inductors to control current and voltage to the lamp.

In metal halide lamp fixtures, electronic ballasts can be used to achieve higher efficiency than magnetic ballasts. In the current metal halide lamp fixtures market, electronic ballasts are direct replacements for magnetic ballasts for most lower to medium-wattage applications (up to 500 W). DOE's review of manufacturer catalogs shows that at higher wattages, few electronic ballasts are available due to the significantly higher cost of components. For electronic ballasts, the only difference in circuit type is either "high" or "low" frequency circuit type. Due to acoustic resonance issues and electromagnetic interference effects, ballast frequencies above 300 Hz become difficult to manufacture and have difficulty complying with Federal Communications Commission (FCC) standards.[l] For low-frequency electronic ballasts, a square current waveform is used to diminish acoustic resonance and maintain lamp life.

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[j] According to NEC2011, luminaires installed in wet or damp locations shall be installed such that water cannot enter or accumulate in wiring components, lampholders, or other electrical parts. All luminaires installed in wet locations shall be marked, "Suitable for Wet Locations." All luminaires installed in damp locations shall be marked "Suitable for Wet locations" or "Suitable for Damp Locations."

[k] According to UL Standard Publication 1598, a wet location is one in which water or other liquid can drip, splash, or flow on or against electrical equipment. A wet location luminaire shall be constructed to prevent the accumulation of water on live parts, electrical components, or conductors not identified for use in contact with water. A luminaire that permits water to enter the luminaire shall be provided with a drain hole.

[l] FCC regulations at 47 CFR part 18, subpart C set forth technical standards for industrial, scientific, and medical equipment that specify frequency bands and ranges tolerances as well as electromagnetic fields strength limits. Some metal halide ballasts may be covered under these "industrial, scientific, and medical (ISM) equipment"

EISA 2007 distinguishes non-pulse-start electronic equipment classes by separating them into two rated lamp wattage ranges (≥150 W and ≤250 W, and >250 W and ≤500 W). According to DOE's review of manufacturer catalogs and information provided by manufacturers during interviews, non-pulse-start electronic metal halide ballasts are not available in the market. While EISA 2007 provisions may have been intended to capture alternative technologies that could be available in the near term, DOE has no information that indicates differences in efficiency or consumer utility based on pulse versus non-pulse-start ballasts. Therefore, DOE does not believe equipment classes should be divided by electronic configuration.

Magnetic metal halide ballasts are available in the market in several circuit types including high-reactance autotransformer, CWI transformer, CWA, linear reactor (reactor), and magnetically regulated lag (regulated lag or mag-reg) ballasts. Each magnetic circuit type listed has different characteristics that could have separate applications. These characteristics include size, efficiency, and power regulation. Each of these characteristics is discussed in section 3.3.4.1. For example, magnetically regulated lag ballasts are typically the largest and heaviest circuit type, but provide the greatest degree of resistance to input voltage variation (which sustains light output). Overall, magnetic ballasts provide much greater resistance to high temperature and voltage transients. DOE recognizes the technological differences between magnetic and electronic ballasts and has incorporated the cost of additional devices or modifications necessary for certain applications into its analysis. In chapter 5 of the NOPR TSD, DOE addresses impacts on manufacturers of a transition to electronic ballasts, but does not consider these impacts in development of equipment classes.

While it is true that consumers make purchasing decisions on electronic versus magnetic ballasts after consideration of several parameters not limited to efficiency, DOE's analysis has found that significant energy savings can be realized through a transition from magnetic to electronic ballasts. DOE continues to take the position that electronic configuration does not impact consumer utility and does not define equipment classes based on that factor.

3.4.4 Rated Lamp Wattage

Metal halide ballasts are available for lamps with rated wattages as low as 20 W and as high as 2000 W. As lamp wattage increases, lamp and ballast systems generally produce increasing amounts of light. Because certain applications require more light that others, wattage often varies depending on application. For example, low-wattage lamps are mainly used in commercial and some residential applications for general lighting purposes. Medium-wattage (*i.e.*, 150 W to 500 W) lamps are the most widely used and include warehouse, street, and general commercial lighting. High-wattage lamps are mainly used in searchlights, stadiums, stage applications, and other applications that require powerful white light. The wattage of the lamp and ballast system provides a consumer utility based on its impact on light output. DOE also determined that the wattage of the lamp and ballast system impacts the efficiency of the ballast. Generally, ballast efficiency increases with increasing power. For electronic ballasts, this efficiency gain can be attributed to the proportion of fixed losses to total losses. For low-wattage electronic ballasts, fixed losses contribute to a larger proportion of total losses than in a high-

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standards, which list the general operating conditions for ISM equipment. Ballasts designed to exceed 9 kHz ballast frequency have to be designed so that interference with transmitted radio frequencies is eliminated. 47 CFR 18.111.

wattage ballast. Magnetic ballasts are essentially transformers (sometimes with capacitors for power correction and igniters for pulse-starting) that are understood to have proportionally lower losses with increased wattage. Because wattage can affect both consumer utility (light output) and efficiency, DOE proposed to establish separate equipment classes on the basis of wattage.

EISA 2007 defines equipment classes with a single rated lamp wattage range (150 to 500 W) for both pulse-start and probe-start metal halide ballasts. For non-pulse-start metal halide ballasts, EISA 2007 separates equipment classes into two rated lamp wattage ranges (≤250 W and >250 W). For the framework document, DOE considered defining metal halide lamp fixture equipment classes by including additional lamp wattage ranges. DOE considered including (1) <150 W, (2) ≥150 W and ≤250 W, (3) >250 W and ≤500 W, and (4) >500 W as separate wattage bins to establish a separation of equipment classes.

DOE carried out additional analysis on the shipment volume and range of efficiencies available in a <150 W equipment class. DOE's efficiency test results for a ballast wattage representative of the low-wattage equipment class (70 W) confirmed that lower wattage ballasts have significant differences in efficiency depending on the technology (*i.e.*, electronic or magnetic ballast). In terms of shipment volume, manufacturers indicated during interviews that lower wattage shipments predominantly fall between 50 W and 150 W. DOE also determined that the ≥50 W and <150 W wattage range warranted additional division.

Efficiency varies more significantly for ballasts that operate 50 W to 150 W lamps than for the other wattage ranges considered. After analysis of specific wattages, DOE found the range of efficiencies available for 150 W ballasts supported more efficiency levels than for 70 W ballasts, suggesting the need for additional divisions in wattage. Based on catalog information and manufacturer interviews, DOE determined that 50 W and 100 W fixtures typically serve the same applications, while 150 W products begin to serve applications with increased light demand such as area or parking. Using this natural division in wattage based on application, DOE developed the equipment class ranges ≥50 W to ≤100 W and >100 W to <150 W.

Furthermore, as discussed in section 3.2.3.1, there is an existing EISA 2007 exemption for ballasts that are rated only for 150 W lamps, used in wet locations, and operate in ambient air temperatures higher than 50 °C. This exemption led to a difference between the commercially available efficiencies for ballasts exempted and those not exempted by EISA 2007. The exempted ballasts have a range of efficiencies more similar to wattages less than 150 W, rather than those greater than 150 W. By contrast, those ballasts not exempted by EISA 2007 have efficiencies more similar to ballasts greater than 150 W rather than less than 150 W. As a result, DOE is proposing 150 W fixtures previously exempted by EISA 2007 would be included in a >100 W and <150 W wattage range, while 150 W fixtures subject to EISA 2007 standards would be included in a ≥150 W to ≤250 W wattage range.

Additionally, when analyzing the >500 W wattage range, DOE's research indicated that there are a number of ballasts available for general lighting applications above 1000 W. The primary example of such applications is outdoor sports lighting. Lighting in sports stadiums and arenas commonly uses metal halide ballasts of 1000 W to 2000 W, and falls into DOE's definition of general illumination. Based on a review of product catalogs, DOE proposed capping the highest wattage bin at 2000 W. Ballasts and lamps operating at more than 2000 W were uncommon and served niche markets.

DOE chooses a representative unit in the engineering analysis (see chapter 5 of the NOPR TSD) to ensure technological feasibility of all product in the proposed classes. For today's rule, DOE is considering defining the metal halide lamp fixture equipment classes by the rated lamp wattage ranges ≥50 W to ≤100 W, >100 W to <150 W, ≥150 W to ≤250 W, >250 W to ≤500 W, and >500 W to ≤2000 W. DOE proposes that 150 W fixtures previously exempted by EISA 2007 would be included in the >100 W and <150 W wattage range, while 150 W fixtures subject to EISA 2007 standards would be included in the ≥150 W to ≤250 W wattage range.

3.4.5 Maximum Number of Lamps Operated

A review of manufacturer catalogs shows that while the vast majority of available ballasts only operate one lamp, a much smaller number are designed for two lamps. The limited catalog information available shows little to no change in efficiency between a one-lamp or two-lamp metal halide ballast. Thus, DOE does not establish separate equipment classes based on maximum number of lamps operated.

3.4.6 Lamp Starting Method

Metal halide ballasts currently available in the market are specifically designed to operate with either a probe-start or pulse-start lamp, but not both types of lamps at the same time.[m] The main differences between these types of starting methods is the inclusion of a third probe in probe-start lamps, the need for an igniter circuit for pulse-start lamps, and the different wiring specification for ballasts of each starting method. Most new applications in the market are pulse-start due to its inherently better efficacy.

DOE does not further divide equipment classes by the ballast starting method (*e.g.*, pulse-start or probe-start). Equipment classes should not be further divided by starting method because of the lack of difference in ballast efficiency and the ability to use either starting method in the same applications. To prevent violation of anti-backsliding provisions under EISA, DOE will maintain EISA minimum ballast efficiency requirements for fixtures with probe-start ballasts.

3.4.7 Equipment Classes Summary

Table 3.8 summarizes the metal halide lamp fixture equipment classes. DOE has developed wattage bins to account for a varying number of efficiency levels, different cost-efficiency relationships in the lower wattages, and the lack of general lighting applications for wattages higher than 2000 W. Additionally, each wattage bin is further divided into indoor and outdoor applications to account for the difference in consumer utility and the cost-efficiency relationships for these application types. Finally each of these classes is then subdivided by input voltage with one class for ballasts tested at 480 V (in accordance with test procedure), and the remaining ballasts in a separate class. Ballasts tested at 480 V would include dedicated 480 V ballasts and any ballasts which are capable of being operated at 480 V, but incapable of being operated at the input voltage specified by the test procedure (either 120 V or 277 V, depending

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[m] DOE is aware of some metal halide lamps that can be operated by a pulse-start or a probe-start ballast. These lamps are much less common than lamps designed to be operated by ballasts of only one starting method.

on lamp wattage). Due to limited information and lack of clear effect on utility or performance, DOE does not divide the equipment classes based on the other types of characteristics and features. Chapter 5 of this NOPR TSD provides detail on the selection of efficiency levels.

Table 3.8 Equipment Classes for Metal Halide Ballasts

Equipment Classes	Rated Lamp Wattage	Indoor/Outdoor[†]	Input Voltage Type[‡]
1	≥50 W and ≤100 W	Indoor	Tested at 480 V
2	≥50 W and ≤100 W	Indoor	All others
3	≥50 W and ≤100 W	Outdoor	Tested at 480 V
4	≥50 W and ≤100 W	Outdoor	All others
5	>100 W and <150 W*	Indoor	Tested at 480 V
6	>100 W and <150 W*	Indoor	All others
7	>100 W and <150 W*	Outdoor	Tested at 480 V
8	>100 W and <150 W*	Outdoor	All others
9	≥150 W** and ≤250 W	Indoor	Tested at 480 V
10	≥150 W** and ≤250 W	Indoor	All others
11	≥150 W** and ≤250 W	Outdoor	Tested at 480 V
12	≥150 W** and ≤250 W	Outdoor	All others
13	>250 W and ≤500 W	Indoor	Tested at 480 V
14	>250 W and ≤500 W	Indoor	All others
15	>250 W and ≤500 W	Outdoor	Tested at 480 V
16	>250 W and ≤500 W	Outdoor	All others
17	>500 W and ≤2000 W	Indoor	Tested at 480 V
18	>500 W and ≤2000 W	Indoor	All others
19	>500 W and ≤2000 W	Outdoor	Tested at 480 V
20	>500 W and ≤2000 W	Outdoor	All others

*Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

**Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

†DOE’s proposed definitions for “indoor” and “outdoor” metal halide lamp fixtures are described in section 3.4.2.
‡Input voltage for testing would be specified by the test procedure. Ballasts rated to operate lamps less than 150 W would be tested at 120 V, and ballasts rated to operate lamps ≥150 W would be tested at 277 V. Ballasts not designed to operate at either of these voltages would be tested at the highest voltage the ballast is designed to operate.

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[1] Ron Runkles. NEMA Premium Efficiency Electronic Ballast Program. *NEMA Lighting Systems Division*. 2007. (Last accessed July 19, 2013). <http://www.slideserve.com/macha/nema-premium-efficiency-electronic-ballast-program>.

[2] National Electrical Manufacturers Association. *Lighting Systems Division*. 2010. (Last accessed July 19, 2013). < http://www.nema.org/Products/Documents/lightingsystemsdivision.pdf >.

[3] U.S. Small Business Administration. *Table of Small Business Size Standards Matched to North American Industry Classification System Codes*. 2008. (Last accessed July 19, 2013). <http://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf>.

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[6] U.S. Environmental Protection Agency and U.S. Department of Energy. Residential Light Fixtures Key Product Criteria. (Last accessed July 19, 2012). <http://www.energystar.gov/index.cfm?c=fixtures.pr_crit_light_fixtures>.

[7] U.S. Environmental Protection Agency and U.S. Department of Energy. ENERGY STAR Lamps Draft 2 Version 1.0 Specification. 2012. (Last accessed July 19, 2012) < http://www.energystar.gov/index.cfm?c=new_specs.lamps>

[8] Northeast Energy Efficiency Partnerships. Commercial Buildings and Technology Initiative. (Last accessed March 24, 2011). <neep.org/regional-initiatives/1/56/Commercial-Buildings-and-Technology-Initiative>.

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[13] National Lighting Product Information Program, Specifier Reports: Occupancy Sensors, Volume 5 No. 1, May 1997.

[14] American Lighting Association, Energy Wise Information, (Last accessed August 16, 2010), <www.americanlightingassoc.com/info_energywise.php>.

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[16] *The Economics of Dimming*, Rowbottom, May 26, 2010.

[17] National Lighting Product Information Program. *Lighting Answers: Electromagnetic Interference Involving Fluorescent Lighting Systems*. 1995. (Last accessed March 24, 2011). <www.lrc.rpi.edu/programs/NLPIP/lightinganswers/pdf/view/LAEMI.pdf>.

CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the U.S. Department of Energy's (DOE's) screening analysis of the technology options identified for metal halide lamp fixtures (MHLF or "fixtures"). As discussed in chapter 3 of the technical support document (TSD), DOE consults with industry, technical experts, and other interested parties to develop a list of technology options for consideration. The purpose of the screening analysis is to determine which options to consider further and which to screen out.

Section 325(o)(2) of the Energy Policy and Conservation Act (EPCA) provides that any new or revised standard must be designed to achieve the maximum improvement in energy efficiency that is determined to be technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)) In view of the EPCA requirements appendix A to subpart C of title 10, Code of Federal Regulations (CFR), part 430 (10 CFR part 430), *Procedures, Interpretations, and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the Process Rule) sets forth procedures to guide DOE in its consideration and promulgation of new or revised energy conservation standards. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295(o) and, in part, eliminate problematic technologies early in the process of prescribing or amending an energy conservation standard. In particular, sections 4(b)(4) and 5(b) of the Process Rule provide guidance to DOE for determining which technology options are unsuitable for further consideration:

1. **Technological feasibility.** DOE will consider technologies incorporated in commercial products or in working prototypes to be technologically feasible.

2. **Practicability to manufacture, install, and service.** If mass production and reliable installation and servicing of a technology in commercial products could be achieved on the scale necessary to serve the relevant market at the time the standard comes into effect, then DOE will consider that technology practicable to manufacture, install, and service.

3. **Adverse impacts on product utility or product availability.** If DOE determines a technology would have significant adverse impact on the utility of the product to significant subgroups of consumers, or would result in the unavailability of any covered product type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not consider this technology further.

4. **Adverse impacts on health or safety.** If DOE determines that a technology will have significant adverse impacts on health or safety, it will not consider this technology further.

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

Several well-established engineering practices and techniques exist for improving the efficiency of a metal halide ballast. Improving the construction materials (*e.g.*, core steel, conductor) and modifying the ballast's geometry (*i.e.*, the stack height and conductor gauge) can make a ballast more energy efficient. Increasing core cross-section, for instance, can reduce core losses but requires a greater length of conductor to encircle the larger core and thus increases resistive losses. In electronic ballasts, substituting for higher grade components (*e.g.*, capacitor) or improving the circuit type can also increase efficiency by reducing conduction and switching losses. It takes a great degree of engineering skill to maximize the efficiency gains in the overall design, and there are multiple pathways to achieve a given efficiency level. Table 4.1 presents a general summary of the options a manufacturer may use to reduce losses in metal halide ballasts.

Table 4.1 Metal Halide Lamp Fixtures Technology Options

Relevant Ballast Type	Technology Option		Description
Magnetic	Improved Core Steel		Use a higher grade of electrical steel, including grain-oriented silicon or amorphous steel, for lower core losses.
	Copper Wiring		Use copper wiring in place of aluminum wiring for lowered resistive losses.
	Increased Stack Height		To a point, adding steel laminations results in lowered core loss.
	Increased Conductor Cross-Section		To a point, increasing conductor cross section results in lowered winding loss.
	Electronic Ballast		Use an electronic ballast in place of a magnetic ballast.
	Amorphous Steel		Create the core of the inductor from laminated sheets of amorphous steel insulated from each other.
Electronic	Improved Components	Magnetics	Use grain-oriented or amorphous electrical steel to reduce core losses.
			Use optimized-gauge copper or litz wire to reduce winding losses.
			To a point, adding steel laminations results in lowered core loss.
			To a point, increasing conductor cross section results in lowered winding loss.
		Diodes	Use diodes with lower losses.
		Capacitors	Use capacitors with a lower effective series resistance and output capacitance.
		Transistors	Use transistors with lower drain-to-source resistance.
	Improved Circuit Design	Integrated Circuits	Substitute discrete components with an integrated circuit.
	Amorphous Steel		Create the core of the inductor from laminated sheets of amorphous steel insulated from each other.

4.3 TECHNOLOGY OPTIONS NOT SCREENED OUT OF THE ANALYSIS

This section discusses the technology options that DOE considers viable means of improving the efficiency of metal halide lamp fixtures.

4.3.1 Improved Core Steel

Electrical steel, placed in a time-variant magnetic field, loses energy in two ways. Eddy currents are small, unproductive currents that dissipate energy resistively, whereas hysteresis is a nonlinearity in the magnetization of a material in response to the magnetic field applied. Electrical steels are made in different grades that correspond to different losses. Inexpensive magnetic ballasts typically use non-oriented steel whose magnetic properties are isotropic. Higher grades of steel can be grain-oriented, where the microscopic structure of the material is optimized for a particular field direction, or amorphous, which has no grain structure at all and the most desirable magnetic properties. Amorphous steel has not yet been incorporated into commercially available metal halide ballasts and DOE screened this technology out (see section 4.4).

Considering the four screening criteria for this technology option, however, DOE did not screen out other improved steel as a core material. Because these materials are in commercial use today, DOE concluded that they are technologically feasible and practicable to manufacture, install, and service. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with higher grades of steel.

4.3.2 Copper Wiring

Most inexpensive magnetic ballasts use aluminum conductor, which is more resistive than copper conductor of the same gauge. Because conductor losses vary in proportion to the resistance of the conductor, lowered resistance yields lower losses and higher ballast efficiency.

Considering the four screening criteria for this technology option, DOE did not screen out copper wiring. Because this material is in commercial use today, DOE concluded that it is technologically feasible and practicable to manufacture, install, and service. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with copper wiring.

4.3.3 Increased Stack Height

Losses in electrical steel vary with magnetic flux density, with higher flux density yielding higher losses. For a given magnetic field, increasing core cross-section will lower flux density and, therefore, lower losses. Because steel laminations are said to be “stacked” to form a core, increasing core cross-section is ordinarily done by adding steel laminations, or increasing the stack height. However, adding steel also adds core losses in the form of eddy currents and hysteresis, and also requires a greater length of conductor, eventually offsetting decreased core losses from increased core cross-section.

Considering the four screening criteria for this technology option, DOE did not screen out increased stack height. Because this practice is in commercial use today, DOE concluded that it is technologically feasible and practical to manufacturer, install, and service. Increasing stack height could affect the overall size and form factor of the ballast, but DOE believes there is sufficient flexibility in fixtures and the space in which they are installed to accommodate these changes. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with increased stack height.

4.3.4 Increased Conductor Cross-Section

The efficiency of a magnetic ballast could be increased with the use of increased conductor cross-sections in the windings of the magnetic choke and step-up transformer. This can be accomplished by both using larger wire gauges (*i.e.*, lower numeric values), multiple strands of wire operating in parallel. Using greater cross-sectional area in the magnetic component windings decreases the winding resistance and associated losses. Increased cross-sectional area in the windings could necessitate a longer core or additional layers of wire if the core length cannot be changed to maintain the same electromagnetic properties. This technology option typically corresponds to an increase in manufacturing cost.

Considering the four screening criteria for this technology option, DOE did not screen out increased conductor cross-section. Because increased conductor cross-section is available in commercially available products today, DOE concluded that this design is technologically feasible and practicable to manufacture, install, and service. Increasing conductor cross-section could affect the overall size and form factor of the ballast, but DOE believes there is sufficient flexibility in fixtures and the space in which they are installed to accommodate these changes. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with the use of increased conductor cross-section.

4.3.5 Electronic Ballast

The efficiency of a metal halide ballast can be increased through the use of an electronic ballast rather than a magnetic ballast, particularly at medium to low wattages. Electronic ballasts use modern, solid-state components and circuits to perform the same function as magnetic ballasts with lower electrical losses. Electronic ballasts are often more expensive than magnetic ballasts.

Considering the four screening criteria for this technology option, DOE did not screen out electronic ballasts. Because electronic ballasts are in commercial use today, DOE concluded that these ballasts are technologically feasible and practicable to manufacture, install, and service. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with the use of electronic ballasts.

4.3.6 Improved Components

The efficiency of electronic metal halide ballasts can be increased through the use of improved components. Improved components can have reduced electrical losses, increasing overall ballast efficiency, though generally at higher cost than standard components. DOE has not screened out improved components not currently used in metal halide ballasts, as these components are used in related power electronics products.

Considering the four screening criteria for this technology option, DOE did not screen out improved components. Because high-grade components are in commercial use today, DOE concluded that these components are technologically feasible and practicable to manufacture, install, and service. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with the use of improved components.

4.3.7 Improved Circuit Design

The efficiency of electronic metal halide ballasts can be increased through the use of improved circuit designs, using integrated circuits. The use of integrated circuits provides for more advanced control of the operation of the ballast. The use of integrated circuits also allows for use of more advanced and higher grade components, such as improved transistors. More advanced control of the ballast makes efficiency gains possible in the overall ballast, though generally at higher cost than standard designs.

Considering the four screening criteria for this technology option, DOE did not screen out improved circuit designs. Because improved circuit designs (such as the use of integrated circuits) are in commercial use today, DOE concluded that these designs are technologically feasible and practicable to manufacture, install, and service. DOE is not aware of any adverse impacts on consumer utility, reliability, health, or safety associated with the use of improved circuit designs.

4.3.8 Summary of Technology Options Not Screened Out

Table 4.2 summarizes the technology options that DOE did not screen out of the analysis, thereby designating them design options.

Table 4.2 Design Options

Relevant Ballast Type	Design Option		Description
Magnetic	Improved Core Steel		Use a higher grade of electrical steel, including grain-oriented silicon, for lower core losses.
	Copper Wiring		Use copper wiring in place of aluminum wiring for lowered resistive losses.
	Increased Stack Height		To a point, adding steel laminations results in lowered core loss.
	Increased Conductor Cross-Section		To a point, increasing conductor cross section results in lowered winding loss.
	Electronic Ballast		Use an electronic ballast in place of a magnetic ballast.
Electronic	Improved Components	Magnetics	Use grain-oriented or amorphous electrical steel to reduce core losses.
			Use optimized-gauge copper or litz wire to reduce winding losses.
			To a point, adding steel laminations results in lowered core loss.
			To a point, increasing conductor cross section results in lowered winding loss.
		Diodes	Use diodes with lower losses.
		Capacitors	Use capacitors with a lower effective series resistance and output capacitance.
		Transistors	Use transistors with lower drain-to-source resistance.
	Improved Circuit Design	Integrated Circuits	Substitute discrete components with an integrated circuit.

4.4 TECHNOLOGY OPTIONS SCREENED OUT OF THE ANALYSIS

This section addresses the technologies that DOE screened out, having considered the following four factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product utility to consumers; and (4) adverse impacts on health or safety.

DOE examined all of the technology options presented in the technology assessment. Of those options, DOE screened out one: laminated sheets of amorphous steel. The following discussion details DOE's consideration of this option in the context of the four screening criteria.

The transformer affects the efficiency of magnetic and electronic ballasts. For electronic metal halide ballasts, transformers influence the efficiency of the electromagnetic interference, power factor correction, and output stage of the ballast. For magnetic metal halide ballasts, the transformer influences the efficiency of the output stage and current-limiting portion of the ballast. Ballast efficiency can be improved by using higher-quality inductors. One method of decreasing transformer losses is to create the core of the inductor from laminated sheets of amorphous steel, insulated from each other.

DOE screened out laminated sheets of amorphous steel because DOE determined that the amorphous steel technology adds a high level of complexity, requires additional specialized machinery and equipment, and increases the size and weight of the ballast, possibly to a degree where the ballast would be too large to fit in a metal halide lamp fixture. These factors made laminated sheets of amorphous steel fail to pass the "practicable to manufacture, install, and service" criterion. DOE also determined that using amorphous steel could have adverse impacts on consumer utility because increasing the size and weight of the ballast may limit the places a consumer could use the ballast. While amorphous steel may be technologically feasible in other products, DOE is unaware of any demonstrated feasibility specific to metal halide lamp fixtures. DOE could find no conclusive evidence whether amorphous steel has adverse impacts on health or safety.

4.4.1 Summary of Technology Options Screened Out of the Analysis

Table 4.3 shows the criteria DOE used to screen laminated sheets of amorphous steel out of the analysis.

Table 4.3 Technology Options Screened Out of the Analysis

Technology Option	Screening Criteria
Amorphous Steel	Technological feasibility; Practicability to manufacture, install, and service; and Adverse impacts on product utility or product availability.

CHAPTER 5 ENGINEERING ANALYSIS

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CHAPTER 5 ENGINEERING ANALYSIS

5.1 INTRODUCTION

The U.S. Department of Energy (DOE) performed an engineering analysis to establish the relationship between the manufacturer production cost (MPC) of metal halide lamp fixtures (MHLF or "fixtures") and the energy efficiency of metal halide ballasts (hereafter "ballasts") contained in the fixtures. The relationship between the MPC and energy efficiency, or the cost-efficiency relationship, serves as the basis for cost-benefit calculations for individual customers, manufacturers, and the Nation. This section provides an overview of the engineering analysis; discusses the equipment classes, wattages, units, and fixtures; establishes baseline unit specifications for each of the equipment classes; discusses incremental efficiency levels (ELs); and discusses the analysis and results for each equipment class.

The primary inputs to the engineering analysis include cost data from teardown and retail price scaling analysis, efficiency data from testing, and design options from the screening analysis. The primary output of the engineering analysis is a set of cost-efficiency curves. In a subsequent life-cycle cost (LCC) analysis (notice of proposed rulemaking (NOPR) technical support document (TSD) chapter 8), DOE used the industry cost-efficiency curves to determine customer prices for the equipment analyzed in the engineering analysis by applying the appropriate distribution channel markups.

5.2 METHODOLOGY OVERVIEW

DOE structured its engineering analysis around two methodologies to estimate manufacturing costs: (1) the design-option approach, which provides the incremental costs of adding the design options (e.g., improved core steels), as discussed in section 5.3, to improve efficiency to a baseline model; and (2) the efficiency-level approach, which estimates the costs of achieving increases in energy efficiency levels through ballast efficiency testing and teardowns, without regard to the design options used to achieve such increases. Deciding which methodology to use for the engineering analysis depends on the equipment, the technologies under study, and any historical data DOE has available. To establish the industry cost-efficiency curves for ballasts included in metal halide lamp fixtures, DOE used both the efficiency-level approach to identify incremental improvements in efficiency for each equipment type and the reverse engineering cost-assessment approach to develop a cost for each EL.

This engineering analysis generally follows seven steps:

Determine Representative Equipment Classes. When multiple equipment classes exist, to streamline testing and analysis DOE selects certain classes as "representative," primarily because of their high market volumes. DOE then extrapolates the ELs from representative equipment classes to those equipment classes it does not analyze directly.

Determine Representative Wattages. Within each representative equipment class, DOE also selects a particular wattage fixture as "representative" of the wattage range, primarily because of the high market volumes. In the NOPR, DOE assigns only one representative wattage per representative equipment class.

Determine Representative Fixture Types. To calculate the typical cost of a fixture at each representative wattage, DOE selected certain types of fixtures to analyze as representative.

Select Baseline Units. DOE establishes a baseline unit for each representative wattage. The baseline unit has attributes (circuit type, input voltage capability, electronic configuration) typical of ballasts used in fixtures of that wattage. The baseline unit also has the lowest (base) efficiency for each equipment class. DOE measures changes resulting from potential amended energy conservation standards compared with this baseline. For fixtures subject to existing federal energy conservation standards, a baseline unit is a metal halide lamp fixture with a commercially available ballast that just meets existing standards. If no standard exists for a fixture, the baseline unit is the metal halide lamp fixture with a ballast within that equipment class with the lowest tested ballast efficiency that is sold. To determine energy savings and changes in price, DOE compares each higher energy efficiency level with the baseline unit.

To determine the ballast efficiency, DOE tested a range of metal halide ballasts from multiple ballast manufacturers. In some cases, DOE selects more than one baseline for a representative wattage to ensure consideration of different fixture and ballast types and their associated consumer economics.

Select More Efficient Units. DOE selects commercially available metal halide lamp fixtures with higher than baseline efficiency ballasts as replacements for each baseline model in each representative equipment class. In general, DOE can identify the design options associated with each more efficient ballast model by considering the 12 design options identified in the technology assessment (Chapter 3 of the NOPR TSD) and screening analysis (Chapter 4 of the NOPR TSD). Where technology design options cannot be identified for that class by the product number or catalog description, DOE uses a database of commercially available ballasts. DOE then tests these ballasts to determine their efficiency. All ballast efficiencies were calculated according to the metal halide ballast test procedure (10 CFR 431.324) unless otherwise specified. DOE estimates the design options likely to be used in the ballast to achieve a higher efficiency based on information gathered during manufacturer interviews.

Determine Efficiency Levels. DOE develops ELs based on: (1) the design options associated with the equipment class studied; and (2) the maximum technologically feasible (hereafter "max tech") EL for that class. As discussed in section 5.5, DOE's ELs are based on catalog data, test data collected from commercially available equipment, manufacturer input, and ballast modeling.

Conduct Price Analysis. DOE generated a bill of material (BOM) by disassembling multiple manufacturers' ballasts from a range of ELs and fixtures that span a range of applications for each equipment class. The BOMs describe the equipment in detail, including all manufacturing steps required to make and/or assemble each part. DOE then developed a cost model to convert the BOMs for each representative unit into MPCs. By applying derived manufacturer markups to the MPCs, DOE calculated the manufacturer selling prices (MSPs)[1] and constructed industry cost-efficiency curves. In cases where DOE was not able to generate a BOM for a given ballast, DOE estimates an MSP based on the relationship between teardown data and retail data. DOE also estimated ballast and fixture cost adders necessary to allow replacement of more efficient substitutes for baseline models.

The sections that follow discuss how DOE applies this methodology to each equipment class to create the engineering analysis and the methodology DOE used to develop ballast and fixture prices.

5.3 PRICING ANALYSIS OVERVIEW

DOE based MSPs for different metal halide lamp fixtures on teardown data. In doing so, DOE determined a manufacturer markup to scale the teardown-sourced MPC to an MSP. DOE generated ballast and empty fixture (physical enclosure and optics) MSPs separately and then combined the prices, as well as any relevant cost adders based on fixture type, to create an overall MHLF MSP. In a few cases, DOE was unable to base MSPs directly on teardowns. DOE discusses these exceptions and the alternative scaling methodologies in sections 5.10 through 5.14.

Developing ballast and empty fixture MSPs involved two main sources: (1) teardown data and (2) a markup analysis to develop the MSP from the teardown-sourced MPC. Figure 5.1 shows the general breakdown of costs and profit associated with manufacturing and selling a product. The full cost of production is broken down into two main costs: the MPC and the non-production cost. The non-production cost plus profits is equal to the manufacturer markup. DOE totaled the cost of materials, labor, and direct overhead used to manufacture a product in order to calculate the MPC.[2] Section 5.3 describes how DOE arrived at the MPC and how DOE established a markup that estimates non-production costs and profit.

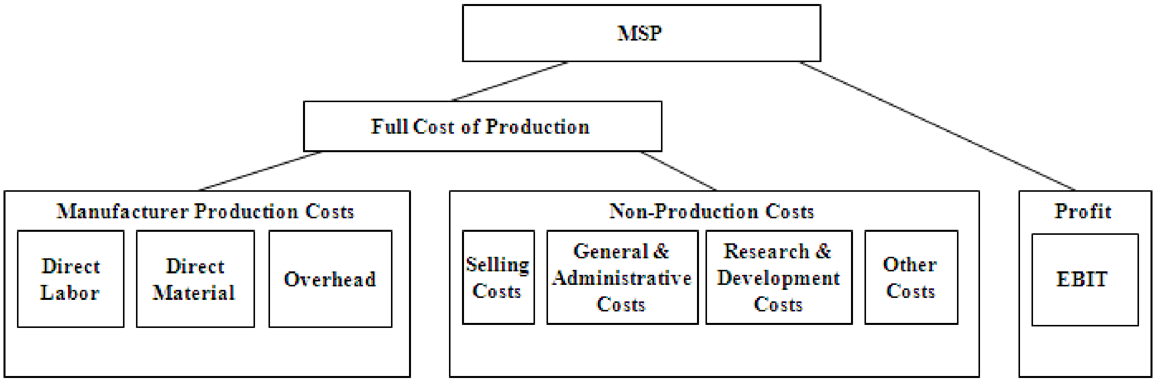

Figure 5.3.1 Manufacturer Selling Price

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[1] The MSP is the price at which the manufacturer can recover all production and non-production costs and earn a profit. Non-production costs include selling, general, and administration (SG&A) costs, the cost of research and development, and interest.

[2] When viewed from the company-wide perspective, the sum of all material, labor, and overhead costs equals the company's sales cost, also referred to as the cost of goods sold (COGS).

5.3.1 Manufacturer Production Costs

The MPC is composed of direct labor, direct material, and overhead costs. In the case of electronic ballasts, direct material costs represent the direct purchase price of components (resistors, connecting wires, etc.). In the case of magnetic ballasts, direct material costs represent the purchase price of steel laminations, copper wires, and other components. Manufacturers commented that the materials involved in fixture manufacturing are highly correlated to commodity pricing. DOE used five year average material prices from 2007 to 2011 when possible.

DOE conducted teardown analyses for select commercially available metal halide ballasts and empty fixtures. The direct labor costs include fabrication and assembly labor. The teardown results also included estimates for direct labor costs associated with the assembly of the product. Separate labor rates were used for components that required manual (hand) insertion versus those that were automated. Based on conversations with manufacturers, DOE assumed the ballasts were generally manufactured in China and Mexico and applied the corresponding labor rates. During manufacturer interviews, DOE learned that fixtures are typically manufactured domestically, so DOE applied a United States labor rate for fixture teardowns.

One of the challenges associated with tearing down magnetic ballasts is identifying the type of electrical steel used. The grade or type of electrical steel affects the cost and overall efficiency of the ballast but is impossible to discern from a visual assessment. During interviews, DOE received feedback from manufacturers regarding the types of steel used at certain ballast wattages and efficiencies. In other cases, DOE used the steel types determined from ballast modeling to calculate the cost of a representative unit. Ballast modeling is discussed in section 5.9.

The teardown results did not include overhead estimates. Overhead includes indirect material and labor costs, maintenance, depreciation, taxes, and insurance related to assets. To calculate overhead, DOE utilized information available in the recent standards rulemaking for fluorescent lamp ballasts.[3] In that rulemaking, DOE used financial data to estimate the overhead cost by calculating it as a percentage of the MPC. DOE estimated the depreciation cost from a representative electronics fabrication company's U.S. Securities and Exchange Commission (SEC) 10-K, finding it to be about 2.6 percent of the cost of goods sold or the MPC. To determine the material and labor percentage, DOE marked down aggregated confidential MSPs to an MPC using the manufacturer markup (section 5.3.3). Then, DOE computed the ratio of aggregated teardown-sourced material and labor costs to the manufacturer markdown sourced MPC. DOE found the material and labor costs to be about 93.8 percent of the MPC. DOE then subtracted the materials and labor and depreciation percentages from 100 percent to back out the remainder of overhead as a percentage of MPC. Overhead was estimated to be 3.6 percent of the MPC, which is reasonable as electronics manufacturing generally has low overhead costs. DOE found overhead and depreciation to be about 6.2 percent of the MPC or 6.6 percent of the material and labor costs. The 6.6 percent factor was then used to mark up the material and labor costs contained in the teardown results to the MPC.

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[3] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/62

5.3.2 Selection of Units

DOE carefully selected fixtures and ballasts for the teardown analysis to generate data useful for estimating MPCs. DOE mapped out a matrix of equipment specifications and then compared ballasts that differ by only one attribute. Ballasts are described by a long list of specifications, so DOE concentrated on the specifications it expected to have the greatest effect on efficiency. Specifications include high versus regular advertised efficiency, rated wattage, input voltage, starting method, electronic configuration, and circuit type. For fixtures, DOE consulted with manufacturers to learn which application types were typically used in particular wattage ranges. In addition to strategically selecting ballast specification characteristics, DOE also selected common ballast and fixture models from major manufacturers. This choice helped DOE capture the most accurate incremental price difference by tearing down high volume, mainstream equipment.

For electronic ballast teardowns, DOE was only able to select unpotted ballasts. Some ballast manufacturers add potting (often an epoxy) to the ballast enclosure to improve performance and durability. The potting is a better conductor of heat than air and helps the electronic elements dissipate heat. Furthermore, the potting can provide mechanical stability that mitigates vibration and seals out moisture. Because the potting completely engulfs the electronics and is not easily removable, DOE was unable to reverse engineer potted ballasts through a teardown analysis. As a result, DOE only conducted electronic ballast teardowns for unpotted ballasts and ballasts removed from a manufacturing facility before the potting procedure.

DOE selected eight metal halide lamp fixtures and 28 metal halide ballasts to tear down for the engineering analysis. Table 5.3.1 lists the ballast types submitted for teardowns, and Table 5.3.2 lists the fixture types selected for teardowns.

Table 5.3.1 Ballast Types for Teardowns

Item	Type	Wattage
1	Magnetic	70
2	Magnetic	70
3	Magnetic	70
4	Magnetic	70
5	Magnetic	70
6	Electronic	70
7	Electronic	70
8	Magnetic	150
9	Electronic	150
10	Magnetic	175
11	Magnetic	250
12	Magnetic	250
13	Magnetic	250
14	Magnetic	250
15	Magnetic	250
16	Electronic	250
17	Electronic	250
18	Magnetic	400
19	Magnetic	400
20	Electronic	400
21	Electronic	400
22	Electronic	400
23	Electronic	400
24	Magnetic	1000
25	Magnetic	1000
26	Magnetic	1000
27	Magnetic	1000
28	Magnetic	1000

Table 5.3.2 Fixture Types for Teardowns

Item	Type	Wattage
29	Canopy	70
30	Wall Pack	250
31	High-Bay Electronic	400
32	High-Bay Magnetic	400
33	Low-Bay Electronic	400
34	Low-Bay Magnetic	400
35	Parking / Area	400
36	Flood	400

5.3.3 Price Adders

DOE applied several price adders to the empty fixture and ballast MPCs based on whether it is an indoor or outdoor fixture and if it uses an electronic or magnetic ballast. Because of the vulnerability of electronic ballasts to high temperatures, DOE applied a 20 percent empty fixture cost adder to all fixtures with electronic ballasts to account for thermal management based on manufacturer input and teardown-sourced data. In aggregate, manufacturers indicated a 20 percent increase in fixture MPC is associated with thermal management. Additionally, DOE conducted teardown analyses of empty metal halide fixtures. Through analysis of pairs of fixtures designed for electronic ballasts and fixtures designed for comparable magnetic ballasts, DOE also found an approximately 20 percent increase in fixture MPCs to include thermal management for electronic ballasts. Accordingly, in the price analysis for this rulemaking, all metal halide lamp fixtures shipped with electronic ballasts are assessed a 20 percent adder to empty fixture MPCs.

In order to be reliable in outdoor applications that are more prone to voltage surges, outdoor fixtures with electronic ballasts were applied an empty fixture cost adder. Based on an MSP of $30 determined from a review of selling prices from transient manufacturers, DOE developed a cost adder of $18.99 ($30 selling price divided by the fixture manufacturer markup) for 10 kilovolts (kV) inline surge protection for electronic ballasts, as most electronic ballasts do not have this feature built in. As such, DOE applies this adder to the fixture MPC for fixtures that include electronic ballasts in outdoor applications.

Lastly, DOE found that about 10 percent of indoor fixtures require 120 volt (V) auxiliary power functionality to which a lamp can be attached for use when emergency lighting is needed and the metal halide lamp needs to cool down before it can be restarted. Using a combination of manufacturer information and market research, DOE determined that the cost of adding this auxiliary tap to magnetic ballasts is so small that no incremental cost was applied to price models. Through the same method, DOE concluded that a representative value for electronic ballasts to incorporate this auxiliary tap is $7.50. Because these taps are only added to 10 percent of ballasts in indoor fixtures, that number is multiplied by 0.10 to get a cost adder of $0.75 per indoor ballast. These three cost adders are summarized in Table 5.3.3 below.

Table 5.3.3 Incremental Costs for Electronically Ballasted Fixtures

	Indoor MPC Adder*	**Outdoor MPC Adder***
Thermal Management	20% fixture MPC increase	20% fixture MPC increase
Voltage Transient Protection	--	$18.99 fixture MPC increase
120 V Auxiliary Power Functionality	$0.75 ballast MPC increase	--

5.3.4 Manufacturer Markup

More efficient equipment typically has higher production costs than baseline equipment. To meet new or amended energy conservation standards, manufacturers often must introduce design changes to their existing products or discontinue less efficient products, resulting in standards-compliant equipment with higher MPCs. Depending on the competitive environment for the particular equipment types, some or all of the increased production costs can be “passed on” from manufacturers to customers in the form of higher purchase prices. As production costs increase, manufacturers also typically incur additional overhead at the factory and corporate levels. The MSP must cover both of these additional contributions to overhead if a company is to maintain its current level of profitability.

As discussed previously, overhead costs within the DOE model are a function of investments, material costs, labor costs, or total costs, depending on the overhead category.

Together, materials, labor, and factory overhead compose the MPC. DOE applies another multiplier to the MPC to account for corporate non-production costs and profit. This latter multiplier, the manufacturer markup, is the focus of this section.

The manufacturer markup is an integral part of the overall markup from production costs to installation costs. However, the manufacturer markup is different than the other markups in the distribution chain (which includes wholesalers, distributors, retailers, contractors, etc.) that convert MSP to customer price. The customer prices and installation costs are key inputs to the LCC analysis, payback period (PBP) analysis, and national impact analysis (NIA). Through the use of the manufacturer and distribution chain markups and installation costs, DOE can calculate the first costs that customers would face under the various ELs. DOE evaluates the tradeoff between the increase in first cost and the resulting energy cost savings at each EL in the LCC and PBP analyses (NOPR TSD chapter 8) and NIA analysis (NOPR TSD chapter 10). In this section, DOE presents its methodology for converting the MPCs to MSPs using the manufacturer markup.

5.3.4.1 Manufacturer Selling Price

DOE calculated the MSP for metal halide lamp fixtures by multiplying the MPC by the calculated manufacturer markup, which is explained in the following section. In general, the manufacturer markup should ensure that the MSP of the equipment is high enough to recover the full cost (i.e., production and non-production costs), and yield a satisfactory profit.

5.3.4.2 Manufacturer Financial Information Sources

Publicly owned companies are required by law to disclose financial information on a regular basis by filing different forms with the SEC. The SEC form 10-K, filed by companies on an annual basis, provides a comprehensive overview of the company's business and financial conditions. Relevant information in the 10-K reports includes the company's revenues and direct and indirect costs. To derive manufacturer markup, DOE used 10-K reports from publicly owned ballast or fixture manufacturing companies and inputs from manufacturer interviews. The financial figures necessary for calculating the manufacturer markup are net sales, costs of sales, and gross profit. The income statement section of the 10-K reports often reports these figures.

DOE calculated the manufacturer markup for both ballasts and fixtures by using financial figures from manufacturers' SEC 10-K reports, such as the net sales (revenues) and cost of sales to calculate gross profit and gross profit margins. DOE used averages of the financial figures spanning 2002 to 2008 to calculate the manufacturer markup for ballasts and 2000 to 2009 for the manufacturer markup for fixtures. DOE used the following equations to calculate the gross profit and gross profit margins:

Equation 5.3-1

$$\text{Gross Profit (\$)} = \text{Net Sales} - \text{Cost of Sales}$$

Equation 5.3-2

$$\text{Gross Profit Margin (\%)} = \frac{\text{Gross Profit}}{\text{Net Sales}}$$

Table 5.3.4 contains the calculated gross profit margins for four sample ballast manufacturers. Table 5.3.5 contains the calculated gross profit margins for six sample fixture manufacturers.

Table 5.3.4 Gross Profit Margin for Four Metal Halide Ballast Manufacturers*

Parameter	Industry-Weighted Average	Manufacturer			
		A	B	C	D
Net Sales Million $	66,614	90,705	46,952	38,118	63,862
Cost of Sales Million $	44,203	58,350	29,567	27,562	44,804
Gross Profit Million $	22,411	32,355	17,385	10,556	19,057
Gross Profit Margin %	**33.6**	**35.7**	**37.0**	**27.7**	**29.8**
* Data taken from 2002, 2003, 2004, 2005, 2006, 2007, and 2008 SEC 10-K reports.					

Table 5.3.5 Gross Profit Margin for Six Metal Halide Lamp Fixture Manufacturers*

Parameter	Industry-Weighted Average	Manufacturer					
		A	B	C	D	E	F
Net Sales Million $	65,337	100,996	44,363	34,988	15,164	15,877	0,978
Cost of Sales Million $	44,237	65,844	31,614	28,824	10,119	11,317	0,489
Gross Profit Million $	20,757	35,152	12,749	6,164	5,045	4,560	0,489
Gross Profit Margin %	**31.8**	**34.8**	**28.7**	**17.6**	**33.3**	**28.7**	**50.0**
* Data taken from 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.							

To calculate the time-averaged gross profit margin for each firm, DOE first summed the gross profit for all the years and then divided the result by the sum of the net sales for those years. Each manufacturer's markup was calculated as:

Equation 5.3-3

$$\text{Manufacturer Markup} = \frac{1}{1 - \text{Gross Profit Margin}} = \frac{\text{Net Sales}}{\text{Cost of Sales}}$$

DOE also asked for manufacturers to comment on reasonable markup values in the market today. Based on DOE's calculations, the information provided in Table 5.3.4 and Table 5.3.5, actual MSPs, and manufacturer input, DOE decided to use a markup of 1.47 for ballast manufacturers and a 1.58 markup for fixture manufacturers. In other words, on average, metal halide ballast manufacturers sell their products to the next party in the distribution channel at 47 percent above the manufacturing production cost, and MHLF manufacturers sell their product at 58 percent above the MPC. DOE also assumed that fixture manufacturers apply the 1.58 markup to the ballasts used in their fixtures rather than to only the empty fixture. The 1.47 markup for ballast manufacturers applies only to ballasts sold to fixture original equipment manufacturers (OEMs) directly impacted by this rulemaking. For the purposes of the LCC analysis, DOE assumes a higher markup of 1.60 for ballasts that are sold to distributors for the replacement market. DOE used these multipliers in the engineering analysis to determine the MSPs for each equipment class. DOE used a constant markup to reflect the MSPs of the baseline products as well as more efficient products. DOE took this approach because amended standards may make high-efficiency products, which currently are considered premium products, the baseline and commodity products in the future.

5.4 REPRESENTATIVE EQUIPMENT CLASSES, WATTAGES, AND FIXTURES

5.4.1 Representative Equipment Classes

As discussed in the market and technology assessment (NOPR TSD chapter 3), DOE is considering revising the Energy Policy and Conservation Act (EPCA) table of standards for metal halide fixtures to contain 20 equipment classes. DOE did not choose to directly analyze the equipment classes containing only fixtures tested at 480 V because their low shipment volume would not make them representative of the MHLF market. Therefore, DOE scaled the non-480 V (typically quad-voltage 120 V, 208 V, 240 V, and 277 V) ballast equipment classes to the ballasts tested at 480 V equipment classes. Further detail on scaling is discussed in section 5.15. DOE selected all other equipment classes as representative, resulting in a total of ten representative classes as listed in Table 5.4.1.

Table 5.4.1 Representative Equipment Classes

Equipment Class	Rated Lamp Wattage	Indoor/Outdoor	Input Voltage Type
1	≥50 W and ≤100 W	Indoor	Tested at 480 V
2 Representative	≥50 W and ≤100 W	Indoor	All others
3	≥50 W and ≤100 W	Outdoor	Tested at 480 V
4 Representative	≥50 W and ≤100 W	Outdoor	All others
5	>100 W and <150 W*	Indoor	Tested at 480 V
6 Representative	>100 W and <150 W*	Indoor	All others
7	>100 W and <150 W*	Outdoor	Tested at 480 V
8 Representative	>100 W and <150 W*	Outdoor	All others
9	≥150 W and ≤250 W**	Indoor	Tested at 480 V
10 Representative	≥150 W and ≤250 W**	Indoor	All others
11	≥150 W and ≤250 W**	Outdoor	Tested at 480 V
12 Representative	≥150 W and ≤250 W**	Outdoor	All others
13	>250 W and ≤500 W	Indoor	Tested at 480 V
14 Representative	>250 W and ≤500 W	Indoor	All others
15	>250 W and ≤500 W	Outdoor	Tested at 480 V
16 Representative	>250 W and ≤500 W	Outdoor	All others
17	>500 W and ≤2000 W	Indoor	Tested at 480 V
18 Representative	>500 W and ≤2000 W	Indoor	All others
19	>500 W and ≤2000 W	Outdoor	Tested at 480 V
20 Representative	>500 W and ≤2000 W	Outdoor	All others

*Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.
**Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

5.4.2 Representative Wattages

DOE selected one representative wattage for each representative equipment class. Based on analysis of product availability in catalogs and manufacturer input, DOE identified the most commonly sold wattage within an equipment class. For the ≥50 W and ≤100 W equipment class, DOE analyzes 70 W fixtures as the representative wattage. For the >100 W and <150 W classes, ≥150 W and ≤250 W classes, >250 W and ≤500 W classes, and >500 W and ≤2000 W classes, DOE analyzes fixture ratings of 150 W, 250 W, 400 W, and 1000 W as the representative wattages, respectively. These representative wattages are summarized with the equipment classes in Table 5.4.2.

Table 5.4.2 Metal Halide Lamp Fixtures NOPR Representative Wattages

Equipment Class	Rated Lamp Wattage	Indoor/Outdoor	Representative Wattage
2	≥50 W and ≤100 W	Indoor	70 W
4	≥50 W and ≤100 W	Outdoor	70 W
6	>100 W and <150 W*	Indoor	150 W
8	>100 W and <150 W*	Outdoor	150 W
10	≥150 W and ≤250 W**	Indoor	250 W
12	≥150 W and ≤250 W**	Outdoor	250 W
14	>250 W and ≤500 W	Indoor	400 W
16	>250 W and ≤500 W	Outdoor	400 W
18	>500 W and ≤2000 W	Indoor	1000 W
20	>500 W and ≤2000 W	Outdoor	1000 W

*Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.
**Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

5.4.3 Representative Fixtures

DOE also identified representative fixture types for each representative wattage. First, DOE identified the applications commonly served by particular wattage ranges. Low-wattage (less than 150 W) lamps are mainly used in commercial and some residential applications for general lighting purposes. Medium-wattage (150-500 W) lamps are the most widely used and include warehouse, street, and general commercial lighting. High-wattage (greater than 500 W) lamps are mainly used in searchlights, stadiums, stage applications, and other applications that require powerful white light. Then, DOE identified fixture types typically used in these applications to assign representative fixture types.

Table 5.4.3 Equipment Classes and Representative Wattages & Fixtures

Equipment Class	Rated Lamp Wattage	Representative Wattage	Representative Fixture Types
1	≥50 W and ≤100 W	70 W	Canopy
2	>100 W and <150 W**	150 W	Low-bay, Canopy, Wallpack*
3	≥150 W and ≤250 W†	250 W	Low-bay, Canopy, Wallpack
4	>250 W and ≤500 W	400 W	Flood, High-bay, Area
5	>500 W and ≤2000 W	1000 W	Flood, Area

* 150 W representative fixtures are a combination of the fixtures identified for the 70 and 250 W categories.
** Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.
† Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

Next, DOE considered whether the fixture cost changes with efficiency and, in particular, with a transition from magnetic to electronic technology. If fixture cost changed with efficiency, DOE would need to assign different fixture costs to different ELs. If fixture cost did not change with efficiency, fixture cost could be the same for all ELs. When determining whether a fixture must be altered to accommodate a given ballast, DOE considered two issues. Most important is whether the ballast will physically fit within the space allotted to it. For all ELs analyzed, DOE found that each fixture type was capable of physically containing the ballast with minimal modification. The second consideration is, particularly in the case of electronic ballasts, whether the fixture must be altered to accommodate an electronic ballast instead of a magnetic ballast to ensure the required reliability and functionality in all applications. In total, DOE found three changes required for a fixture to accommodate an electronic ballast rather than a magnetic ballast.

The first requirement is that electronic ballasts are able to withstand a voltage transient of up to 10 kV. This is based on American National Standards Institute (ANSI) standard C62.41.1-2002 for area and roadway lighting in the utility division and ANSI C82.14-2006 for low-frequency square wave electronic ballasts. ANSI C62.41.1-2002 serves as the guideline to manufacturers for the classification of surge protection definitions and equipment. ANSI C82.14-2006 specifies the requirement of ballasts in roadway applications to be designed with a transient insulation level of 10 kV when the maximum rated supply voltage exceeds 600 V. An inline surge protection device external to the ballast, also called a metal oxide varistor (MOV) is required for electronic ballasts in outdoor luminaires. The MOV is used to clamp off the circuit if the energy surge exceeds 10 kV. This technology is also discussed in chapter 3 of this NOPR TSD. A portion of commercially available electronic ballasts have 10 kV surge protection built in, but most electronic ballasts are rated for 6 kV voltage spikes. Thus, DOE applied incremental costs for transient protection in outdoor locations, further discussed in section 5.3.

The second requirement relates to thermal management. Generally, electronic ballasts are more vulnerable than magnetic ballasts to high ambient temperatures. In order to correct for this difference, fixtures housing electronic ballasts would need to be redesigned to account for thermal management in both indoor and outdoor applications. Magnetic ballasts can operate at temperatures as high as 150^{o}C, while electronic ballasts generally cannot operate at temperatures exceeding 90^{o}C. This temperature limit makes it impossible to place electronic ballasts in a luminaire in the traditional location near the lamp. Furthermore, electronic ballasts are more efficient than magnetic ballasts, and therefore generate less heat and run at cooler temperatures. Additionally, these ballasts also use a power foldback feature to manage the temperature of the ballast and prevent damage to the ballast in extreme high heat conditions. The sensitivity of electronics to thermal conditions can involve the redesign of the fixture or ballast such as larger ballast housing, additional potting material to create adequate thermal contact between the ballast and fixture, thermal shields, or luminaire venting to sink the heat outside of the fixture. Thus, DOE applied incremental costs for electronic ballast thermal management is discussed in section 5.3.

The third requirement is for ballasts to include 120 V auxiliary power functionality. This input is typically used for an emergency incandescent lamp that operates only after a temporary loss of power while the metal halide lamp is still too hot to restart. These taps are primarily used in indoor applications and because this auxiliary tap is primarily required for emergency lighting purposes, they are only needed in about one out of every ten indoor lamp fixtures. A 120 V tap is easily incorporated in to a magnetic ballast due to its traditional core and coil design, and incurs a negligible cost increment. Electronic ballasts, though, require modification to add this 120 V auxiliary power functionality. Incremental costs for this 120 V tap is discussed section 5.3.

In summary, DOE applied empty fixture incremental costs due to the three requirements discussed above. The empty fixture MPC for a representative wattage was calculated as the average teardown cost of each of the fixture types identified as representative. This resulted in a “composite” fixture price representative of all the fixture types commonly used at a particular representative wattage. Therefore, changes in the total fixture MSP are based on changes in ballast cost and the incremental costs due to switching from magnetic to electronic ballasts. In the sections that follow, DOE describes its analysis of the representative wattage assigned to each equipment class.

5.5 EFFICIENCY LEVELS

5.5.1 General Methodology

When developing equations for efficiency in each wattage range, DOE used its own efficiency test data and catalog efficiency data to look at the trends of efficiencies currently on the market. DOE considered power-law, exponential, and linear best-fit regressions and found that using power-law fit equations resulted in the lowest coefficient of determination (R^2) in matching the efficiency data when compared to other equation types. Once power-law fits were decided upon, DOE considered three approaches for deriving equation-based ELs: (1) applying one power-law fit across all wattages; (2) using a power-law fit for some wattage ranges, and adjusting the coefficients of the equation to the representative units in each wattage range; and (3) using a power-law fit for some wattage ranges, and adjusting the exponents and the coefficients to best fit the test and catalog data to allow the majority of ballasts with a particular technology option to meet the EL. DOE tested many different types of metal halide ballasts from various manufacturers which included extensive testing of the representative wattages. DOE tested 57[4] models of ballasts included in the representative wattages and six non-representative wattage models.

By focusing on specific wattage bins (equipment classes) in options two and three, DOE can focus on the characteristics within a specific wattage bin individually rather than classifying all of the wattage bins together. DOE performed a best-fit regression on the test and catalog data of various manufacturers to determine the most appropriate type of fit for the data. For all of the electronic ballasts and the low-wattage magnetic ballasts, DOE determined that the power-law function best characterized the test and catalog data points (better than exponential and logarithmic fits). However, due to the Energy Independence and Security Act of 2007 (EISA 2007) efficiency standard of 88 percent that applies to 150 to 500 W ballasts, DOE could not maintain a consistent power-law function across all wattage bins. DOE discusses the equations and fits within each wattage bin for both magnetic and electronic ballasts below. The ELs apply to both indoor and outdoor applications.

For option one, power-law fitting across all the wattages, DOE examined the test and catalog data, and determined the best power-law fit that would meet the ELs for the electronic ballasts. For the magnetic ballast ELs, DOE performed a power-law fit across all wattages, but determined it did not closely match all the representative units. The available ballasts in the 150 to 500 W range did not follow the same trend as other wattages because the EISA 2007 standards had already required an increase in efficiency. from 50 W to 150 W, then applied the EISA 2007 88 percent efficiency requirement to wattages from 150 W to 200 W. Above 200 W, DOE used a linear fit between 200 W and 250 W using the 250 W representative unit. Between 250 and 500 W, DOE maintained a flat efficiency requirement for the two magnetic ballast ELs to ensure that both representative units would meet the ELs. Above 500 W through 2000 W, DOE performed a linear fit from above 500 W to 1000 W ballasts, then a flat efficiency trend above 1000 W in order to best fit the data.

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[4] Some ballasts in the representative wattages were tested with less than four, but at least three samples. This was because certain models were placed on backorder due to limited supply/production.

For option two, DOE used a power-law fit for some wattage ranges, and adjusted the coefficients of the equation to the ELs in each wattage range. DOE calculated the best-fit exponent for the EL equations by determining the power-law fit for each manufacturer's product lines then averaging the exponents. This approach was used for the magnetic ballast ELs from 50 W to 100 W and 100 W to 150 W equipment classes. For 50 W to 150 W, DOE applied the EISA 2007 88 percent efficiency requirement to wattages from 150 W to 200 W. Above 200 W, DOE used a linear fit between 200 W and 250 W using the 250 W representative unit. Between 250 W and 500 W, DOE maintained a flat efficiency requirement for the two magnetic ballast ELs to ensure that both representative units would meet the ELs. Above 500 W through 2000 W, DOE performed a linear fit from above 500 W to 1000 W ballasts, then a flat efficiency trend above 1000 W in order to best fit the data. For electronic ballasts, DOE performed the same type of power-law fit across the manufacturers' product lines with averaged exponents and varying the coefficients to match the representative units at the appropriate equipment classes.

For option three, DOE used a power-law fit for some wattage ranges, and adjusted the coefficients and exponents of the equation for each EL in each wattage range in order to best fit the test and catalog data. This was done for the magnetic ballast ELs from 50 W to 150 W, after which DOE used the same type of fits as previously described in option two for wattages ≥150 W. For electronic ballasts, DOE performed the same type of power-law fit across the test and catalog data with varied exponents and coefficients to match the representative units at the appropriate equipment classes. DOE used option three in the NOPR to set the ELs further described below.

For the lowest wattage bin, which consists of 50 W through 100 W ballasts, DOE used the power-law best-fit exponent for the magnetic ballasts as the first EL, and then changed the coefficient so that it would fit the next representative unit. DOE performed the same analysis for the electronic ballast ELs as well to determine the next two ELs. DOE used the 70 W ballast as the representative unit for the wattage bin. DOE found from manufacturer input and testing of commercially available ballasts that there was relatively little efficiency variation at 70 W. DOE tore down commercially available 70 W ballasts and used ballast modeling (discussed in section 5.9) to obtain cost-efficiency data at higher efficiencies that are not currently available in the market.

For the wattage bin that consists of ballasts greater than 100 W, less than 150 W, and including the 150 W ballasts exempted from EISA 2007, DOE used the same power-law exponents and coefficients from the previous wattage bin to continue the power-law function from the previous wattage bin into this wattage bin for both the magnetic and electronic ballast ELs. For both magnetic and electronic ballast ELs, DOE used the 150 W as the representative wattage for this equipment class.

The next wattage bin consists of ballasts 150 W, excluding the 150 W ballasts exempted from EISA 2007, up through and including 250 W ballasts. Because EISA 2007 covered products in this wattage bin, DOE can only evaluate efficiencies equivalent or above the existing standards to avoid backsliding. Manufacturers stated during interviews that 150 W magnetic ballasts could not be designed to meet 88 percent and that 175 W ballasts only reached 88 percent by using the high grade core steel and increasing the ballast's footprint. DOE's test data also indicated there are no 150 or 175 W magnetic ballasts available that exceed 88 percent efficiency. DOE did not test any 200 W ballasts. However, a review of catalog data indicates 200 W magnetic ballasts are only available at 88 percent efficiency. Because DOE has no specific information indicating these ballasts can be designed to be more efficient, DOE assumed that 88 percent is also the max tech efficiency for 200 W magnetic ballasts. Thus, DOE maintained the EISA 2007 efficiency requirement of 88 percent for ELs designed to represent levels met by magnetic ballasts. DOE does not have any information about the achievable efficiencies for ballasts greater than 200 W and less than 250 W as products in this range are not currently commercially available. Therefore, DOE gradually increased the magnetic ELs (EL1 and EL2) between 200 W and 250 W using a linear trend from 88 percent to the efficiency of the EL1 and EL2 250 W representative units. For the electronic ballast ELs (EL3 and EL4), DOE continued the power-law trend from the 50 to 150 W wattage range up to 250 W. DOE used 250 W as the representative wattage for this equipment class.

The next wattage bin consists of ballasts higher than 250 W up through and including 500 W. At the 250 W and 400 W representative wattages, DOE learned from the manufacturers that consumers tend to purchase ballasts that just meet EISA standards. As a result, manufacturers often do not offer magnetic ballast above the baseline level, though DOE found several commercially available ballasts that were advertised as energy efficient above EISA standards. DOE tore down the ballasts with these higher efficiencies when available, but found that there were still gaps in the incremental efficiencies DOE was considering. For these data points, manufacturers provided input to DOE during interviews on specific changes required with the electrical steel to improve efficiencies of the baseline magnetic ballasts. For the magnetic ballasts in these equipment classes, DOE tore down baseline efficiency units and then changed the electrical steel input to the cost model for more efficient magnetic ballasts using the manufacturer input. DOE refers to these magnetic units as “modeled” teardowns when it discusses them in section 5.9. Because the 250 W and 400 W representative units have the same efficiency as well as similar design options, DOE created a flat efficiency requirement for magnetic ballasts within this wattage bin. For the electronic ballast ELs (EL3 and EL4), DOE continued the power-law function fit from the 250 to 500 W wattage range up through 500 W. DOE used 400 W as the representative wattage for this equipment class.

The highest wattage bin consists of ballasts higher than 500 W up through and including 2000 W. DOE examined catalog data, market availability, and received manufacturer feedback that there are no electronic ballasts currently commercially available above 500 W. Thus, there are only two ELs at the highest wattage range rather than four. DOE used a linear fit for ballasts above 500 W through 1000 W after examining the efficiency trends within manufacturers’ product lines in this wattage bin. DOE fit the linear trend from the previous wattage bin’s 500 W efficiencies at ELs 1 and 2 through the representative units at 1000 W. However, due to the lack of test data and limited wattage offerings for ballasts over 1000 W, DOE could not develop a conclusive trend between wattage and efficiency. Thus, DOE created a flat efficiency requirement extending from the tested efficiency of the 1000 W representative unit to 2000 W. For all of the ELs in the greater than 500 W to 2000 W wattage bin, DOE used the 1000 W ballast as the representative units for the wattage bin. DOE received manufacturer feedback for what changes would be required to reach specific efficiencies at 1000 W.

DOE then generated curves that corresponded to these divisions. DOE presents all of the sets of equations in sections 5.10 through 5.14. The energy conservation standard proposal uses these EL equations.

5.5.2 Maximum Technologically Feasible Efficiency Levels

The most stringent EL in each equipment class represents the maximum technologically feasible level of efficiency identified by DOE. All max tech ELs were developed based on commercially available ballasts.

5.6 TESTING

5.6.1 Current Test Procedure

The current test procedures for metal halide ballasts and fixtures are outlined in 10 CFR Part 431. The test conditions for the power supply, ballast, lamp, and test instrumentation is specified in section 4.0 of ANSI C82.6. Testing requires the use of a reference lamp, which is to be driven by the ballast under test conditions until the ballast reaches operational stability. Ballast efficiency for the fixture is then calculated as the measured ballast output power divided by the ballast input power. In the NOPR, DOE proposes changes to the input voltage for testing, high-frequency electronic (HFE) ballast testing, and rounding requirements. DOE followed these proposed changes (discussed below in sections 5.6.2 and 5.6.3) during the testing carried out for this rulemaking.

5.6.2 Test Input Voltage

Metal halide ballasts can be operated at a variety of voltages, with different voltages chosen based on the application and use of the fixture. The most common voltages are 120 V, 208 V, 240 V, 277 V, and 480 V. Ballasts will also commonly be rated for more than one, such as dual-input-voltage ballasts that can be operated on 120 V or 277 V, or quad-input-voltage ballasts that can be operated on 120 V, 208 V, 240 V, or 277 V. DOE observed changes in efficiency (on the level of several percent) were possible in individual ballasts based on DOE’s own testing of multiple-input-voltage ballasts.

The existing test procedure does not specify the voltage at which a ballast is to be tested. To ensure consistency among testing and reported efficiencies, the input voltage should be specified in the test procedure. To set an energy conservation standard based on test data, DOE needed to determine which input voltage to use for its data. In addition, manufacturers would need to test their products at the same input voltage as DOE used when developing energy conservation standards for the regulations to have the intended impact. Because the majority of ballasts sold are capable of operating at multiple input voltages, DOE proposed standardizing this aspect of testing.

In manufacturer interviews, DOE received feedback on usage of different input voltages. DOE learned that 208 V is the least used and least optimized voltage. DOE also received feedback that efficiencies at 277 V and 240 V are similar. In general, DOE determined that fixtures with wattages less than 150 W were most often at 120 V. Wattages including and above

150 W were most commonly at 277 V. Thus, the NOPR proposes that testing of metal halide ballasts use the following input voltages:

- For ballasts less than 150 W that have 120 V as an available input voltage, ballasts are to be tested at 120 V.
- For ballasts less than 150 W that lack 120 V as an available voltage, ballasts should be tested at the highest available input voltage.
- For ballasts operated at greater than or equal to 150 W and less than or equal to 2000 W that also have 277 V as an available input voltage, ballasts are to be tested at 277 V.
- For ballasts greater than or equal to 150 W and less than or equal to 2000 W that lack 277 V as an available input voltage, ballasts should be tested at the highest available input voltage.

5.6.3 Testing Electronic Ballasts

Because HFE ballast testing is not adequately specified, DOE is proposing to amend the MHLF test procedure to specify the equipment required for testing HFE ballasts. DOE found that the equipment commonly used for high-frequency metal halide ballast testing is the same equipment used for fluorescent ballast testing. DOE proposed that equipment at least as accurate as required by ANSI C82.6 be used to assess the output frequency of the ballast. Once the output frequency is determined to be greater than or equal to 1000 hertz (Hz), (the frequency at which DOE proposes to define HFE ballasts), the test procedure equipment would be required to include a power analyzer that conforms to ANSI C82.6 with a maximum of 100 picofarads (pF) capacitance to ground and frequency response between 40 Hz and one megahertz (MHz). The test procedure would also require a current probe compliant with ANSI C82.6 that is galvanically isolated and has a frequency response between 40 Hz and 20 MHz, and lamp current measurement where the full transducer ratio is set in the power analyzer to match the current to the analyzer. The full transducer ratio would be required to satisfy:

$$\frac{\mathrm{I_{in}}}{\mathrm{V_{out}}} \times \frac{\mathrm{R_{in}}}{\mathrm{R_{in}} + \mathrm{R_s}}$$

Where:

I_{in} is current through the current transducer;
V_{out} is the voltage out of the transducer;
R_{in} is the power analyzer impedance; and
R_s is the current probe output impedance.

5.7 DESIGN STANDARD

EISA 2007 gave DOE the authority to set design, in addition to performance, standards for metal halide lamp fixtures. In so doing, DOE may specify or prohibit certain features or qualities, which can be useful when more energy savings can be realized than with a performance standard alone. Ballasts commonly use two different starting methods, probe-start and pulse-start, which can affect efficacy, color rendition, re-strike time, and lumen depreciation.

As discussed in Chapter 3 of the NOPR TSD, pulse-start lamps have two electrodes that are used to both start and operate the lamp. The ballast alone is unable to supply a breakdown voltage and requires a separate component called an igniter to provide the arc-establishing voltage pulse. The igniter also allows an extinguished lamp to be re-ignited well before the gas has cooled to temperatures at which a probe-start ballast could re-strike the arc.

Probe-start lamps overcome the cold gas' breakdown voltage through use of a third, starting electrode. The starting electrode is longer and allows an arc to be struck with a lower voltage. As the lamp runs and heats, a bimetal switch disconnects the starting electrode, and the primary, running electrode takes over. With the starting electrode, however, probe-start lamps cannot be pressurized to the more efficient levels that pulse-start lamps are. EISA 2007 required probe-start ballasts to be 94 percent efficient, effectively relegating them to uncovered wattage ranges.

In researching current market availability, DOE found commercially available probe-start ballasts below 500 W, specifically in the 175 W to 400 W range. DOE found that there are no 70 W probe-start ballasts currently available on the market and is not using any 70 W probe-start ballasts as a representative wattage. DOE also found that probe-start ballasts are technologically feasible starting at 150 W and above. As mentioned before, EISA 2007 allowed probe-start ballasts in the 150 W to 500 W range, but set a minimum efficiency standard of 94 percent. None of the probe-start ballasts DOE identified have an efficiency that meets this minimum, effectively prohibiting probe-start ballasts below 500 W. However, because certain fixtures designed for use with lamps rated at 150 W are exempted from EISA 2007 standards, probe-start ballasts are permitted to be used at 150 W in new fixtures. However, DOE's review of manufacturer catalogs indicates probe-start ballasts are not sold at 150 W. Therefore, the only wattage range in which probe-start ballasts are available for use in new fixtures is the greater than 500 W to 2000 W wattage range. Therefore, DOE is analyzing the impact of a design standard that would prohibit probe-start ballasts from being sold in new fixtures in the greater than 500 W to 2000 W equipment class.

A major motivation for prohibiting probe-start ballasts is not based on an efficiency difference between the ballasts, but the decreased mean efficacy of probe-start lamps when compared to pulse-start lamps. As previously mentioned, DOE is considering a design standard that would prohibit the use of probe-start systems and analyzed technologically feasible efficiency standards and energy savings, as well as the market impact, of such a design standard. DOE also notes that it does not plan on having a single efficiency standard for the sub-500 W ranges and is analyzing the best formulas to use in an equation-based efficiency standard.

Probe-start lamps tend to exhibit poorer lumen maintenance than their pulse-start counterparts. Because acceptable lighting levels must be maintained over the life of the lamp, this implies that a space lit with probe-start fixtures needs either more or higher wattage fixtures than if than same space were lit with pulse-start fixtures. Many manufacturers market pulse-start fixtures as lower-wattage replacements for probe-start, especially at low and mid wattages. 1000 W probe-start ballasts, for instance, could be replaced with a lower wattage pulse-start ballast. Alternatively, a consumer could opt to save energy by replacing a certain number of 1000 W probe-start fixtures with fewer pulse-start fixtures of the same wattage.

To quantify the difference in mean lumen output of probe-start lamps relative to pulse-start lamps of the same wattage, DOE compared several major manufacturers' 1000 W lamp catalog data for these two lamp start types. DOE paired these lamps from the same manufacturer and of the same characteristics (open-rated vs. enclosed-rated, color rendering index, percentage of rated life at which the mean lumen value is recorded) and calculated the ratio of probe-start mean lumens divided by pulse-start mean lumens. Then, DOE averaged the ratio of each pairing from every manufacturer and determined that, on average, probe-start metal halide lamps are 5.6 percent less efficacious than comparable pulse-start lamps. Thus, pulse-start metal halide lamp and ballast fixtures can output 5.6 percent more lumens per watt (lm/W) than probe-start fixtures. Energy savings could be achieved in two ways. Because each pulse-start lamp fixture outputs 5.6 percent more lumens (for a given wattage) than comparable probe-start lamp fixtures, customers could:

1. Illuminate an area to the same level with 5.6 percent fewer fixtures if they switch from probe-start to pulse-start; or

2. Switch from full wattage probe-start lamp fixtures to the same number reduced wattage pulse-start lamp fixtures, maintaining light output, but reducing energy consumption.

Using fewer fixtures (option one) would lead to reduced energy consumption and could save administrative and maintenance costs associated with purchasing and maintaining fewer fixtures. However, this response to the design standard is only feasible in applications that have flexibility in fixture spacing. In some applications, such as in small parking lots, changing spacing means moving poles and conductors, which would be expensive and could change the targeting of light in certain areas. For applications in which the height of the fixture is limited, the additional light output of a full wattage pulse-start system might not be adequately distributed over a larger floor space (larger floor space because the number of fixtures has been reduced) without fixture redesign.

For customers using reduced wattage pulse-start fixtures (option two), a customer could, for example, change a 1000 W probe-start fixture for an 875 W pulse-start fixture, maintaining light output to near the original level. DOE's view is that replacing probe-start lamp fixtures with reduced wattage pulse-start lamp fixtures is generally more realistic and practical than replacing them with fewer pulse-start lamp fixtures because fixture spacing does not need to be changed. For this reason, DOE assumed reduced wattage replacements in its analysis of a proposed design standard to prohibit metal halide lamp fixtures that use probe-start as their starting method.

When analyzing the energy savings impact of a design standard EL, DOE multiplied the normalized input power of the 1000 W ballast tested by 0.944. Because DOE determined that using the same number of reduced wattage fixtures is the most likely market response to a design standard, DOE did not also scale the cost of a design standard EL by 0.944. Instead, DOE assumed reduced wattage systems would cost approximately the same amount as a full wattage system with the exception of the addition of an igniter (device that provides a voltage pulse to start the lamp). In the non-design standard scenario, DOE assumed the representative cost of a

1000 W ballast would equal the cost of a probe-start ballast, as this starting method is the most common in the greater than 500 W but less than or equal to 2000 W equipment classes. However, in the design standard scenario, an igniter would need to be added as only pulse-start ballast could be included in new fixtures.

5.8 CALCULATION OF EFFICIENCY AND INPUT POWER

All ballast efficiency values were calculated according to the metal halide ballast test procedure (10 CFR 431.324), with the revisions discussed in section 5.6, using tested input power and tested output power, while all input power values were normalized by dividing rated lamp wattage by efficiency, instead of using tested input wattage values directly. Although the input power derived this way can differ from a particular test value, DOE believes that ballasts are generally designed to operate lamps at their rated wattages. DOE reviewed its test data and found no evidence of a trend or correlation between efficiency and the ratio of rated lamp power to tested ballast output power. So as to avoid confusion with tested input power, DOE is using the term “normalized input power” hereafter when referring to the quantity rated lamp power divided by tested ballast efficiency. DOE sought to present an input power representative of the EL and not an artifact of the particular model chosen. If it finds operating a lamp at wattages greater or less than its rating affects either ballast efficiency or lamp efficacy, DOE will consider amending this approach.

DOE accounted for the increase in wattage for magnetic ballasts by using a multiplier when calculating magnetic efficiencies. DOE assumed that magnetic ballasts’ wattage increase occurs in a linear fashion over the life of the ballast, such that the input power at the end of rated life was 11 percent higher than at the beginning of life. With this assumption, the ballast would average a 5.5 percent increase in output wattage (relative to the tested value at the beginning of life) over its lifetime. Therefore, DOE multiplied the rated lamp wattage by 1.055 when calculating the input power normalized to rated lamp power for all magnetic ballasts, but not for electronic ballasts.

Pursuant to the metal halide ballast certification, compliance, and enforcement procedures (10 CFR 429.54), DOE used the representative value of estimated energy efficiency. This is calculated as the lower of:

1) The mean of the sample, calculated as

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

where $\bar{x}$ is the sample mean; *n* is the number of samples, and x_i is the i^{th} sample; or

2) The lower 99-percent confidence limit (LCL) of the true mean divided by 0.99, calculated as:

$$LCL = \bar{x} - t_{.99}\left(\frac{s}{\sqrt{n}}\right)$$

where $\bar{x}$ is the sample mean; s is the sample standard deviation; n is the number of samples; and $t_{0.99}$ is the t statistic for a 99 percent two-tailed confidence interval with n-1 degrees of freedom.

Any represented value of estimated energy efficiency given by a manufacturer is required to be less than or equal to either the mean or the lower 99-percent confidence limit, so DOE calculated this value in its testing and these are the ballast efficiency values used for all subsequent analysis.

5.9 MODELED FIXTURES AND BALLASTS

For some representative equipment classes, neither commercially available ballasts nor manufacturer input was available at a particular level of efficiency. In these cases, DOE modified the physical characteristics of tested and torn down ballasts, such as type of core steel and winding type, and calculated the resulting efficiency and MPC. For example, DOE upgraded the core steel used in the baseline 150 W ballast to model the cost and efficiency of the EL1 and EL2 designs. DOE also used this modeling method to verify the efficiency of manufacturer-provided ballast model specifications. Using the provided information core mass, core material, winding gauge, winding mass, and winding material, DOE used the modeled ballast calculation method to verify the efficiency provided by the manufacturer.

To estimate the efficiency of a modeled ballast, DOE began with the magnetic core. DOE started with the core mass of a ballast it tore down. Keeping the footprint and stack height constant, DOE calculated the modeled ballast's core's mass using a ratio of the density of the original core material and the material of the modeled ballast. Because the density of the different grades of core steel was very similar, the mass of the modeled core was nearly the same as the original core. Next, DOE compiled watts loss per pound of core steel constants, shown below in Table 5.9.1. These values were found on the Lamination Specialties Corporation (LSI) Steel Processing Division website, http://www.lsisteel.com/max.html. These values were used to estimate core losses based on the calculated mass of the modeled core.

Table 5.9.1 Core Steel Constants Used for Magnetic Modeling

Steel Type	**Core Loss (Watts/lb)**
M3	0.45
M4	0.51
M6	0.66
M9	1.43*
M12	1.56*
M15	1.60
M18	1.83*
M19	2.00
M22	2.10
M27	2.25
M36	2.35
M43	2.50
M45	2.75
M47	3.20
M50	2.84
M55	3.50
* denotes a value that was not available on the LSI website, and was instead extrapolated using an exponential relationship with other steel type prices.	

In addition to losses associated with the magnetic core, DOE also estimated the resistive losses associated with the transformer windings. DOE began by compiling data on the resistive losses associated with the different gauges of copper and aluminum wire used for the windings, summarized in Table 5.9.2. Values for copper wire resistivity were taken from the website for PowerStream, at http://www.powerstream.com/Wire_Size.htm. Values for aluminum wire resistivity were taken from the website for Interface Bus, at http://www.interfacebus.com/Aluminum_Wire_AWG_Size.html. DOE assumed the current in the primary side of the transformer was approximately the input current to the ballast. For the current in the secondary side of the transformer, DOE made an estimate based on specifications provided in ballast datasheets. Then, assuming the same overall length of windings as the original ballast, DOE calculated the overall resistance of the wire by multiplying the overall length by the resistivity. Finally, DOE calculated the resistive losses in the windings as the square of current multiplied by the overall resistance of the wire.

Table 5.9.2 Resistivity of Wire Grades Used for Magnetic Modeling

Wire Material	Wire Gauge	Resistivity (ohm/feet)
Aluminum	19.5	0.01320*
Aluminum	17	0.00831
Copper	16	0.00402
Copper	16.5	0.00454*
Copper	18	0.00639
Copper	19	0.00805
Copper	20	0.01015
Copper	21.5	0.01280*
Copper	23	0.02036
Copper	24	0.02567
* denotes a value that was not available on the website, and was instead extrapolated using linear relationship with other resistivity values.		

After calculating core and winding losses, DOE then calculated the expected efficiency. Efficiency was calculated as the ratio of the quantity input power minus core and winding losses divided by input power.

5.10 70 WATT METAL HALIDE LAMP FIXTURES

In this section, DOE analyzes 70 W fixtures as the representative wattage for the ≥ 50 W and ≤ 100 W equipment class. Whether a fixture is indoor or outdoor can affect the design and price of the fixture and ballast, but not the ballast efficiency. Therefore, all discussion of efficiency and ELs in this chapter applies to both the indoor and outdoor equipment classes.

5.10.1 Baseline Models

DOE selected baseline models as reference points for each equipment class, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.2, a baseline model just meets current Federal energy conservation standards (if any exist) and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy EL with the baseline unit.

DOE chose to analyze two baseline ballasts for the 70 W representative wattage. DOE selected a baseline magnetic ballast, as this would represent the least efficient commercially available ballast. DOE also selected a baseline electronic ballast because electronic ballasts compose a significant portion (estimated at nearly 25 percent) of this equipment class's market.

Because EISA 2007 did not regulate 70 W units, the least efficient ballasts (which are magnetic ballasts) have efficiencies near 70 percent, which is characteristic of equipment purchased based on first cost. DOE considered the ballast's characteristics in choosing the most appropriate equipment, including starting method, input voltage, and electronic configuration. In considering these characteristics, DOE sought to choose a baseline ballast that exhibits characteristics of a common, less efficient ballast. Magnetic 70 W ballasts typically use the high reactance autotransformer (HX-HPF) circuit type, but constant wattage autotransformer (CWA) ballasts are also common. The baseline magnetic unit selected by DOE is a magnetic CWA ballast that operates at 120, 208, 240, and 277 V and has an efficiency of 72.0 percent. Electronic 70 W ballasts typically use low frequency electronic (LFE) circuit type. The baseline electronic unit selected by DOE is an electronic LFE ballast that operates at quad-voltage and has an efficiency of 88.0 percent.

Table 5.10.1 Baseline Models for the 70 W Representative Wattage

Type	Starting Method	Normalized Input Power *W*	Ballast Efficiency	Current Federal Standard
Magnetic	Pulse	102.6	72.0%	(none)
Electronic	Pulse	79.5	88.0%	(none)

5.10.2 Efficiency Levels

For the 70 W representative wattage, DOE surveyed and tested many manufacturer product offerings for ballast efficiency to identify the efficiency levels corresponding to the highest number of models. DOE identified the most prevalent ballast efficiency values in the range of available equipment and established ELs based on that equipment. DOE determined the max tech design option to attain the highest ballast efficiency for metal halide lamp fixtures, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)) To determine this level, DOE conducted a survey of the MHLF market and the research fields that support the market. DOE believes that, within a given equipment class, no working prototypes exist that have a distinguishably higher ballast efficiency than currently available equipment. Therefore the highest EL presented, which represents the most efficient tier of commercially available equipment, is the max tech level that DOE determined for this rulemaking.

The following section identifies the steps and technologies associated with each EL DOE considered for the 70 W representative wattage. As discussed in the screening analysis (chapter 4 of the NOPR TSD), DOE used design options that achieve a higher ballast efficiency than the baseline model. Efficiency improvements to the magnetic baseline unit required a higher grade of steel and an eventual move to electronic circuitry.

EL1.[5] Efficiency (%): *100/(1+3.90*P^(-0.60))*

This level corresponds to a magnetic ballast with higher grade steel than that of the baseline unit.

EL2. Efficiency (%): *100/(1+2.50*P^(-0.55))*

This level requires the use of even better grade of steel, which might have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added to reach this efficiency, and it is almost certainly copper.

EL3. Efficiency (%): *100/(1+0.60*P^(-0.34))*

This level corresponds to a move from magnetic to electronic circuitry.

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[5] P is defined as the rated wattage of the lamp the fixture is designed to operate

EL4. Efficiency: *100/(1+0.36*P^(-0.30))*

This level corresponds to an improved electronic design with more efficient components. It represents the maximum technologically feasible EL.

Table 5.10.2 Summary of the ELs for the 70 W Equipment Class

Efficiency Level	Ballast Efficiency Requirement %
EL1	100/(1+3.90*P^(-0.60))*
EL2	100/(1+2.50*P^(-0.55))
EL3	100/(1+0.60*P^(-0.34))
EL4	100/(1+0.36*P^(-0.30))
*P is defined as the rated wattage of the lamp the fixture is designed to operate	

Figure 5.10.1 illustrates four ELs on a plot of the 70 W equipment class. A square indicates a representative unit. Diamonds indicate other 70 W ballasts tested by DOE.

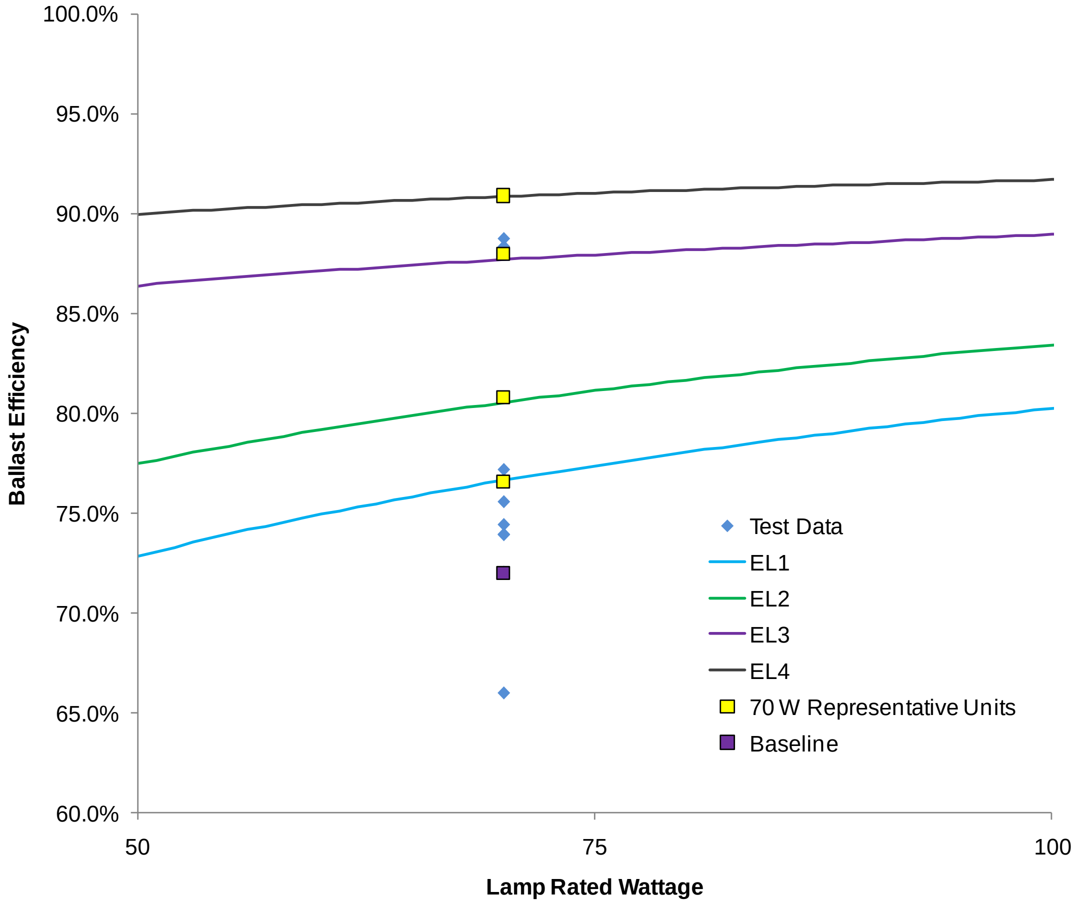

Figure 5.10.1 Efficiency Levels for the 70 W Equipment Class

Table 5.10.3 Ballast Designs for the 70 W Representative Wattage

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Input Power (W)	Rated Lamp Power (W)	Ballast Efficiency (%)
Baseline	Magnetic	Pulse	Quad	102.6	70.0	72.0
EL1	Magnetic	Pulse	Quad	96.4	70.0	76.6
EL2	Magnetic	Pulse	Quad	92.2	70.0	80.1
EL3	Electronic	Pulse	Quad	79.5	70.0	88.0
EL4	Electronic	Pulse	Quad	77.0	70.0	90.9
Note: "Quad" input voltage means 120, 208, 240, and 277 V.						

5.10.3 Ballast and Fixture Prices

DOE analyzed each EL for the 70 W representative wattage to develop appropriate MSPs. When calculating the MHLF MSPs for this rulemaking, DOE calculated the ballast MPC and added any relevant ballast cost adders to get the total ballast MPC. This total ballast MPC was multiplied by a calculated ballast manufacturer markup to determine the total ballast MSP to a fixture manufacturer. DOE also calculated an empty fixture MPC (fixture without a ballast or adders) and added any relevant fixture cost adders to get a total empty fixture MPC. This total empty fixture MPC was then added to the total ballast MSP to calculate the total fixture MPC. As discussed in section 5.3, fixtures using electronic ballasts had certain MPC adders applied based on if the fixture was indoor or outdoor to account for thermal management, transient voltage protection, and 120 V auxiliary tap capability. Finally, the total fixture MPC was multiplied by a fixture manufacturer markup to calculate the total fixture MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Therefore, MSP variance across ELs is due to changes in the ballast itself and certain fixture and ballast adders.

For the baseline unit and for EL1, DOE based the ballast price on teardown-sourced MSPs. DOE used input from manufacturers to determine which grade of electrical steel would be used to achieve the levels of efficiency represented by those levels. EL2 corresponds to a magnetic ballast, whose price DOE calculated using the MPC of a baseline ballast and adding the calculated expected increase in price for the increase in steel grade needed to achieve EL2 efficiency. EL3 (also the baseline electronic ballast) is based on teardown-sourced MSPs. EL4 is scaled from a comparable 250 W ballast using a ratio of retail data between the two wattages. Total fixture MSP increases with increased ballast efficiency.

Table 5.10.4 Summary of the Manufacturing Selling Prices for the 70 W Representative Wattage

Efficiency Level	Total Indoor Fixture MSP 2010$	Total Outdoor Fixture MSP 2010$
Baseline	68.01	68.01
EL1	68.94	68.94
EL2	78.97	78.97
Baseline Electronic/EL3	81.21	109.47
EL4	91.38	119.64

5.10.4 Results

The following table summarizes the engineering characteristics for each ballast replacement option in the 70 W representative equipment class.

Table 5.10.5 Indoor 70 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency (%)	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MPC	Total Fixture MSP
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	102.6	72.0%	18.22	-	18.22	16.26	-	43.04	68.01
EL1	HX-HPF	Pulse	Quad	96.4	76.6%	18.62	-	18.62	16.26	-	43.63	68.94
EL2	CWA	Pulse	Quad	92.2	80.1%	22.94	-	22.94	16.26	-	49.98	78.97
Baseline Electronic/ EL3	Electronic	Pulse	Quad	79.5	88%	20.94	0.75	21.69	16.26	3.25	51.40	81.21
EL4	Electronic	Pulse	Quad	77.0	90.9%	25.32	0.75	26.07	16.26	3.25	57.83	91.38

* “Quad” input voltage means 120, 208, 240, and 277 V.

Table 5.10.6 Outdoor 70 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency (%)	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MPC	Total Fixture Manufacturer Selling Price
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	102.6	72.0%	18.22	-	26.78	16.26	-	43.04	68.01
EL1	HX-HPF	Pulse	Quad	96.4	76.6%	18.62	-	27.37	16.26	-	43.63	68.94
EL2	CWA	Pulse	Quad	92.2	80.1%	22.94	-	33.72	16.26	-	49.98	78.97
Baseline Electronic/ EL3	Electronic	Pulse	Quad	79.5	88%	20.94	-	30.79	16.26	22.24	69.29	109.47
EL4	Electronic	Pulse	Quad	77.0	90.9%	25.32	-	37.22	16.26	22.24	75.72	119.64

* “Quad” input voltage means 120, 208, 240, and 277 V.

5.11 150 WATT METAL HALIDE LAMP FIXTURES

In this section, DOE analyzes 150 W fixtures as the representative wattage for the >100 W and <150 W equipment class. Whether a fixture is indoor or outdoor can affect the design and price of the fixture and ballast, but not the ballast efficiency. Therefore, all discussion of efficiency and ELs in this chapter applies to both the indoor and outdoor equipment classes.

5.11.1 Baseline Models

DOE selected baseline models as reference points for each equipment class, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.2, a baseline model just meets current Federal energy conservation standards (if any exist) and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy EL with the baseline unit.

DOE chose to analyze one baseline ballast for the 150 W representative wattage. For outdoor applications, 150 W ballasts are sold in fixtures rated for use in wet locations and operation in ambient air temperatures over 50°C and are therefore exempted from standards prescribed by EISA 2007 as described in NOPR TSD chapter 3. As a result, the baseline unit for the 150 W representative wattage has an efficiency lower than 88 percent. Furthermore, though electronic ballasts are available at 150 W, magnetic 150 W pulse-start, quad-voltage units dominate in the lower efficiency range. Both CWA and HX-HPF ballasts are common at the 150 W level and DOE considered them both to be representative of 150 W shipments. Based on test results, DOE found the lowest efficiency ballast that could be incorporated into a fixture exempt from EISA 2007 standards was a magnetic pulse-start, quad-voltage CWA ballast with an efficiency of 81.2 percent, and thus analyzed this ballast as a baseline. Electronic 150 W ballasts typically use LFE circuit type and multiple-input-voltage capability. DOE used manufacturer-provided, test, and catalog data regarding which grade of steel would be required to achieve the higher ELs.

Table 5.11.1 Baseline Model for the 150 W Representative Wattage

Type	Starting Method	Normalized Input Power *W*	Ballast Efficiency	Current Federal Standard
Magnetic	Pulse	195.4	81.2%	None

5.11.2 Efficiency Levels

For the 150 W representative wattage, DOE surveyed and tested many manufacturer product offerings for ballast efficiency to identify the ELs corresponding to the highest number of models. DOE identified the most prevalent ballast efficiency values in the range of available equipment and established ELs based on that equipment. DOE determined the max tech ballast efficiency for metal halide lamp fixtures, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)) To determine this level, DOE conducted a survey of the MHLF market and the research fields that support the market. DOE believes that, within a given equipment class, no working prototypes exist that have a distinguishably higher ballast efficiency than currently available equipment. Therefore the highest EL presented, which represents the most efficient tier of commercially available equipment, is the max tech level that DOE determined for this rulemaking.

The following section identifies the steps and technologies associated with each EL DOE considered for the 150 W representative wattage. As discussed in the screening analysis (NOPR TSD chapter 4), DOE used design options that achieve a higher ballast efficiency than the baseline model. Efficiency improvements to the magnetic baseline unit required a higher grade of steel, more and better conductor, and an eventual move to electronic circuitry.

These ELs represent modeled ballasts, where the efficiencies were specified (as opposed to tested) and the costs modeled (as opposed to teardown-derived).

EL1.[6] Efficiency (%): *100/(1+3.90*P^(-0.60))*

This level corresponds to a magnetic ballast with higher grade steel than that of the baseline unit. The stack height and ballast footprint are maintained relative to the baseline ballast. DOE used manufacturer input to specify the steel grade required to meet EL1.

EL2. Efficiency (%): *100/(1+2.50*P^(-0.55))*

This level requires the use of an even better grade of steel, which might have thinner laminations. The stack height and ballast footprint are maintained relative to the baseline ballast. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added to reach this efficiency, and it is almost certainly copper.

EL3. Efficiency (%): *100/(1+0.60*P^(-0.34))*

This level corresponds to a move from magnetic to electronic circuitry.

EL4. Efficiency (%): *100/(1+0.36*P^(-0.30))*

This level corresponds to an improved electronic design with more efficient components. It represents the maximum technologically feasible EL.

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[6] P is defined as the rated wattage of the lamp the fixture is designed to operate

Table 5.11.2 Summary of the ELs for the 150 W Representative Wattage

Efficiency Level	Ballast Efficiency Requirement %
EL1	100/(1+3.90*P^(-0.60))*
EL2	100/(1+2.50*P^(-0.55))
EL3	100/(1+0.60*P^(-0.34))
EL4	100/(1+0.36*P^(-0.30))
*P is defined as the rated wattage of the lamp the fixture is designed to operate	

Figure 5.11.1 illustrates four ELs on a plot of the 150 W equipment class. A square indicates a representative unit. Diamonds indicate other 150 W ballasts tested by DOE.

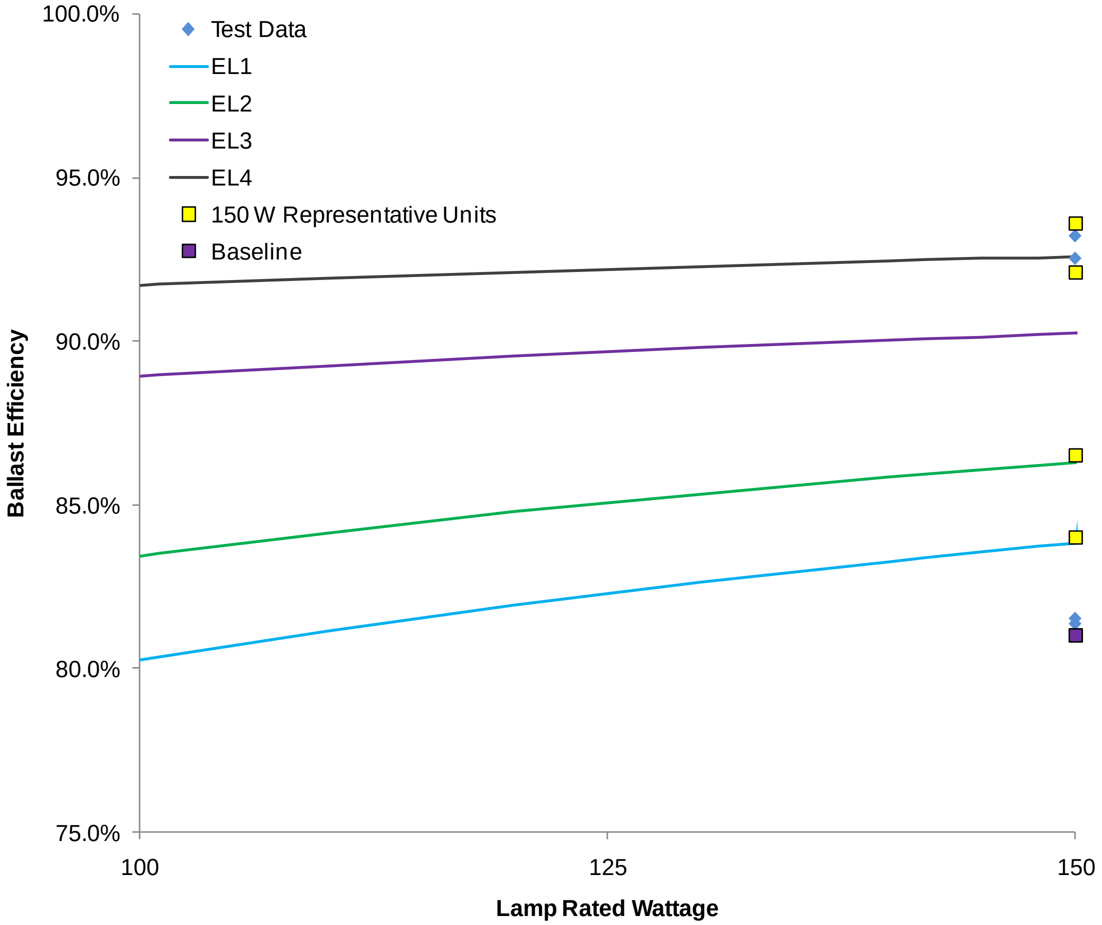

Figure 5.11.1 Efficiency Levels for the 150 W Equipment Class

Table 5.11.3 Ballast Designs for the 150 W Representative Wattage

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Input Power (W)	Rated Lamp Power (W)	Ballast Efficiency (%)
Baseline	Magnetic	Pulse	Quad	102.6	150.0	72.0
EL1	Magnetic	Pulse	Quad	96.4	150.0	76.6
EL2	Magnetic	Pulse	Quad	92.2	150.0	80.1
EL3	Electronic	Pulse	Quad	79.5	150.0	88.0
EL4	Electronic	Pulse	Quad	77.0	150.0	90.9
Note: "Quad" input voltage means 120, 208, 240, and 277 V.						

5.11.3 Ballast and Fixture Prices

DOE analyzed each EL for the 150 W representative wattage to develop appropriate MSPs. When calculating the MHLF MSPs for this rulemaking, DOE calculated the ballast MPC and added any relevant ballast cost adders to get the total ballast MPC. This total ballast MPC was multiplied by a calculated ballast manufacturer markup to determine the total ballast MSP to a fixture manufacturer. DOE also calculated an empty fixture MPC (fixture without a ballast or adders) and added any relevant fixture cost adders to get a total empty fixture MPC. This total empty fixture MPC was then added to the total ballast MSP to calculate the total fixture MPC. As discussed in section 5.3, fixtures using electronic ballasts had certain MPC adders applied based on if the fixture was indoor or outdoor to account for thermal management, transient voltage protection, and 120 V auxiliary tap capability. Finally, the total fixture MPC was multiplied by a fixture manufacturer markup to calculate the total fixture MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Therefore, MSP variance across ELs is due to changes in the ballast itself and certain fixture and ballast adders.

The total fixture MSP is equal to the sum of the empty fixture MSP and the ballast MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Therefore, MSP variance across ELs is due only to changes in the ballast itself.

DOE did not perform any teardown analysis on 150 W empty fixtures. However, because 150 W products serve similar applications to both 70 W and 250 W fixtures, DOE found it appropriate to average the fixture prices of the 70 W and the 250 W fixtures that were determined in the preliminary analysis to determine a 150 W fixture price.

For the baseline ballast, DOE used teardown-sourced pricing that was also confirmed by a modeled ballast where a magnetic ballast of similar size and wattage is torn down and then modeled as if it had features (*e.g.*, better steel, more conductor) that enabled higher efficiency. DOE interviewed manufacturers to determine which features were required to reach a given EL.

For the ballast component, ELs 1 and 2 also correspond to modeled ballasts. The ballast price for EL3 is based on teardown-sourced data. EL4 pricing was determined by scaling MSPs from 70 W electronic ballasts using a ratio of retail data between the two wattages.

Table 5.11.4 Summary of the Manufacturing Selling Prices for the 150 W Representative Wattage

Efficiency Level	Total Indoor Fixture MSP 2010$	Total Outdoor Fixture MSP 2010$
Baseline	109.83	109.83
EL1	122.12	122.12
EL2	128.02	128.02
EL3	124.73	152.99
EL4	139.32	167.58

5.11.4 Engineering Summary

The following table summarizes the engineering data developed for each EL for the 150 W representative wattage.

Table 5.11.5 Indoor 150 W Representative Wattage Engineering Summary

Efficiency Level	**Ballast Type**	**Starting Method**	**Input Voltage**	**Normalized Input Power**	**Ballast Efficiency**	**Ballast MPC**	**Ballast MPC Adder**	**Total Ballast MSP to OEM**	**Empty Fixture MPC**	**Empty Fixture MPC Adder**	**Total Fixture MSP**
			V	***W***		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	195.4	81.0%	28.22	-	41.48	28.03	-	109.83
EL1	CWA	Pulse	Quad	188.4	84.0%	33.51	-	49.26	28.03	-	122.12
EL2	CWA	Pulse	Quad	182.9	86.5%	36.05	-	52.99	28.03	-	128.02
EL3	Electronic	Pulse	Quad	162.9	92.1%	30.07	0.75	45.31	28.03	5.61	124.73
EL4	Electronic	Pulse	Quad	160.3	93.6%	36.35	0.75	54.54	28.03	5.61	139.32

* “Quad” input voltage means 120, 208, 240, and 277 V.

Table 5.11.6 Outdoor 150 W Representative Wattage Engineering Summary

Efficiency Level	**Ballast Type**	**Starting Method**	**Input Voltage**	**Normalized Input Power**	**Ballast Efficiency**	**Ballast MPC**	**Ballast MPC Adder**	**Total Ballast MSP to OEM**	**Empty Fixture MPC**	**Empty Fixture MPC Adder**	**Total Fixture MSP**
			V	***W***		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad *	195.4	81.0%	28.22	-	41.48	28.03	-	109.83
EL1	CWA	Pulse	Quad	188.4	84.0%	33.51	-	49.26	28.03	-	122.12
EL2	CWA	Pulse	Quad	182.9	86.5%	36.05	-	52.99	28.03	-	128.02
EL3	Electronic	Pulse	Quad	162.9	92.1%	30.07	-	44.20	28.03	24.59	152.99
EL4	Electronic	Pulse	Quad	160.3	93.6%	36.35	-	53.44	28.03	24.59	167.58

* “Quad” input voltage means 120, 208, 240, and 277 V.

5.12 250 WATT METAL HALIDE LAMP FIXTURES

In this section, DOE analyzes 250 W fixtures as the representative wattage for the ≥150 W and ≤250 W equipment class. Whether a fixture is indoor or outdoor can affect the design and price of the fixture and ballast, but not the ballast efficiency. Therefore, all discussion of efficiency and ELs in this chapter applies to both the indoor and outdoor equipment classes.

5.12.1 Baseline Models

DOE selected baseline models as reference points for each equipment class, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.2, a baseline model just meets current Federal energy conservation standards (if any exist) and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy EL with the baseline unit.

DOE chose to analyze one baseline ballast for the 250 W representative wattage. EISA 2007 covered 250 W ballasts in new fixtures and no model could be less than 88 percent efficient. Although electronic ballasts are not uncommon for 250 W ballasts, magnetic, pulse-start, CWA, quad-voltage units predominate. For the 250 W baseline, DOE did not test a ballast that just met the 88 percent level, and instead used a ballast from an EISA-compliant fixture and assumed it to be 88 percent efficient.

Table 5.12.1 Baseline Model for the 250 W Representative Wattage

Type	Starting Method	Normalized Input Power *W*	Ballast Efficiency	Current Federal Standard
Magnetic	Pulse	299.7	88.0%	88.0%

5.12.2 Efficiency Levels

For the 250 W representative wattage, DOE surveyed and tested many manufacturer product offerings for ballast efficiency to identify the ELs corresponding to the highest number of models. DOE identified the most prevalent ballast efficiency values in the range of available equipment and established ELs based on that equipment. DOE determined the max tech ballast for metal halide lamp fixtures, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)) To determine this level, DOE conducted a survey of the MHLF market and the research fields that support the market. DOE believes that, within a given equipment class, no working prototypes exist that have a distinguishably higher ballast efficiency than currently available equipment. Therefore, the highest EL presented, which represents the most efficient tier of commercially available equipment, is the max tech level that DOE determined for this rulemaking.

Through a survey of commercially available products and manufacturer input, DOE determined that the max tech efficiency achievable for magnetic ballasts ≥150 W and ≤200 W is at the prescribed EISA 2007 efficiency standard and thus set the magnetic levels (ELs 1 and 2) at 88 percent.

The following section identifies the steps and technologies associated with each EL DOE considered for the 250 W representative wattage. As discussed in the screening analysis (NOPR TSD chapter 4), DOE used design options that achieve a higher ballast efficiency than the baseline model. Efficiency improvements to the magnetic baseline unit required a higher grade of steel, more and better conductor, and an eventual move to electronic circuitry.

As with the baseline unit, DOE relied on manufacturer-furnished data regarding what types and sizes of core and windings would be required to achieve a given EL (for ELs 1 and 2). EL1 is based on a teardown and EL2 represents a modeled ballast, where the efficiency was specified (as opposed to tested) and the cost modeled (as opposed to teardown-derived).

EL1.[7] Efficiency for ≥150 W and ≤200 W (%): 88.0
Efficiency for >200 W and ≤250 W (%): $4.0E\text{-}2*P + 80.0$

For ≥150 W and ≤200 W, DOE determined that 88 percent was the maximum technologically feasible EL for magnetic ballasts, so no design change is required at EL1. For >200 W and ≤250 W, this level requires a lower loss grade of steel, which may have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added and partially or wholly changed from aluminum to copper.

EL2. Efficiency for ≥150 W and ≤200 W (%): 88.0
Efficiency for >200 W and ≤250 W (%): $7.0E\text{-}2*P + 74.0$

For ballasts ≥150 W and ≤200 W, DOE determined that 88 percent was the maximum technologically feasible EL for magnetic ballasts, so no design change is required at EL2. For ballasts >200 W and ≤250 W, this level requires the use of even better grade of steel, which might have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added to reach this efficiency, and it is almost certainly copper.

EL3. Efficiency (%): $100/(1+0.60*P^{\wedge}(-0.34))$

This level corresponds to the use of electronic ballasts.

EL4. Efficiency (%): $100/(1+0.36*P^{\wedge}(-0.30))$

This level represents the maximum technologically feasible level and represents a slight improvement in efficiency over EL3. This level corresponds to electronic ballasts built with improved components relative to EL3.

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[7] P is defined as the rated wattage of the lamp the fixture is designed to operate

Table 5.12.2 Summary of the ELs for the 250 W Representative Wattage

Efficiency Level	Ballast Efficiency Requirement %
EL1	88.0 (≥150 W and ≤200 W) 4.0E-2*P + 80.0 (>200 W and ≤250 W)
EL2	88.0 (≥150 W and ≤200 W) 7.0E-2*P + 74.0 (>200 W and ≤250 W)
EL3	100/(1+0.60*P^(-0.34))
EL4	100/(1+0.36*P^(-0.30))

Figure 5.12.1 illustrates four ELs on a plot of the 250 W equipment class. A square indicates a representative unit. Diamonds indicate other 250 W ballasts tested by DOE.

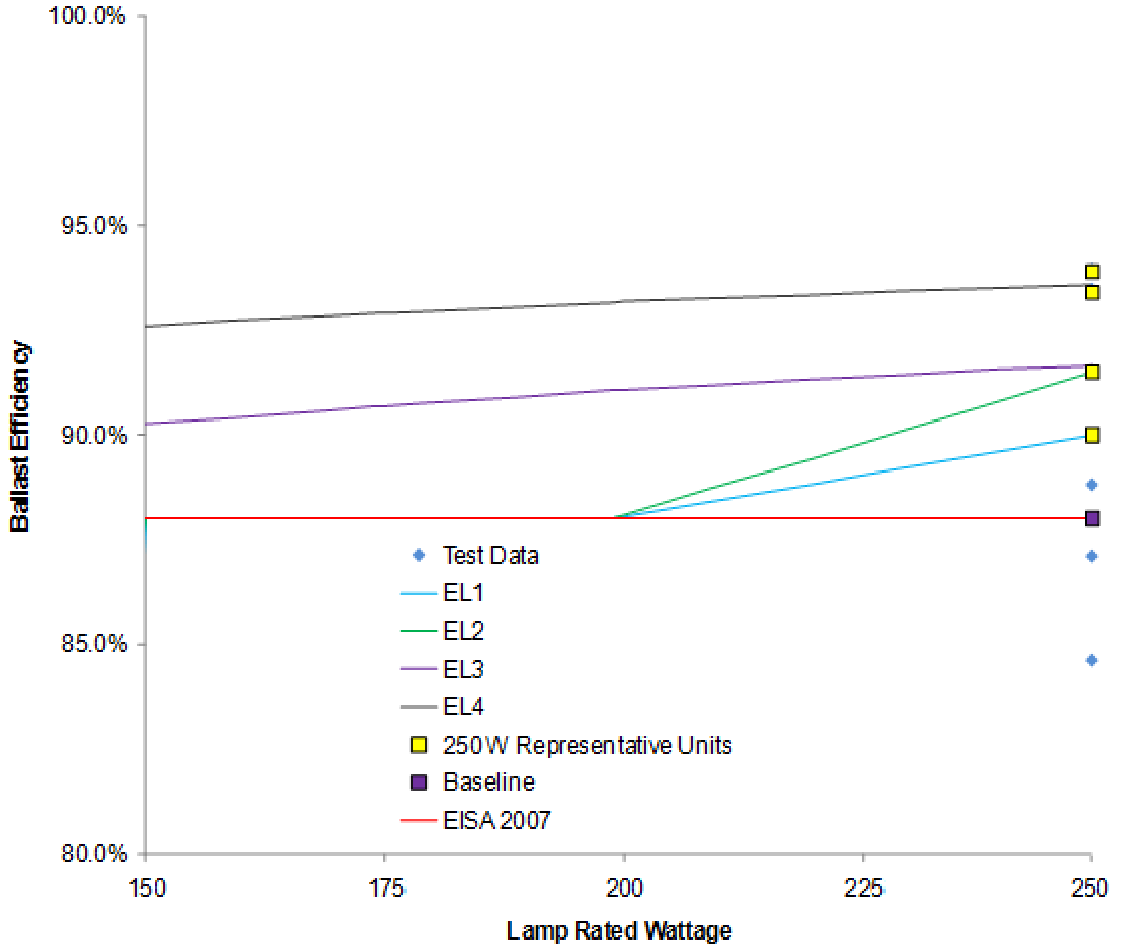

Figure 5.12.1 Efficiency Levels for the 250 W Equipment Class

Table 5.12.3 Ballast Designs for the 250 W Representative Wattage

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Input Power (W)	Rated Lamp Power (W)	Ballast Efficiency (%)
Baseline	Magnetic	Pulse	Quad	299.7	250.0	88.0
EL1	Magnetic	Pulse	Quad	293.1	250.0	90.0
EL2	Magnetic	Pulse	Quad	288.3	250.0	91.5
EL3	Electronic	Pulse	Tri	267.7	250.0	93.4
EL4	Electronic	Pulse	Dual	266.2	250.0	93.9
Note: "Dual" input voltage means 120 and 277 V. "Tri" input voltage means 208, 240, and 277 V. "Quad" adds 120 V to tri.						

5.12.3 Ballast and Fixture Prices

DOE analyzed each EL for the 250 W representative wattage to develop appropriate MSPs. When calculating the MHLF MSPs for this rulemaking, DOE calculated the ballast MPC and added any relevant ballast cost adders to get the total ballast MPC. This total ballast MPC was multiplied by a calculated ballast manufacturer markup to determine the total ballast MSP to a fixture manufacturer. DOE also calculated an empty fixture MPC (fixture without a ballast or adders) and added any relevant fixture cost adders to get a total empty fixture MPC. This total empty fixture MPC was then added to the total ballast MSP to calculate the total fixture MPC. As discussed in section 5.3, fixtures using electronic ballasts had certain MPC adders applied based on if the fixture was indoor or outdoor to account for thermal management, transient voltage protection, and 120 V auxiliary tap capability. Finally, the total fixture MPC was multiplied by a fixture manufacturer markup to calculate the total fixture MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Therefore, MSP variance across ELs is due to changes in the ballast itself and certain fixture and ballast adders.

For the ballast component, baseline price is based on teardown-sourced data of a ballast assumed to be 88 percent efficient based on its use in an EISA-compliant fixture. EL1 is also based on teardown-sourced data of a ballast tested to be 90 percent efficient. EL2 corresponds to ballast modeling, where a magnetic ballast of similar size and wattage is torn down and then modeled as if it had features (*e.g.*, better steel, more conductor) that enabled higher efficiency. DOE interviewed manufacturers to determine which features were required to reach a given EL. ELs 3 and 4 corresponded to electronic ballasts torn down directly. Note that EL3 carries a higher MSP than EL4. This unusual situation arises from the fact that the EL3 ballast is rated for operation at wattages up to 400 W and includes non-electronic parts that would ordinarily be considered part of a fixture. The EL4 ballast is a dedicated wattage unit, and can use smaller, less costly circuit elements.

Table 5.12.4 Summary of the Manufacturing Selling Prices for the 250 W Representative Wattage

Efficiency Level	Total Indoor Fixture MSP 2010$	Total Outdoor Fixture MSP 2010$
Baseline	142.20	142.20
EL1	159.99	159.99
EL2	171.81	171.81
EL3	202.62	230.88
EL4	197.14	225.40

5.12.4 Engineering Summary

The following table summarizes the engineering data developed for each EL for the 250 W representative wattage.

Table 5.12.5 Indoor 250 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	299.7	88.0%	34.15	-	50.20	39.80	-	142.20
EL1	CWA	Pulse	Quad	293.1	90.0%	41.81	-	61.46	39.80	-	159.99
EL2	CWA	Pulse	Quad	288.3	91.5%	46.90	-	68.94	39.80	-	171.81
EL3	Electronic	Pulse	Tri	267.7	93.4%	54.00	0.75	80.48	39.80	7.96	202.62
EL4	Electronic	Pulse	Dual	266.2	93.9%	51.64	0.75	77.01	39.80	7.96	197.14
* “Dual” input voltage means 120 and 277 V. “Tri” input voltage means 208, 240, and 277 V. “Quad” adds 120 V to tri.											

Table 5.12.6 Outdoor 250 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	299.7	88.0%	34.15	-	50.20	39.80	-	142.20
EL1	CWA	Pulse	Quad	293.1	90.0%	41.81	-	61.46	39.80	-	159.99
EL2	CWA	Pulse	Quad	288.3	91.5%	46.90	-	68.94	39.80	-	171.81
EL3	Electronic	Pulse	Tri	267.7	93.4%	54.00	-	79.38	39.80	26.95	230.88
EL4	Electronic	Pulse	Dual	266.2	93.9%	51.64	-	75.91	39.80	26.95	225.40
* “Dual” input voltage means 120 and 277 V. “Tri” input voltage means 208, 240, and 277 V. “Quad” adds 120 V to tri.											

5.13 400 WATT METAL HALIDE LAMP FIXTURES

In this section, DOE analyzes 400 W fixtures as the representative wattage for the > 250 W and ≤ 500 W equipment class. Whether a fixture is indoor or outdoor can affect the design and price of the fixture and ballast, but not the ballast efficiency. Therefore, all discussion of efficiency and ELs in this chapter applies to both the indoor and outdoor equipment classes.

5.13.1 Baseline Models

DOE selected baseline models as reference points for each equipment class, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.2, a baseline model just meets current Federal energy conservation standards (if any exist) and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy EL with the baseline unit.

DOE chose to analyze one baseline ballast for the 400 W representative wattage. EISA 2007 covered 400 W ballasts in new fixtures, and no model could be less than 88 percent efficient. Although electronic ballasts are not uncommon for 400 W ballasts, magnetic, pulse-start, CWA, quad-voltage units dominate. For the 400 W baseline, DOE did not test a ballast that just met the 88 percent level. Instead, DOE used a ballast from an EISA-compliant fixture and assumed it to be 88 percent efficient. DOE tore down the ballast, using manufacturer-provided data regarding which grade of steel would be required to achieve baseline efficiency.

Table 5.13.1 Baseline Models for the 400 W Representative Wattage

Type	Starting Method	Normalized Input Power *W*	Ballast Efficiency	Current Federal Standard
Magnetic	Pulse	479.5	88.0%	88.0%

5.13.2 Efficiency Levels

For the 400 W representative wattage, DOE surveyed and tested many manufacturer product offerings for ballast efficiency to identify the ELs corresponding to the highest number of models. DOE identified the most prevalent ballast efficiency values in the range of available equipment and established ELs based on that equipment. DOE determined the max tech ballast efficiency for metal halide lamp fixtures, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)) To determine this level, DOE conducted a survey of the MHLF market and the research fields that support the market. DOE believes that, within a given equipment class, no working prototypes exist that have a distinguishably higher ballast efficiency than currently available equipment. Therefore the highest EL presented, which represents the most efficient tier of commercially available equipment, is the max tech level that DOE determined for this rulemaking.

The following section identifies the steps and technologies associated with each EL DOE considered for the 400 W representative wattage. As discussed in the screening analysis (NOPR TSD chapter 4), DOE used design options that achieve a higher ballast efficiency than the baseline model. Efficiency improvements to the magnetic baseline unit required a higher grade of steel, more and better conductor, and an eventual move to electronic circuitry.

As with the baseline unit, DOE relied on manufacturer-furnished data regarding what types and sizes of core and windings would be required to achieve a given EL (for ELs 1 and 2). These ELs represent “model” ballasts, where the efficiencies were specified (as opposed to tested) and the costs modeled (as opposed to teardown-derived).

EL1. Efficiency (%): 90.0

This level requires a lower loss grade of steel, which might have thinner laminations. The stack height is maintained, as is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added and partially or wholly changed from aluminum to copper.

EL2. Efficiency (%): 91.5

This level requires the use of even better grade of steel, which might have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added to reach this efficiency, and the conductor material is almost certainly copper.

EL3.[8] Efficiency (%): *100/(1+0.60*P^((-0.34))*

This level requires the use of electronic ballasts rather than magnetic ballasts. The least efficient electronic ballasts meet EL3. The EL3 representative unit is a low frequency electronic ballast.

EL4. Efficiency (%): *100/(1+0.36*P^(-0.30))*

This level represents the maximum technologically feasible level and represents a slight improvement in efficiency over EL3. This level corresponds to electronic ballasts built with the better components and improved circuit designs compared to EL3. The representative unit at EL4 is an HFE ballast. HFE ballasts are some of the most efficient ballasts currently on the market, but there are no ANSI standards defining the way they should operate a lamp. Therefore, lamp and ballast compatibility could be an issue for high HFE ballasts in the proposed energy conservation standards. Under a ballast efficiency approach, DOE considers the feasibility and market impact of a standard that would encourage wide-spread use of HFE ballasts when there are lamp-ballast compatibility concerns and lack of industry-endorsed ANSI standards. DOE recognizes the incompatibility of HFE ballasts with certain particularly efficacious lamps, including ceramic metal halide. DOE does not intend to set standards that would preclude the use of these lamps and takes lamp-ballast compatibility issues into account in the proposed standards.

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[8] P is defined as the rated wattage of the lamp the fixture is designed to operate

Table 5.13.2 Summary of the ELs for 400 W Representative Wattages

Efficiency Level	Ballast Efficiency Requirement %
EL1	90.0
EL2	91.5
EL3	100/(1+0.60*P^(-0.34))
EL4	100/(1+0.36*P^(-0.30))

Figure 5.13.1 illustrates four ELs on a plot of the 400 W equipment class. A star indicates a representative unit tested by DOE. Diamonds indicate other 400 W ballasts tested by DOE.

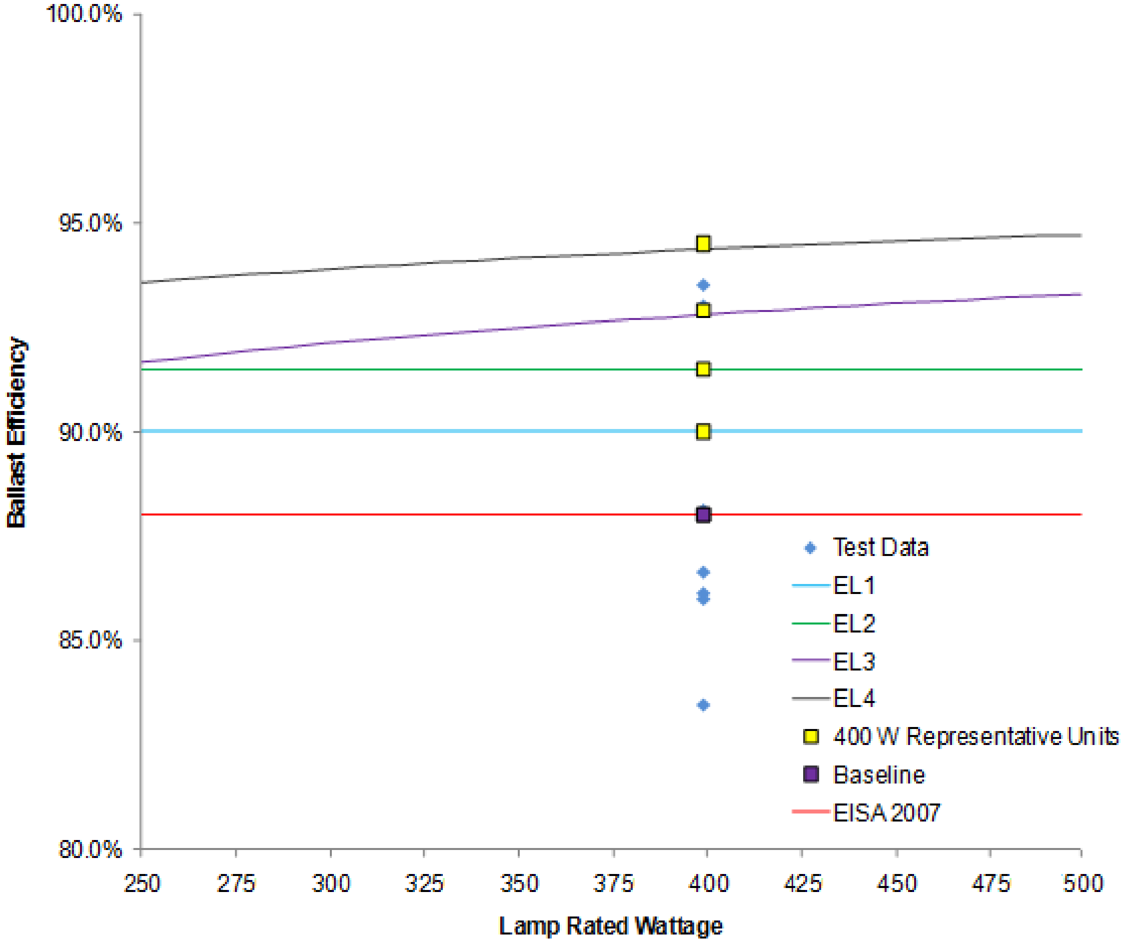

Figure 5.13.1 Efficiency Level for the 400 W Equipment Class

Table 5.13.3 Ballast Designs for the 400 W Representative Wattage

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Input Power (W)	Rated Lamp Power (W)	Ballast Efficiency (%)
Baseline	Magnetic	Pulse	Quad	479.5	400.0	88.0
EL1	Magnetic	Pulse	Quad	468.9	400.0	90.0
EL2	Magnetic	Pulse	Quad	461.2	400.0	91.5
EL3	Electronic	Pulse	Quad	430.6	400.0	92.9
EL4	Electronic	Pulse	Tri	423.3	400.0	94.5
Note: “Tri” input voltage means 208, 240, and 277 V. “Quad” adds 120 V to tri.						

5.13.3 Ballast and Fixture Prices

DOE analyzed each EL for the 400 W representative wattage to develop appropriate MSPs. When calculating the MHLF MSPs for this rulemaking, DOE calculated the ballast MPC and added any relevant ballast cost adders to get the total ballast MPC. This total ballast MPC was multiplied by a calculated ballast manufacturer markup to determine the total ballast MSP to a fixture manufacturer. DOE also calculated an empty fixture MPC (fixture without a ballast or adders) and added any relevant fixture cost adders to get a total empty fixture MPC. This total empty fixture MPC was then added to the total ballast MSP to calculate the total fixture MPC. As discussed in section 5.3, fixtures using electronic ballasts had certain MPC adders applied based on if the fixture was indoor or outdoor to account for thermal management, transient voltage protector, and 120 V auxiliary tap capability. Finally, the total fixture MPC was multiplied by a fixture manufacturer markup to calculate the total fixture MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Therefore, MSP variance across ELs is due to changes in the ballast itself and certain fixture and ballast adders.

For the ballast component, baseline price was determined by a direct teardown of a magnetic ballast assumed to be 88 percent efficient based on its use in an EISA-compliant fixture. EL1 is also based on teardown-sourced data of a ballast tested to be 90 percent efficient. EL2 corresponds to ballast modeling, where a magnetic ballast of similar size and wattage is torn down and then modeled as if it had features (*e.g.,* better steel, more conductor) that enabled higher efficiency. DOE interviewed manufacturers to determine which features were required to reach a given EL. EL3 corresponded to an electronic ballast torn down directly. EL4 corresponded to an electronic ballast, with a cost estimated by dividing the manufacturer’s retail price by a distributor markup (with the assumption being that the manufacturer had internalized the cost of distribution), and then by the ballast manufacturer markup, to arrive at an MPC.

Table 5.13.4 Summary of the Manufacturing Selling Prices for the 400 W Representative Wattage

Efficiency Level	Total Indoor Fixture MSP 2010$	Total Outdoor Fixture MSP 2010$
Baseline	163.77	163.77
EL1	192.99	192.99
EL2	207.20	207.20
EL3	267.14	295.40
EL4	298.45	326.71

5.13.4 Engineering Summary

The following table summarizes the engineering data developed for each EL for the 400 W representative wattage

Table 5.13.5 Indoor 400 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad*	479.5	88.0%	28.58	-	42.01	61.64	-	163.77
EL1	CWA	Pulse	Quad	468.9	90.0%	41.16	-	60.51	61.64	-	192.99
EL2	CWA	Pulse	Quad	461.2	91.5%	47.28	-	69.50	61.64	-	207.20
EL3	Electronic	Pulse	Quad	430.6	92.9%	63.95	0.75	95.11	61.64	12.33	267.14
EL4	Electronic	Pulse	Tri	423.3	94.5%	77.43	0.75	114.92	61.64	12.33	298.45
* “Tri” input voltage means 208, 240, and 277 V. “Quad” adds 120 V to tri.											

Table 5.13.6 Outdoor 400 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	*W*		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Pulse	Quad	479.5	88.0%	28.58	-	42.01	61.64	-	163.77
EL1	CWA	Pulse	Quad	468.9	90.0%	41.16	-	60.51	61.64	-	192.99
EL2	CWA	Pulse	Quad	461.2	91.5%	47.28	-	69.50	61.64	-	207.20
EL3	Electronic	Pulse	Quad	430.6	92.9%	63.95	-	94.01	61.64	31.32	295.40
EL4	Electronic	Pulse	Tri	423.3	94.5%	77.43	-	113.82	61.64	31.32	326.71
* “Tri” input voltage means 208, 240, and 277 V. “Quad” adds 120 V to tri.											

5.14 1000 WATT METAL HALIDE LAMP FIXTURES

In this section, DOE analyzes 1000 W fixtures as the representative wattage for the >500 W and ≤2000 W equipment class. Whether a fixture is indoor or outdoor can affect the design and price of the fixture and ballast, but not the ballast efficiency. Therefore, all discussion of efficiency and ELs in this chapter applies to both the indoor and outdoor equipment classes.

5.14.1 Baseline Models

DOE selected baseline models as reference points for each equipment class, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.2, a baseline model just meets current Federal energy conservation standards (if any exist) and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy EL with the baseline unit.

DOE chose to analyze one baseline ballast for the 1000 W representative wattage. Although ballasts above 500 W are currently unregulated, they tend to be efficient relative to smaller units. DOE did not test any ballasts below 91 percent in efficiency. DOE identified no 1000 W electronic ballasts for general lighting on the market today. This could be partly because magnetic ballasts can be quite efficient at the 1000 W level and partly because of thermal challenges for high-wattage electronic ballasts. Pulse-start ballasts are available at the 1000 W level, but probe-start, CWA, quad-voltage units dominate. DOE selected the least efficient, quad-voltage ballast as its baseline. Although the unit happened to be pulse-start, efficiency (as measured by the test procedure) is not directly affected by starting method, which is part of the reason DOE is considering a design standard that eliminates probe-starting.

Table 5.14.1 Baseline Models for the 1000 W Representative Wattage

Type	Starting Method	Normalized Input Power *W*	Ballast Efficiency	Current Federal Standard
Magnetic	Pulse	1049.2	91.8%	(none)

5.14.2 Efficiency Levels

For the 1000 W representative wattage, DOE surveyed and tested many manufacturer product offerings for ballast efficiency to identify the ELs corresponding to the highest number of models. DOE identified the most prevalent ballast efficiency values in the range of available equipment and established ELs based on that equipment. DOE determined the max tech ballast efficiency for metal halide lamp fixtures, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)) To determine this level, DOE conducted a survey of the MHLF market and the research fields that support the market. DOE believes that, within a given equipment class, no working prototypes exist that have a distinguishably higher ballast efficiency than currently available equipment. Therefore the highest EL presented, which represents the most efficient tier of commercially available equipment, is the max tech level that DOE determined for this rulemaking.

The following section identifies the steps and technologies associated with each EL DOE considered for the 1000 W representative wattage. As discussed in the screening analysis (NOPR TSD chapter 4), DOE used design options that achieve a higher ballast efficiency than the baseline model. Efficiency improvements to the magnetic baseline unit required a higher grade of steel and an eventual move to electronic circuitry. DOE's research found that any 1000 W electronic ballasts on the market today appear to be for specialized functions, such as hydroponics and aquariums, rather than general illumination applications. Because these fixtures may have unique thermal characteristics, DOE cannot be certain that incorporating 1000 W electronic ballasts into general lighting fixtures is technologically feasible. As such, all ELs represent magnetic ballasts.

As mentioned in section 5.7, DOE is considering a design standard that would prohibit the use of probe-start ballasts in new fixtures. DOE compared several major manufacturers' 1000 W lamp catalog data for these two lamp start types and calculated the ratio of probe-start mean lumens divided by pulse-start mean lumens and found probe-start metal halide lamps to be 5.6 percent less efficacious than comparable pulse-start lamps. To account for this in energy ELs, DOE multiplied the normalized input power of the 1000 W ballasts tested by 0.944. In calculating the cost-efficiency relationships, DOE kept the ELs the same in the scenarios with and without the design standard and adjusted the prices.

EL1.[9] Efficiency for >500 W and ≤1000 W (%): *5.0E-3*P + 87.5*
Efficiency for >1000 W and ≤2000 W (%): 92.5

This level requires a lower loss grade of steel, which might have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added and partially or wholly changed from aluminum to copper.

EL2. Efficiency for >500 W and ≤1000 W (%): *3.2E-3*P + 89.9*
Efficiency for >1000 W and ≤2000 W (%): 93.1

This level requires the use of even better grade of steel, which might have thinner laminations. The stack height is maintained, and so is the ballast footprint. A decrease in steel thickness due to the steel grade and no change in the stack height equates to additional laminations and thus an improvement in efficiency. Conductor may be added to reach this efficiency, and the conductor material is almost certainly copper.

The 1000 W level is unique in that its max tech unit is magnetic; the lower-wattage equipment classes all had electronic max tech units. DOE has not identified any currently available 1000 W electronic ballasts used for general lighting applications and has learned of several possible reasons for this in its interviews with manufacturers. First, the high power levels

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[9] P is defined as the rated wattage of the lamp the fixture is designed to operate

make thermal management a challenge. Maintaining an operating temperature tolerable to electronic elements would require spacing those elements and heat sinking them extensively. Those changes would add size, weight, cost, and complexity to ballasts, and possibly require larger fixtures. Second, magnetic ballasts at the 1000 W level tend to be relatively efficient. At lower wattages, using electronic ballasts may increase efficiency by 15 or 20 percent. Use of electronic ballasts at 1000 W would be likely increase the efficiency of electronic ballasts by only two or three percent. Finally, 1000 W ballasts are overwhelmingly used outdoors, where they more often subjected to high voltage transients that can damage electronic elements. Using an electronic ballast could require adding inline transient protection, and further increase cost and complexity relative to their magnetic counterparts. Although this concern applies equally to lower wattage ballasts placed outdoors, those wattages are less often used outdoors. DOE concluded that, although not a technical impossibility, constructing a reliable 1000 W electronic ballast would result in a product not suitable for use as a substitute for magnetic ballasts based on increased size, weight, and, potentially, cost.

Table 5.14.2 Summary of the ELs for the 1000 W Representative Wattage

Efficiency Level	**Ballast Efficiency Requirement %**
Baseline + DS**	No ballast efficiency requirement, only a prohibition on the sale of probe-start ballasts in new fixtures
EL1	5.0E-3*P + 87.5 (>500 W and ≤1000 W) 92.5 (>1000 W and ≤2000 W)*
EL1+DS	5.0E-3*P + 87.5 (>500 W and ≤1000 W) 92.5% (>1000 W and ≤2000 W)
EL2	3.2E-3*P + 89.9(>500 W and ≤1000 W) 93.1% (>1000 W and ≤2000 W)
EL2+DS	3.2E-3*P + 89.9 (>500 W and ≤1000 W) 93.1% (>1000 W and ≤2000 W)
*P is defined as the rated wattage of the lamp the fixture is designed to operate ** DS = Design Standard requiring all ballasts sold in new fixtures to be pulse-start	

Figure 5.14.1 illustrates two ELs on a plot of the 1000 W equipment class. A star indicates a representative unit tested by DOE. Diamonds indicate other 1000 W ballasts tested by DOE.

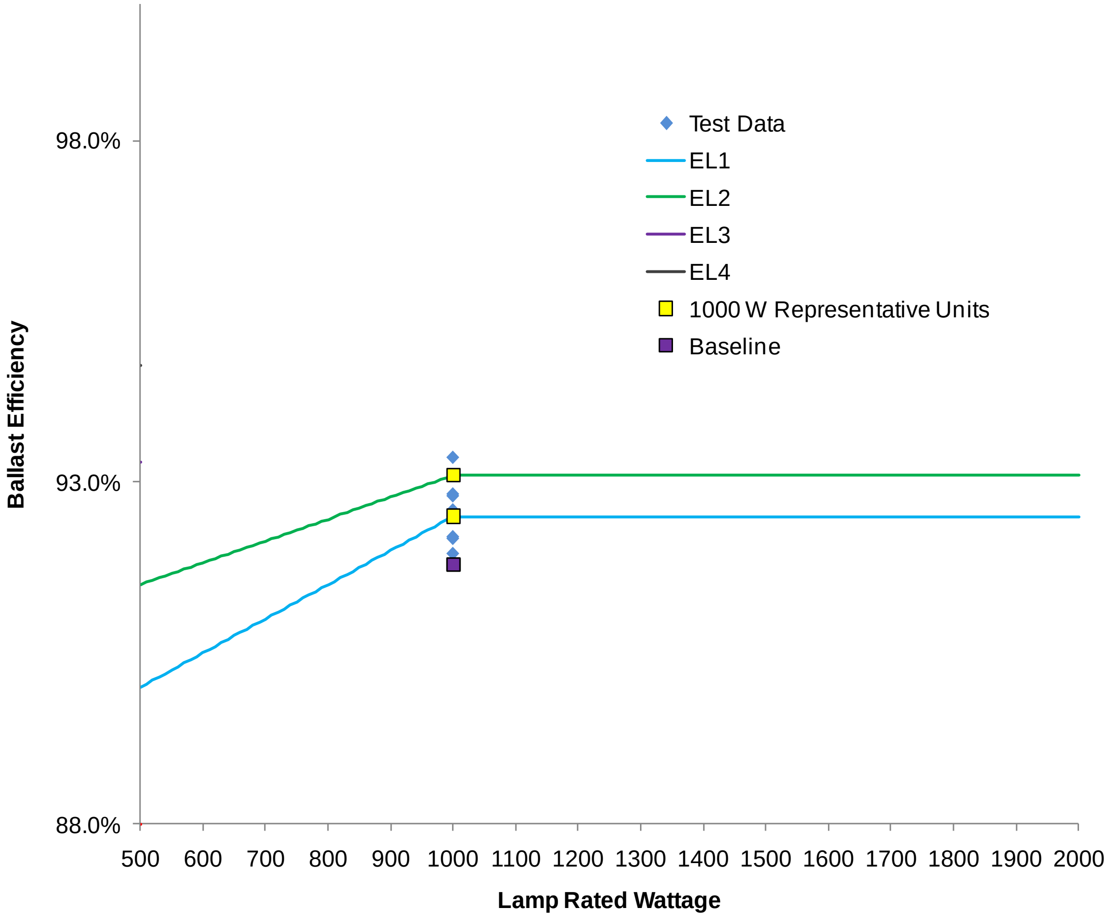

Figure 5.14.1 Efficiency Levels for the 1000 W Equipment Class

Table 5.14.3 Ballast Designs for the 1000 W Representative Wattage

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Input Power (W) †	Rated Lamp Power (W)	Ballast Efficiency (%)
Baseline	Magnetic	Probe	Quad**	1149.2	1000	91.8
Baseline+DS*	Magnetic	Pulse	Quad	1084.9	944	91.8
EL1	Magnetic	Probe	Quint	1140.5	1000	92.5
EL1+DS	Magnetic	Pulse	Quint	1076.7	944	92.5
EL2	Magnetic	Probe	Quad	1133.2	1000	93.1
EL2+DS	Magnetic	Pulse	Quad	1069.7	944	93.1

* DS = Design Standard requiring all ballasts sold in new fixtures to be pulse-start
** “Quad” input voltage means 120, 208, 240, and 277 V. “Quint” is Quad with 480 V.
†Input Power normalized to light output

5.14.3 Ballast and Fixture Prices

DOE analyzed each EL for the 1000 W representative wattage to develop appropriate MSPs. When calculating the MHLF MSPs for this rulemaking, DOE calculated the ballast MPC and multiplied by a calculated ballast manufacturer markup to determine the total ballast MSP to a fixture manufacturer. DOE also calculated an empty fixture MPC (fixture without a ballast or fixture adders) and added this to the total ballast MSP to calculate the total fixture MPC. Finally, the total fixture MPC was multiplied by a fixture manufacturer markup to calculate the total fixture MSP. As discussed in section 5.4, the empty fixture cost is the same for each EL (does not change with increasing efficiency) and is calculated as the average of the teardown MPCs for all fixture types identified as representative. Because the 1000 W ELs do not require an electronic ballast design option, there are no fixture or ballast cost adders associated with these equipment classes. Therefore, MSP variance across ELs is due only to changes in the ballast itself.

DOE did not perform teardowns for the 1000 W empty fixtures. Instead, DOE scaled the 400 W empty fixture teardown prices using ratios of 400 W and 1000 W retail prices from the same retailers. DOE selected pairs of 400 W and 1000 W fixtures of parking/area type and averaged their respective retail price ratios to develop a 400 W to 1000 W empty fixture ratio.

For the baseline and for both ELs, DOE based the price on teardown-sourced MSPs. DOE used input from manufacturers on the type of steel used to achieve the level of efficiency exhibited by these ballasts. Each EL is also separated into levels with and without a design standard that would require all ballasts sold in new fixtures to be pulse-start. To determine the price of the ballasts difference between probe-start and the design standard pulse-start, DOE applied a 0.944 probe/pulse adjustment factor. This meant that a ballast that was pulse-start that is $100 would be $94.40 as a probe-start.

As discussed in section 5.7, DOE determined that the most likely market response to a design standard that prohibited the use of probe-start ballasts in new fixtures would be using the same number of reduced wattage fixtures, DOE did not scale the cost of a design standard efficiency by the 0.944 level used to scale the efficiencies. Instead, DOE assumed reduced wattage systems would cost approximately the same amount as a full wattage system with the exception of the addition of an igniter (device that provides a voltage pulse to start the lamp). In the non-design standard scenario, DOE assumed the representative cost of a 1000 W ballast would equal the cost of a probe-start ballast as this starting method is most common in the greater than 500 W but less than or equal to 2000 W equipment classes. However, in the design standard scenario, an igniter would need to be added as only pulse-start ballasts could be included in new fixtures.

Table 5.14.4 Summary of the Manufacturing Selling Prices for the 1000 W Representative Wattage

Efficiency Level	Total Indoor Fixture MSP 2010$	Total Outdoor Fixture MSP 2010$
Baseline	293.48	293.48
Baseline + DS*	310.04	310.04
EL1	325.26	325.26
EL1 + DS	341.82	341.82
EL2	335.94	335.94
EL2 + DS	352.50	352.50
*DS = Design Standard requiring all ballasts sold in new fixtures to be pulse-start		

5.14.4 Engineering Summary

The following table summarizes the engineering data developed for each EL for the 1000 W representative wattage.

Table 5.14.5 Indoor 1000 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	***W***		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Probe	Quad*	1149.2	91.8%	36.04	-	52.98	132.77	-	293.48
Baseline + DS*	CWA	Pulse	Quad	1084.9	91.8%	43.17	-	63.46	132.77	-	310.04
EL1	CWA	Probe	Quint	1140.5	92.5%	49.72	-	73.09	132.77	-	325.26
EL1 + DS	CWA	Pulse	Quint	1076.7	92.5%	56.85	-	83.57	132.77	-	341.82
EL2	CWA	Probe	Quad	1133.2	93.1%	54.32	-	79.85	132.77	-	335.94
EL 2 + DS	CWA	Pulse	Quad	1069.7	93.1%	61.45	-	90.33	132.77	-	352.50
*“Quad” input voltage implies 120, 208, 240, and 277 V.											

Table 5.14.6 Outdoor 1000 W Representative Wattage Engineering Summary

Efficiency Level	Ballast Type	Starting Method	Input Voltage	Normalized Input Power	Ballast Efficiency	Ballast MPC	Ballast MPC Adder	Total Ballast MSP to OEM	Empty Fixture MPC	Empty Fixture MPC Adder	Total Fixture MSP
			V	***W***		**2010$**	**2010$**	**2010$**	**2010$**	**2010$**	**2010$**
Baseline	CWA	Probe	Quad*	1149.2	91.8%	36.04	-	52.98	132.77	-	293.48
Baseline + DS*	CWA	Pulse	Quad	1084.9	91.8%	43.17	-	63.46	132.77	-	310.04
EL1	CWA	Probe	Quint	1140.5	92.5%	49.72	-	73.09	132.77	-	325.26
EL1 + DS	CWA	Pulse	Quint	1076.7	92.5%	56.85	-	83.57	132.77	-	341.82
EL2	CWA	Probe	Quad	1133.2	93.1%	54.32	-	79.85	132.77	-	335.94
EL 2 + DS	CWA	Pulse	Quad	1069.7	93.1%	61.45	-	90.33	132.77	-	352.50
*“Quad” input voltage implies 120, 208, 240, and 277 V.											

5.15 SCALING TO EQUIPMENT CLASSES NOT ANALYZED

DOE identified and selected certain equipment classes as “representative” equipment classes on which to concentrate its analytical effort. DOE chose these representative equipment classes primarily due to their high market volumes. As a result, DOE analyzed ten representative equipment classes, leaving ten equipment classes for scaling. DOE analyzed the quad-voltage ballasts directly and scaled the results to develop ELs for the equipment classes for ballasts tested at 480 V (“tested at 480 V” equipment class).

To scale to the tested at 480 V equipment class, DOE developed a relationship between quad-voltage and dedicated 480 V ballasts. DOE paired quad-voltage and dedicated 480 V ballasts of the same product family and from the same manufacturer and calculated the average ratio in ballast efficiency for all the pairs. DOE found that on average, dedicated 480 V ballasts were 0.6 percent less efficient than comparable quad-voltage ballasts. Therefore, DOE multiplied the EL equations assigned to the quad-voltage ballasts by 0.994 to generate the dedicated 480 V EL equations, as shown in Table 5.15.1.

In the ≥150 W and ≤250 W equipment class, the equations for EL1 and EL2 would drop below the EISA standard (88 percent) when applying the scaling factor for dedicated 480 V EL equations. In order to prevent backsliding, DOE adjusted these equations to make sure the minimum ballast efficiency was at least 88 percent, as prescribed by EISA. As such, the EL1 and EL2 standard for dedicated 480 V ballasts ≥150 W and ≤200 W was kept at 88%. For dedicated 480 V ballasts >200 W and ≤250 W, instead of scaling the representative equations by 0.994 DOE used an equation that set the 200 W standard at 88 percent and calculated a linear equation up to the scaled EL1 and EL2 values of the >250 W and ≤500 W equipment class of 89.5% and 91.0%, respectively.

Table 5.15.1 Efficiency Levels Scaled to Equipment Classes Not Analyzed Directly

<table>
<tr><th>Representative Equipment Class*</th><th>Rep. Unit</th><th>EL</th><th colspan="2">Minimum Efficiency Equation Developed for Ballasts Not Tested at 480 V (%)**</th><th colspan="2">Minimum Efficiency Equation Developed for Ballasts Tested at 480 V (%)</th></tr>
<tr><td rowspan="4">≥50 W and ≤100 W</td><td rowspan="4">70 W</td><td>EL1</td><td colspan="2">100/(1+3.90*P^(-0.60))[††]</td><td colspan="2">99.4/(1+3.90*P^(-0.60))</td></tr>
<tr><td>EL2</td><td colspan="2">100/(1+2.50*P^(-0.55))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td>EL3</td><td colspan="2">100/(1+0.60*P^(-0.34))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td>EL4</td><td colspan="2">100/(1+0.36*P^(-0.30))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td rowspan="4">>100 W and <150 W***</td><td rowspan="4">150 W</td><td>EL1</td><td colspan="2">100/(1+3.90*P^(-0.60))</td><td colspan="2">99.4/(1+3.90*P^(-0.60))</td></tr>
<tr><td>EL2</td><td colspan="2">100/(1+2.50*P^(-0.55))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td>EL3</td><td colspan="2">100/(1+0.60*P^(-0.34))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td>EL4</td><td colspan="2">100/(1+0.36*P^(-0.30))</td><td colspan="2">99.4/(1+2.50*P^(-0.55))</td></tr>
<tr><td rowspan="4">≥150 W[†] and ≤250 W</td><td rowspan="4">250 W</td><td>EL1</td><td>≥150 W and ≤200 W: 88.0</td><td>>200 W and ≤250 W: (4.0E-2)*P + 80.0</td><td>≥150 W and ≤200 W: 88.0</td><td>>200 W and ≤250 W: (3.0E-2)*P + 82.0</td></tr>
<tr><td>EL2</td><td>≥150 W and ≤200 W: 88.0</td><td>>200 W and ≤250 W: (7.0E-2)*P + 74.0</td><td>≥150 W and ≤200 W: 88.0</td><td>>200 W and ≤250 W: (6.0E-2)*P+76.0</td></tr>
<tr><td>EL3</td><td colspan="2">100/(1+0.60*P^(-0.34))</td><td colspan="2">99.4/(1+0.60*P^(-0.34))</td></tr>
<tr><td>EL4</td><td colspan="2">100/(1+0.36*P^(-0.30))</td><td colspan="2">99.4/(1+0.36*P^(-0.30))</td></tr>
<tr><td rowspan="4">>250 W and ≤500 W</td><td rowspan="4">400 W</td><td>EL1</td><td colspan="2">90.0</td><td colspan="2">89.5</td></tr>
<tr><td>EL2</td><td colspan="2">91.5</td><td colspan="2">91.0</td></tr>
<tr><td>EL3</td><td colspan="2">100/(1+0.60*P^(-0.34))</td><td colspan="2">99.4/(1+0.60*P^(-0.34))</td></tr>
<tr><td>EL4</td><td colspan="2">100/(1+0.36*P^(-0.30))</td><td colspan="2">99.4/(1+0.36*P^(-0.30))</td></tr>
<tr><td rowspan="2">>500 W and ≤2000 W</td><td rowspan="2">1000 W</td><td>EL1</td><td>>500 W and ≤1000 W: (5.0E-3)*P + 87.5</td><td>>1000 W and ≤2000 W: 92.5</td><td>>500 W and ≤1000 W: 0.994*((5.0E-3)*P + 87.5)</td><td>>1000 W and ≤2000 W: 91.9</td></tr>
<tr><td>EL2</td><td>>500 W and ≤1000 W: (3.2E-3)*P + 89.9</td><td>>1000 W and ≤2000 W: 93.1</td><td>>500 W and ≤1000 W: 0.994*((3.2E-3)*P + 89.9)</td><td>>1000 W and ≤2000 W: 92.5</td></tr>
<tr><td colspan="7">*Equations apply to both the indoor and outdoor equipment classes for the given wattage range and testing voltage.
**Column including equations for non-scaled equipment classes included for comparison purposes.
***Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.
†Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.
††P is defined as the rated wattage of the lamp the fixture is designed to operate</td></tr>
</table>

5.16 EFFICIENCY LEVEL SUMMARY

Table 5.16.1 lists the EL equations developed by DOE for the representative equipment classes.

Table 5.16.1 NOPR Efficiency Level Descriptions for the Representative Equipment Class

Representative Equipment Class*	Rep. Unit	EL	Minimum Efficiency Equation (%)	
≥50 W and ≤100 W	70 W	EL1	100/(1+3.90*P^(-0.60))††	
		EL2	100/(1+2.50*P^(-0.55))	
		EL3	100/(1+0.60*P^(-0.34))	
		EL4	100/(1+0.36*P^(-0.30))	
>100 W and <150 W**	150 W	EL1	100/(1+3.90*P^(-0.60))	
		EL2	100/(1+2.50*P^(-0.55))	
		EL3	100/(1+0.60*P^(-0.34))	
		EL4	100/(1+0.36*P^(-0.30))	
≥150 W† and ≤250 W	250 W	EL1	≥150 W and ≤200 W: 88.0	>200 W and ≤250 W: (4.0E-2)*P + 80.0
		EL2	≥150 W and ≤200 W: 88.0	>200 W and ≤250 W: (7.0E-2)*P + 74.0
		EL3	100/(1+0.60*P^(-0.34))	
		EL4	100/(1+0.36*P^(-0.30))	
>250 W and ≤500 W	400 W	EL1	90.0	
		EL2	91.5	
		EL3	100/(1+0.60*P^(-0.34))	
		EL4	100/(1+0.36*P^(-0.30))	
>500 W and ≤2000 W	1000 W	EL1	>500 W and ≤1000 W: (5.0E-3)*P + 87.5	>1000 W and ≤2000 W: 92.5
		EL2	>500 W and ≤1000 W: (3.2E-3)*P + 89.9	>1000 W and ≤2000 W 93.1

* Equations apply to both the indoor and outdoor representative equipment classes for the given wattage range.

**Includes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

†Excludes 150 W fixtures exempted by EISA 2007, which are fixtures rated only for 150 watt lamps; rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and containing a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

††P is defined as the rated wattage of the lamp the fixture is designed to operate

Figure 5.16.1 and Figure 5.16.2 depict the EL equation plots and the tested ballasts over a wide range of input powers.

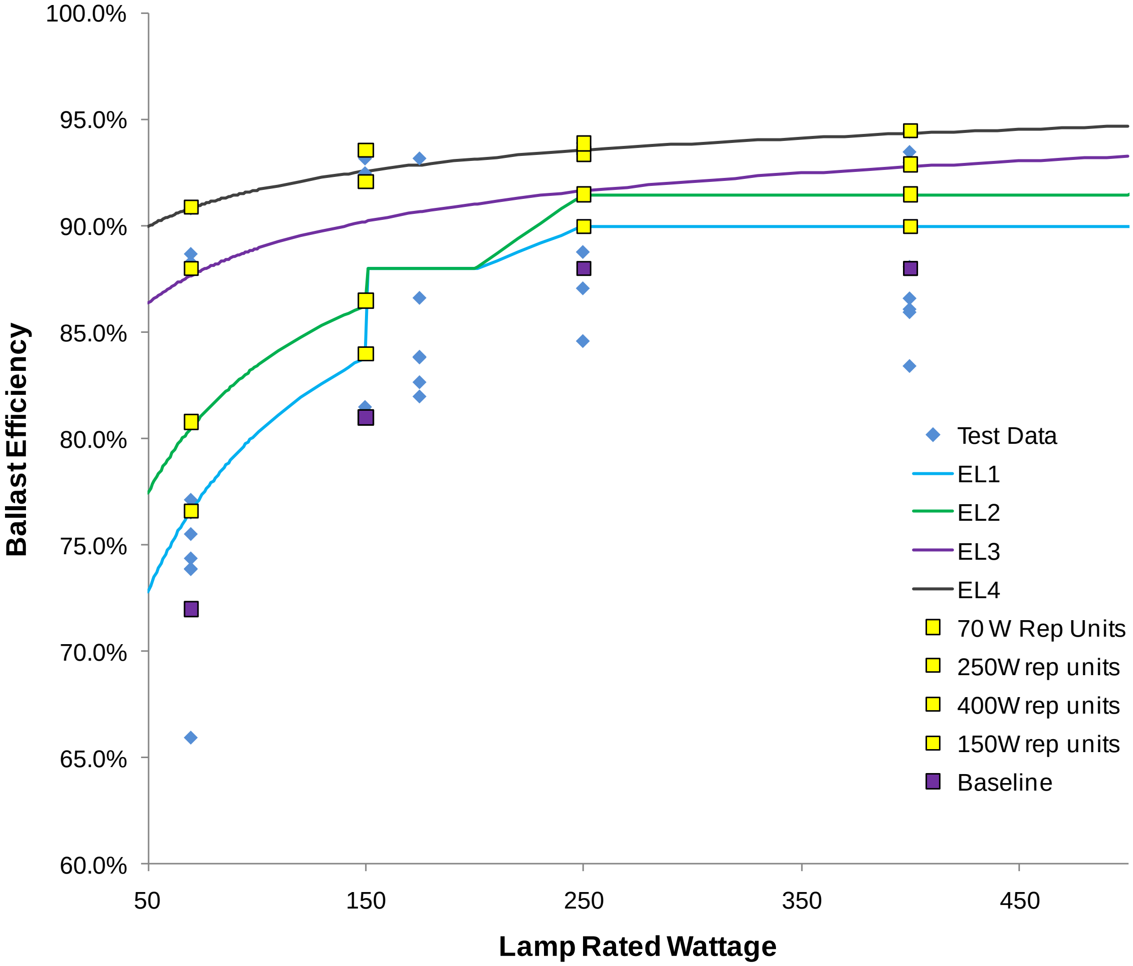

Figure 5.16.1 Efficiency Level Plots for 50 through 500 W

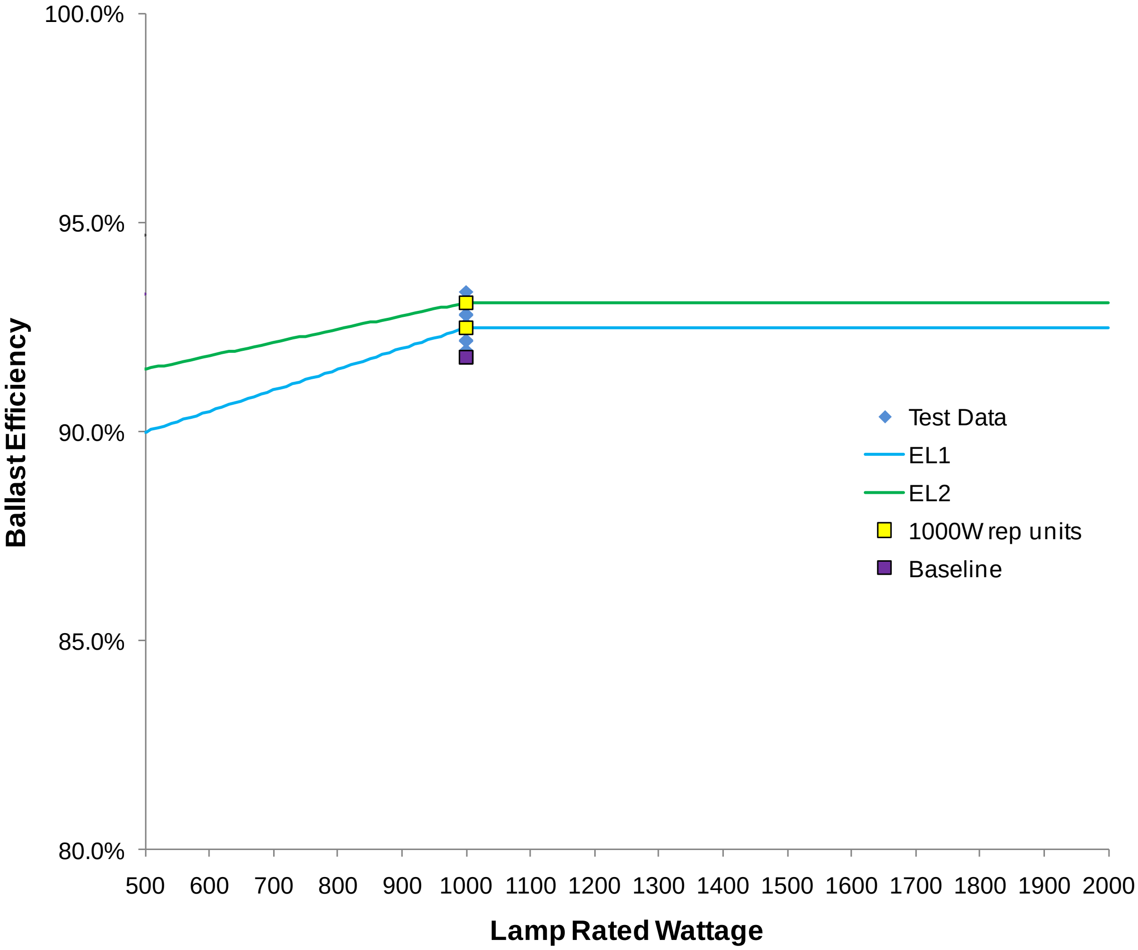

Figure 5.16.2 Efficiency Level Plots for 500 through 2000 W

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

This notice of proposed rulemaking (NOPR) technical support document (TSD) chapter describes the methodology the U.S. Department of Energy (DOE) followed in developing end-user prices and sales tax in the rulemaking analysis for metal halide lamp fixtures (MHLF or fixtures). This chapter also provides initial results for fixture end-user prices and sales tax.

In this rulemaking, DOE performed teardown analyses and a manufacturer markup analysis to develop manufacturer selling prices (MSPs) for representative fixture designs (NOPR TSD chapter 5). DOE then applied distribution channel markups and sales tax to derive end-user prices. By combining the engineering analysis results and the distribution channel markups analysis, DOE derived inputs for use in the life-cycle cost (LCC) analysis and the national impact analysis (NIA). In particular, DOE developed end-user prices for fixture designs associated with any given trial standard level.

The end-user equipment price depends on how the end-user purchases the equipment. For its NOPR analysis, DOE assumed there are three primary distribution channels through which fixture manufacturers sell fixtures to an end-user, as shown in Figure 6.1.1.

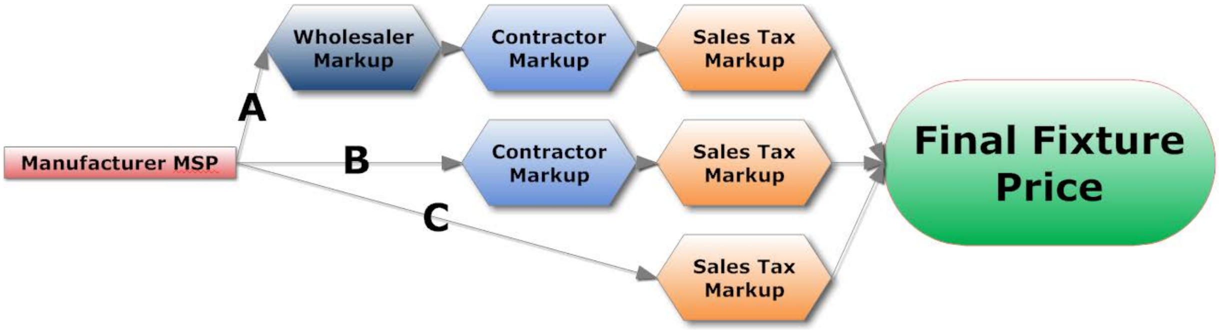

Figure 6.1.1 Metal Halide Lamp Fixture Distribution Channels

For the main LCC analysis, DOE assumed that all indoor fixtures pass through distribution channel (A), as shown in Figure 6.1.1. DOE assumed that different percentages of outdoor fixtures pass through all three distribution channels, as shown in Table 6.1.1.

In distribution channel (A), a fixture manufacturer sells the fixture to an electrical wholesaler (*i.e.*, electrical distributor), who in turn sells it to a contractor, who sells it to the end user. In distribution channel (B), a fixture manufacturer bypasses a wholesaler and sells the fixture directly to a contractor, who sells it to the end user. In distribution channel (C), a fixture manufacturer bypasses both wholesalers and contractors, and sells the fixture directly to the end user (*i.e.*, electrical utility).

Table 6.1.1 Outdoor Fixture Distribution Channel Percentages

Distribution Channel	Percentage
A	60%
B	20%
C	20%

To meet new or amended energy conservation standards, manufacturers often introduce design changes to their equipment lines that result in increased production costs and MSPs. DOE assumes that some or all of the increased production costs can be passed through the distribution channels and eventually to end users in the form of higher sales prices.

At each point in the distribution channel, companies apply a "markup" to the MSP to cover their business costs and profit margin. DOE models this markup as a multiplier. In financial statements, gross profit is the difference between the company revenue and the company cost of sales. It includes all corporate overhead costs (sales, general, and administration), materials and labor costs, research and development and interest expenses, depreciation and taxes, and profits. In order for sales of equipment to contribute positively to company cash flow, the equipment's markup must be greater than the sum of cost of sales and business costs for that equipment. DOE calculates the end-user sales price by multiplying the MSP by the various markups and applying sales tax.

The end-user prices and installation costs are key inputs to the LCC analysis, payback period (PBP) analysis, and the NIA. Through use of the distribution channel markups and installation costs, DOE can calculate the first costs that customers would face under the various efficiency levels evaluated. DOE evaluates the tradeoff between the increase in first cost and the resulting energy cost savings at each efficiency level in the LCC and PBP analysis (NOPR TSD chapter 8) and NIA analysis (NOPR TSD chapter 11).

The following equation shows how DOE determined the equipment prices for fixtures in distribution channel (A):

$$P_{END} = (P_{MFR} \times MU_{WHOLE} \times MU_{CONT} \times MU_{TAX})$$

Eq. 6.1

Where:

P_{END} = equipment price to the end-user ($),
P_{MFR} = MSP of baseline or standard-level equipment ($),
MU_{WHOLE} = wholesaler markup,
MU_{CONT} = contractor markup, and
MU_{TAX} = sales tax markup.

To determine equipment prices for fixtures going through the other distribution channels, Eq. 6.1 is used with the MU_{WHOLE} and $MU_{WHOLE} \times MU_{CONT}$ terms excluded for channels (B) and (C), respectively. For each of the parties involved in the distribution of the equipment, the markups presented above are further differentiated between a "baseline markup" and an "incremental markup," as described below. A third type of markup, the "overall markup," describes the product of all the markups within a distribution channel.

6.1.1 Baseline Markups

Baseline markups are defined as coefficients that relate the manufacturer price of baseline fixture designs to the wholesaler or contractor baseline sales price. The following equations show the calculation of baseline markups for distribution channel (A):

$$P_{WHOLE\_BASE} = (P_{MFR\_BASE} \times MU_{WHOLE\_BASE})$$

Eq. 6.2

$$P_{CONT\_BASE} = (P_{WHOLE\_BASE} \times MU_{CONT\_BASE})$$

Eq. 6.3

$$P_{END\_BASE} = (P_{CONT\_BASE} \times MU_{TAX})$$

Eq. 6.4

Where:

P_{MFR_BASE} = MSP of baseline equipment (\$),
P_{WHOLE_BASE} = wholesaler selling price of baseline equipment (\$),
P_{CONT_BASE} = contractor selling price of baseline equipment (\$),
P_{END_BASE} = end-user purchase price for baseline equipment (\$),
MU_{WHOLE_BASE} = wholesaler markup for baseline equipment,
MU_{CONT_BASE} = contractor markup for baseline equipment, and
MU_{TAX} = sales tax markup.

6.1.2 Incremental Markups

Incremental markups are defined as coefficients that relate changes in the manufacturer price of higher efficiency equipment to changes in the wholesale and contractor sales price, as shown in the following equations for distribution channel (A):

$$P_{WHOLE\_INCR} = (P_{MFR\_INCR} \times MU_{WHOLE\_INCR})$$

Eq. 6.5

$$P_{CONT\_INCR} = (P_{WHOLE\_INCR} \times MU_{CONT\_INCR})$$

Eq. 6.6

$$P_{END\_INCR} = (P_{WHOLE\_INCR} \times MU_{TAX})$$

Eq. 6.7

Where:

P_{MFR_INCR} = incremental manufacturer price for equipment with increased efficiency ($),
P_{WHOLE_INCR} = incremental wholesaler price for equipment with increased efficiency ($),
P_{CONT_INCR} = incremental contractor price for equipment with increased efficiency ($),
P_{END_INCR} = incremental end-user price for equipment with increased efficiency ($),
MU_{WHOLE_INCR} = incremental wholesaler markup for equipment with increased efficiency,
MU_{CONT_INCR} = incremental contractor markup for equipment with increased efficiency, and
MU_{TAX} = sales tax markup.

6.1.3 Overall Markups

Overall markups, including both overall baseline and overall incremental markups, relate the manufacturer price to the final customer price (P_{END}), as shown by the following equation:

$$P_{END} = (P_{END\_BASE} + P_{END\_INCR})$$

Eq. 6.8

6.2 ESTIMATION OF WHOLESALER, CONTRACTOR, AND SALES TAX MARKUPS

6.2.1 Financial Information Sources

Publicly owned companies are required by law to disclose financial information on a regular basis by filing different forms with the U.S. Securities and Exchange Commission (SEC). Filed annually, the SEC form 10-K provides a comprehensive overview of the company's business and financial conditions. Relevant information in the 10-K reports includes the company's revenues and direct and indirect costs. For the wholesaler markup, DOE used 10-K reports from publicly owned lighting fixture manufacturers and electrical wholesalers, respectively. The financial figures necessary for calculating the company markup are net sales, costs of sales, and gross profit. The income statement section of the 10-K reports often lists these figures. DOE used averages of the financial figures spanning 2007 to 2011 to calculate the markups.

DOE used the following equations to calculate the gross profit and gross profit margins:

$$\text{Gross Profit (\$)} = \text{Net Sales} - \text{Cost of Sales}$$

Eq. 6.9

$$\text{Gross Profit Margin} = \frac{\text{Gross Profit}}{\text{Net Sales}}$$

Eq. 6.10

To calculate the time-average gross profit margin for each company, DOE first summed the gross profit for all the years and then divided the result by the sum of the net sales for the same years. DOE then used the gross profit margins to calculate baseline markups on existing equipment (*i.e.*, prior to efficiency changes resulting from enactment of proposed efficiency standards). Each company's baseline markup was calculated as:

$$\text{Baseline Markup} = \frac{1}{(1 - \text{Gross Profit Margin})} = \frac{\text{Net Sales}}{\text{Cost of Sales}}$$

Eq. 6.11

Table 6.2.1 contains the calculated gross profit margins for a sample of electrical wholesalers.

Table 6.2.1 Gross Profit Margins for Electrical Wholesalers[*]

Company	Financial Figure $	Year				
		2011	2010	2009	2008	2007
A	Net Sales	5,374,800	4,616,377	4,377,882	5,400,154	5,258,301
	Cost of Sales	4,379,541	3,749,736	3,522,932	4,354,935	4,225,983
	Gross Profit	995,259	866,641	854,950	1,045,219	1,032,318
	Gross Profit Margin (%)	18.5	18.8	19.5	19.4	19.6
	Average Gross Profit Margin: 19.2%					
B	Net Sales	6,125,718	5,063,862	4,263,954	6,110,840	6,003,452
	Cost of Sales	4,889,149	4,065,425	3,724,061	4,904,164	4,781,336
	Gross Profit	1,236,569	988,437	539,893	1,206,676	1,222,116
	Gross Profit Margin (%)	20.2	19.7	12.7	19.7	20.4
	Average Gross Profit Margin: 18.5%					

[*] Unless noted, all numbers are in thousands of dollars. This table includes 2007, 2008, 2009, 2010, and 2011 SEC 10-K reports.

The baseline markup covers non-production costs and profit. Table 6.2.2 shows the baseline markups using this method for electrical wholesalers.

Table 6.2.2 Calculated Electrical Wholesaler Baseline Markups for Metal Halide Lamp Fixtures

Company	Baseline Markup
Wholesaler A	1.24
Wholesaler B	1.23
Average	1.23

The incremental markup applied to higher efficiency equipment is lower than the baseline markup because DOE assumed that expenses like labor and occupancy costs remain fixed and need not be recovered in the markup. Profits and other operating costs were assumed to be variable and to scale with the MSP.

The surveyed SEC 10-K reports did not typically separate labor and occupancy costs from overall expenses, so DOE assumed that these fixed costs are encompassed by "selling, distribution, and administrative expenses" (the most common terminology observed in the surveyed reports). DOE assumed that "operating profit" (operating income) covers other operating costs and profit (*i.e.*, variable costs). Each company's incremental markup was calculated as:

$$\text{Incremental Markup} = 1 + \left(\frac{\text{Operating Profit}}{\text{Cost of Sales}} \right)$$

Eq. 6.12

Table 6.2.3 contains the calculated incremental markups for the sampled fixture electrical wholesalers.

Table 6.2.3 Calculated Electrical Wholesaler Incremental Markups for Metal Halide Lamp Fixtures[*]

Company	Financial Figure $	Year				
		2011	**2010**	**2009**	**2008**	**2007**
A	Cost of Sales	4,379,541	3,749,736	3,522,932	4,354,935	4,225,983
	Operating Profit	143,210	77,536	72,498	153,125	162,126
	Calculated Incremental Markup	1.03	1.02	1.02	1.03	1.04
	Average Incremental Markup: 1.03					
B	Cost of Sales	4,889,149	4,065,425	3,724,061	4,904,164	4,781,336
	Operating Profit	332,979	210,919	179,952	345,667	394,224
	Calculated Incremental Markup	1.07	1.05	1.05	1.07	1.08
	Average Incremental Markup: 1.06					
ALL	Average Incremental Markup (All Wholesalers): 1.05					

[*] Except for calculated incremental markup, all numbers are in thousands of dollars. This table includes 2007, 2008, 2009, 2010, and 2011 SEC 10-K reports.

6.2.2 Sales Tax

The sales tax rate represents state and local sales taxes applied to fixtures, and is a multiplicative factor that increases the end-user cost. DOE obtained information on state and local sales tax from the Sales Tax Clearinghouse (Table 6.2.4).[1] These data represent weighted averages that include county and city rates. DOE also calculated a national population-weighted average sales tax for use in the NIA, where DOE did not use a distribution of inputs.[2]

Table 6.2.4 shows the distribution of sales tax rates that DOE developed for the LCC and PBP analysis. The distribution ranges from a minimum of 0 percent in some states to a maximum of 9.45 percent in Tennessee (as shown in Table 6.2.4), with a national weighted average of 7.09 percent.

Table 6.2.4 State and Local Sales Tax Rates

State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %
Alabama	8.45	Kentucky	6.00	North Dakota	5.85
Alaska	1.35	Louisiana	8.75	Ohio	6.85
Arizona	8.15	Maine	5.00	Oklahoma	8.30
Arkansas	8.35	Maryland	6.00	Oregon	0.00
California	8.20	Massachusetts	6.25	Pennsylvania	6.40
Colorado	6.10	Michigan	6.00	Rhode Island	7.00
Connecticut	6.35	Minnesota	7.20	South Carolina	7.10
Delaware	0.00	Mississippi	7.00	South Dakota	5.35
D.C.	6.00	Missouri	6.55	Tennessee	9.45
Florida	6.65	Montana	0.00	Texas	7.95
Georgia	6.95	Nebraska	6.00	Utah	6.70
Hawaii	4.40	Nevada	7.85	Vermont	6.05
Idaho	6.05	New Hampshire	0.00	Virginia	5.00
Illinois	8.15	New Jersey	6.95	Washington	8.90
Indiana	7.00	New Mexico	6.60	West Virginia	6.05
Iowa	6.85	New York	8.40	Wisconsin	5.45
Kansas	8.00	North Carolina	6.85	Wyoming	5.15
				National Average	**7.09**

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1. The Sales Clearinghouse. State Aggregate Tax Rates. 2011. (Last accessed October 22, 2012.) <http://thestc.com/STrates.stm>

2. U.S. Census Bureau. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico. 2011. (Last accessed March 28, 2012.) <http://www.census.gov/popest/data/state/totals/2011/index.html>

CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 PURPOSE OF THE DOCUMENT

This chapter presents the methodology the U.S. Department of Energy (DOE) followed to estimate the annual energy use of the metal halide (MH) system designs DOE considered in the metal halide lamp fixture (MHLF or fixtures) rulemaking analyses. MH lamps will not be regulated under the proposed MHLF rulemaking, which instead focuses on the ballasts within a fixture. However, the input power of the complete (power drawn when operating the lamp) metal halide lamp fixture must be considered for the energy use analysis. The results of this analysis, which represent typical energy use in the field, are critical inputs to the life-cycle cost (LCC) and payback period (PBP) analysis (notice of proposed rulemaking [NOPR] technical support document [TSD] chapter 8) and the national impact analysis (NIA; NOPR TSD chapter 11). DOE required information on annual energy use to determine the potential energy and operating cost savings to consumers from the use of more efficient equipment.

DOE determined the annual energy use of the MHLF systems using information on their measured input power (*i.e.*, the rate of energy they use) and the way consumers use them (*i.e.*, operating hours per year). The engineering analysis (NOPR TSD chapter 5) discusses the input power ratings of MHLF systems. The following sections discuss the inputs and calculations DOE used to develop annual operating hours and annual energy use for the equipment considered in this analysis.

7.2 METAL HALIDE LAMP FIXTURE SYSTEM OPERATING HOURS

To characterize the country's average use of metal halide lamp fixtures for a typical year, DOE developed annual operating hours by sector. For the LCC analysis, DOE accounts for variability in operating hours by developing a distribution of operating hours for the LCC spreadsheet. The operating hour distributions capture variation across building types and metal halide lamp fixtures in three sectors (commercial, industrial, and outdoor stationary).

DOE primarily uses data from the 2010 U.S. Lighting Market Characterization (LMC)[1] to develop operating hours by sector. The LMC, which is based on thousands of building audits and surveys, provides national-level data on annual operating hours by building type . These operating hours are divided by application for the commercial, industrial, and outdoor stationary sectors.

For the commercial sector, DOE used LMC commercial sector operating hours data by facility type to develop a distribution of annual operating hours for MHLF systems. To develop a distribution of annual operating hours in the industrial sector, DOE used an approach similar to that used for the commercial sector. DOE aggregated LMC annual operating hour data by industry to develop weighted average annual operating hours.

For the outdoor stationary sector, DOE used LMC operating hour data to develop a distribution of annual operating hours for MHLF systems. LMC data for outdoor stationary sources is aggregated by installation type (*e.g.*, unlike the commercial and industrial sectors, DOE aggregates LMC annual operating hour data by application to develop average annual operating hours by installation type). Table 7.2.1 summarizes the weighted average annual operating hours by sector.

Table 7.2.1 Average Annual Metal Halide Lamp Fixture Operating Hours by Sector

Sector	Average Annual Operating Hours *hr/yr*
Commercial	3,615
Industrial	6,113
Outdoor Stationary	4,493

Figure 7.2.1 displays the annual operating hours DOE used for MHLF systems in the commercial sector. DOE used these annual operating hours in the LCC calculations.

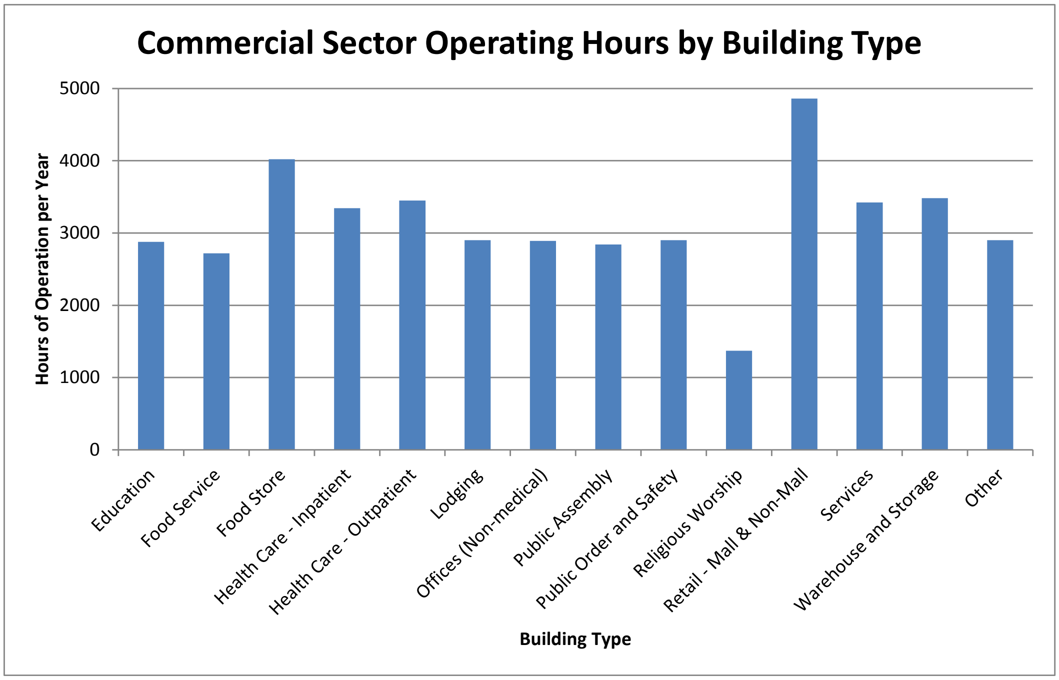

Figure 7.2.1 Commercial Sector Annual Operating Hour Distribution by Building Type

Figure 7.2.2 displays the annual operating hours for MHLF systems operating in the industrial sector. DOE used this distribution of annual operating hours in the LCC calculations.

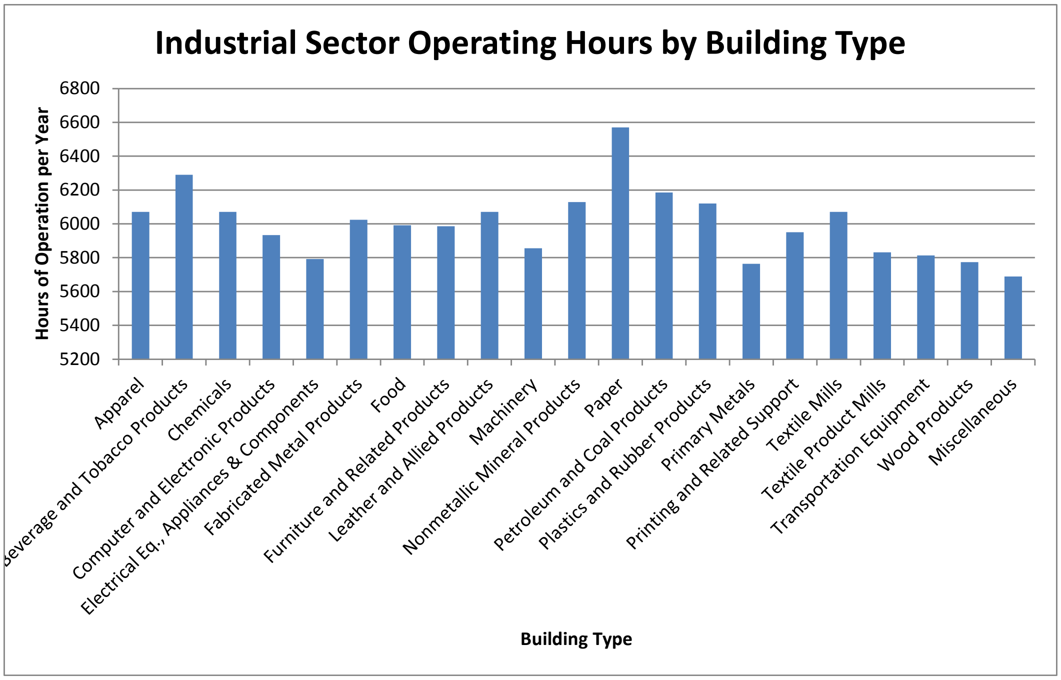

Figure 7.2.2 Industrial Sector Annual Operating Hour Distribution by Building Type

Figure 7.2.3 displays the annual operating hours for MHLF systems operating in the outdoor stationary sector. DOE used this distribution of annual operating hours in the LCC calculations.

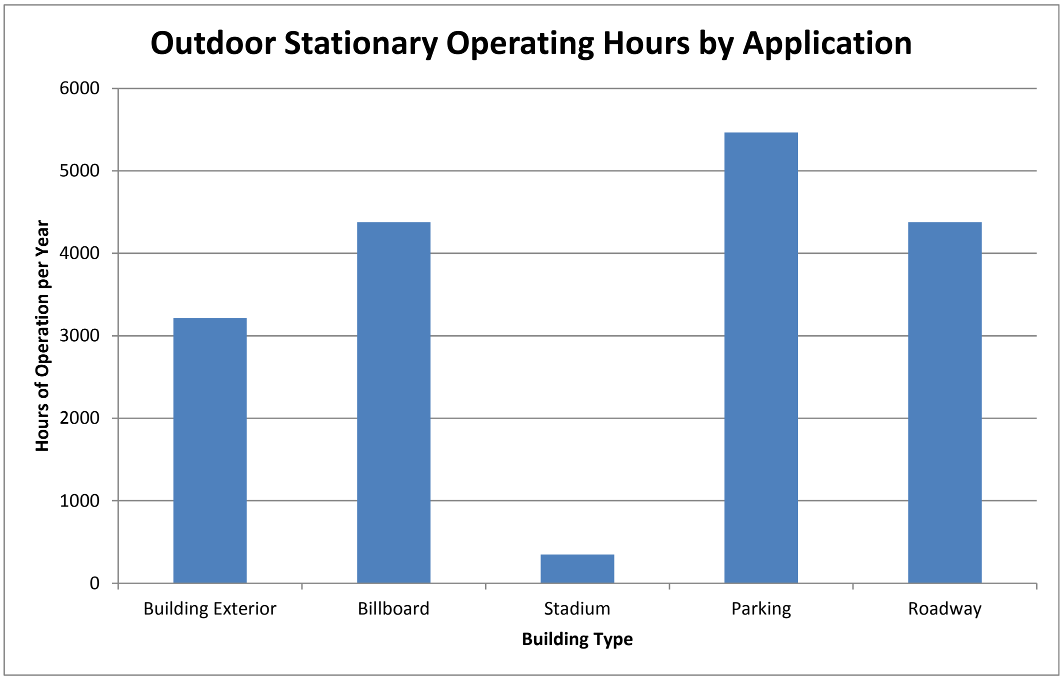

Figure 7.2.3 Outdoor Stationary Sector Annual Operating Hour Distribution by Installation Type

7.3 RESULTS OF THE ENERGY USE ANALYSIS

This section presents the annual energy use estimates for MHLF system designs. DOE calculated the annual energy use using annual operating hours and measured input power rating estimates. DOE used the annual energy use results in the LCC and PBP analysis and the NIA to calculate the operating costs of systems and to estimate the potential energy savings of trial standard levels.

Table 7.3.1 through Table 7.3.5 detail (1) the measured input power ratings for all the MHLF systems DOE assessed in the LCC and PBP analysis for each equipment class; and (2) average annual energy use per fixture based on measured input power for indoor and outdoor fixtures, using the U.S. weighted average of annual operating hours in each sector.

Table 7.3.1 70 W Equipment Class Input Power and Annual Energy Use

EL	Input Power *watts*	Annual Energy Use (Indoor) *kWh/yr*	Annual Energy Use (Outdoor) *kWh/yr*
Baseline	102.6	440.7	460.8
1	96.4	414.2	433.1
2	92.2	396.1	414.2
3	79.5	341.7	357.4
4	77.0	330.8	346.0

kWh = kilowatt-hours

Table 7.3.2 150 W Equipment Class Input Power and Annual Energy Use

EL	Input Power *watts*	Annual Energy Use (Indoor) *kWh/yr*	Annual Energy Use (Outdoor) *kWh/yr*
Baseline	195.4	879.4	877.7
1	188.4	848.0	846.4
2	182.9	823.5	821.9
3	162.9	733.1	731.7
4	160.3	721.4	720.0

Table 7.3.3 250 W Equipment Class Input Power and Annual Energy Use

EL	Input Power *watts*	Annual Energy Use (Indoor) *kWh/yr*	Annual Energy Use (Outdoor) *kWh/yr*
Baseline	299.7	1,349.1	1,346.5
1	293.1	1,319.1	1,316.6
2	288.3	1,297.5	1,295.0
3	267.7	1,204.9	1,202.5
4	266.2	1,198.4	1,196.1

Table 7.3.4 400 W Equipment Class Input Power and Annual Energy Use

EL	Input Power *watts*	Annual Energy Use (Indoor) *kWh/yr*	Annual Energy Use (Outdoor) *kWh/yr*
Baseline	479.5	2,158.6	2,154.4
1	468.9	2,110.6	2,106.5
2	461.2	2,076.0	2,072.0
3	430.6	1,938.1	1,934.4
4	423.3	1,905.3	1,901.6

Table 7.3.5 1,000 W Equipment Class Input Power and Annual Energy Use

EL	Input Power *watts*	Annual Energy Use (Indoor) *kWh/yr*	Annual Energy Use (Outdoor) *kWh/yr*
Baseline	1,149.2	7,025.2	5,163.1
Baseline + DS	1,084.9	6,631.8	4,873.9
1	1,140.5	6,972.0	5,124.0
1 + DS	1,076.7	6,581.6	4,837.0
2	1,133.2	6,927.1	5,091.0
2 + DS	1,069.7	6,539.2	4,805.9

REFERENCES

1. U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. Building Technologies Program: *U.S. Lighting Market Characterization*. January 2012. Washington, D.C. <http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf>

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducted to evaluate the economic impacts on individual customers of proposed amended energy conservation standards for metal halide lamp fixtures (MHLF or fixtures). Because fixtures are designed to operate metal halide (MH) ballasts and lamps, DOE chose the most common ballast and lamp used with each fixture to develop representative MHLF systems. MH lamps will not be regulated under the proposed amended energy conservation standards for fixtures; however, the characteristics of complete MHLF systems (energy use, installed cost, etc.) must be considered for estimating economic impacts of analyzed fixture designs.

New and amended standards usually decrease operating costs and increase purchase costs for customers. This chapter describes the three metrics used in this analysis to determine the effect of standards on individual customers:

- **Life-cycle cost** (LCC) is the total (discounted) customer cost over the analysis period including purchase price, operating costs (including energy expenditures), and installation costs.

- **Payback period** (PBP) is the number of years it takes a customer to recover the generally higher purchase price of more energy efficient equipment through the operating cost savings of using the more energy efficient equipment. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

- **Rebuttable payback period** is a special case in which the PBP is calculated based on laboratory conditions, specifically DOE test procedure inputs. DOE calculated the aforementioned LCC and PBP using a range of inputs, which are designed to reflect actual conditions.

Sections 8.2 and 8.3 discuss inputs to the LCC and PBP analysis, respectively. Section 8.4 presents the results for the LCC and PBP calculations. Key variables and calculations are presented for each metric. DOE performed the calculations discussed here using a series of Microsoft Excel spreadsheets developed for this rulemaking. Interested parties are invited to download and examine the spreadsheets, available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16. Details and instructions for using the spreadsheets are presented in appendix 8A, available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analysis

Recognizing that several inputs to the LCC and PBP analysis are either variable or uncertain, DOE incorporated Monte Carlo simulation and probability distributions into its LCC and PBP model in this notice of proposed rulemaking (NOPR) stage of the MHLF rulemaking. DOE incorporated both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in program.

The relationship between increasing selling price and increasing energy efficiency is the predominant influence on the LCC and PBP results. However, other factors related to the characteristics of the customer using the equipment also affect the results. Based on the geographic region, sector, and application in which a customer uses the fixtures, factors such as energy prices, sales tax, and energy usage can vary. DOE will account for this variability by using the Monte Carlo simulation, which reflects separate sensitivity runs.

For the LCC and PBP analysis, DOE considered variability in the discount rate, operating hours by sector, and building application. By developing samples by building type in the commercial and industrial sectors, DOE could perform the LCC and PBP calculations and account for the variability in operating hours, electricity price, and sales tax among a variety of buildings. DOE used the 2010 U.S. Lighting Market Characterization (LMC)[1] to develop the operating hour characteristics by application in those buildings. The LCC and PBP spreadsheets present the results of the analysis as average values, relative to the baseline conditions.

DOE conducted the LCC and PBP analysis on the baseline fixtures from the representative equipment classes identified in the fixture market and technology assessment (NOPR technical support document (TSD) chapter 3). The following list shows the representative equipment classes that DOE evaluated in this analysis.

- 70 Watt Metal Halide Fixture
- 150 Watt Metal Halide Fixture
- 250 Watt Metal Halide Fixture
- 400 Watt Metal Halide Fixture
- 1000 Watt Metal Halide Fixture

The time periods used for the LCC and PBP analysis in this rulemaking vary by fixture location. DOE analyzed indoor and outdoor fixtures over 20 year and 25 year lifetimes, respectively.

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

As mentioned previously, the LCC represents the total customer expense over the lifetime of each fixture. Costs include purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounted future operating costs to the time of purchase and summed them over the analysis period. The PBP represents the number of years it takes customers to recover the purchase price of more energy efficient equipment through lower operating costs. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year of the analysis period.

DOE categorized inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during operation of the fixture, otherwise known as the operating cost.

The primary inputs for calculating the installed cost include the following:

- End-User Equipment Price: The end-user equipment prices represent the customer price before tax and installation.
- Sales Tax: DOE then applied sales tax to convert the end-user equipment price to a final equipment price including sales tax. Chapter 6 of the NOPR TSD describes the sales tax markup in detail.
- Installation Cost: This input represents the cost to customers of installing the fixture, and differs from “installed cost.” The installation cost represents all costs required to install the system but does not include the final equipment price. The installation cost includes labor and overhead. Thus, the total installed cost equals the final equipment price plus the installation cost.

The primary inputs for calculating the operating cost include the following:

- Annual Operating Hours: The annual operating hours are the hours that a fixture is estimated to be in use during 1 year. The energy use analysis (NOPR TSD chapter 7) details how DOE determined the system operating hours as a function of end-user sector and building type.
- Power Rating: The power drawn is the site-energy usage rate associated with operating the fixture. The energy use analysis (NOPR TSD chapter 7) details how DOE determined the power ratings for the fixtures considered in the analysis.
- Electricity Prices: DOE used the average price per kilowatt-hour (*i.e.*, $/kWh) paid by customers. DOE determined electricity prices using national average commercial and industrial electricity prices. For the Monte Carlo analysis, DOE will sample from a distribution of electricity prices that includes commercial and industrial prices for all 50 states, including the District of Columbia. DOE developed all electricity price inputs using 2013 EIA data.
- Electricity Price Trends: DOE used the EIA’s *Annual Energy Outlook 2013* (*AEO2013*) to project electricity prices.[2] For the results presented in this chapter, DOE used the April 2012 *AEO2013* Reference Case.
- Lifetime: Lifetime is the total number of years of operation after which the customer retires the fixture from service.
- Discount Rate: The discount rate is the rate at which DOE discounts future expenditures to establish their present value.
- Analysis Period: The analysis period for this NOPR is 2016–2074. In the LCC and PBP analysis, the analysis periods are distributions with averages of 20 and 25 years for indoor and outdoor fixtures, respectively.

Figure 8.1.1 depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP. In this figure, the rectangular boxes indicate the inputs, the hexagons indicate intermediate calculated values, and the circles indicate the analysis outputs (LCCs and PBPs).

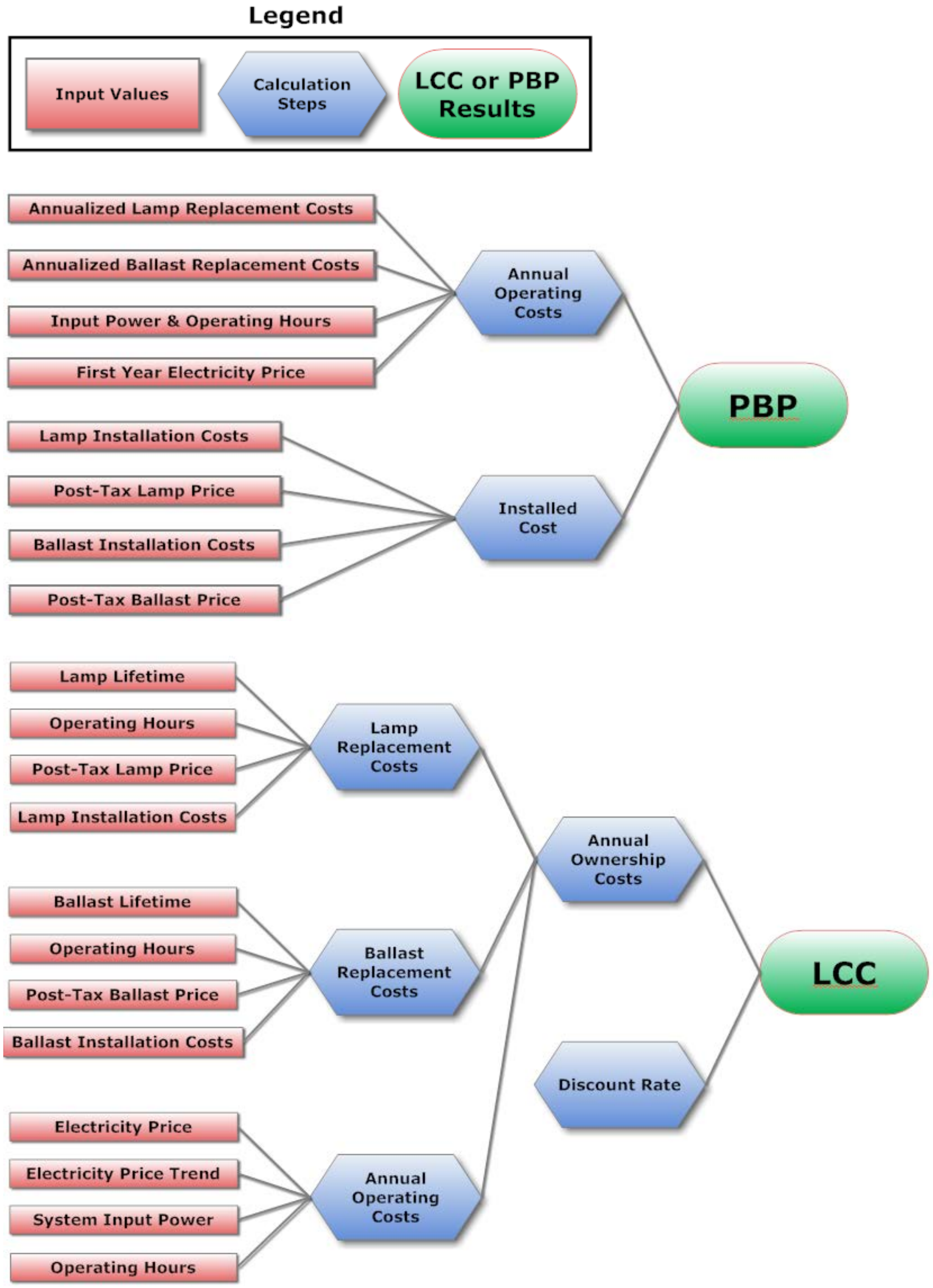

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 summarizes the input values that DOE used to calculate the LCC and PBP for fixtures. In the “main” LCC analysis, DOE characterized all of the total cost inputs with single-point values. In the Monte Carlo analysis, DOE characterized several of the operating cost inputs with probability distributions that capture the input’s uncertainty and/or variability. Table 8.1.1 also lists the NOPR TSD chapters that detail the inputs.

Table 8.1.1 Summary Information of Inputs for the Life-Cycle Cost and Payback Period Analysis

Factor	Input Value	TSD Reference Section
Total Installed Cost Primary Inputs		
End-User Equipment Price	Varies with MHLF system	Chapters 5, 6
Sales Tax	Varies by state	Chapter 6
Installation Cost	Varies by equipment class	Chapter 8
Operating Cost Primary Inputs		
Annual Operating Hours	Vary by equipment class, sector, application, and building type	Chapter 7
Power Rating	Varies with MHLF system	Chapter 6
Electricity Prices	Vary by sector and state	Chapter 8
Electricity Price Trends	Vary with price projection scenario	Chapter 8
Lifetime	Varies by fixture location	Chapter 8
Discount Rate	Varies with sector	Chapter 8
Analysis Period	Varies with fixture lifetime	Chapter 8
Replacement Cost Primary Inputs		
Total Installed Cost	Varies with MHLF system, state, and sector	Chapters 6, 8
Ballast Lifetime	Varies with MHLF system	Chapters 5, 8
Lamp Lifetime	Varies with MHLF system	Chapters 5, 8

Sections 8.2 and 8.3 discuss the inputs depicted in this table of installed costs and operating costs.

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition

LCC is the total customer cost over the life of the equipment, including total installed costs, operating costs, replacement costs, and residual value. Future operating costs and replacement costs are discounted to the analysis start year (2016) and summed over the analysis period. The LCC is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N}\left(\frac{OC_t + RC_t}{(1+r)^t}\right)$$

Eq. 8.1

Where:

LCC = life-cycle cost (\$),
IC = total installed cost (\$),
N = fixture lifetime,
$\sum$ = sum over the fixture lifetime, from year 1 to year N,

OC = operating cost ($),
RC = lamp and ballast replacement costs ($),
r = discount rate, and
t = year for which operating cost or replacement cost is determined.

DOE expresses all the costs in its LCC and PBP analysis in 2012 dollars (2012$).

8.2.2 Total Installed Cost Inputs

The total installed cost to the customer is defined by the following equation:

$$IC = FPP + INST$$

Eq. 8.2

Where:

FPP = final equipment price (*i.e.*, customer price for the equipment only, including sales tax; $), and
$INST$ = installation cost or the customer price to install equipment (*i.e.*, the cost for labor and materials; $).

In the markups analysis (NOPR TSD chapter 6), DOE developed end-user equipment prices and sales taxes to derive final equipment prices. DOE then applied installation costs where necessary to derive the total installed costs for use in the LCC. The inputs to determine total installed costs are:

- end-user equipment price ($),
- sales tax ($), and
- installation cost ($).

The end-user equipment price represents the average purchase price a customer pays before sales tax for MHLF systems. The sales tax represents state and local sales taxes applied to the end-user equipment price. It is a multiplicative factor that increases the end-user equipment price. The installation cost represents all costs required to install the fixture but does not include the final equipment price. The installation cost includes labor and overhead. Thus, the total installed cost equals the final equipment price plus the installation cost. DOE calculated the total installed cost for the fixtures analyzed based on the following equation:

$$\begin{aligned} IC &= FPP + INST \\ &= PRICE \times MU_{TAX} + INST \end{aligned}$$

Eq. 8.3

Where:

IC = total installed cost,

FPP = final equipment price,
$INST$ = installation cost,
$PRICE$ = end-user equipment price, and
MU_{TAX} = sales tax mark up.

On February 22, 2011, DOE published a notice of data availability (NODA; 76 FR at 9696) stating that DOE may consider improving regulatory analysis by addressing equipment price trends. For this proposed rule and consistent with the NODA, DOE examined two methods for estimating price trends for metal halide lamp fixtures: using historical producer price indices (PPI), and using projected price indices (called deflators). With PPI data, DOE found both positive and negative real price trends, depending on the specific time period examined, and did not use this method to adjust fixture prices. DOE instead adjusted fixture prices using deflators used by EIA to develop the *AEO*. When adjusted for inflation, the deflator-based price indices decline from 1.00 in 2011 to approximately 0.76 in 2045. DOE used these indices to adjust product prices across the national impact analysis (NIA) analysis period (see NOPR TSD chapter 11). For the LCC analysis, DOE used the deflator-based price index of 1.00, reflecting the price an individual customer would pay in 2016. DOE also examined LCC in the absence of deflator-based equipment price adjustments, and determined the impacts on results to be insignificant. A more detailed discussion of price trend modeling and calculations is provided in appendix 8B of the NOPR TSD.

Chapter 6 of the NOPR TSD provides further detail on the end-user equipment price and sales tax. Discussion about installation costs follows.

8.2.2.1 Installation Costs

Installation costs for fixtures include the installation of the fixture, maintenance of the ballast, and replacement of the lamp. DOE used data gathered in the high-intensity discharge (HID) lamps determination of 2010[3] as well as other research to estimate the installation costs.

During the January public meeting for the Framework document for the MHLF energy conservation standards, a manufacturer commented:

> As far as maintenance costs, we'd urge you to consider that, particularly in exterior environments; maintenance costs can be quite significant. It's difficult to get a bucket truck to a site to work on pole-mounted luminaires for less than a thousand dollars just to get it there and the average that our experience shows needs to be attributed somewhere between $150 and $300 per luminaire per servicing. So that is higher than you would traditionally think it would be for interior and just wanted to make that comment. (Philips, No. 8 at p. 16)[a]

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[a] A notation in this form provides a reference for information that is in the docket of DOE's rulemaking to develop energy conservation standards for metal halide lamp fixtures (Docket No. EERE-2009-BT-STD-0018), which is maintained at www.regulations.gov. This notation indicates that the statement preceding the reference is document number 8 in the docket for the MHLF energy conservation standards rulemaking, and appears at page 16 of that document.

In the HID lamp determination, DOE estimated $225 for exterior lamp maintenance costs and $75 for interior maintenance costs. These maintenance costs factor in the equipment needed to reach the fixture and provide necessary maintenance. More resolution of costs were needed for MHLF systems than the HID lamp determination, so DOE estimated the labor costs of indoor and outdoor fixtures per equipment class and developed installation and maintenance costs accordingly.

For MHLF systems, DOE derived labor rates for electricians from *RS Means*.[4] Labor rates are the sum of the wage rate, employer-paid fringe benefits (*i.e.*, vacation pay, employer-paid health, and welfare costs), and any appropriate training and industry advancement funds costs. According to *RS Means* and when combined with a gross domestic product (GDP) index,[5] an electrician's average hourly rate with overhead and profit is typically $72.72 (in 2012$).

Table 8.2.1 lists the estimated price of pulse-start lamps by equipment class.

Table 8.2.1 Pulse-Start Metal Halide Lamp Prices

Rated Lamp Power	**Lamp Price** ***2012$***
70 W	30.31
150 W	39.34
250 W	42.95
400 W	52.54
1000 W	89.13

To help determine installation costs, DOE estimated a portion of each equipment class to be either an indoor or outdoor fixture. This allowed DOE to estimate costs related to fixture installations. One of the guiding principles of the estimate was that higher powered fixtures tend to be more expensive to install. Table 8.2.2 lists the fixture mixture based on indoor and outdoor installation expenses.

Table 8.2.2 Percentage of Indoor and Outdoor Fixtures by Equipment Class

Equipment Class	**% Indoor**	**% Outdoor**
70 W	25	75
150 W	30	70
250 W	30	70
400 W	30	70
1000 W	25	75

To estimate fixture maintenance costs, DOE multiplied the baseline maintenance rate of $75 (indoor) and $225 (outdoor) by the percentage mix of the equipment class, and then added additional labor hours.

DOE assumed that installation of a fixture takes 2 labor hours of an electrician's time. Table 8.2.3 lists the fixture installation/replacement costs DOE used in the LCC-PBP analysis.

Table 8.2.3 MHLF Fixture Installation/Replacement Labor Costs

Equipment Class	**Cost** ***2012$***
70 W	257.94
150 W	280.44
250 W	280.44
400 W	295.44
1000 W	355.44

DOE assumed that installation of a metal halide fixture ballast takes 1 labor hour of an electrician's time. Table 8.2.4 lists the MHLF ballast installation/replacement costs DOE used in the LCC-PBP analysis.

Table 8.2.4 MHLF Ballast Replacement Labor Costs

Equipment Class	**Cost** ***2012$***
70 W	185.22
150 W	207.72
250 W	207.72
400 W	222.72
1000 W	282.72

DOE assumed that installation of a metal halide lamp takes 0.24 labor hours of an electrician's time. Table 8.2.5 lists the metal halide lamp fixture lamp installation/replacement costs DOE used in the LCC-PBP analysis.

Table 8.2.5 MHLF Lamp Replacement Labor Costs

Equipment Class	**Cost** ***2012$***
70 W	141.59
150 W	164.09
250 W	164.09
400 W	179.09
1000 W	239.09

8.2.3 Operating Cost Inputs

The operating cost represents the costs incurred in the operation of fixtures. The inputs for operating costs are:

- annual operating hours,
- power rating (W),
- electricity prices ($/kWh),
- electricity price trends,
- discount rate (%), and
- lifetime (yr).

The lifetime, discount rate, and effective date of the amended standard are required for determining the operating cost and for establishing the operating cost present value. The electricity use for the baseline and other efficiency levels examined enable comparison of standards' operating costs.

The annual operating hours are the estimated hours that a fixture is in use during 1 year. Power rating refers to the rate of site energy usage associated with operating the fixture. Both the annual operating hours and power rating are used to calculate the total annual energy consumption. Electricity prices used in the analysis are the price per kilowatt-hour in cents or dollars (*e.g.*, \$/kWh) paid by each customer for electricity. DOE used electricity price trends to project electricity prices for future year analysis. These trends with the electricity price and annual energy consumption were used to calculate the energy cost in each year. DOE defined energy cost by the following equation:

$$\begin{aligned} OC &= E_{cons} \times EP \times EPT \\ &= (PWR \times OH) \times EP \times EPT \end{aligned}$$

Eq. 8.4

Where:

OC = operating energy costs,
E_{cons} = annual energy consumed,
EP = electricity price,
EPT = electricity price trend factor relative to 2012,
PWR = power rating (rate of energy use, measured in kilowatts), and
OH = annual operating hours.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs.

8.2.3.1 Operating Hours

The energy use analysis (NOPR TSD chapter 7) details how DOE determined the annual energy use for baseline and standards-compliant equipment. An important input to determining the energy use is the total hours per year that the equipment is in operation. The operating hours are also used to calculate the fixture service life, which is ultimately used in calculating the LCC and PBP.

As described in NOPR TSD chapter 7, DOE established operating hour distributions for MHLF systems using data from the 2010 LMC. Table 8.2.6 presents the mean operating hours for fixtures in each sector.

Table 8.2.6 Average Operating Hours by Sector

Sector	Average Annual Operating *hr/yr*
Commercial	3,615
Industrial	6,113
Outdoor Stationary	4,493

8.2.3.2 Power Rating

As described in the energy use analysis (NOPR TSD chapter 7), DOE used the power rating (in watts) with the annual operating hours (in hours) to calculate the annual energy usage (in kilowatt-hours) of the fixture designs DOE considered.

8.2.3.3 Electricity Prices

DOE estimated electricity prices for commercial, industrial, and outdoor stationary customers in each state by using EIA form 826 data.[6] EIA form 826, Sales and Revenue Spreadsheets, contains average retail electricity prices for each sector. The spreadsheet contains average electricity prices for each state, by year, by sector. In the LCC and subsequent analyses, DOE used 2012 electricity prices from the 826 worksheet, last accessed in June, 2013. Table 8.2.8 lists electricity prices by state.

In the preliminary analysis stage of this rulemaking, DOE assumed that outdoor stationary electricity prices were identical to commercial sector prices. In response to comments from interested parties, for this NOPR analysis for outdoor stationary electricity prices, DOE multiplied the average commercial sector electricity rate by a factor of 0.82. In the absence of sufficient data, DOE developed a distribution of scaling factors that were applied to commercial sector electricity prices to derive outdoor stationary prices. Table 8.2.7 presents the multipliers and their probabilities of outdoor stationary electricity price factors that were applied to commercial sector prices in the Monte Carlo analysis. In the main LCC and PBP analysis, DOE multiplied the average commercial sector electricity prices by 0.82 to develop outdoor stationary electricity prices.

Table 8.2.7 Outdoor Stationary Electricity Price Factors Relative to Commercial Prices

Scaling Factor	Probability
1.0	0.3
0.9	0.2
0.8	0.2
0.7	0.1
0.6	0.1
0.5	0.1

Table 8.2.8 Electricity Prices by State, 2012

State	**Electricity Prices*** ***2012$/kWh***		
	Commercial	**Industrial**	**Outdoor Stationary**
Alabama	0.106	0.062	0.087
Alaska	0.148	0.168	0.121
Arizona	0.095	0.065	0.078
Arkansas	0.077	0.057	0.063
California	0.136	0.107	0.112
Colorado	0.093	0.069	0.077
Connecticut	0.147	0.128	0.121
Delaware	0.101	0.083	0.083
Dist. of Columbia	0.120	0.054	0.098
Florida	0.098	0.080	0.080
Georgia	0.095	0.059	0.078
Hawaii	0.348	0.308	0.286
Idaho	0.068	0.056	0.056
Illinois	0.082	0.059	0.067
Indiana	0.091	0.064	0.074
Iowa	0.080	0.053	0.066
Kansas	0.091	0.069	0.075
Kentucky	0.087	0.054	0.071
Louisiana	0.078	0.048	0.064
Maine	0.116	0.079	0.095
Maryland	0.105	0.081	0.086
Massachusetts	0.140	0.129	0.115
Michigan	0.110	0.077	0.090
Minnesota	0.089	0.066	0.073
Mississippi	0.093	0.062	0.076
Missouri	0.082	0.059	0.067
Montana	0.092	0.050	0.075
Nebraska	0.084	0.068	0.069
Nevada	0.089	0.065	0.073
New Hampshire	0.134	0.118	0.110
New Jersey	0.128	0.105	0.105
New Mexico	0.093	0.058	0.076
New York	0.151	0.067	0.124
North Carolina	0.086	0.063	0.071
North Dakota	0.080	0.067	0.065
Ohio	0.095	0.062	0.078
Oklahoma	0.073	0.050	0.060
Oregon	0.083	0.056	0.068
Pennsylvania	0.094	0.072	0.077
Rhode Island	0.120	0.109	0.099
South Carolina	0.096	0.060	0.078
South Dakota	0.080	0.066	0.066
Tennessee	0.103	0.071	0.084
Texas	0.082	0.057	0.067
Utah	0.081	0.056	0.066
Vermont	0.143	0.100	0.117
Virginia	0.081	0.067	0.067

Table 8.2.8 (cont)

State	Electricity Prices* *2012$/kWh*		
	Commercial	**Industrial**	**Outdoor Stationary**
Washington	0.077	0.041	0.063
West Virginia	0.084	0.063	0.069
Wisconsin	0.105	0.074	0.086
Wyoming	0.082	0.060	0.067
U.S. Weighted Average	0.104	0.075	0.085

* DOE used average retail electricity prices for each of the sectors, across all available months in 2012.

8.2.3.4 Electricity Price Trend

The electricity price trend projects the future cost of electricity to 2040. DOE calculated the LCC and PBP using three separate projections from *AEO2013*: low economic growth, Reference Case, and high economic growth. These three cases reflect the uncertainty of economic growth in the projection period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. DOE normalized these three *AEO2013* scenarios to the 2012 electricity price, and then used the corresponding electricity price factors to scale the 2012 electricity prices. Figure 8.2.1 through Figure 8.2.3 show the commercial, industrial, and outdoor stationary electricity price trends, respectively, based on the three *AEO2013* projections. DOE calculated average growth rates from all years of the projections to predict electricity price trends from 2041–2045. The LCC results presented in this chapter are based on the *AEO2013* Reference Case.

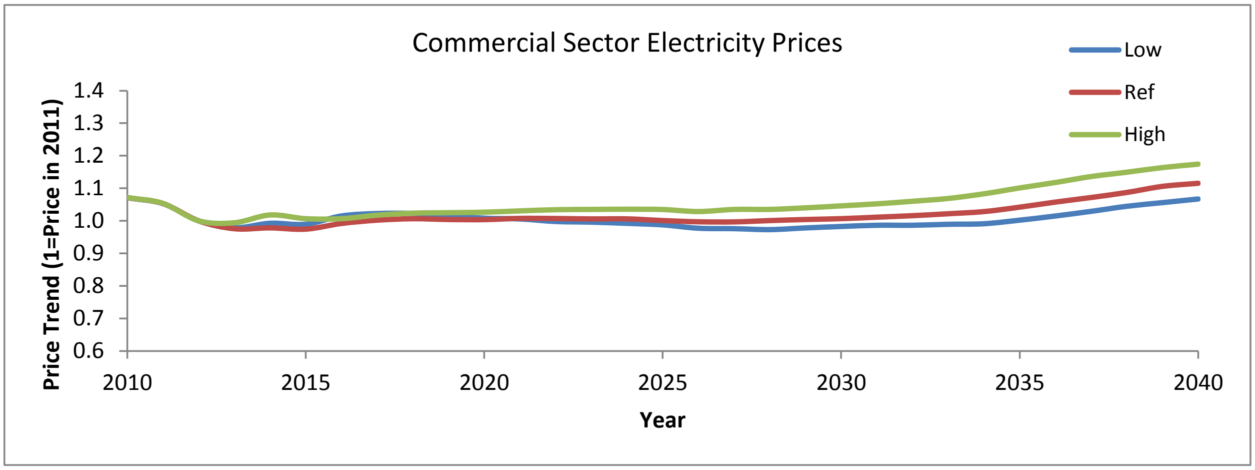

Figure 8.2.1 Commercial Sector Electricity Price Trend

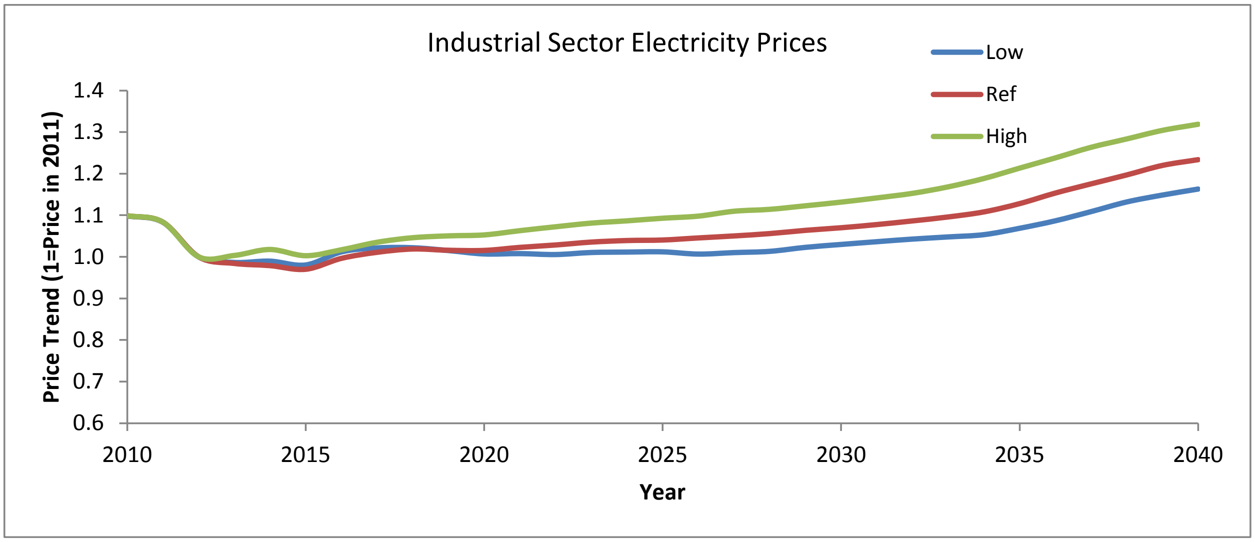

Figure 8.2.2 Industrial Sector Electricity Price Trend

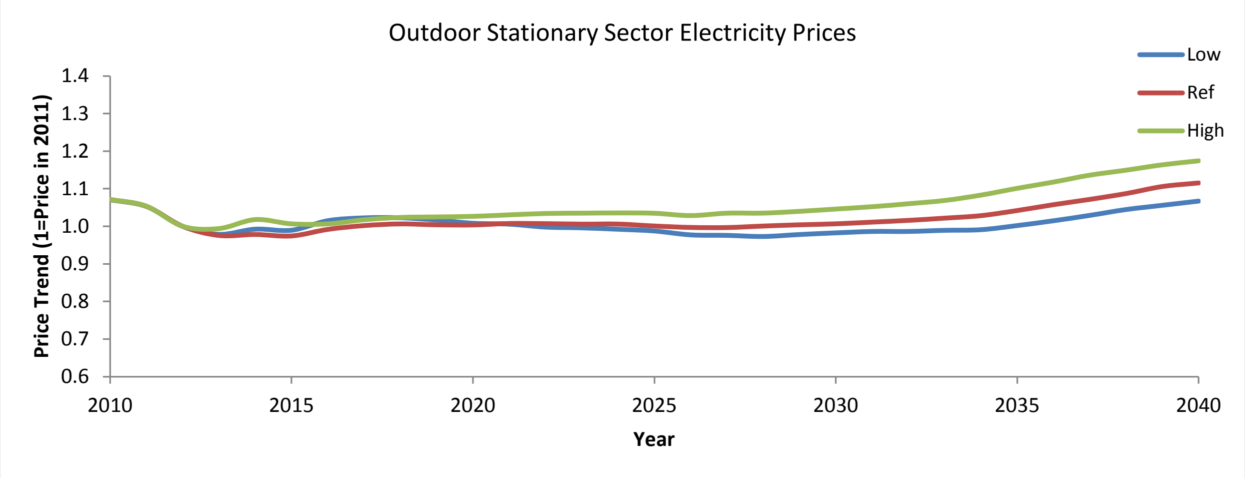

Figure 8.2.3 Outdoor Stationary Sector Electricity Price Trend

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in both the LCC spreadsheets and the LCC results tables in this chapter.

8.2.4 Lifetime

DOE defined lifetime as the age in hours in operation when a fixture, ballast, or lamp is retired from service.

8.2.4.1 Estimated Fixture Life

For fixtures in all equipment classes, DOE assumed lifetimes for indoor and outdoor fixtures as 20 and 25 years, respectively. In response to the preliminary TSD, several interested parties, including the National Electrical Manufacturers Association (NEMA), Philips, and OSRAM SYLVANIA, urged DOE to consider that fixtures are often removed before end of service life due to remodels or especially as new energy efficient alternatives appear on the market. (NEMA, No. 34 at p. 18; Philips, Public Meeting Transcript, No. 33 at p. 107; OSRAM SYLVANIA, No. 27 at p. 6) The Northwest Energy Efficiency Alliance (NEEA) commented that DOE should use a distribution of component lifetimes. (NEEA, No. 31 at p. 7)

8.2.4.2 Estimated Ballast Life

Metal halide lamp fixtures are operated by either magnetic or electronic ballasts. Although electronic ballasts utilize the newest and most efficient technology, they do not last as long as magnetic ballasts. In the preliminary analysis, DOE assumed that magnetic ballasts last for 50,000 hours, and electronic ballasts last for 30,000 hours. However, comments following the April 2011 metal halide lamp fixture public meeting[7] and recently verified published manufacturer data on ballast lifetimes have caused DOE to change its estimate of lifetime for electronic ballasts to an average of 40,000 hours. For ballasts in the commercial and industrial sectors, DOE reviewed the websites and where applicable, contacted ballast manufacturers, including Philips Advance, AMF Lighting Technology, Fulham Inc., GE Lighting, Hatch, Howard Lighting, OSRAM SYLVANIA, Powerselect Inc., Robertson Worldwide, Sunny Intelligent, Sunpark Electronics Corp., Ultrasave Lighting Ltd., Universal Lighting Technologies, Venture Lighting International, Inc., and Vossloh-Schwabe. In total DOE found only five manufacturers that had at least one model of ballast lifetime stated in print.

The Howard Lighting Products Ballast Catalog[8] gives specifications for HID magnetic ballasts. These ballasts are designed to operate for 60,000 hours of continuous operation at maximum rated temperature.

Holophane, an Acuity Brands Company, offers the Elite Series luminaire product families that contain Holophane's high-frequency electronic HID ballasts. Holophane's documentation states that the operating life of the ballast is directly related to operating temperature. The average lifetime for the ballast is stated as 50,000 hours with increased temperatures dramatically shortening ballast life while decreased operating temperatures will increase ballast life.[9]

OSRAM SYLVANIA has published an instructional manual, *Metal halide lamps, instructions for the use and application.*[10] Section 3.2.2, page 13 describes some of the pros and cons of electronic ballasts, including the more complicated influence of operating temperature on ballast service life. As an example, electronic ballasts in the POWERTRONIC PTi product family for lamp wattages between 20–150 W are listed as having a nominal service life of 40,000 hours with a failure probability maximum of 10 percent when operated at maximum permissible temperatures. The service life is influenced by the temperature surrounding the ballast and electronics during operation, which is typically much higher than the ambient temperature due to the heat generated by the components in the luminaire. Any temperature below the maximum permitted temperature will always prolong the service life. If the operating temperature of the ballast is 10 °C below the maximum permitted operating temperature, the service life of the electronic ballast is estimated to approximately double. However, the rule of stating the maximum permitted operating temperature has not become established in the electronic ballast industry, and in practice many electronic ballasts only achieve half of their service life at maximum permitted operating temperature.

Philips CosmoPolis is a lamp+ballast system requiring specific lamps designed to work with specific ballasts. The ballast claims a 60,000 hour outdoor lifetime with 5 percent failure rate and has a fully potted box to protect components from dust, moisture and vibration. The ballasts are rated for ambient temperatures up to 50 °C.

Electronic ballasts manufactured by Vossloh-Schwabe have stated mean service life ranging from 26,000 hours to 50,000 hours.[11] There are 15 different models offered, with 4 of the models being offered with three different maximum permissible operating temperatures. The vast majority of the electronic ballasts listed are fitted with a temperature switch to protect against overheating. Electronic ballast failure rate is given as 0.2 percent per 1,000 hours. Electronic ballasts designed for lower operating temperatures have mean service lives of 50,000 hours, while those designed for higher operating temperatures have lower service life. As an example, a 20 W electronic ballast designed for 80 °C has a 50,000 hour lifetime, while to achieve the same lifetime, a 35 W and 75 W electronic ballast are limited to maximum operating temperatures of 75 °C and 70 °C, respectively.

DOE intends to apply these lifetimes in the LCC analysis. DOE also agrees that ballast lifetimes can vary due to both physical failure and economic factors (*e.g.*, early replacements due to retrofits). Consequently, DOE accounted for variability in lifetime in LCC and PBP via the Monte Carlo simulation, and in the shipments and NIA analyses by assuming a Weibull distribution for lifetimes to accommodate failures and replacement.

8.2.4.3 Estimated Lamp Life

Metal halide lamp lifetimes vary by equipment class. DOE assumed that lamps in the 70 W, 150 W, 250 W, 400 W, and 1000 W equipment classes have lifetimes of 12,841, 13,882, 16,785, 20,720, and 11,700 hours, respectively.

As summarized in Table 8.2.9, DOE reviewed manufacturer catalog data for 70 W MH lamps for both horizontal and vertical operation. The majority of 70 W MH lamps have a rated life of 6,000 hours when operated in vertical orientation. However, when combined, the majority of lamps have higher lifetime ratings. DOE does not have specific data on the mixture of fixtures that operate a lamp in a given orientation. Therefore, DOE used a weighted average of all available lamps and published life rating data. DOE used a value of 12,841 hours for 70 W MH lamps.

Table 8.2.9 70 W MH Lamp Rated Life

Lamp Start	Lamp Start Hours	Vertical Operation Percent Offered	Horizontal Percent Offered
Pulse	3,200	1.65%	0.00%
	3,600	1.65%	0.00%
	4,300	1.65%	0.00%
	6,000	31.40%	4.13%
	7,500	1.65%	0.00%
	8,500	2.48%	0.00%
	9,000	7.44%	1.65%
	10,000	6.61%	5.79%
	11,250	0.00%	9.09%
	12,000	9.09%	0.00%
	15,000	23.14%	0.00%
	16,000	6.61%	0.00%
	20,000	6.61%	0.83%

DOE reviewed manufacturer catalog data for 150 W and 250 W MH lamps for both horizontal and vertical operation, with results summarized in Table 8.2.10. The majority of probe-start 250 W MH lamps have a rated life of 10,000 hours and pulse-start 250 W MH lamps have a rated life of 15,000 hours when operated in vertical orientation. DOE does not have specific data on the mixture of fixtures that operate a lamp in a given orientation. Therefore, DOE used a weighted average of all available lamps and published life rating data. Therefore, DOE used a value of 13,882 hours for 150 W and 16,785 hours for 250 W MH lamps.

Table 8.2.10 150 W/250 W MH Lamp Rated Life

Lamp Start	Lamp Start Hours	Vertical Operation Percent Offered	Horizontal Percent Offered
Probe	1000	4.00%	0.00%
	6000	0.00%	68.18%
	7500	2.00%	18.18%
	8000	2.00%	0.00%
	10000	88.00%	13.64%
	15000	4.00%	0.00%
Pulse	6000	0.00%	2.56%
	10000	20.51%	0.00%
	12000	0.00%	7.69%
	14000	2.56%	0.00%
	15000	56.41%	0.00%
	20000	20.51%	0.00%

As summarized in Table 8.2.11, DOE reviewed manufacturer catalog data for 400 W MH lamps for both horizontal and vertical operation. The majority of 400 W MH lamps have a rated life of 20,000 hours when operated in either orientation. DOE does not have specific data on the mixture of fixtures that operate a lamp in a given orientation. Therefore, DOE used a weighted average of all available lamps and published life rating data. Therefore, DOE used a value of 20,720 hours for 400 W MH lamps.

Table 8.2.11 400 W MH Lamp Rated Life

Lamp Start	Lamp Start Hours	Vertical Operation Percent Offered	Horizontal Percent Offered
Probe	8,000	0.83%	0.00%
	10,000	2.48%	6.38%
	12,000	3.31%	0.00%
	15,000	5.79%	74.47%
	20,000	87.60%	19.15%
Pulse	10,000	1.45%	0.00%
	12,000	5.80%	0.00%
	15,000	4.35%	5.80%
	20,000	88.41%	0.00%

DOE reviewed manufacturer catalog data for 1000 W MH lamps for both horizontal and vertical operation, with results summarized in Table 8.2.12. The majority of 1000 W MH lamps when operated vertically have a rated life of 12,000 hours and when operated horizontally have a rated life of 9,000 hours. DOE does not have specific data on the mixture of fixtures that operate a lamp in a given orientation. Therefore, DOE used a weighted average of all available lamps and published life rating data. Therefore, DOE used a value of 11,700 hours for 1000 W MH lamps.

Table 8.2.12 1000 W MH Lamp Rated Life

Lamp Start	Lamp Start Hours	Vertical Operation Percent Offered	Horizontal Percent Offered
Probe	3,500	2.47%	0.00%
	5,000	1.23%	0.00%
	6,000	1.23%	0.00%
	9,000	1.23%	64.10%
	10,000	4.94%	0.00%
	11,000	2.47%	5.13%
	12,000	56.79%	5.13%
	15,000	8.64%	5.13%
	18,000	6.17%	0.00%
Pulse	3,500	0.00%	0.00%
	5,000	1.23%	0.00%
	6,000	1.23%	2.56%
	9,000	0.00%	17.95%
	12,000	7.41%	0.00%
	15,000	4.94%	0.00%

8.2.5 Replacement Cost

As stated previously, the lifetime is the age (total hours in operation) at which a fixture, ballast, or lamp is retired from service. The lifetime paired with the operating hours yields the service life of the fixture, ballast, or lamp in years. Because lamp lifetimes are typically shorter than ballast lifetimes and ballast lifetimes are shorter than fixture lifetimes, DOE must address ballast and lamp replacements within fixture lifetimes for the metal halide lamp fixture designs considered. Replacement costs include the labor and materials costs associated with replacing a lamp at the end of its lifetime. By using the service life and replacement cost, one can calculate the total replacement cost each year.

Each year in which a ballast or lamp reaches the end of its life, a new ballast or lamp is purchased and installed at the beginning of that year, and the first cost and installation cost are discounted back to the base year of the analysis period. During years in which replacement is necessary, DOE based the replacement costs on the total installed cost inputs, as seen in the following equation:

$$\begin{aligned} RC &= FPP_B + INST_B + FPP_L + INST_L \\ &= PRICE_B \times MU_{TAX} + INST_B + PRICE_L \times MU_{TAX} + INST_L \end{aligned}$$

Eq. 8.5

Where:

RC = replacement cost, expressed in dollars,
FPP_B = final equipment price (price for the ballast only) expressed in dollars,
$INST_B$ = ballast installation cost,
$PRICE_B$ = end-user ballast equipment price expressed in dollars,
FPP_L = final equipment price (price for the lamp only) expressed in dollars,
$INST_L$ = lamp installation cost,
$PRICE_L$ = end-user lamp equipment price expressed in dollars, and
MU_{TAX} = sales tax.

Replacement costs are annualized in such a way that national net present value (NOPR TSD chapter 11) calculations are unaffected by computing annualized values instead of capital costs. Similar to calculating the monthly premiums on a loan, replacement costs during a fixture lifetime are discounted to the beginning of the analysis period, and monthly payments are calculated such that the sum of annualized, discounted replacement costs equals the sum of discounted capital costs across a fixture's lifetime. The replacement costs only include the end-user equipment price of the ballast or lamp and the installation cost of the ballast or lamp, rather than prices or costs associated with the entire metal halide lamp fixture. For the LCC and PBP analysis, the analysis period corresponds with the fixture lifetime; for this reason, ballast and lamp prices and labor costs are included in the calculation of total installed costs.

8.2.6 Analysis Period

The analysis period is the time span over which the LCC is calculated. DOE based the analysis period on the baseline fixture lifetimes. In this NOPR analysis, DOE analyzed two scenarios in its LCC and PBP analysis: indoor and outdoor. The analysis periods corresponding to indoor and outdoor fixtures are 20 and 25 years, respectively.

8.2.7 Discount Rate

The discount rate is the rate at which DOE discounts future expenditures to establish their present values. DOE derived the discount rates for this rulemaking separately for commercial and industrial customers. The discount rate used for the outdoor stationary sector is assumed to be the same as the commercial sector discount rate. For all customers, DOE estimated the cost of capital for commercial and industrial companies by examining both debt and equity capital, and developed an appropriately weighted average of the cost to the company of equity and debt financing.

8.2.7.1 Commercial and Industrial Discount Rates

Most companies use both debt and equity capital to fund investments; for most companies, therefore, the cost of capital is the weighted average of the cost to the firm of equity and debt financing.[12]

DOE estimated the cost of equity financing using the Capital Asset Pricing Model (CAPM). Among the most widely used models to estimate the cost of equity financing, the CAPM assumes that the cost of equity is proportional to the amount of systematic risk associated with a firm. For example, the cost of equity financing tends to be high when a firm faces a large degree of systematic risk, and the cost tends to be low when the firm faces a small degree of systematic risk.

The degree of systematic risk facing a firm and the subsequent cost of equity financing are determined by several variables, including the risk coefficient of a firm (beta, β), the expected return on risk-free assets (R_f), and the additional return expected on assets facing average market risk (known as the equity risk premium, or ERP). The beta indicates the degree of risk associated with a given firm, relative to the level of risk (or price variability) in the overall stock market. Betas usually vary between 0.5 and 2.0. A firm with a beta of 0.5 faces half the risk of other stocks in the market; a firm with a beta of 2.0 faces twice the overall stock market risk.

Following this approach, the cost of equity financing for a particular company is determined by the equation:

$$k_e = R_f + (\beta \times ERP)$$

Eq. 8.6

Where:

k_e = the cost of equity for a company, expressed in dollars,
R_f = the expected return of the risk free asset, expressed in dollars,
β = the risk coefficient, and
ERP = the expected equity risk premium, expressed in dollars.

The cost of debt financing (k_d) is the yield or interest rate paid on money borrowed by a company (raised, for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk and excludes deductions for taxes.

DOE estimated the cost of debt for companies by adding a risk adjustment factor to the current yield on long-term corporate bonds (the risk-free rate). This procedure is used to estimate current and future company costs to obtain debt financing. The adjustment factor is based on indicators of company risk, such as credit rating or variability of stock returns.

The discount rate of companies is the weighted average cost of debt and equity financing, less expected inflation. DOE estimated the discount rate using the equation:

$$k = k_e \times w_e + k_d \times w_d$$

Eq. 8.7

Where:

k = the (nominal) cost of capital,
k_e and k_d = the expected rates of return on equity and debt, respectively, and
w_e and w_d = the proportion of equity and debt financing, respectively.

The real discount rate is the nominal discount rate adjusted for expected inflation.

The expected return on risk-free assets, or the risk-free rate, is defined by the current yield on long-term (20-year) government bonds, as suggested by Damodaran.[13] The ERP represents the difference between the expected (average) stock market return and the risk-free rate. As Table 8.2.13 shows, DOE used an ERP estimate of 2.9 percent, which it took from the Damodaran Online site (a private website associated with New York University's Stern School of Business, which aggregates information on corporate finance, investment, and valuation).[14]

Table 8.2.13 Variables Used to Estimate Company Discount Rates

Variable	Symbol	Average Value %	Source
Risk-Free Asset Return	R_f	6.1	Damodaran Online
Equity Risk Premium	ERP	2.9	Damodaran Online
Expected Inflation	R	3.8	U.S. Bureau of Economic Analysis
Cost of Debt (After Tax)	k_d	8.0	Damodaran Online
Percent Debt Financing	w_d	25.0	Damodaran Online
Systematic Firm Risk	B	1.0	Damodaran Online

DOE calculated an expected inflation of 3.8 percent from the average of the inflation rate from 1972–2011. DOE obtained the cost of debt, percent debt financing, and systematic firm risk from the Damodaran Online website. Table 8.2.13 shows average values across all private companies. However, the cost of debt, percent debt financing, and systematic firm risk vary by sector.

DOE took a sample from the list of companies included in the Value Line investment survey[15] and listed on the Damodaran Online website to calculate cost of capital by sector. The sample includes the cost of debt, the firm beta, the percent of debt and equity financing, the risk-free return, and the equity risk premium, and contains 1,234 entities in the commercial sector, 3,490 entities in the industrial sector, and 4,680 entities in the outdoor stationary sector.

DOE estimates the cost of debt financing for these companies from the long-term government bond rate and the standard deviation of the stock price. For publicly owned entities, the discount rate represents an average of the Federal rate and the state and local bond rate. DOE drew the Federal rate directly from the U.S. Office of Management and Budget discount rate for investments in government building energy efficiency.[16] DOE estimated the state and local discount rate from the interest rate on state and local bonds between 1977 and 2001.[17] DOE used this information to estimate the weighted-average cost of capital for all sectors. DOE estimates discount rate distributions for the different sectors as a weighted average of the distributions for the different ownership types. The resulting weighted average discount rates are summarized in Table 8.2.14.

Table 8.2.14 Average Discount Rate by Sector

Sector	Discount Rate %
Commercial	4.5
Industrial	4.3
Outdoor Stationary	3.4

8.2.7.2 Outdoor Stationary Discount Rate

While metal halide lamp fixtures in the outdoor stationary sector are operated by many different types of institutions, the majority of fixtures in this sector are operated by commercial companies. Thus, DOE assumed that the discount rate for metal halide lamp fixtures in this sector is the same as the commercial sector discount rate. DOE invites comment on the discount rate for metal halide lamp fixtures in the outdoor stationary sector.

8.2.8 Effective Date of Standard

The effective date is the date when an amended standard becomes operative (*i.e.*, the date by which fixtures manufacturers must manufacture equipment that complies with the amended standard). DOE's publication of a final rule in this standards rulemaking is scheduled for completion in 2013. For metal halide lamp fixtures not currently covered (*i.e.*, fixtures with rated wattage below 150 W and above 500 W), the effective date of any new energy conservation standards for these metal halide lamp fixtures or amended energy conservations standards is January 2016. (42 U.S.C. 6295(hh)(2)(B)(ii))

DOE calculated the LCCs for all customers as if each would purchase new equipment in the year the amended standard takes effect. However, DOE based the cost of the equipment on the most recent available data; all dollar values are expressed in 2012$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

The PBP is the amount of time it takes the customer to recover the assumed higher purchase cost of more energy efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" PBP, because it does not take into account changes in operating cost over time or the time value of money. That is, the calculation is done at an effective discount rate of 0 percent.

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC}$$

Eq. 8.8

Where:

PBP = payback period (years),
ΔIC = difference in the total installed cost between the more efficient standards-level equipment (efficiency levels 1, 2, etc.), and baseline (efficiency level 0) equipment, and
ΔOC = difference in annual operating costs.

PBPs are expressed in years. PBPs greater than the life of the equipment mean that the increased total installed cost of the more efficient equipment is not recovered in reduced operating costs over the lifetime of that equipment. Because most MHLF designs in the LCC and PBP analysis save energy and thus yield a positive ΔOC, negative PBPs indicate that the total installed cost of the more efficient trial standard level (TSL) equipment is less than that of the baseline. PBPs that are "N/A" indicate TSLs that actually have higher operating costs than the baseline fixtures, and thus are not economically viable.

8.3.2 Rebuttable Presumption Payback Period

Section 325(o)(2)(B)(iii) of the Energy Policy and Conservation Act establishes a rebuttable presumption that an amended standard for fixtures is economically justified if the Secretary finds that "the additional cost to the customer of purchasing equipment complying with an energy conservation standard level will be less than three times the value of the energy. . . savings during the first year that the customer will receive as a result of the standard, as calculated under the applicable test procedure." (42 U.S.C. 6295(o)(2)(B)(iii)) This rebuttable presumption test is an alternative path to establishing economic justification compared to consideration of the seven factors set forth in 42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII).

The applicable fixture test procedure uses a lamp load and requires that the power to the lamp (known as power out (P_{out}) of the ballast) and the power into the ballast (known as power in (P_{in}) to the ballast) be measured. Ballast Efficiency is calculated by dividing P_{out}/P_{in}. Input power to the metal halide lamp fixture is measured rather than measure energy consumption (*i.e.*, measured over a duration or operating time period). Therefore, to calculate energy savings for the rebuttable presumption payback period, one would need to multiply the input power of the metal halide lamp fixture by the usage profile (*i.e.*, hours of operation) of that system. For the engineering analysis, DOE measured the input power of fixtures operating actual ballasts and lamps, essentially duplicating real-world operating conditions for these metal halide lamp fixtures. Energy savings calculations in the LCC and PBP analysis use both the real-world system power ratings as well as the applicable usage profiles. Because DOE calculated PBPs in a methodology consistent with the rebuttable presumption test in the LCC and PBP analysis, DOE did not perform a stand-alone rebuttable presumption analysis, as it is already embodied in the LCC and PBP analysis.

8.3.3 Inputs

The data inputs to PBP are the total installed cost of the equipment to the customer for each TSL and the annual (first year) operating costs for each TSL. The inputs to the total installed cost are the final equipment price and the installation cost. The inputs to the operating costs are the fixture input power rating, annual operating hours, and electricity cost. The PBP uses the same inputs as the LCC calculation described in section 8.2, except that electricity price trends are not required. Since the PBP is a "simple" (undiscounted) PBP, the required electricity cost is only for the year corresponding with the beginning of the analysis period (*i.e.*, 2016). The electricity price DOE used in the PBP calculation for electricity cost is the price projected for 2016, expressed in 2012$. DOE did not use discount rates in the PBP calculation.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents LCC results for each metal halide lamp fixture design DOE considered. This section uses the terms "positive LCC savings" and "negative LCC savings." When an amended standard results in "positive LCC savings," the LCC of the standards-compliant system is less than the LCC of the baseline system and the customer benefits. A customer is adversely affected when an amended standard results in "negative LCC savings" (*i.e.*, when the LCC of the standards-compliant system is higher than the LCC of the baseline system).

A customer is also adversely affected when an amended standard results in "N/A" PBP values. In this situation, more efficient fixtures are not only more expensive to install, but they are also more expensive to operate. In general, switching from magnetic to electronic ballasts increases PBP values, since the increased maintenance costs acquired during replacement of the shorter-lived electronic ballasts are costly.

As stated earlier, DOE conducted a series of LCC calculations for each baseline metal halide lamp fixture. Key inputs consisted of using historical electricity prices from electricity price projections from the *AEO2013* Reference Case, and an analysis period of with averages of 20 or 25 years. Table 8.4.1 through Table 8.4.12 give LCC and PBP values from the LCC model.

DOE analyzed five representative equipment classes for fixtures, as discussed in section 8.1.1. Table 8.4.1 through Table 8.4.12 present the results for each of these representative equipment classes by fixture location (indoor or outdoor), which influenced the LCC and PBP results. DOE also presented the installed prices of the metal halide lamp fixtures in order to compare the up-front costs that customers must bear when purchasing baseline or standards-case systems.

In general, the results show higher installed prices and lower operating costs at higher efficiency levels. However, this is not always the case. For example, fixtures operating electronic ballasts in any equipment class may have higher operating costs at higher efficiency levels than fixtures in the base case and some lower efficiency levels, which operate magnetic ballasts. This is because electronic ballasts have shorter lifetimes than magnetic ballasts. Due to the higher cost of electronic ballasts and the labor costs associated with replacing failed ballasts, fixtures with electronic ballasts have higher annual maintenance costs than magnetic fixtures. These additional maintenance costs sometimes outweigh the monetary savings achieved from the efficiency gains in electronic ballasts.

Table 8.4.1 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Indoor, Magnetic Baseline): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** ***2012$***			**Life-Cycle Cost Savings**			**Median Payback Period** ***years***
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** ***2012$***	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
	Baseline	537.80	1,379.32	1,917.12	--	--	--	--
1	1	539.03	1,345.26	1,884.28	32.84	0.0	100.0	0.5
2, 3, 4	2	552.28	1,326.43	1,878.71	38.41	0.0	100.0	4.2
--	3	555.25	1,379.56	1,934.80	-17.68	24	76	3.3
5	4	568.68	1,374.61	1,943.29	-26.16	28	72	5.4

Table 8.4.2 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Indoor, Electronic Baseline): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** ***2012$***			**Life-Cycle Cost Savings**			**Median Payback Period** ***years***
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** ***2012$***	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
1, 2, 3, 4	Baseline / 3	555.25	1,379.56	1,934.80	--	--	--	--
5	4	568.68	1,374.61	1,943.29	-8.48	96	4	32.3

Table 8.4.3 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Outdoor, Magnetic Baseline): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** ***2012$***			**Life-Cycle Cost Savings**			**Median Payback Period** ***years***
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** ***2012$***	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
	Baseline	527.98	1,844.61	2,372.59	--	--	--	--
1	1	529.16	1,803.94	2,333.09	39.50	0.0	100.0	0.6
2, 3	2	541.86	1,784.29	2,326.15	46.44	0.0	100.0	4.4
4	3	580.46	1,722.54	2,303.00	69.59	42	58	12.8
5	4	593.33	1,715.50	2,308.82	63.77	43	57	14.6

Table 8.4.4 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Outdoor, Electronic Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
1, 2, 3, 4	Baseline / 3	580.46	1,722.54	2,303.00	--	--	--	--
5	4	593.33	1,715.50	2,308.82	-5.82	84	16	44.7

Table 8.4.5 Equipment Class 2 - 150 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
	Baseline	657.04	2,110.32	2,767.36	--	--	--	--
1	1	673.27	2,075.60	2,748.87	18.50	1	99	7.2
2	2	681.07	2,046.61	2,727.68	39.68	0	100	5.8
--	3	676.72	2,063.23	2,739.95	27.41	15	85	2.4
3, 4, 5	4	696.00	2,061.22	2,757.23	10.14	23	77	4.7

Table 8.4.6 Equipment Class 2 - 150 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
	Baseline	641.19	2,681.81	3,322.99	--	--	--	--
1	1	656.74	2,645.59	3,302.33	20.66	0	100	8.3
2	2	664.20	2,614.09	3,278.30	44.70	0	100	6.6
--	3	695.81	2,499.35	3,195.16	127.84	16	84	7.9
3, 4, 5	4	714.28	2,496.20	3,210.48	112.51	26	74	10.5

Table 8.4.7 Equipment Class 3 - 250 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
	Baseline	710.86	2,485.37	3,196.24	--	--	--	--
1	1	734.37	2,455.32	3,189.69	6.55	36	64	12.4
2, 3, 4	2	749.99	2,433.12	3,183.11	13.12	31	69	11.8
--	3	790.69	2,485.61	3,276.30	-80.07	52	48	14.4
5	4	783.45	2,472.23	3,255.68	-59.44	44	56	11.5

Table 8.4.8 Equipment Class 3 - 250 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
	Baseline	690.34	3,132.65	3,822.99	--	--	--	--
1	1	712.86	3,103.40	3,816.26	6.73	20	80	14.8
2, 3, 4	2	727.82	3,081.42	3,809.24	13.75	15	85	14.0
--	3	802.58	2,996.28	3,798.86	24.13	65	35	28.0
5	4	795.64	2,981.26	3,776.91	46.08	54	46	21.4

Table 8.4.9 Equipment Class 4 - 400 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
	Baseline	784.44	3,453.98	4,238.41	--	--	--	--
1	1	823.04	3,406.28	4,229.31	9.10	40	60	12.8
2, 3, 4	2	841.82	3,368.36	4,210.18	28.23	18	82	10.5
--	3	921.01	3,389.35	4,310.36	-71.95	49	51	13.8
5	4	962.37	3,375.11	4,337.48	-99.07	61	39	16.2

Table 8.4.10 Equipment Class 4 - 400 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
--	Baseline	760.80	4,173.10	4,933.90	--	--	--	--
1	1	797.78	4,126.96	4,924.74	9.16	22	78	15.4
2, 3, 4	2	815.77	4,087.66	4,903.43	30.47	7	93	12.3
--	3	927.40	3,958.53	4,885.93	47.97	56	44	21.3
5	4	967.02	3,940.38	4,907.40	26.49	63	37	24.4

Table 8.4.11 Equipment Class 5 - 1000 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
--	Baseline	1,143.88	11,657.30	12,801.18	--	--	--	--
--	1	1,185.86	11,619.06	12,804.91	-3.73	62	38	16.3
1	1 + DS*	1,207.74	11,122.24	12,329.98	471.20	0.0	100.0	1.8
--	2	1,199.97	11,570.62	12,770.60	30.58	12	88	9.7
2, 3, 4, 5	2 + DS*	1,221.85	11,077.12	12,298.97	502.21	0.0	100.0	2.0

* DS = Design standard requiring that all fixtures sold shall not contain a probe-start ballast.

Table 8.4.12 Equipment Class 5 - 1000 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
--	Baseline	1,101.52	9,854.56	10,956.08	--	--	--	--
--	1	1,141.74	9,823.86	10,965.59	-9.52	67	33	24.9
1	1 + DS*	1,162.70	9,408.20	10,570.89	385.18	0.0	100.0	2.7
--	2	1,155.26	9,783.72	10,938.98	17.10	18	82	14.5
2, 3, 4, 5	2 + DS*	1,176.22	9,370.84	10,547.05	409.02	0.0	100.0	3.0

* DS = Design standard requiring that all fixtures sold shall not contain a probe-start ballast.

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CHAPTER 9. TRIAL STANDARD LEVELS

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CHAPTER 9. TRIAL STANDARD LEVELS

9.1 INTRODUCTION

The U.S. Department of Energy (DOE) generated national energy savings (NES) and net present value (NPV) results based on trial standard levels (TSLs). The TSLs designate an efficiency level (EL) for each equipment class. ELs are developed for each equipment class in the engineering analysis. In this chapter, DOE is only presenting the TSLs of the equipment classes that DOE analyzed directly (the "representative equipment classes").

9.2 REPRESENTATIVE EQUIPMENT CLASSES

In chapter 3 of the technical support document (TSD), DOE identifies 20 equipment classes for metal halide lamp fixtures. Rather than analyze all equipment classes, DOE selected 10 equipment classes as "representative" to analyze in further detail. Representative equipment classes include (1) indoor fixtures with rated lamp wattage ≥50 watts (W) and ≤100 W that are tested at an input voltage other than 480 volts (V); (2) outdoor fixtures with rated lamp wattage ≥50 W and ≤100 W that are tested at an input voltage other than 480 V; (3) indoor fixtures with rated lamp wattage >100 W and <150 W that are tested at an input voltage other than 480 V; (4) outdoor fixtures with rated lamp wattage >100 W and ≤150 W that are tested at an input voltage other than 480 V; (5) indoor fixtures with rated lamp wattage ≥150 W and ≤250 W that are tested at an input voltage other than 480 V; (6) outdoor fixtures with rated lamp wattage >150 W and ≤250 W that are tested at an input voltage other than 480 V; (7) indoor fixtures with rated lamp wattage >250 W and ≤500 W that are tested at an input voltage other than 480 V; (8) outdoor fixtures with rated lamp wattage >250 W and ≤500 W that are tested at an input voltage other than 480 V; (9) indoor fixtures with rated lamp wattage >500 W and ≤2000 W that are tested at an input voltage other than 480 V; and (10) outdoor fixtures with rated lamp wattage >500 W and ≤2000 W that are tested at an input voltage other than 480 V. Details on how these equipment classes were selected can be found in chapter 5 of the NOPR TSD. Table 9.2.1 shows all of the equipment classes and designates which were considered to be representative.

Table 9.2.1 Metal Halide Lamp Fixture Equipment Classes

Equipment Class	Rated Lamp Wattage	Indoor/Outdoor	Input Voltage Type
1	≥50 W and ≤100 W	Indoor	Tested at 480 V
2 Representative	≥50 W and ≤100 W	Indoor	All others
3	≥50 W and ≤100 W	Outdoor	Tested at 480 V
4 Representative	≥50 W and ≤100 W	Outdoor	All others
5	>100 W and <150 W*	Indoor	Tested at 480 V
6 Representative	>100 W and <150 W*	Indoor	All others
7	>100 W and <150 W*	Outdoor	Tested at 480 V
8 Representative	>100 W and <150 W*	Outdoor	All others
9	≥150 W** and ≤250 W	Indoor	Tested at 480 V
10 Representative	≥150 W** and ≤250 W	Indoor	All others
11	≥150 W** and ≤250 W	Outdoor	Tested at 480 V
12 Representative	≥150 W** and ≤250 W	Outdoor	All others
13	>250 W and ≤500 W	Indoor	Tested at 480 V
14 Representative	>250 W and ≤500 W	Indoor	All others
15	>250 W and ≤500 W	Outdoor	Tested at 480 V
16 Representative	>250 W and ≤500 W	Outdoor	All others
17	>500 W and ≤2000 W	Indoor	Tested at 480 V
18 Representative	>500 W and ≤2000 W	Indoor	All others
19	>500 W and ≤2000 W	Outdoor	Tested at 480 V
20 Representative	>500 W and ≤2000 W	Outdoor	All others

*Includes 150 W fixtures exempted by EISA 2007 which are fixtures rated only for 150 watt lamps; that are also rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and contain a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

**Excludes 150 W fixtures exempted by EISA 2007 which are fixtures rated only for 150 watt lamps; that are also rated for use in wet locations, as specified by the National Electrical Code 2002, section 410.4(A); and contain a ballast that is rated to operate at ambient air temperatures above 50°C, as specified by UL 1029–2001.

9.3 TRIAL STANDARD LEVELS

DOE analyzed the benefits and burdens of five TSLs for the fixtures that are the subject of today's proposed rule. Table 9.3.1 presents these TSLs and the corresponding equipment class ELs. See the engineering analysis in chapter 5 of the NOPR TSD for a more detailed discussion of the ELs.

Table 9.3.1 Trial Standard Levels

Rep. Wattage	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
70 W Indoor	EL1	EL2	EL2	EL2	EL4
70 W Outdoor	EL1	EL2	EL2	EL3	EL4
150 W Indoor	EL1	EL2	EL4	EL4	EL4
150 W Outdoor	EL1	EL2	EL4	EL4	EL4
250 W Indoor	EL1	EL2	EL2	EL2	EL4
250 W Outdoor	EL1	EL2	EL2	EL2	EL4
400 W Indoor	EL1	EL2	EL2	EL2	EL4
400 W Outdoor	EL1	EL2	EL2	EL2	EL4
1000 W Indoor	EL1 +DS	EL2 +DS	EL2 +DS	EL2 +DS	EL2 +DS
1000 W Outdoor	EL1 +DS*	EL2 +DS	EL2 +DS	EL2 +DS	EL2 +DS

* DS is a design standard that prohibits the use of probe-start ballasts in new metal halide lamp fixtures.

TSL 1 represents EL1 for each equipment class with a positive NPV at EL1. TSL 1 would set energy conservation standards at EL1 for the indoor and outdoor fixtures at 70 W, 150 W, 250 W, 400 W, and 1000 W. Standards included in TSL 1 typically can be satisfied by magnetic ballasts with mid-grade steel and copper windings. These ballasts are commercially available for the ballasts in indoor and outdoor 70 W, 250 W, and 1000 W fixtures, with the rest being modeled. TSL 1 includes a design standard for indoor and outdoor 1000 W fixtures that prohibits the sale of probe-start ballasts in new fixtures.

TSL 2 represents the max tech magnetic ballast EL for each equipment class. TSL 2 would set energy conservation standards at EL2 for the indoor and outdoor fixtures at 70 W, 150 W, 250 W, 400 W, and 1000 W. EL2 is the max tech EL for the indoor and outdoor 1000 W fixtures. Standards included in TSL 2 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings. These ballasts are modeled, except for the 1000 W ballasts, which are commercially available. TSL 2 includes a design standard for the indoor and outdoor 1000 W fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 2 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

TSL 3 represents the maximum energy savings achievable with positive NPV with the requirement that the same efficiency levels for fixtures operating indoors and outdoors be analyzed. TSL 3 would set energy conservation standards at EL2 for indoor and outdoor fixtures at 70 W, 250 W, 400 W, and 1000 W, and EL4 for indoor and outdoor fixtures at 150 W. EL4 is the max tech EL for indoor and outdoor fixtures at 150 W, and EL2 is the max tech EL for indoor and outdoor fixtures at 1000 W. Standards included in TSL 3 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings, except for the 150 W fixtures, which require max tech electronic ballasts with high-grade electronic components. The 150 W and 1000 W ballasts are commercially available, while the rest are modeled. TSL 3 includes a design standard for indoor and outdoor 1000 W fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 3 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

TSL 4 represents the maximum energy savings achievable with a positive NPV for each equipment class, considering indoor and outdoor fixtures separately. TSL 4 would set energy conservation standards at EL2 for indoor and outdoor 250 W, 400 W, and 1000 W fixtures and indoor 70 W fixtures, EL3 for outdoor 70 W fixtures, and EL4 for indoor and outdoor 150 W fixtures. EL4 is the max tech EL for indoor and outdoor fixtures at 150 W, and EL2 is the max tech EL for indoor and outdoor fixtures at 1000 W. Standards included in TSL 4 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings, except for 70 W outdoor fixtures, which require standard-grade electronic ballasts, and 150 W fixtures, which require max tech electronic ballasts with high-grade electronic components. The ballasts for indoor and outdoor 150 W and 1000 W fixtures and outdoor 70 W fixtures are commercially available, and the rest are modeled. TSL 4 includes a design standard for indoor and outdoor 1000 W fixtures that prohibits the sale of probe-start ballasts in new fixtures.

TSL 5 represents all of the max tech efficiency levels, which would set energy conservation standards at EL4 for indoor and outdoor 70, 150, 250, and 400 W fixtures, and EL2 for indoor and outdoor 1000 W fixtures. Standards included in TSL 5 require fixtures to contain the max tech electronic ballasts with high-grade electronic components for indoor and outdoor 70, 150, 250, and 400 W fixtures. High-grade core steel and copper windings are typically used in the ballasts included in 1000 W fixtures. Commercially available ballasts meet TSL 5 for all equipment classes. TSL 5 would require high-frequency electronic ballasts for 400 W indoor and outdoor fixtures, which have limited compatibility with CMH technology. See Chapter 5 of the NOPR TSD for additional detail. TSL 5 includes a design standard for indoor and outdoor 1000 W fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 5 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

CHAPTER 10. SHIPMENTS ANALYSIS

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CHAPTER 10. SHIPMENTS ANALYSIS

10.1 INTRODUCTION

Shipments of metal halide lamp fixtures (MHLF or fixtures) are key inputs to the national energy savings (NES) and net present value (NPV) calculations. Shipments are also a necessary input to the manufacturer impact analysis (chapter 11 of the notice of proposed rulemaking (NOPR) technical support document (TSD)). For the NOPR, the U.S Department of Energy (DOE) analyzed annual shipments and presents inputs and results for fixtures in this chapter of the TSD.

In the shipments analysis, DOE developed a base-case shipment projection for each MHLF type to depict what would happen to energy use and customer costs for the purchase and operation of fixtures in the absence of new and amended Federal energy conservation standards. In determining the base case, DOE considered historical shipments, emerging technologies, the mix of efficiencies sold in the absence of amended standards, and how that mix might change over time. To evaluate the effects of standards on fixtures, DOE then compared the base-case projection with projections of what could happen if DOE promulgates amended standards (the standards case). DOE considered multiple shipments scenarios to characterize both the base-case and the standards-case shipments. To determine the cumulative NES and NPV of standards, DOE compared projected shipments of a base case to a standards case over the national impact analysis period, 2016–2074.

The shipments model and the national impacts model are integrated into a single Microsoft Excel spreadsheet accessible at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

Section 10.2 presents the shipments model methodology for fixtures; section 10.3 describes the data inputs, historical shipments, base-case scenarios, and shipments projections; section 10.4 discusses the effects of proposed amended standards on the mix of fixture designs; and section 10.5 presents the shipments results for the different trial standard levels (TSLs).

10.2 SHIPMENTS MODEL METHODOLOGY

In general, DOE followed a three-step process to project fixture shipments. First, DOE used a combination of historical fixture shipment data from U.S. Census Bureau and metal halide lamp shipment data from the National Electrical Manufacturers Association (NEMA) to estimate the total historical shipments of each fixture type analyzed. Second, DOE calculated an installed stock for each fixture in 2016 based on the average service lifetime of each fixture type. Third, by modeling fixture purchasing events, such as replacement and new construction, and applying growth rate, replacement rate, and emerging technologies penetration rate assumptions, DOE developed annual shipment projections for 2016–2045.

10.2.1 Historical Shipments

DOE reviewed U.S. Census Bureau data from 1993 to 2001 for fixtures.[1] DOE compared the MHLF census data to historical lamp data from NEMA from 1990 to 2010 taken from DOE's ongoing high-intensity discharge (HID) lamps energy conservation standard. DOE found a correlation between HID fixtures and HID lamp shipments. From 1993 to 2001, the number of HID fixture shipments on average represented 37 percent of the total HID lamp shipments, with a standard deviation of 3 percent (see Table 10.2.1).

Table 10.2.1 Comparison of HID Lamp Shipments and HID Fixture Shipments from 1993 - 2001

Year	HID Lamp Shipments	HID Fixture Shipments	Ratio of Lamps to Fixture Shipments
1993	21,600,000	8,358,000	39%
1994	24,100,000	9,141,000	38%
1995	25,800,000	9,005,000	35%
1996	27,900,000	11,018,000	39%
1997	28,600,000	11,937,000	42%
1998	30,400,000	10,618,000	35%
1999	33,400,000	12,806,000	38%
2000	31,400,000	11,546,000	37%
2001	32,400,000	10,416,000	32%

For this same period (1993 – 2001), metal halide lamps increased from 34 percent to 56 percent of total HID lamps (see Table 10.2.2).

Table 10.2.2 Comparison of Metal Halide Lamp Shipments and HID Lamp Shipments from 1993 - 2001

Year	Metal Halide Lamp Shipments	HID Lamp Shipments	Portion of Metal Halide Lamps to HID lamps
1993	7,300,000	21,600,000	34%
1994	8,700,000	24,100,000	36%
1995	10,500,000	25,800,000	41%
1996	11,600,000	27,900,000	42%
1997	13,200,000	28,600,000	46%
1998	15,400,000	30,400,000	51%
1999	18,100,000	33,400,000	54%
2000	18,100,000	31,400,000	58%
2001	18,300,000	32,400,000	56%

Using the portion of metal halide lamps compared to overall HID lamps shipped between 1993 and 2001 and the ratio of HID fixtures shipped to the total amount of HID lamps shipped between 1993 and 2001, DOE estimated the amount of metal halide lamp fixtures shipped between 1993 and 2001 (see Table 10.2.3).

Table 10.2.3 Comparison of Metal Halide Lamp Shipments and HID Lamp Shipments from 1993 - 2001

Year	Metal Halide Lamp Fixture Shipments
1993	2,701,000
1994	3,219,000
1995	3,885,000
1996	4,292,000
1997	4,884,000
1998	5,698,000
1999	6,697,000
2000	6,697,000
2001	6,771,000

DOE used the historical lamp data from 1990 to 2010 of HID lamps and metal halide lamps and the assumed portion of 37 percent of each year's lamp shipments correlating to metal halide lamp fixture shipments to estimate historic shipments.

10.2.2 Analyzed Equipment Classes and Lifetime Values

DOE projected annual shipments for all equipment classes. The shipments model analyzes all fixture types at TSLs that assign efficiency levels (ELs) for each equipment class. DOE assumed that indoor and outdoor fixtures have average lifetimes of 20 and 25 years, respectively. Table 10.2.4 gives the assumed lifetime values for each MHLF equipment class. This information was also presented in NOPR TSD chapter 8.

Table 10.2.4 Equipment Class Lifetime Assumptions

Representative Equipment Class	Indoor Lifetime *years*	Outdoor Lifetime *years*
70 Watt Metal Halide Lamp Fixture	20	25
150 Watt Metal Halide Lamp Fixture	20	25
250 Watt Metal Halide Lamp Fixture	20	25
400 Watt Metal Halide Lamp Fixture	20	25
1000 Watt Metal Halide Lamp Fixture	20	25

10.2.2.1 Fixture Failure

For those customer purchases triggered by a fixture failure, DOE assumed that the customer will purchase a fixture identical to the one that has retired, if it is available. If in the standards case, the base-case fixture design was not standards-compliant (and therefore unavailable as a replacement option), then DOE assumed customers will purchase a new, standards-compliant fixture from the same equipment class with comparable light output.

DOE established the timing of fixture replacements in response to fixture failure by tracking fixture shipments and then predicting when these fixtures are expected to retire based on their service lifetime. DOE recognizes that fixture lifetimes vary, but was unable to identify an industry consensus on failure distributions for different fixture designs. For the preliminary as well as NOPR analyses, DOE used two Weibull distributions to determine the time until failure of fixtures in each of the equipment classes. Figure 10.2.1 and Figure 10.2.2 give the probabilities of fixtures failing at a given age for indoor and outdoor fixtures, respectively.

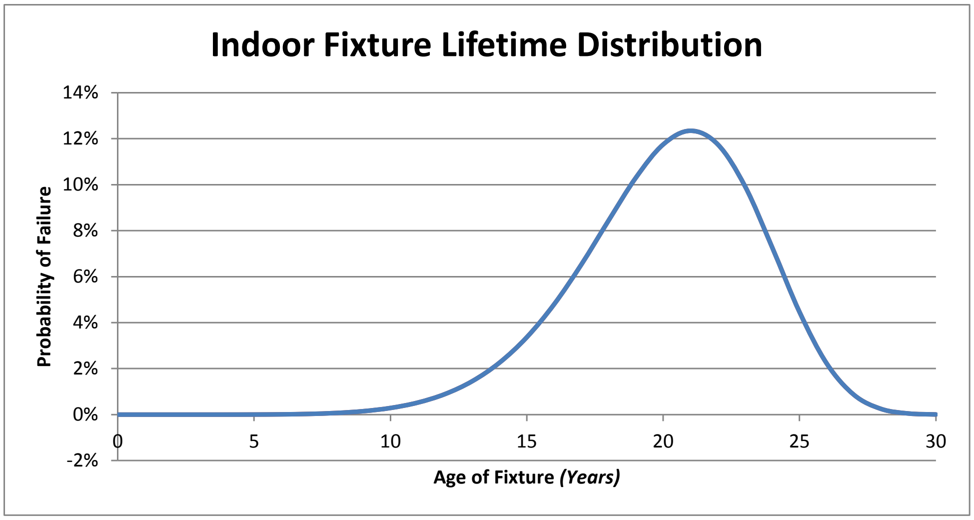

Figure 10.2.1 Lifetime Distribution for Indoor Fixtures

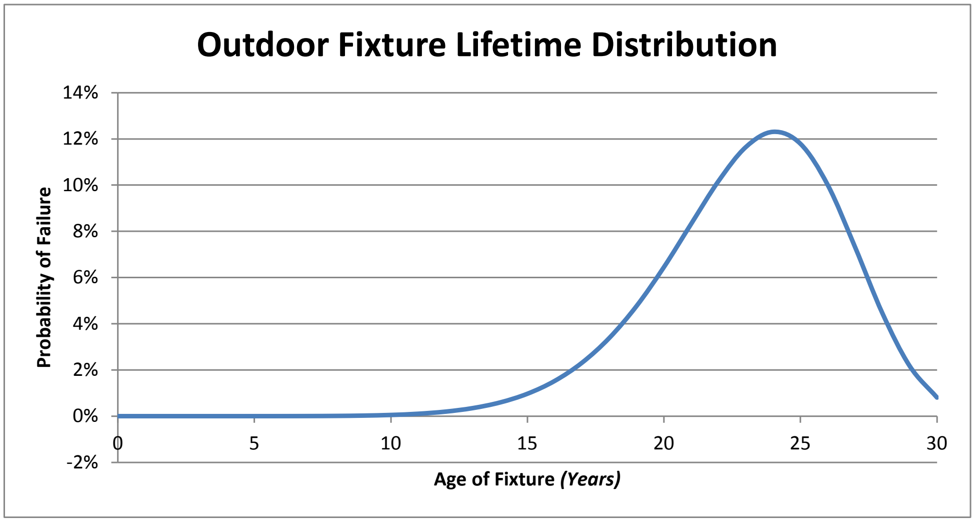

Figure 10.2.2 Lifetime Distribution for Outdoor Fixtures

As noted in NOPR TSD chapter 8 and Table 10.2.4, the service lifetimes in all equipment classes are assumed as approximately 20 and 25 years for indoor and outdoor fixtures, respectively.

10.3 BASE-CASE INPUTS AND PROJECTIONS

This section describes the base-case scenario DOE employed in its analysis and presents the base-case projections for each fixture type along with historical fixture shipments data.

10.3.1 Base-Case Scenario

DOE reviewed U.S. Census Bureau data from 1993 to 2001 for metal halide lamp fixtures. For 2010 lamp data, DOE has confidential lamp shipment estimates per wattage group low (149 W and under), medium (150 to 500 W), and high (501 W and above). Table 10.3.1 provides the 2010 metal halide lamp shipments shares by wattage classification. DOE applied this distribution of shipments per wattage group to fixtures for historical estimates as well. DOE assumed that metal halide lamps represented 63 percent of all HID lamp shipments in the future.

Table 10.3.1 2010 HID Lamp Shipments by Wattage Category

Wattage Group	Wattage Range	Portion of Metal Halide Lamp Shipments
Low	1–149 W	35%
Medium	150–500 W	47%
High	501 W and above	18%

10.3.1.1 Base-Case Projection Results

Figure 10.3.1 presents DOE's base-case projections from the preliminary analysis alongside the high and low shipment scenarios projected during the NOPR phase. During the MHLF preliminary analysis public meeting, interested parties indicated that projections for fixtures should be much lower than shown. DOE modeled new shipments scenarios reviewing additional data (market projections, changes in design practices, etc.) and developed a high and low projection.

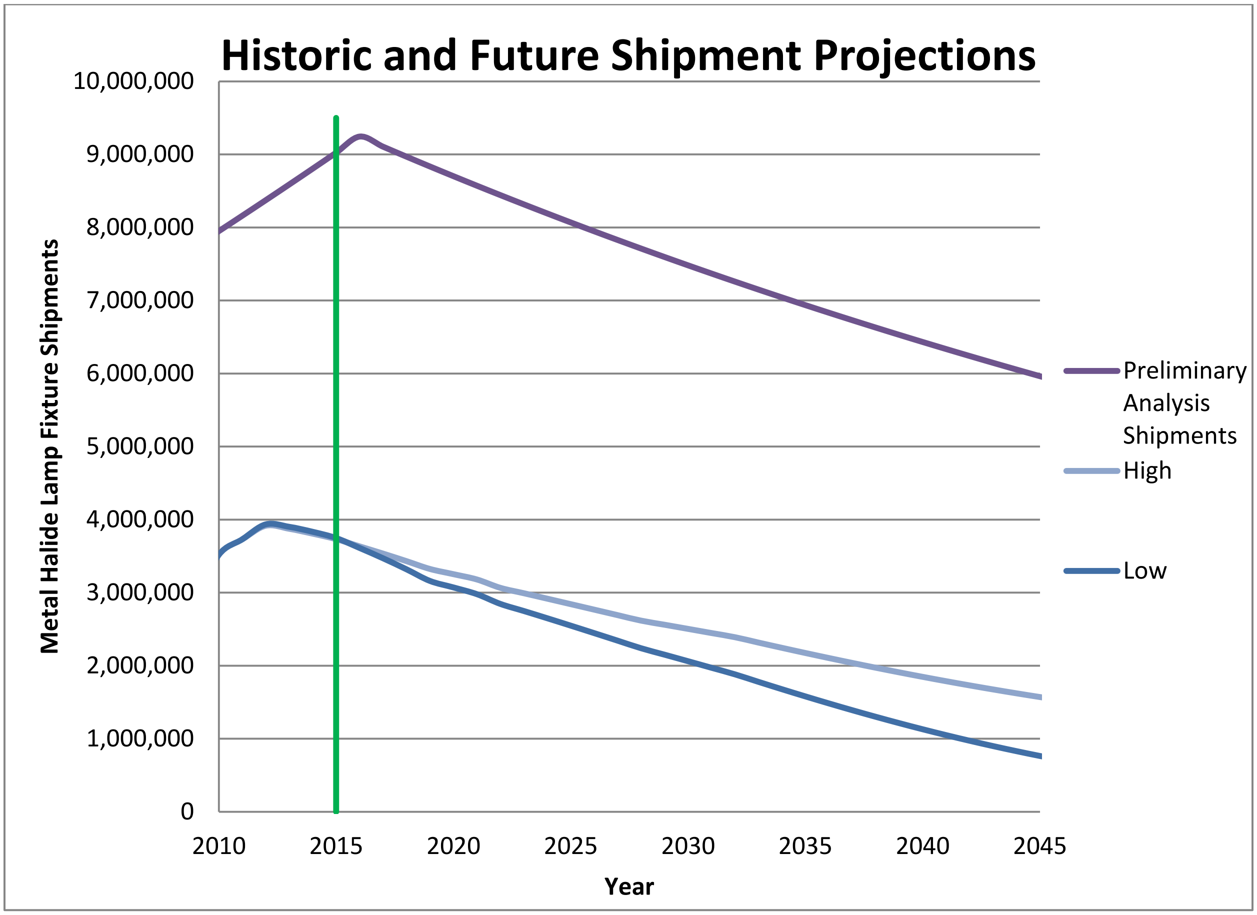

Figure 10.3.1 Comparison of Preliminary Analysis Shipments and NOPR Shipments

Figure 10.3.2 through Figure 10.3.11 present the base-case fixture shipments projections (both high and low scenarios) for 2016–2045, modeled from the installed stock (based on historical shipments) and growth rates. For each equipment class, there are two figures. One figure shows the projected shipments for indoor and outdoor fixtures in both high and low shipments scenarios. The other figure shows the projected shipments for fixtures with magnetic and electronic ballasts in both high and low shipments scenarios. Figure 10.3.10, which depicts the shipments of fixtures by ballast type for 1000 W only, shows fixtures with magnetic ballasts since this equipment class does not have fixtures with electronic ballasts.

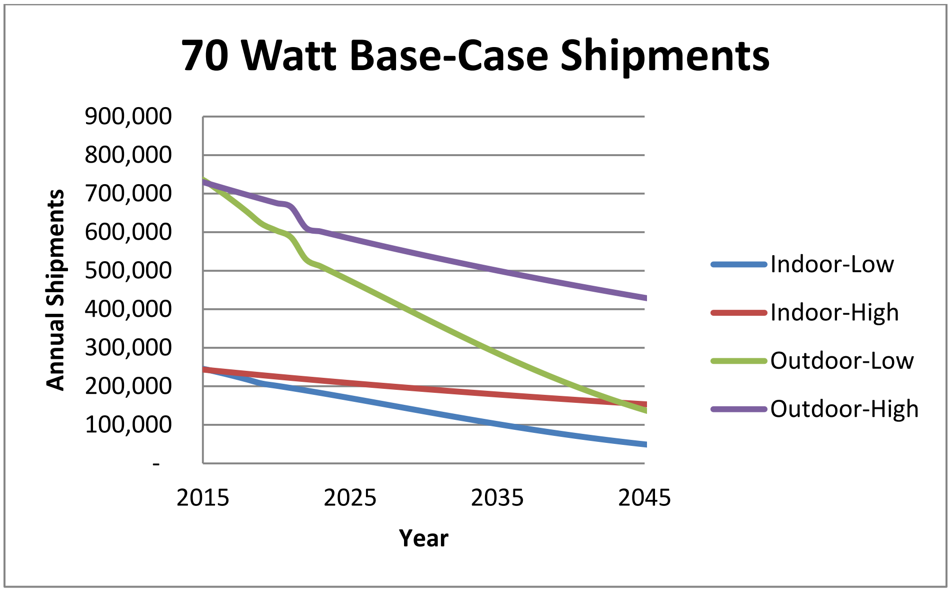

Figure 10.3.2 70 W Equipment Class Fixture Shipments by Indoor and Outdoor Environment

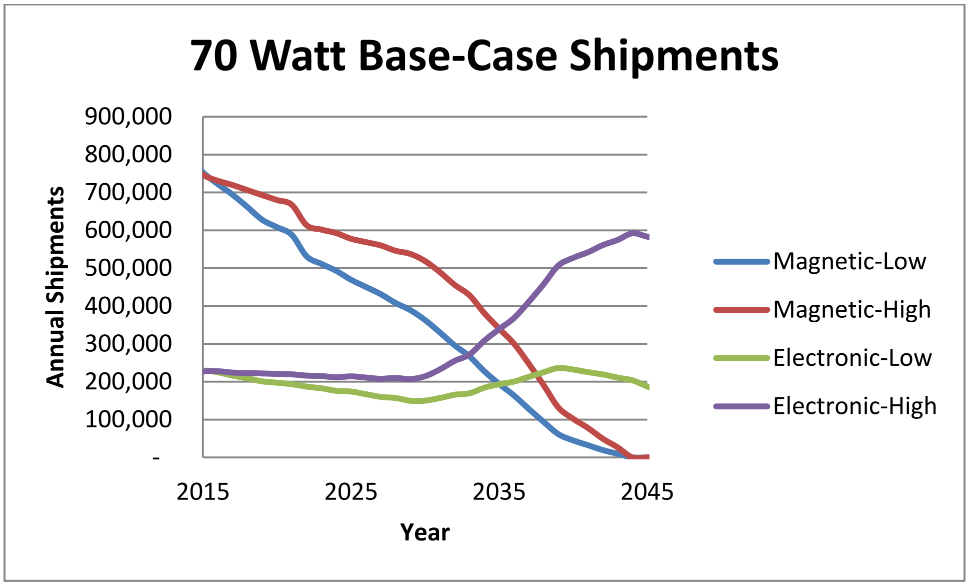

Figure 10.3.3 70 W Equipment Class Fixture Shipments by Ballast Type

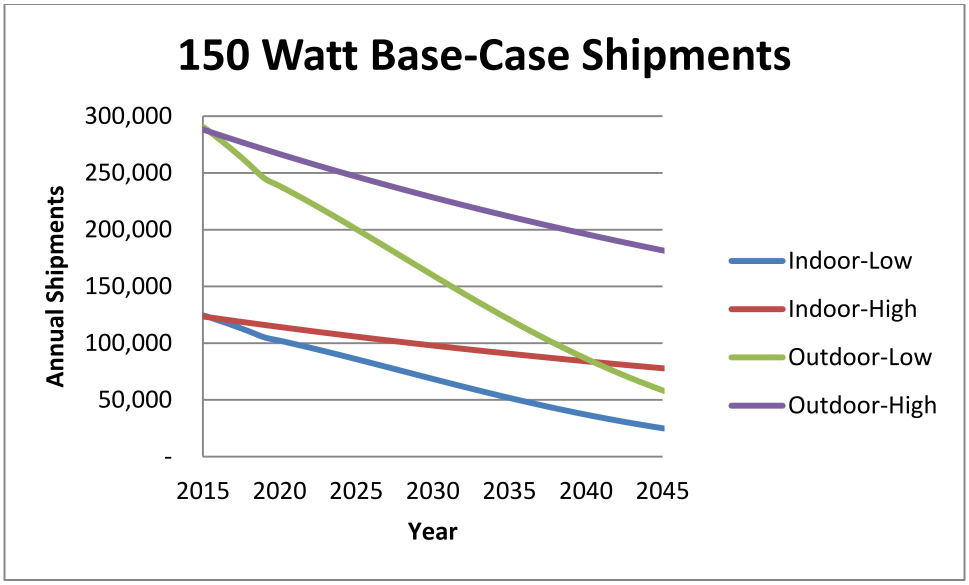

Figure 10.3.4 150 W Equipment Class Fixture Shipments by Indoor and Outdoor Environment

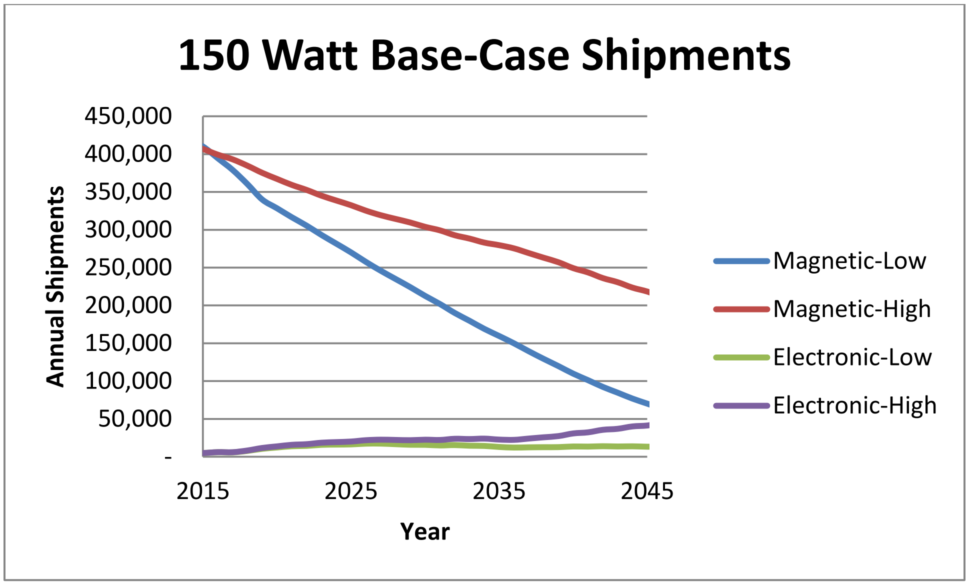

Figure 10.3.5 150 W Equipment Class Fixture Shipments by Ballast Type

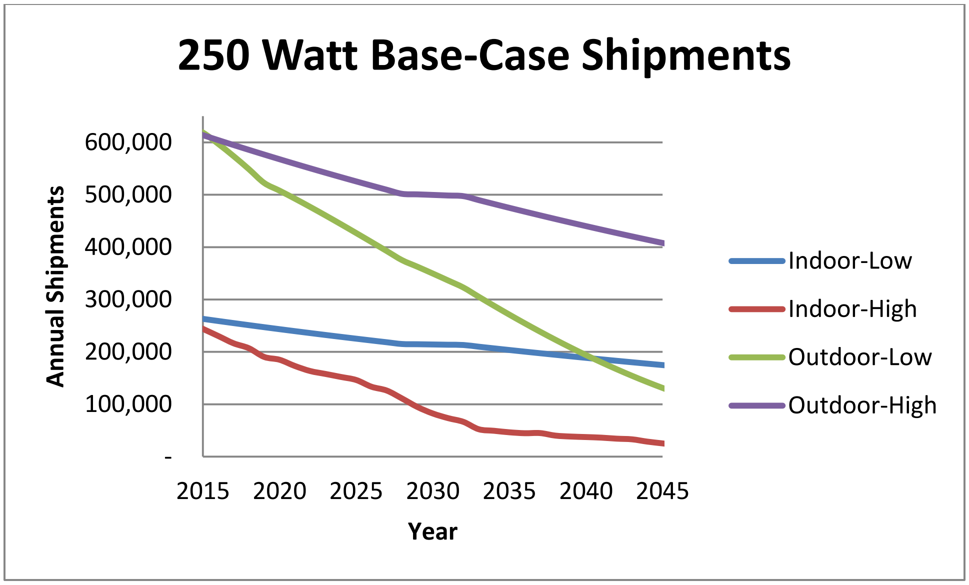

Figure 10.3.6 250 W Equipment Class Fixture Shipments by Indoor and Outdoor Environment

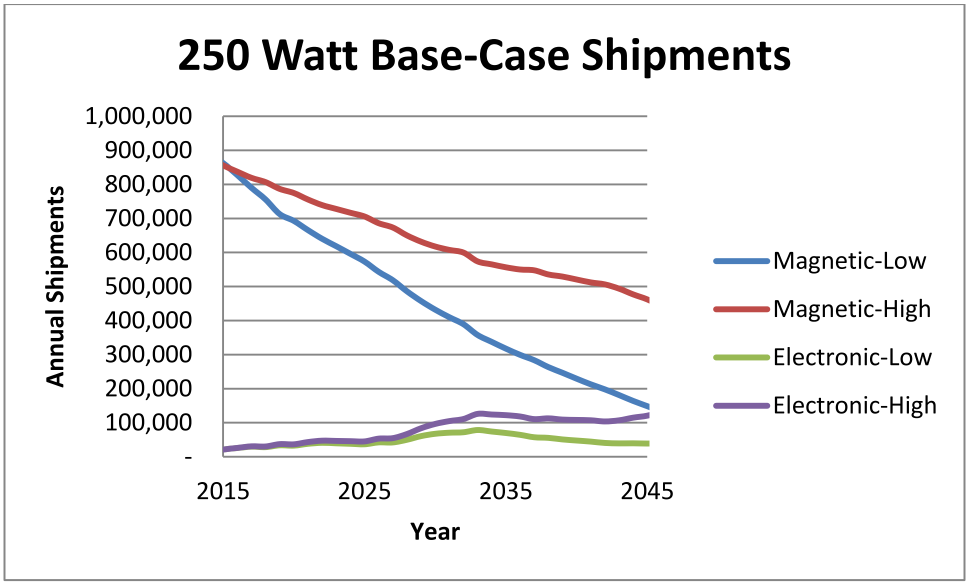

Figure 10.3.7 250 W Equipment Class Fixture Shipments by Ballast Type

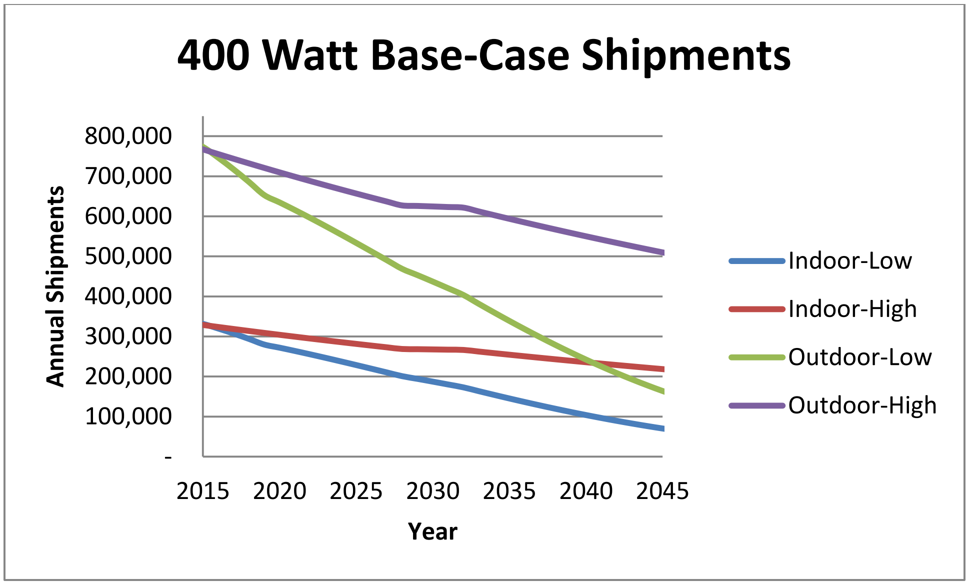

Figure 10.3.8 400 W Equipment Class Fixture Shipments by Indoor and Outdoor Environment

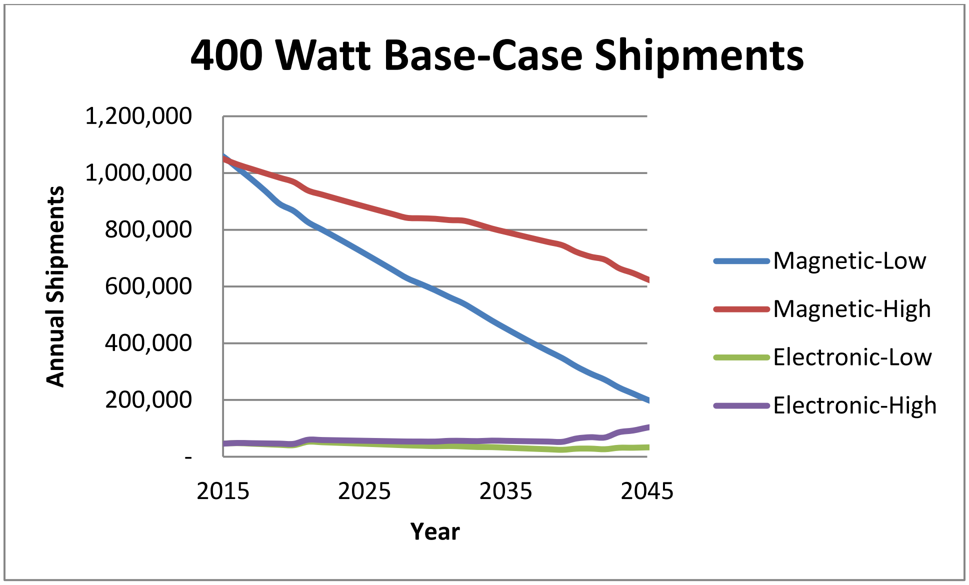

Figure 10.3.9 400 W Equipment Class Fixture Shipments by Ballast Type

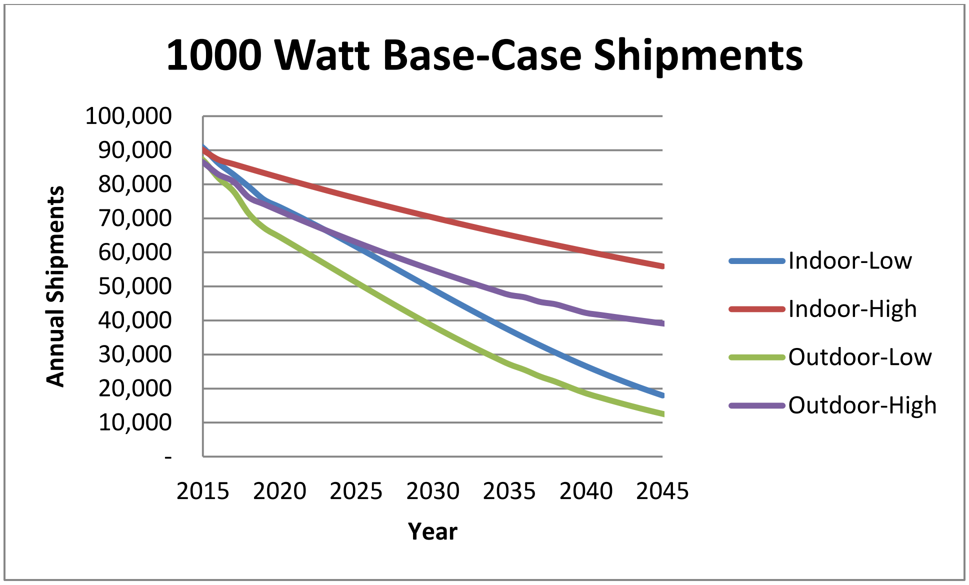

Figure 10.3.10 1000 W Equipment Class Fixture Shipments by Indoor and Outdoor Environment

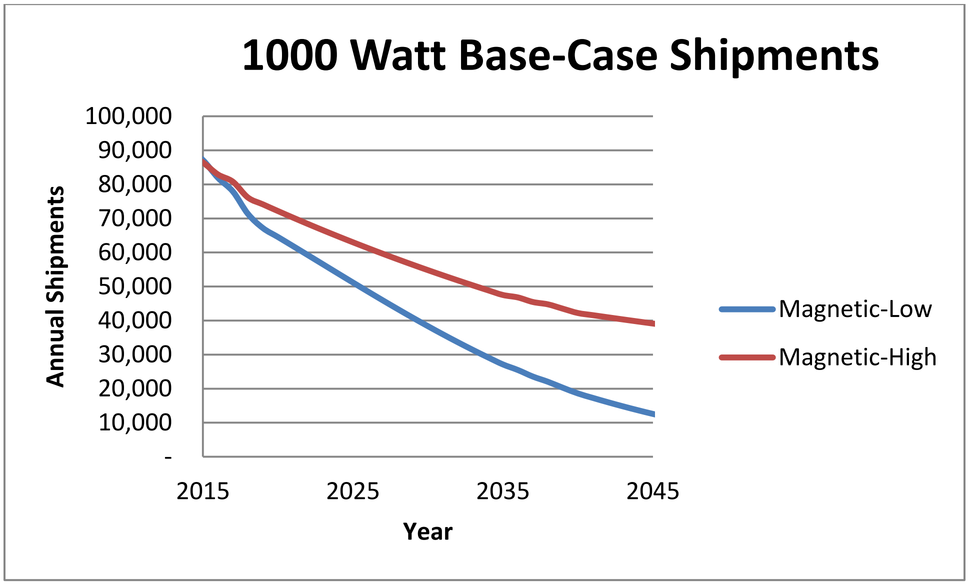

Figure 10.3.11 1000 W Equipment Class Fixture Shipments by Ballast Type

10.4 STANDARDS-CASE INPUTS

10.4.1 Shipments Scenarios

To characterize customer behavior in the standards case, DOE considered many characteristics that customers take into account when purchasing fixtures. Specifically, DOE regarded fixture price and system energy use as two key drivers of customer purchases.

DOE developed two sets (low and high) of shipments scenarios to characterize the range in future decisions customers may make. To evaluate a standards case, DOE modeled a standards-case scenario and compared it to the base case.

The standards-case scenario for fixtures includes a roll-up scenario. The roll-up scenario represents a standards case in which all equipment efficiencies in the base case that do not meet the standard would roll up to meet the new standard level. Customers in the base case who purchase fixtures above the standard level are not affected as they are assumed to continue to purchase the same base-case fixture in the roll-up scenario. The roll-up scenario characterizes customers primarily driven by the first cost of the analyzed equipment. In a roll-up scenario, DOE assumes customers will buy the first standard-compliant fixtures available. In the standards-case shipments scenario, customers will attempt to buy a fixture from the same equipment class as their previously demanded system.

For its analysis, DOE evaluated the principal events that prompt fixture purchases: (1) fixture failure/replacement; and (2) new construction/renovation. DOE assumed that all replacement fixture shipments were due to fixture failure, and all new fixture shipments were considered renovation or new construction.

10.5 RESULTS

The following tables shows the cumulative shipments projections for the various TSLs. DOE's projections of the resultant stock for the various TSLs over time and by scenario can be found in the national impact analysis spreadsheet model.

Quantities of fixture shipments depend on the occurrence of fixture purchasing events, such as fixture failure/replacement, and new construction/renovation. As discussed earlier, instead of using each particular fixture's individual lifetime to time fixture replacements, DOE uses the same fixture lifetime assumptions for all fixture designs within a given equipment class. For this reason, the rate of fixture replacement does not change between different shipments scenarios.

Table 10.5.1 and Table 10.5.2 show the cumulative shipments caused by each of the standards cases (column labels) out to 2045 for the low and high roll-up shipment scenarios. TSL levels in the first column indicate the equipment TSL. As discussed earlier, quantities of fixture shipments in the standards case are based on fixture replacement rates and shipments due to new construction/renovation. However, because all fixtures within a particular equipment class are assumed to have the same lifetime, fixture replacement rates in the base case and standards case are equal. In addition, because the fixture lifetime never varies within a particular market sector, fixture replacement rates are equal in the base case and standards case. The only aspects that vary are the distribution of fixtures by efficiency levels.

Note that cumulative shipments effects are different from effects on the stock, because of fixture replacements over time. Effects on the efficiency distributions in the fixture stock are addressed in the NOPR TSD chapter 11.

Table 10.5.1 Cumulative Fixture Shipments by Trial Standard Level, Low Shipments Scenario, 2016–2045 (Roll-Up Scenario)

TSL Scenario Selected	**Fixture Equipment Class**	**Shipments at Equipment EL for TSL Scenario Chosen** ***EL***			
		1	**2**	**3**	**4**
1	70 W	9,680,428	135,220	3,977,002	1,807,184
	150 W	6,338,516	87,057	368,231	37,578
	250 W	12,575,110	789,222	1,239,077	209,296
	400 W	7,898,832	1,194,312	1,124,729	7,440
	1000 W	5,025,646	857,207	0	0
	TOTAL	**41,518,532**	**3,063,018**	**6,709,039**	**2,061,497**
2	70 W	0	9,815,648	3,977,002	1,807,184
	150 W	0	6,425,573	368,231	37,578
	250 W	0	13,364,331	1,239,077	209,296
	400 W	0	17,383,711	1,124,729	7,440
	1000 W	0	5,882,852	0	0
	TOTAL	**0**	**52,872,116**	**6,709,039**	**2,061,497**
3	70 W	0	9,815,648	3,977,002	1,807,184
	150 W	0	0	0	6,831,382
	250 W	0	13,364,331	1,239,077	209,296
	400 W	0	17,383,711	1,124,729	7,440
	1000 W	0	5,882,852	0	0
	TOTAL	**0**	**46,446,543**	**6,340,808**	**8,855,302**
4	70 W	0	46,004	13,746,646	1,807,184
	150 W	0	0	0	6,831,382
	250 W	0	13,364,331	1,239,077	209,296
	400 W	0	17,383,711	1,124,729	7,440
	1000 W	0	5,882,852	0	0
	TOTAL	**0**	**36,676,899**	**16,110,451**	**8,855,302**
5	70 W	0	0	0	15,599,834
	150 W	0	0	0	6,831,382
	250 W	0	0	0	14,812,704
	400 W	0	0	0	18,515,880
	1000 W	0	5,882,852	0	0
	TOTAL	**0**	**5,882,852**	**0**	**55,759,800**

Table 10.5.2 Cumulative Fixture Shipments by Trial Standard Level, High Shipments Scenario, 2016–2045 (Roll-Up Scenario)

TSL Scenario Selected	**Fixture Equipment Class**	**Shipments at Equipment EL for TSL Scenario Chosen** *EL*			
		1	**2**	**3**	**4**
1	70 W	12,307,216	226,416	6,238,084	3,544,596
	150 W	8,930,698	204,435	604,113	73,987
	250 W	17,179,412	1,800,832	2,010,812	425,500
	400 W	11,756,520	2,611,701	1,743,406	21,483
	1000 W	7,045,107	1,405,568	0	0
	TOTAL	**57,218,954**	**6,248,951**	**10,596,416**	**4,065,566**
2	70 W	0	12,533,632	6,238,084	3,544,596
	150 W	0	9,135,133	604,113	73,987
	250 W	0	18,980,244	2,010,812	425,500
	400 W	0	25,005,806	1,743,406	21,483
	1000 W	0	8,450,676	0	0
	TOTAL	**0**	**74,105,490**	**10,596,416**	**4,065,566**
3	70 W	0	12,533,632	6,238,084	3,544,596
	150 W	0	0	0	9,813,232
	250 W	0	18,980,244	2,010,812	425,500
	400 W	0	25,005,806	1,743,406	21,483
	1000 W	0	8,450,676	0	0
	TOTAL	**0**	**64,970,357**	**9,992,303**	**13,804,811**
4	70 W	0	48,827	18,722,889	3,544,596
	150 W	0	0	0	9,813,232
	250 W	0	18,980,244	2,010,812	425,500
	400 W	0	25,005,806	1,743,406	21,483
	1000 W	0	8,450,676	0	0
	TOTAL	**0**	**52,485,553**	**22,477,107**	**13,804,811**
5	70 W	0	0	0	22,316,312
	150 W	0	0	0	9,813,232
	250 W	0	0	0	21,416,556
	400 W	0	0	0	26,770,695
	1000 W	0	8,450,676	0	0
	TOTAL	**0**	**8,450,676**	**0**	**80,316,795**

REFERENCES

1. U.S. Census Bureau. *Manufacturing, Mining, and Construction Statistics*. Current Industrial Reports, Fluorescent Lamp Ballasts, MQ335C. 2008. (Last accessed September 1, 2010). <http://www.census.gov/mcd/>

CHAPTER 11. NATIONAL IMPACTS ANALYSIS

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CHAPTER 11. NATIONAL IMPACTS ANALYSIS

11.1 INTRODUCTION

This chapter describes the method for estimating the national impacts of trial standard levels (TSLs) for analyzed metal halide lamp fixtures (MHLF or fixtures). Because fixtures are designed to operate metal halide (MH) ballasts and lamps, the U.S. Department of Energy (DOE) chose the most common MH lamp and ballast used with each fixture to develop representative MHLF systems. MH lamps will not be regulated under the proposed amended energy conservation standards for fixtures; however, the characteristics of complete MHLF systems (energy use, installed cost, etc.) must be considered for estimating national impacts of fixture TSLs.

In the national impacts analysis (NIA), DOE assessed the cumulative national energy savings (NES) and the cumulative national economic impacts of TSLs. DOE measured energy savings as the cumulative quadrillion British thermal units (quads) of energy a TSL is expected to save the nation. DOE measured economic impacts as the net present value (NPV) in dollars of total customer costs and savings expected to result from a TSL. The analysis period over which DOE calculated the NPV and NES is from 2016 to 2074.

DOE determined both the NPV and NES for each TSL and each representative equipment class it selected in the engineering analysis (notice of proposed rulemaking (NOPR) technical support document (TSD) chapter 5). In this rulemaking, DOE considered up to five TSLs for each of the representative fixture equipment classes.

DOE performed all NIA calculations using a Microsoft Excel spreadsheet, available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16. Appendix 11A provides instructions for using the spreadsheet.

The following sections describe in detail the methodology and inputs for the NIA. Several NIA inputs, including per-unit costs, per-unit energy use, and national shipments, are discussed in other analyses. In describing the inputs to the NIA, this chapter references those analyses and presents new information on installed stock. Section 11.2 discusses DOE's fixture shipment projections by TSL, the installed stock of fixtures, and the mix of efficiencies of that stock. Section 11.3 discusses DOE's calculation of national energy consumption in the base and standards cases, and the resulting difference in NES between these cases. Section 11.4 discusses the NPV calculation. Section 11.5 presents the NES and NPV results by representative equipment class.

11.2 BASE-CASE AND STANDARDS-CASE PROJECTED EFFICIENCY DISTRIBUTIONS AND FIXTURE STOCKS

The characteristics of DOE's shipment projections (such as equipment costs and operating costs) and projected fixture stocks (such as average efficiency and energy use) are key aspects of DOE's NES and NPV estimates. This section describes these key characteristics of stock and shipments as they relate to the NES and NPV.

The projected distribution of fixture efficiencies shipped and fixture efficiencies in stock are key factors in determining the NPV. Two inputs to the NPV are the per-unit total installed cost and per-unit annual operating cost. The per-unit total installed cost often varies with the efficiency of fixtures shipped. Therefore, when higher efficiency fixtures are shipped, higher installed costs are often incurred. Chapter 8 of the NOPR TSD describes how per-unit total installed costs vary as a function of efficiency for each fixture.

Per-unit annual energy consumption (AEC) is a key input to the NPV (as an input to the per-unit operating cost) and NES. The per-unit AEC is a function of MHLF system characteristics in the installed stock. The total installed stock of MHLF systems is used to determine total annual energy use, a key input into the NES and NPV calculations.

Also important for determining NES and NPV is the average efficiency of the fixture stock. The engineering analysis (NOPR TSD chapter 5) discusses the relationship between MHLF system design, system input power, and fixture efficiency. The energy use analysis (NOPR TSD chapter 7) describes how the per-unit energy consumption varies as a function of system input power and market sector application for each MHLF system design.

Sections 11.3.3 and 11.4.2 discuss inputs to calculation of the NES and NPV in further detail.

11.2.1 Base-Case and Standards-Case Efficiency Distributions

Because the end-user price of fixtures varies with efficiency level, the base-case and standards-case projected efficiency distributions of shipments affect the average total installed cost per unit. Generally, as the efficiency of an MHLF system's design increases, the total installed cost increases as well. In addition, the base-case and standards-case efficiency distributions affect the average fixture efficiency in the installed stock, an indication of annual energy use. For fixtures, DOE first presented the market share apportionments in the base case in NOPR TSD chapter 10. These market share apportionments characterize the shipments of fixtures for each analyzed equipment class. The projected efficiency distributions of shipments for fixtures depend directly on these apportionments and the total shipments of a particular fixture type in each year of the analysis period.

11.2.2 Installed Fixture Stock

The installed fixture stock in a given year is the total number of fixtures shipped that year and in prior years that are still operating. The NES model tracks the fixtures shipped each year, and fixtures are retired when they reach the end of their lifetime. From this information and the shipments projections presented in the NOPR TSD chapter 10, DOE established the installed fixture stock profile for all analyzed fixture equipment classes.

For some types of fixtures, installed stock increases over time. However, most fixture types experience a decline in stocks over the analysis period due to the encroachment of newer technologies such as induction, high-intensity fluorescent, and light-emitting diode fixtures.

11.3 NATIONAL ENERGY SAVINGS

11.3.2 National Energy Savings Definition

DOE calculated annual national energy savings as the difference in energy consumption by MHLF systems between the base case (without new standards) and the standards case (with new standards). Positive values of NES correspond to net energy savings following standards implementation; *i.e.*, national AEC with standards is less than AEC in the base case.

$$NES_t = (AEC_{t,base} - AEC_{t,std}) \times src\_conv_t$$

Eq. 11.1

Where:

NES_t = national energy savings in year t,
AEC = annual national energy consumption each year (at the site - kWh),
t = year in the projection (*e.g.*, 2016 to 2074),
$base$ = base case,
std = standards case, and
src_conv_t = time-dependent conversion factor to convert from site energy (kWh) to source energy (quads).

Cumulative energy savings are the sum over a defined time period (from 2016 to 2074) of the annual national energy savings.

$$NES_{cum} = \sum_t NES_t$$

Eq. 11.2

Where:

NES_{cum} = cumulative national energy savings.

DOE calculated the AEC (in any year) by multiplying the number or stock of fixtures by the annual unit energy consumption, shown by the following equation:

$$AEC = \sum_{fd} STOCK_{fd} \times UEC_{fd}$$

Eq. 11.3

Where:

fd = fixture ID number,
$STOCK_{fd}$ = stock of fixtures for a given design surviving in the year for which DOE calculated AEC, and
UEC_{fd} = unit energy consumption (kWh per year).
.

11.3.3 National Energy Savings Inputs

Table 11.3.1 lists the inputs for the determination of NES.

Table 11.3.1 National Energy Saving Inputs

Input
Unit Energy Consumption, UEC
Fixture Stock by Design (*STOCKfd*)
Site-to-Source Conversion Factor (*src_conv*)

11.3.3.1 Unit Energy Consumption (UEC)

DOE presents the per-unit UEC for each MHLF system design in the energy use analysis in NOPR TSD chapter 7. For the NES and NPV calculations, DOE used an average number of annual operating hours for each sector in calculating the UEC of each MHLF system design.

11.3.3.2 Fixture Stock

The fixture stock in a given year is the sum of the shipments in that year and the total number of fixtures shipped in prior years that are still surviving in that year. The NES spreadsheet model keeps track of the fixtures shipped (and surviving) each year. DOE discusses projected shipments for the base case and all standards cases in NOPR TSD chapter 10. To generate the shipments that eventually comprise the fixture stock, the shipments analysis incorporates one set of base-case scenarios and one set of standards-case scenarios that can affect shipments. The base-case scenarios determine the total volume of fixture shipments and installed stock. The standards-case scenarios are composed of numerous roll-up scenarios. These scenarios dictate the inputs to the market-share apportionments, and therefore affect the breakdown of the installed stock by fixture design from 2016 to 2074.

11.3.3.3 Site-to-Source Conversion Factors

The site-to-source conversion factor is the multiplier DOE used for converting site-energy consumption into primary or source energy consumption. For electricity, the conversion factors can vary over time due to projected changes in generation sources (*i.e.*, the power plant types projected to provide electricity to the country). For this NOPR analysis, DOE used time-dependent site-to-source conversion factors derived from the 2013 version of the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook* (*AEO2013*).[1] Table 11.3.2 presents site-to-source conversion factors used in the NES spreadsheet model. The conversion factors vary over time, due to projected changes in electricity generation sources.

Table 11.3.2 Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor, Low Shipments Scenario *Btu/kWh*
2016	8631.9
2017	8631.9
2018	8631.9
2019	8631.9
2020	8631.9
2021	8440.0
2022	8440.0
2023	8440.0
2024	8440.0
2025	8440.0
2026	8288.5
2027	8288.5
2028	8288.5
2029	8288.5
2030	8288.5
2031	8362.1
2032	8362.1
2033	8362.1
2034	8362.1
2035	8362.1
2036	8290.8
2037	8290.8
2038	8290.8
2039	8290.8
2040	8290.8
2041	8425.0
2042	8425.0
2043	8425.0
2044	8425.0
2045	8425.0

11.3.3.4 Full-Fuel-Cycle Energy

The full-fuel-cycle (FFC) measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's traditional approach encompasses site energy and the energy losses associated with generation, transmission, and distribution of electricity. To complete the full-fuel-cycle by encompassing the energy consumed in extracting, processing, and transporting or distributing primary fuels, which are referred to as "upstream" activities, DOE developed FFC multipliers using the data and projections generated by the National Energy Modeling System (NEMS) and published in *AEO2013*. While the *AEO* does not provide direct calculations of FFC metrics, it does provide extensive information about the energy system, including projections of future oil, natural gas, and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production.

Table 11.3.3 shows the FFC energy multipliers used for metal halide lamp fixtures for selected years. The method used to calculate a time series of FFC energy multipliers is described in appendix 11B of the NOPR TSD.

Table 11.3.3 Full-Fuel-Cycle Energy Multipliers (Based on *AEO2013*)

Fuel	2020	2025	2030	2035	2040
Electricity (power plant energy use)	1.041	1.040	1.040	1.041	1.040

11.3.3.5 Interactions with Heating, Ventilation, and Air-Conditioning (HVAC) Systems

Interactions with HVAC systems in the commercial and industrial sectors are represented by an HVAC factor, as given in Eq. 11.3. The HVAC factor reflects the extent to which the energy savings from more efficient equipment are offset by increased demands placed on heating and cooling equipment in the presence of more efficient equipment. Typically, this takes the form of increased efficiency being achieved through less energy wasted as heat, increasing the burden on HVAC equipment in winter months.

In a previous rulemaking (the 2000 Ballast Rule, 65 FR 56740; 10 CFR 430.23(m)(4)), DOE found that the rebound rate is highly dependent on the composition of building stock. Due to the high level of uncertainty in building stock, DOE used an HVAC factor of 1, which indicates no HVAC effect, for calculating energy savings in this NOPR analysis.

11.3.3.6 Rebound Rate

In its analysis, DOE considered the rebound effect that occurs after installation of energy efficient lighting equipment. Under economic theory, “rebound effect” refers to the tendency of a consumer to respond to the cost savings associated with more efficient equipment in a manner that actually leads to marginally greater equipment usage, thereby diminishing some portion of anticipated benefits related to improved efficiency. DOE examined a summary of the literature regarding the rebound effect in relation to lighting equipment.[2] Based on four studies, the summary estimated that for a 100-percent increase in energy efficiency, “take-back” or rebound values for commercial and industrial lighting are between zero and 2 percent. In this NOPR analysis, DOE assumed a zero percent rebound rate in all three sectors analyzed.

11.4 NET PRESENT VALUE

11.4.1 Net Present Value Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is calculated as follows:

$$NPV = PVS - PVC$$

Eq. 11.4

Where:

PVS = present value of operating cost savings, and
PVC = present value of increased total installed costs.

The PVS and PVC are determined according to the following expressions:

$$PVS = \sum OCS_t \times DF_t$$

Eq. 11.5

$$PVC = \sum TIC_t \times DF_t$$

Eq. 11.6

Where:

OCS_t =total annual operating cost savings in year t,
TIC_t = total annual installed cost increases in year t,
DF_t = discount factor associated with year t, and
t = year (PVS and PVC are summed over 2016–2074).

DOE determined the contributions to *PVC* and *PVS* for each year from 2016 to 2074, and discounted these costs to 2013. DOE calculated savings as the difference between a standards case (*i.e.*, with amended standards) and a base case (*i.e.*, without amended standards). DOE discounted savings using the discount rate and the number of years between the "present" (*i.e.*, year to which the sum is being discounted) and the year in which the costs and savings occur. DOE calculated the net present value as the sum over time of the discounted net savings (which is equivalent to the approach shown in Eq. 11.4 through Eq. 11.6).

11.4.2 Net Present Value Inputs

Table 11.4.1 summarizes the inputs to the NPV calculation.

Table 11.4.1 Net Present Value Inputs

Input
Total Annual Installed Cost Increases (*TICt*)
Total Annual Operating Cost Savings (*OCSt*)
Discount Factor

11.4.2.1 Total Annual Installed Cost Increases

DOE calculated the increase in total annual installed costs as the difference between the total annual installed costs in the standards case minus those in the base case. For each case, the total annual installed costs equal the product of the shipments and per unit installed cost (summed over each fixture design). DOE used an average lifetime of each fixture type for each equipment class.

11.4.2.2 Total Annual Operating Cost Savings

As the life-cycle cost (LCC) and payback period (PBP) analysis (NOPR TSD chapter 8) describes, DOE calculated total annual operating costs based on national average electricity prices and other costs incurred during a fixture's lifetime. DOE calculated annual operating cost savings (OCS_t) as the annual base case operating cost ($OC_{t,b}$) minus the annual standards case operating cost ($OC_{t,s}$).

$$OC_{t,(b,s)} = \sum_{fd,(b,s)} STOCK_{fd,(b,s)} \times UEC_{fd,(b,s)} \times electricity\ price$$

Eq. 11.7

Where:

$OC_{t,(b,s)}$ = total annual operating costs in the base case (b) or standards case (s), in year t,
$STOCK_{fd,(b,s)}$ = total stock of fixture type fd in case b or s,
$UEC_{fd,(b,s)}$ = unit energy consumption of fixture type fd in case b or s,
electricity price = electricity price associated with fixture type fd,
t = year, and
fd = fixture identifier.

DOE used an average number of annual operating hours for each sector and fixture type in calculating the UEC of each MHLF system. DOE used *AEO2013* to establish all electricity prices. Chapter 8 of the NOPR TSD provides the electricity price projections DOE used to calculate the NPV.

11.4.2.3 Discount Factor

DOE multiplied monetary values in future years by the discount factor (DF) to calculate the present value. The following equation describes how to calculate the discount factor:

$$DF = 1/(1+r)^{(t-t_p)}$$

Eq. 11.8

Where:

r = discount rate,
t = year of the monetary value, and
t_p = year in which the present value is being determined.

DOE estimated national impacts with both a 3-percent and a 7-percent real discount rate as the average real rate of return on private investment in the U.S. economy. These discount rates were used in accordance with Office of Management and Budget (OMB) guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E, "Identifying and Measuring Benefits and Costs," therein.[3] DOE defined the present year as 2012 for the NOPR analysis, and discounted all future costs to 2013.

11.5 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various TSLs. The inputs to the NES spreadsheet are discussed in sections 11.3.3 and 11.4.2. DOE generated the NES and NPV results using Microsoft Excel spreadsheets, accessible at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/23.

11.5.1 National Energy Savings and Net Present Value Input Summary

Table 11.5.1 summarizes the inputs to the NES spreadsheet model. A brief description of the data is given for each input.

Table 11.5.1 Approach and Data Used for National Energy Savings and Consumer Net Present Value Analyses

Inputs	Preliminary TSD	Changes for the Proposed Rule
Shipments	Developed annual shipments from shipments model	No change
Annual Energy Consumption per Unit	Established in the energy use analysis (preliminary TSD chapter 7)	Established in the energy use analysis (NOPR TSD chapter 7)
Rebound Effect	0%	No change
Electricity Price Projection	*AEO2010*	*AEO2013*
Energy Site-to-Source Conversion Factor	Assumed to be constant across time: 1 site kWh = 10,239 source Btu	Used annually variable site kWh to source Btu conversion factors
Discount Rate	3% and 7% real	No change
Present Year	2011	2012

11.5.2 National Energy Savings Results

The following section provides NES results for each TSL that DOE considered for fixtures. Results are cumulative to 2074 and are shown as primary energy savings measured in quads. Table 11.5.2 shows the NES results without FFC under low and high shipments scenarios, which reflect the lower and upper bounds, respectively. Table 11.5.3 shows the NES results with FFC under low and high shipments scenarios.

Table 11.5.2 Cumulative National Primary Energy Savings for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2045.

Trial Standard Level	Equipment Class	National Energy Savings *quads* Low Shipments Scenario	National Energy Savings *quads* High Shipments Scenario
1	70 W	0.01	0.01
	150 W	0.03	0.05
	250 W	0.02	0.03
	400 W	0.10	0.13
	1,000 W	0.27	0.37
	Total	0.44	0.58
2	70 W	0.05	0.06
	150 W	0.06	0.09
	250 W	0.04	0.06
	400 W	0.20	0.27
	1,000 W	0.31	0.42
	Total	0.66	0.89
3	70 W	0.05	0.06
	150 W	0.19	0.26
	250 W	0.04	0.06
	400 W	0.20	0.27
	1,000 W	0.31	0.42
	Total	0.79	1.06
4	70 W	0.15	0.19
	150 W	0.19	0.26
	250 W	0.04	0.06
	400 W	0.20	0.27
	1,000 W	0.31	0.42
	Total	0.89	1.20
5	70 W	0.18	0.24
	150 W	0.19	0.26
	250 W	0.35	0.49
	400 W	0.77	1.08
	1,000 W	0.31	0.42
	Total	1.80	2.49

Table 11.5.3 Cumulative National Full-Fuel-Cycle Energy Savings for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2045.

Trial Standard Level	Equipment Class	National Energy Savings *quads*	
		Low Shipments Scenario	High Shipments Scenario
1	70 W	0.01	0.01
	150 W	0.03	0.05
	250 W	0.02	0.03
	400 W	0.10	0.13
	1,000 W	0.28	0.38
	Total	0.45	0.59
2	70 W	0.05	0.06
	150 W	0.06	0.09
	250 W	0.04	0.06
	400 W	0.21	0.28
	1,000 W	0.31	0.42
	Total	0.67	0.90
3	70 W	0.05	0.06
	150 W	0.19	0.27
	250 W	0.04	0.06
	400 W	0.21	0.28
	1,000 W	0.31	0.42
	Total	0.80	1.08
4	70 W	0.16	0.20
	150 W	0.19	0.27
	250 W	0.04	0.06
	400 W	0.21	0.28
	1,000 W	0.31	0.42
	Total	0.91	1.22
5	70 W	0.19	0.24
	150 W	0.19	0.27
	250 W	0.36	0.50
	400 W	0.78	1.10
	1,000 W	0.31	0.42
	Total	1.83	2.53

For this rulemaking, DOE undertook a sensitivity analysis using 9 rather than 30 years of fixture shipments. The choice of a 9-year period is a proxy for the timeline in EPCA for the review of certain energy conservation standards and potential revision of and compliance with such revised standards.[a] This time frame may not be statistically relevant with regard to the equipment lifetime, equipment manufacturing cycles, or other factors specific to metal halide lamp fixtures. Thus, this information is presented for informational purposes only and does not indicate any change in DOE's analytical methodology. The NES results based on a 9-year analytical period without FFC are presented in Table 11.5.4. The NES results based on a 9-year

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[a] EPCA requires DOE to review its standards at least once every 6 years, and requires, for certain products, a 3 year period after any new standard is promulgated before compliance is required, except that in no case may any new standards be required within 6 years of the compliance date of the previous standards. While adding a 6-year review to the 3-year compliance period adds up to 9 years, DOE notes that it may undertake reviews at any time within the 6 year period and that the 3-year compliance date may yield to the 6-year backstop.

analytical period without FFC are presented in Table 11.5.5. The impacts are considered over the lifetime of fixtures purchased in 2016–2024.

Table 11.5.4 Cumulative National Primary Energy Savings for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2024

Trial Standard Level	Equipment Class	National Energy Savings *quads*	
		Low-Shipments Scenario	High-Shipments Scenario
1	70 W	0.01	0.01
	150 W	0.02	0.02
	250 W	0.01	0.01
	400 W	0.06	0.07
	1,000 W	0.15	0.16
	Total	0.25	0.28
2	70 W	0.03	0.03
	150 W	0.03	0.03
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.16	0.18
	Total	0.36	0.40
3	70 W	0.03	0.03
	150 W	0.09	0.10
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.16	0.18
	Total	0.42	0.46
4	70 W	0.09	0.10
	150 W	0.09	0.10
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.16	0.18
	Total	0.48	0.53
5	70 W	0.11	0.12
	150 W	0.09	0.10
	250 W	0.17	0.19
	400 W	0.36	0.40
	1,000 W	0.16	0.18
	Total	0.89	0.99

Table 11.5.5 Cumulative National Full-Fuel-Cycle Energy Savings for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2024

Trial Standard Level	Equipment Class	National Energy Savings *quads*	
		Low-Shipments Scenario	High-Shipments Scenario
1	70 W	0.01	0.01
	150 W	0.02	0.02
	250 W	0.01	0.02
	400 W	0.06	0.07
	1,000 W	0.15	0.17
	Total	0.25	0.28
2	70 W	0.03	0.03
	150 W	0.03	0.04
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.17	0.18
	Total	0.37	0.40
3	70 W	0.03	0.03
	150 W	0.09	0.10
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.17	0.18
	Total	0.42	0.47
4	70 W	0.09	0.10
	150 W	0.09	0.10
	250 W	0.02	0.03
	400 W	0.11	0.12
	1,000 W	0.17	0.18
	Total	0.49	0.54
5	70 W	0.11	0.12
	150 W	0.09	0.10
	250 W	0.18	0.19
	400 W	0.37	0.41
	1,000 W	0.17	0.18
	Total	0.91	1.00

11.5.3 Net Present Value Analysis

The NPV calculation attempts to calculate the total monetary costs and benefits of the standard for all customers of fixtures. This calculation relies primarily on two inputs: (1) the NES calculations described in the previous section, which are translated into a decrease (or in some cases increase) in operating costs; and (2) the increase (or in some cases decrease) in installed costs.

In most cases the operating cost savings, installed costs increases, and NPV all trend toward zero over time, reflecting the impacts of discounting.

NPV results are cumulative and shown as the discounted value of these savings in dollar terms. DOE used national averages for key inputs such as electricity pricing and sector-specific point values for operating hours in calculating operating cost savings and installed cost increases.

Thus, the NPV results are discrete point values rather than a distribution of values as in the LCC and PBP analysis.

The present value of increased total installed costs is the total installed cost increase (*i.e.*, the difference between the standards case and base case in a given year), discounted to the present, and summed over the time period in which DOE evaluated the impact of standards (*i.e.*, from 2016 to 2074).

Savings are decreases in operating costs associated with higher efficiency fixtures purchased in the standards case compared to the base case. DOE calculated total annual operating cost savings as the difference between total annual operating costs in the base case minus those in the standards case. Eq. 11.7 gives the total annual operating costs in each case.

In general, the NPV results at each TSL largely reflect the LCC savings at the corresponding efficiency levels. As discussed in the LCC and PBP analysis (NOPR TSD chapter 8), for most fixture purchasing events and most baseline fixture designs, increasing efficiency levels generally results in increased LCC savings; however, at certain efficiency levels (which differ by equipment class), electronic ballasts are used instead of magnetic ballasts. Electronic ballasts are more expensive and have a shorter lifetime than magnetic ballasts, and the maintenance costs associated with replacing electronic ballasts more frequently outweigh the monetary benefits of energy savings. Therefore, the efficiency levels that require electronic ballasts in general do not generate positive LCC savings.

11.5.4 Net Present Value Results

Table 11.5.6 shows the NPV results in tabular format for both the low and the high shipments scenarios, which represent the lower and upper energy savings, respectively. Within each of these scenarios, results are also shown for 7- and 3-percent discount rates. Increases in energy savings do not necessarily correspond to increases in NPV savings.

Table 11.5.6 Net Present Value of Customer Benefits for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2045

Trial Standard Level	Equipment Class	Net Present Value *billion 2012$*			
		Low-Shipments Scenario		High-Shipments Scenario	
		7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
1	70 W	0.039	0.068	0.042	0.073
	150 W	0.036	0.094	0.044	0.124
	250 W	0.009	0.065	0.012	0.084
	400 W	0.009	0.109	0.014	0.140
	1,000 W	0.596	1.292	0.728	1.680
	Total	0.688	1.629	0.840	2.100
2	70 W	0.054	0.124	0.060	0.144
	150 W	0.083	0.205	0.104	0.274
	250 W	0.028	0.146	0.038	0.194
	400 W	0.108	0.383	0.140	0.507
	1,000 W	0.636	1.393	0.779	1.815
	Total	0.909	2.251	1.121	2.933
3	70 W	0.054	0.124	0.060	0.144
	150 W	0.125	0.408	0.162	0.558
	250 W	0.028	0.146	0.038	0.194
	400 W	0.108	0.383	0.140	0.507
	1,000 W	0.636	1.393	0.779	1.815
	Total	0.951	2.454	1.179	3.217
4	70 W	0.029	0.330	0.034	0.406
	150 W	0.125	0.408	0.162	0.558
	250 W	0.028	0.146	0.038	0.194
	400 W	0.108	0.383	0.140	0.507
	1,000 W	0.636	1.393	0.779	1.815
	Total	0.927	2.660	1.153	3.479
5	70 W	-0.015	0.278	-0.018	0.344
	150 W	0.125	0.408	0.162	0.558
	250 W	-0.055	0.287	-0.050	0.430
	400 W	-0.344	0.134	-0.394	0.256
	1,000 W	0.636	1.393	0.779	1.815
	Total	0.347	2.500	0.478	3.401

The NPV results based on the afore-mentioned 9-year analytical period are presented in Table 11.5.7. The impacts are considered over the lifetime of fixtures purchased in 2016–2024. As mentioned previously, this information is presented for informational purposes only and is not indicative of any change in DOE's analytical methodology or decision criteria.

Table 11.5.7 Net Present Value of Customer Benefits for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2024

Trial Standard Level	Equipment Class	Net Present Value *billion 2012$*			
		Low-Shipments Scenario		High-Shipments Scenario	
		7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
1	70 W	0.039	0.068	0.042	0.073
	150 W	0.023	0.053	0.025	0.058
	250 W	0.004	0.037	0.004	0.041
	400 W	0.001	0.062	0.001	0.069
	1,000 W	0.419	0.779	0.457	0.856
	Total	0.485	0.999	0.530	1.097
2	70 W	0.047	0.099	0.051	0.107
	150 W	0.053	0.113	0.059	0.124
	250 W	0.013	0.078	0.015	0.086
	400 W	0.061	0.206	0.068	0.227
	1,000 W	0.445	0.834	0.486	0.916
	Total	0.620	1.329	0.678	1.461
3	70 W	0.047	0.099	0.051	0.107
	150 W	0.075	0.209	0.082	0.231
	250 W	0.013	0.078	0.015	0.086
	400 W	0.061	0.206	0.068	0.227
	1,000 W	0.445	0.834	0.486	0.916
	Total	0.642	1.426	0.702	1.567
4	70 W	0.024	0.216	0.025	0.236
	150 W	0.075	0.209	0.082	0.231
	250 W	0.013	0.078	0.015	0.086
	400 W	0.061	0.206	0.068	0.227
	1,000 W	0.445	0.834	0.486	0.916
	Total	0.618	1.542	0.676	1.696
5	70 W	-0.010	0.178	-0.012	0.194
	150 W	0.075	0.209	0.082	0.231
	250 W	-0.063	0.099	-0.068	0.110
	400 W	-0.280	-0.027	-0.305	-0.027
	1,000 W	0.445	0.834	0.486	0.916
	Total	0.166	1.292	0.183	1.424

DOE's NPV estimates use incremental equipment and maintenance costs that reflect a declining trend for equipment prices, using *AEO* price trends (deflators). The derivation and application of price trends for equipment prices is explained in appendix 8B of this NOPR TSD. DOE also estimated NPV without deflator-based equipment price adjustments, as presented in Table 11.5.8. The impacts are considered over the lifetime of fixtures purchased in 2016–2045, and are presented for informational purposes only.

Table 11.5.8 Net Present Value of Customer Benefits for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2045 (No Equipment Price Adjustment)

Trial Standard Level	Equipment Class	Net Present Value *billion 2012$*			
		Low-Shipments Scenario		High-Shipments Scenario	
		7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
1	70 W	0.039	0.068	0.042	0.073
	150 W	0.031	0.083	0.038	0.108
	250 W	-0.003	0.040	-0.002	0.050
	400 W	-0.014	0.060	-0.015	0.076
	1,000 W	0.580	1.258	0.708	1.632
	Total	0.634	1.508	0.770	1.939
2	70 W	0.046	0.107	0.050	0.122
	150 W	0.075	0.188	0.094	0.249
	250 W	0.006	0.097	0.009	0.127
	400 W	0.069	0.296	0.089	0.389
	1,000 W	0.617	1.349	0.754	1.753
	Total	0.813	2.037	0.995	2.641
3	70 W	0.046	0.107	0.050	0.122
	150 W	0.105	0.368	0.134	0.498
	250 W	0.006	0.097	0.009	0.127
	400 W	0.069	0.296	0.089	0.389
	1,000 W	0.617	1.349	0.754	1.753
	Total	0.843	2.217	1.036	2.889
4	70 W	0.012	0.304	0.011	0.368
	150 W	0.105	0.368	0.134	0.498
	250 W	0.006	0.097	0.009	0.127
	400 W	0.069	0.296	0.089	0.389
	1,000 W	0.617	1.349	0.754	1.753
	Total	0.809	2.413	0.997	3.135
5	70 W	-0.043	0.228	-0.055	0.273
	150 W	0.105	0.368	0.134	0.498
	250 W	-0.116	0.164	-0.134	0.252
	400 W	-0.519	-0.246	-0.637	-0.301
	1,000 W	0.617	1.349	0.754	1.753
	Total	0.045	1.863	0.062	2.474

Finally, DOE evaluated the NPV results for both indoor and outdoor fixtures for each equipment class. Table 11.5.9 gives the NPV associated with each equipment class segregated by indoor and outdoor fixture environments.

Table 11.5.9 Net Present Value of Customer Benefits for Metal Halide Lamp Fixture Trial Standard Levels for Units Sold in 2016–2045 (Low Shipments, by Fixture Environment)

Trial Standard Level	Equipment Class	Net Present Value *billion 2012$*			
		Indoor Fixtures		Outdoor Fixtures	
		7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
1	70 W	0.000	0.000	0.039	0.068
	150 W	0.011	0.028	0.025	0.066
	250 W	0.005	0.024	0.004	0.041
	400 W	0.007	0.037	0.002	0.072
	1,000 W	0.183	0.378	0.413	0.914
	Total	0.205	0.468	0.483	1.161
2	70 W	0.000	0.000	0.054	0.124
	150 W	0.025	0.059	0.058	0.146
	250 W	0.012	0.048	0.017	0.098
	400 W	0.036	0.115	0.072	0.268
	1,000 W	0.197	0.411	0.439	0.981
	Total	0.269	0.633	0.640	1.618
3	70 W	0.000	0.000	0.054	0.124
	150 W	0.019	0.012	0.106	0.396
	250 W	0.012	0.048	0.017	0.098
	400 W	0.036	0.115	0.072	0.268
	1,000 W	0.197	0.411	0.439	0.981
	Total	0.263	0.586	0.688	1.868
4	70 W	0.000	0.000	0.029	0.330
	150 W	0.019	0.012	0.106	0.396
	250 W	0.012	0.048	0.017	0.098
	400 W	0.036	0.115	0.072	0.268
	1000 W	0.197	0.411	0.439	0.981
	Total	0.263	0.586	0.664	2.074
5	70 W	-0.012	-0.018	-0.003	0.296
	150 W	0.019	0.012	0.106	0.396
	250 W	-0.042	-0.120	-0.012	0.407
	400 W	-0.148	-0.284	-0.196	0.418
	1,000 W	0.197	0.411	0.439	0.981
	Total	0.013	0.002	0.334	2.499

11.6 ANNUALIZED NATIONAL COSTS AND BENEFITS

The benefits and costs of the proposed standards, for equipment sold in 2016–2045, can be expressed in terms of annualized values. The annualized monetary values are the sum of (1) the annualized national economic value of the benefits from consumer operation of equipment that meets the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, which is another way of representing consumer NPV); and (2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions. The derivation of the monetary value of the benefits of emission reductions is described in chapter 17 of the NOPR TSD. The value of the CO_2 reductions, or SCC, is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the time series of SCC values is discussed in appendix 17A of the NOPR TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating cost savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of equipment shipped in the 30-year analysis period during which equipment is installed. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of 1 ton of carbon dioxide in each year. These impacts go well beyond 2100.

11.6.1 Calculation Method

DOE uses a two-step calculation process to convert each time-series of costs and benefits into annualized values. First, DOE calculates a present value in the "present" year used in discounting the NPV of total consumer costs and savings.[b] For this calculation, DOE uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE uses the discount rate appropriate for each SCC time-series (see NOPR TSD chapter 17 for discussion).

$$PV_x = \sum\nolimits_{t=y_1,y_\mathrm{T}} \left(x(t) \cdot (1 + r_x)^{y_\mathrm{NPV}-t}\right)$$

Eq. 11.9

Where:

$x(t)$= time-series under evaluation,
PV_x= present value of the time-series x,
y_1= first year in the analysis period,
y_T = last year in the analysis period,
y_NPV= year to which the NPV of consumers' costs and savings are being discounted, and
r_x = discount rate used to discount the annual values of time-series x to year y_NPV.

In the second step, DOE calculates, from the present values, the fixed annual payments over a 30-year period, starting in the first year of the analysis period, which yields the same present values with discount rates of 3 and 7 percent. This requires projecting the present values in the "present" year ahead to the first year of the analysis period. The fixed annual payments are the annualized values.

$$Ann_{x,r} = PV_x \cdot f_{y_1-y_\mathrm{NPV},r} \cdot a_{30,r} = PV_x \cdot (1+r)^{y_1-y_\mathrm{NPV}} \cdot \frac{r \cdot (1+r)^{30}}{(1+r)^{30} - 1}$$

Eq. 11.10

Where:

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[b] For the value of emissions reductions, DOE uses a time series that corresponds to the time period used in calculating the operating cost savings (*i.e.*, through the final year in which equipment shipped is still operating).

$Ann_{x,r}$= annualized value of the time-series x,
$f_{n,r}$ = factor to project a value n years ahead[c] with r discount rate, and
$a_{30,r}$ = factor to annualize present values over a 30-year period with r discount rate.

Although DOE calculates annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

11.6.2 Results for the Proposed Standards

The NOPR associated with this TSD states that DOE is proposing energy conservation standards for metal halide lamp fixtures that correspond to TSL 3. Estimates of annualized values for the proposed standards are shown in Table 11.6.1.

The low benefits and high benefits estimates are based on projected MHLF shipments. In addition, all estimates use incremental equipment costs that reflect deflator-based prices for equipment prices. See appendix 8B for a discussion of the equipment price trends.

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[c] *n* is the number of years between the "present" year and the first year of the analysis period.

Table 11.6.1 Annualized Benefits and Costs of Proposed Standards for Metal Halide Lamp Fixtures Sold in 2016-2045

	Discount Rate	Primary (Low) Estimate*	High Estimate*
		Monetized Values *million 2012$/year*	
Benefits			
Operating Cost Savings	7%	129	156
	3%	169	216
CO_2 Reduction at \$12.9/t**	5%	18	22
CO_2 Reduction at \$40.8/t**	3%	65	83
CO_2 Reduction at \$62.2/t**	2.5%	97	125
CO_2 Reduction at \$117/t**	3%	198	256
NO_X Reduction at \$2,639/t**	7%	2.89	3.47
	3%	3.83	4.88
Total (Operating Cost Savings, CO_2 Reduction and NO_x Reduction)†	7% plus CO_2 range	149 to 329	182 to 415
	7%	196	243
	3%	237	305
	3% plus CO_2 range	190 to 370	244 to 477
Costs			
Incremental Equipment Costs	7%	59	70
	3%	56	69
Net Benefits/Costs			
Total (Operating Cost Savings, CO_2 Reduction and NO_x Reduction, minus Incremental Equipment Costs)†	7% plus CO_2 range	90 to 270	112 to 345
	7%	137	173
	3%	181	235
	3% plus CO_2 range	134 to 315	174 to 408

* This table presents the annualized costs and benefits associated with fixtures shipped in 2016 and 2045. These results include benefits to customers which accrue after 2045 from the fixtures purchased in 2016 to 2045. Costs incurred by manufacturers, some of which may be incurred prior to 2016 in preparation for the rule, are not directly included, but are indirectly included as part of incremental equipment costs. The Primary, Low, and High Estimates utilize forecasts of energy prices from the Energy Information Administration's 2012 *AEO2013* from the *AEO2013* Reference case, with the Low and High Estimates based on projected fixture shipments in the Low Shipments, Roll-up and High Shipments, Roll-up scenarios, respectively. In addition, all estimates use incremental equipment costs that reflect a declining trend for equipment prices, using *AEO* price trends (deflators). The derivation and application of price trends for equipment prices is explained in appendix 8B of this NOPR TSD.

** The interagency group selected four sets of SCC values for use in regulatory analyses. Three sets of values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth set, which represents the 95th percentile SCC estimate across all three models at a 3-percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. The values in parentheses represent the SCC in 2015. The SCC time series incorporate an escalation factor. The value for NO_X is the average of the low and high values used in DOE's analysis.

† Total Benefits for both the 3-percent and 7-percent cases are derived using the series corresponding to average SCC with 3-percent discount rate. In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

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CHAPTER 12. LIFE-CYCLE COST SUBGROUP ANALYSIS

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CHAPTER 12. LIFE-CYCLE COST SUBGROUP ANALYSIS

12.1 INTRODUCTION

The life-cycle cost (LCC) subgroup analysis evaluates the effects of standards on identifiable groups, such as different customer populations or business types that may be disproportionately affected by any national energy conservation standard level. For the notice of proposed rulemaking (NOPR) for metal halide lamp fixtures (MHLF or fixtures), the U.S. Department of Energy (DOE) analyzed the LCCs and payback periods (PBPs) for customers that fall into such groups. The analysis determined whether any particular group of customers would be adversely affected by any of the trial standard levels (TSLs).

DOE determined the effects of TSLs on customer subgroups using the LCC spreadsheet model. Chapter 8 of the NOPR technical support document explains in detail the inputs to the model used in determining LCC impacts and PBPs.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroups.

12.2 SUBGROUPS DESCRIPTION

Using the LCC spreadsheet model, DOE determined the effect of the TSLs on the following customer subgroups: utilities, transportation facilities, and warehouses.

12.2.1 Utilities

Utilities own 40 percent of the roadway lighting in United States and own a number of area and parking lot fixtures as well. Maintenance costs are more significant for utilities than most other customer groups because utilities maintain a larger volume of fixtures. Furthermore, the failure of the fixtures is not always obvious, requiring utilities to constantly monitor the status of the luminaires. DOE assumed that maintenance costs for utilities were 1.5 times those of the general public.

12.2.2 Transportation Facility Owners

DOE found that transportation facilities (*e.g.*, airports, bus terminals, train stations, ports) operate more hours per year than any other buildings that use significant numbers of metal halide lamp fixtures in the industrial sector, according to the 2010 U.S. Lighting Market Characterization[1] (LMC) and 2003 Commercial Buildings Energy Consumption Survey[2] (CBECS). For transportation facilities, DOE assumed that this subgroup has more annual operating hours than the industrial sector average used in the main LCC analysis. Specifically, DOE used 7,300 operating hours instead of the national average of 6,113 in the industrial sector for the subgroup analysis.

In general, because of the large number of transportation facilities across the country, DOE does not expect differences in other inputs like electricity prices or sales tax that vary significantly on average from the commercial sector as a whole. Therefore, with the exception of operating hours, DOE used the same inputs in the transportation facilities subgroup analysis as it used for the general population.

12.2.3 Warehouse Owners

DOE found that warehouses operate for fewer hours per year than most other buildings that use significant numbers of metal halide lamp fixtures in the commercial sector, according to the LMC and CBECS. DOE assumed that the warehouses subgroup has lower annual operating hours than the commercial sector average used in the main LCC analysis. Specifically, DOE estimated the typical hours of operation for non-refrigerated warehouses at 3,541 hours instead of 3,961 hours, for the commercial sector.

In general, because of the large diversity of warehouses in the commercial sector, DOE does not expect differences in other inputs like electricity prices or sales tax that vary significantly on average from the commercial sector as a whole. Therefore, with the exception of operating hours, DOE used the same inputs in the warehouse owners subgroup analysis as it used for the general population.

12.3 LCC SUBGROUP RESULTS

Table 12.3.1 through Table 12.3.12 show the LCC effects and PBPs for identified subgroups that purchase fixtures.

Table 12.3.1 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Indoor, Magnetic Baseline): LCC Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
	Baseline	650.30	1,632.71	2,283.01	--	--	--	--
1	1	651.53	1,598.65	2,250.17	32.84	0.0	100.0	0.5
2, 3, 4	2	664.78	1,579.82	2,244.60	38.41	0.0	100.0	4.2
--	3	667.75	1,663.46	2,331.20	-48.19	35	65	3.5
5	4	681.18	1,658.51	2,339.68	-56.67	36	64	5.8
Subgroup: Transportation Facility Owners								
	Baseline	537.80	1,428.88	1,966.68	--	--	--	--
1	1	539.03	1,392.23	1,931.26	35.41	0.0	100.0	0.5
2, 3, 4	2	552.28	1,371.90	1,924.18	42.49	0.0	100.0	3.9
--	3	555.25	1,413.15	1,968.39	-1.72	26	74	3.0
5	4	568.68	1,407.13	1,975.80	-9.13	29	71	5.0

Table 12.3.1 (cont)

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Warehouse Owners								
	Baseline	537.80	1,372.08	1,909.88	--	--	--	--
1	1	539.03	1,338.45	1,877.47	32.40	0.0	100.0	0.4
2, 3, 4	2	552.28	1,319.92	1,872.20	37.68	0.0	100.0	3.4
--	3	555.25	1,373.94	1,929.19	-19.31	14	86	1.9
5	4	568.68	1,369.17	1,937.85	-27.97	15	85	3.2

Table 12.3.2 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Indoor, Electronic Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
1, 2, 3, 4	Baseline / 3	667.75	1,663.46	2,331.20	--	--	--	--
5	4	681.18	1,658.51	2,339.68	-8.48	96	4	32.4
Subgroup: Transportation Facility Owners								
1, 2, 3, 4	Baseline / 3	555.25	1,413.15	1,968.39	--	--	--	--
5	4	568.68	1,407.13	1,975.80	-7.41	95	5	31.3
Subgroup: Warehouse Owners								
1, 2, 3, 4	Baseline / 3	555.25	1,373.94	1,929.19	--	--	--	--
5	4	568.68	1,369.17	1,937.85	-8.66	98	2	21.9

Table 12.3.3 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Outdoor, Magnetic Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
	Baseline	640.48	2,205.61	2,846.10	--	--	--	--
1	1	641.66	2,164.94	2,806.60	39.50	0.0	100.0	0.6
2, 3	2	654.36	2,145.30	2,799.66	46.44	0.0	100.0	4.4
4	3	692.96	2,090.08	2,783.04	63.06	46	54	16.9
5	4	705.83	2,083.03	2,788.86	57.23	48	52	18.7
Subgroup: Transportation Facility Owners								
	Baseline	527.98	1,844.61	2,372.59	--	--	--	--
1	1	529.16	1,803.94	2,333.09	39.50	0.0	100.0	0.6
2, 3	2	541.86	1,784.29	2,326.15	46.44	0.0	100.0	4.4
4	3	580.46	1,722.54	2,303.00	69.59	46	54	16.9
5	4	593.33	1,715.50	2,308.82	63.77	48	52	18.7
Subgroup: Warehouse Owners								
	Baseline	527.98	1,844.61	2,372.59	--	--	--	--
1	1	529.16	1,803.94	2,333.09	39.50	0.0	100.0	0.6
2, 3	2	541.86	1,784.29	2,326.15	46.44	0.0	100.0	4.4
4	3	580.46	1,722.54	2,303.00	69.59	38	62	12.4
5	4	593.33	1,715.50	2,308.82	63.77	41	59	14.2

Table 12.3.4 Equipment Class 1 - 70 Watt Metal Halide Lamp Fixtures (Outdoor, Electronic Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$* Installed Cost	Discounted Operating Cost	LCC	Life-Cycle Cost Savings: Average Savings *2012$*	Percent of Customers that Experience: Net Cost	Net Benefit	Median Payback Period *years*
Subgroup: Utilities								
1, 2, 3, 4	Baseline / 3	692.96	2,090.08	2,783.04	--	--	--	--
5	4	705.83	2,083.03	2,788.86	-5.82	85	15	44.3
Subgroup: Transportation Facility Owners								
1, 2, 3, 4	Baseline / 3	580.46	1,722.54	2,303.00	--	--	--	--
5	4	593.33	1,715.50	2,308.82	-5.82	95	5	31.0
Subgroup: Warehouse Owners								
1, 2, 3, 4	Baseline / 3	580.46	1,722.54	2,303.00	--	--	--	--
5	4	593.33	1,715.50	2,308.82	-5.82	85	15	44.3

Table 12.3.5 Equipment Class 2 - 150 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
	Baseline	792.04	2,416.48	3,208.52	--	--	--	--
1	1	808.27	2,381.76	3,190.03	18.50	1	99	7.2
2	2	816.07	2,352.77	3,168.84	39.68	0	100	5.8
--	3	811.72	2,404.29	3,216.01	-7.48	29	71	2.7
3, 4, 5	4	831.00	2,402.28	3,233.28	-24.76	34	66	5.2
Subgroup: Transportation Facility Owners								
	Baseline	657.04	2,225.70	2,882.74	--	--	--	--
1	1	673.27	2,187.50	2,860.77	21.97	1	99	6.8
2	2	681.07	2,155.69	2,836.76	45.98	0	100	5.4
--	3	676.72	2,173.66	2,850.38	32.36	12	88	2.2
3, 4, 5	4	696.00	2,171.29	2,867.29	15.45	20	80	4.4
Subgroup: Warehouse Owners								
	Baseline	657.04	2,098.07	2,755.11	--	--	--	--
1	1	673.27	2,063.78	2,737.05	18.06	0	100	5.8
2	2	681.07	2,035.14	2,716.20	38.91	0	100	4.7
--	3	676.72	2,053.01	2,729.73	25.37	8	92	1.3
3, 4, 5	4	696.00	2,051.17	2,747.17	7.93	12	88	2.6

Table 12.3.6 Equipment Class 2 - 150 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
Subgroup: Utilities								
	Baseline	776.19	3,115.02	3,891.20	--	--	--	--
1	1	791.74	3,078.80	3,870.54	20.66	0	100	8.3
2	2	799.20	3,047.30	3,846.51	44.70	0	100	6.5
--	3	830.81	2,940.40	3,771.21	120.00	33	67	9.2
3, 4, 5	4	849.28	2,937.25	3,786.53	104.67	38	62	12.2
Subgroup: Transportation Facility Owners								
	Baseline	641.19	2,681.81	3,322.99	--	--	--	--
1	1	656.74	2,645.59	3,302.33	20.66	0	100	8.3
2	2	664.20	2,614.09	3,278.30	44.70	0	100	6.5
--	3	695.81	2,499.35	3,195.16	127.84	33	67	9.2
3, 4, 5	4	714.28	2,496.20	3,210.48	112.51	38	62	12.2
Subgroup: Warehouse Owners								
	Baseline	641.19	2,681.81	3,322.99	--	--	--	--
1	1	656.74	2,645.59	3,302.33	20.66	0	100	8.3
2	2	664.20	2,614.09	3,278.30	44.70	0	100	6.5
--	3	695.81	2,499.35	3,195.16	127.84	16	84	7.7
3, 4, 5	4	714.28	2,496.20	3,210.48	112.51	25	75	10.3

Table 12.3.7 Equipment Class 3 - 250 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** ***2012$***			**Life-Cycle Cost Savings**			**Median Payback Period** ***years***
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** ***2012$***	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
Subgroup: Utilities								
	Baseline	845.86	2,706.30	3,552.16	--	--	--	--
1	1	869.37	2,676.24	3,545.61	6.55	36	64	12.4
2, 3, 4	2	884.99	2,654.05	3,539.04	13.12	30	70	11.9
--	3	925.69	2,741.43	3,667.13	-114.96	57	43	16.9
5	4	918.45	2,728.05	3,646.50	-94.34	49	51	13.0
Subgroup: Transportation Facility Owners								
	Baseline	710.86	2,918.78	3,629.64	--	--	--	--
1	1	734.37	2,885.59	3,619.96	9.69	29	71	11.8
2, 3, 4	2	749.99	2,861.10	3,611.09	18.56	24	76	11.2
--	3	790.69	2,918.08	3,708.78	-79.13	50	50	14.3
5	4	783.45	2,903.52	3,686.97	-57.32	43	57	11.1
Subgroup: Warehouse Owners								
	Baseline	710.86	2,466.57	3,177.44	--	--	--	--
1	1	734.37	2,436.94	3,171.31	6.13	17	83	10.1
2, 3, 4	2	749.99	2,415.04	3,165.03	12.40	15	85	9.6
--	3	790.69	2,468.82	3,259.52	-82.08	26	74	6.7
5	4	783.45	2,455.53	3,238.98	-61.54	22	78	5.6

Table 12.3.8 Equipment Class 3 - 250 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
Subgroup: Utilities								
	Baseline	825.34	3,472.93	4,298.27	--	--	--	--
1	1	847.86	3,443.68	4,291.54	6.73	20	80	14.8
2, 3, 4	2	862.82	3,421.70	4,284.52	13.75	16	84	14.1
--	3	937.58	3,344.40	4,281.98	16.29	72	28	39.8
5	4	930.64	3,329.38	4,260.03	38.25	61	39	28.2
Subgroup: Transportation Facility Owners								
	Baseline	690.34	3,132.65	3,822.99	--	--	--	--
1	1	712.86	3,103.40	3,816.26	6.73	20	80	14.8
2, 3, 4	2	727.82	3,081.42	3,809.24	13.75	16	84	14.1
--	3	802.58	2,996.28	3,798.86	24.13	72	28	39.8
5	4	795.64	2,981.26	3,776.91	46.08	61	39	28.2
Subgroup: Warehouse Owners								
	Baseline	690.34	3,132.65	3,822.99	--	--	--	--
1	1	712.86	3,103.40	3,816.26	6.73	20	80	14.8
2, 3, 4	2	727.82	3,081.42	3,809.24	13.75	16	84	14.1
--	3	802.58	2,996.28	3,798.86	24.13	64	36	27.1
5	4	795.64	2,981.26	3,776.91	46.08	54	46	20.7

Table 12.3.9 Equipment Class 4 - 400 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
	Baseline	934.44	3,649.31	4,583.74	--	--	--	--
1	1	973.04	3,601.60	4,574.64	9.10	40	60	12.9
2, 3, 4	2	991.82	3,563.69	4,555.51	28.23	18	82	10.5
--	3	1,071.01	3,623.45	4,694.47	-110.72	56	44	15.5
5	4	1,112.37	3,609.21	4,721.58	-137.84	66	34	18.2
Subgroup: Transportation Facility Owners								
	Baseline	784.44	3,880.58	4,665.01	--	--	--	--
1	1	823.04	3,827.87	4,650.91	14.10	34	66	12.2
2, 3, 4	2	841.82	3,786.15	4,627.97	37.04	14	86	10.0
--	3	921.01	3,808.34	4,729.36	-64.34	48	52	13.4
5	4	962.37	3,792.38	4,754.75	-89.74	58	42	15.9
Subgroup: Warehouse Owners								
	Baseline	784.44	3,423.90	4,208.33	--	--	--	--
1	1	823.04	3,376.86	4,199.90	8.43	20	80	10.4
2, 3, 4	2	841.82	3,339.44	4,181.25	27.08	9	91	8.5
--	3	921.01	3,362.34	4,283.36	-75.02	25	75	7.5
5	4	962.37	3,348.56	4,310.93	-102.59	30	70	8.9

Table 12.3.10 Equipment Class 4 - 400 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
--	Baseline	910.80	4,462.71	5,373.51	--	--	--	--
1	1	947.78	4,416.57	5,364.35	9.16	23	77	15.4
2, 3, 4	2	965.77	4,377.27	5,343.04	30.47	7	93	12.4
--	3	1,077.40	4,256.85	5,334.25	39.26	61	39	24.5
5	4	1,117.02	4,238.70	5,355.73	17.79	68	32	27.7
Subgroup: Transportation Facility Owners								
--	Baseline	760.80	4,173.10	4,933.90	--	--	--	--
1	1	797.78	4,126.96	4,924.74	9.16	23	77	15.4
2, 3, 4	2	815.77	4,087.66	4,903.43	30.47	7	93	12.4
--	3	927.40	3,958.53	4,885.93	47.97	61	39	24.5
5	4	967.02	3,940.38	4,907.40	26.49	68	32	27.7
Subgroup: Warehouse Owners								
--	Baseline	760.80	4,173.10	4,933.90	--	--	--	--
1	1	797.78	4,126.96	4,924.74	9.16	23	77	15.4
2, 3, 4	2	815.77	4,087.66	4,903.43	30.47	7	93	12.4
--	3	927.40	3,958.53	4,885.93	47.97	55	45	21.0
5	4	967.02	3,940.38	4,907.40	26.49	62	38	24.1

Table 12.3.11 Equipment Class 5 – 1,000 Watt Metal Halide Lamp Fixtures (Indoor): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2012$*	Percent of Customers that Experience		
						Net Cost	Net Benefit	
Subgroup: Utilities								
--	Baseline	1,353.88	12,420.47	13,774.35	--	--	--	--
1	1 + DS*	1,417.74	11,885.42	13,303.15	471.20	0.0	100.0	1.8
2, 3, 4, 5	2 + DS*	1,431.85	11,840.29	13,272.15	502.21	0.0	100.0	2.0
Subgroup: Transportation Facility Owners								
--	Baseline	1,143.88	13,479.99	14,623.87	--	--	--	--
1	1 + DS*	1,207.74	12,835.48	14,043.22	580.65	0.0	100.0	1.5
2, 3, 4, 5	2 + DS*	1,221.85	12,780.37	14,002.23	621.64	0.0	100.0	1.7
Subgroup: Warehouse Owners								
--	Baseline	1,143.88	11,657.30	12,801.18	--	--	--	--
1	1 + DS*	1,207.74	11,122.24	12,329.98	471.20	0.0	100.0	1.4
2, 3, 4, 5	2 + DS*	1,221.85	11,077.12	12,298.97	502.21	0.0	100.0	1.6

* DS = Design Standard prohibits fixtures from containing a probe-start ballast.

Table 12.3.12 Equipment Class 5 – 1,000 Watt Metal Halide Lamp Fixtures (Outdoor): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings**			**Median Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2012$*	**Percent of Customers that Experience**		
						Net Cost	**Net Benefit**	
Subgroup: Utilities								
--	Baseline	1,311.52	10,528.44	11,839.96	--	--	--	--
1	1 + DS*	1,372.70	10,082.08	11,454.77	385.18	0.0	100.0	2.6
2, 3, 4, 5	2 + DS*	1,386.22	10,044.72	11,430.93	409.02	0.0	100.0	3.0
Subgroup: Transportation Facility Owners								
--	Baseline	1,101.52	9,854.56	10,956.08	--	--	--	--
1	1 + DS*	1,162.70	9,408.20	10,570.89	385.18	0.0	100.0	2.6
2, 3, 4, 5	2 + DS*	1,176.22	9,370.84	10,547.05	409.02	0.0	100.0	3.0
Subgroup: Warehouse Owners								
--	Baseline	1,101.52	9,854.56	10,956.08	--	--	--	--
1	1 + DS*	1,162.70	9,408.20	10,570.89	385.18	0.0	100.0	2.6
2, 3, 4, 5	2 + DS*	1,176.22	9,370.84	10,547.05	409.02	0.0	100.0	3.0

* DS = Design Standard prohibits fixtures from containing a probe-start ballast.

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CHAPTER 13. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 13. MANUFACTURER IMPACT ANALYSIS

13.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard." (42 U.S.C. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id*. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of new and amended energy conservation standards on manufacturers of metal halide lamp fixtures and ballasts, and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash flow model adapted for the products in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards for each product by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

13.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the metal halide lamp fixture and ballast industries, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE used the GRIM to assess the impacts of new and amended energy conservation standards on metal halide lamp fixtures and ballasts.

In Phase II, DOE created a GRIM for metal halide lamp fixtures and ballasts and an interview guide to gather information on the potential impacts on manufacturers. DOE presented the MIA results for metal halide lamp fixtures and ballasts based on a set of considered TSLs. These TSLs are described in section 13.4.5 below.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing more than 65 percent of metal halide lamp fixture sales and more than 90 percent of metal halide lamp ballast sales. Interviewees included large and small manufacturers with various market shares and market focus, providing a representative cross-section of the industries. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the industry. The interviews provided DOE with valuable information for evaluating the impacts of new and amended energy conservation standards on manufacturer cash flows, investment requirements, and employment.

13.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the metal halide lamp fixture and ballast industries that built upon the market and technology assessment prepared for this rulemaking. (See chapter 3 of this Technical Support Document (TSD).) Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of each industry. This information included market share data, product shipments, manufacturer markups, and the cost structure for various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment; selling, general and administrative (SG&A) expenses; cost of goods sold, *etc.;* and (4) trends in the number of firms, market, and product characteristics. The industry profile included a top-down cost analysis of metal halide lamp fixture and ballast manufacturers that DOE used to derive preliminary financial inputs for the GRIM (*e.g.,* revenues, depreciation, SG&A, and research and development (R&D) expenses).

DOE also used public information to further calibrate its initial characterization of the metal halide lamp fixture and ballast industries, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

13.2.2 Phase II: Industry Cash Flow Analysis and Interview Guide

Phase II focused on the financial impacts of potential new and amended energy conservation standards on manufacturers of metal halide lamp fixtures and ballasts. More stringent energy conservation standards can affect manufacturer cash flows in three distinct ways: (1) create a need for increased investment, (2) raise production costs per unit, and (3) alter revenue due to higher per-unit prices and/or possible changes in sales volumes. To quantify these impacts, DOE used the GRIM to perform a cash flow analysis for metal halide lamp fixtures and ballasts. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the national impact analysis (NIA). In Phase II, DOE performed these preliminary industry cash flow analyses and prepared written guides for manufacturer interviews.

13.2.2.1 Industry Cash Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows from 2013 until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, taxes, and capital expenditures related to the new and amended standards. Inputs to the GRIM include manufacturing production costs, selling prices, and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry and estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios for the GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 10 of this TSD, provided the basis for the shipment projections in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to base case projections for the industries. The financial impact of new and amended energy conservation standards is the difference between the discounted annual cash flows in the base case and standards case at each TSL.

13.2.2.2 Interview Guides

During Phase III of the MIA, DOE interviewed manufacturers to gather information on the effects of new and amended energy conservation on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE developed separate interview guides for metal halide lamp fixture and ballast manufacturers. The interview guide provided a starting point to identify relevant issues and help identify the impacts of new and amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each site visit or telephone interview, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. The MIA interview topics included (1) key impacts on your company; (2) test procedure; (3) scope of coverage; (4) engineering; (5) manufacturer markups and profitability; (6) company overview and organization characteristics; (7) shipment projections; (8) financial parameters; (9) conversion costs; (10) cumulative regulator burden; (11) direct employment assessment; (12) manufacturing capacity and non-US sales (13) impact on competition; and (14) impacts on small business. The interview guides are presented in appendix 13A.

13.2.3 Phase III: Subgroup Analysis

For its analysis, DOE presented the impacts of all metal halide lamp fixture equipment classes as a whole and all metal halide lamp ballast equipment classes as a whole. While conducting the MIA, DOE interviewed a representative cross-section of metal halide lamp fixture and ballast manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought to obtain feedback from each industry on the approaches used in the GRIMs and to isolate key issues and concerns. During interviews, DOE defined one manufacturer subgroup, small manufacturers, that could be disproportionately impacted by new and amended energy conservation standards. These subgroups are described in detail below.

13.2.3.1 Manufacturing Interviews

The information gathered in Phase I and the cash flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor the GRIM to reflect unique financial characteristics for metal halide lamp fixture and ballast manufacturers. DOE contacted companies from its database of manufacturers and interviewed small and large companies, subsidiaries and independent firms, and public and private corporations to provide a representation of the industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM developed for the equipment classes.

13.2.3.2 Revised Industry Cash Flow Analysis

In Phase II of the MIA, DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested comments on the values it selected for the parameters. DOE revised its industry cash flow models based on this feedback. Section 13.4.3 provides more information on how DOE calculated the parameters.

13.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among manufacturer subgroups. Small manufacturers and other manufacturers with a cost structure significantly different from the industry average could be more negatively affected. DOE uses the results of the industry characterization to group manufacturers exhibiting similar characteristics. During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As described in section 13.2.3, DOE presents the industry impacts on metal halide lamp fixtures as a whole because most of the equipment classes represent the same market served by the same manufacturers. The same is done for metal halide lamp ballasts. However, as discussed below, DOE identified one additional manufacturer subgroup that warranted a separate impact analysis, small manufacturers.

13.2.3.4 Small-Business Manufacturer Subgroup

DOE investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the Small Business Administration (SBA) small business size standards published on August 22, 2008, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 13.2.1, to determine whether any small entities would be affected by the rulemaking.[a] For the equipment classes under review, the SBA bases its small business definition on the total number of employees for a business, its

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[a] The size standards are available on the SBA's website at www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf.

subsidiaries, and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business.

Table 13.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing	N/A	500	335122
Power, Distribution and Specialty Transformer Manufacturing	N/A	750	335311

DOE used the National Electrical Manufacturers Association (NEMA)[3] member directory to identify manufacturers of metal halide lamp fixtures and ballasts. DOE also used market research tools (e.g., Dun and Bradstreet reports and Hoovers reports) to create a list of every company that manufactures or sells metal halide ballasts or fixtures covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered metal halide lamp fixtures and ballasts. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

During its research, DOE identified approximately 54 metal halide lamp fixture manufacturers and five metal halide lamp ballast manufacturers that produce products covered by this rulemaking and qualify as small businesses per the applicable SBA definition. DOE contacted the small businesses to solicit feedback on the potential impacts of energy conservation standards. Two metal halide lamp fixture small businesses and one metal halide lamp ballast small business consented to being interviewed during the MIA interviews. In addition to posing the standard MIA interview questions, DOE solicited data from other manufacturers on differential impacts these companies might experience from new and amended energy conservation standards. Because DOE was not able to certify that the proposed rulemaking would not have a significant economic impact on a substantial number of small entities, DOE has analyzed small manufacturers as a subgroup. The results of this subgroup analysis are presented in section 13.6.

13.2.3.5 Manufacturing Capacity Impact

One significant outcome of new and amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of new and amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States and North America, with and without new and amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIM. These estimates can be found in section 13.4.8 and DOE's discussion of the capacity impact can be found in section 13.7.2.

13.2.3.6 Employment Impact

The impact of new and amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the metal halide lamp fixture and ballast industry. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without new and amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 13.7.1.

13.2.3.7 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to new and amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified regulations relevant to metal halide lamp fixture and ballast manufacturers, such as State regulations and other Federal regulations that impact other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 13.7.3.

13.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview starts by asking: "What are the key issues for your company regarding the energy conservation standard rulemaking?" This question prompts manufacturers to identify the issues they feel DOE should explore and discuss further during the interview. The following sections describe the most significant issues identified by manufacturers. These summaries are provided in aggregate to protect manufacturer confidentiality.

13.3.1 Ability to Recoup Investments

Several manufacturers worried that new and amended energy conservation standards would force them to invest while their market was shrinking. The increasing market penetration of emerging technologies could strand these investments, particularly as metal halide lamp fixture standards hasten the switch to emerging technologies by narrowing the difference between metal halide lamp fixtures and emerging technology purchase prices. If the standard threatens to accelerate the ongoing migration to new technology, manufacturers would be more likely to abandon their metal halide product lines.

To address the emerging technologies issues discussed by manufacturers, DOE included several shipment scenarios in both the NIA and the GRIM. See chapter 10 of the NOPR TSD for a discussion of the shipment scenarios used in the respective analyses.

13.3.2 Efficiency Metric Used

Some manufacturers disagreed over which metric should be used to regulate efficiency for metal halide lamp fixtures. Manufacturers agreed that ballast efficiency is the most straightforward metric to use and the simplest for compliance purposes, but they noted that it ignores opportunities for energy savings from lamps and the fixture itself. At the same time, some manufacturers did not favor a lamp-and-ballast metric because a lamp-and-ballast metric could confer a competitive advantage to those manufacturers who produce both metal halide lamps and ballasts. Lastly, several manufacturers opposed the use of a fixture efficiency metric.

DOE is proposing a ballast efficiency metric for the reasons described in chapter 2 of the TSD. DOE notes that it is concurrently conducting a rulemaking for high-intensity discharge (HID) lamps, including metal halide lamps, which will examine the lamp efficiency component of the metal halide system.

13.3.3 Maintenance of 150 W Exemption

Nearly all manufacturers said that DOE should maintain its exemption for 150 W only fixtures rated for wet (e.g. outdoor) locations and containing ballasts rated to operate in air temperatures higher than 50 °C. Manufacturers stated that it is cost-prohibitive to meet EISA 2007 standard levels with magnetic ballasts, and electronic ballasts are currently less reliable for outdoor applications. Furthermore, manufacturers acknowledged that this exemption created energy savings by pushing consumers of the more expensive 175 W ballasts to the less expensive 150 W magnetic ballasts. Manufacturers contended consumers would revert back to the 175 W products if the exemption were not maintained because of the significant price increase caused by bringing the 150 W ballast into compliance. This cost increase would cause consumers to revert to 175 W, they said, thereby negating any potential energy savings that could have been achieved by regulating 150 W products.

DOE, however, is proposing not to maintain the 150 W exemption for the reasons detailed in chapter 2 of the TSD.

13.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to new and amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without new and amended energy conservation standards.

13.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 13.4.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2013, and continuing to 2045. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[4]

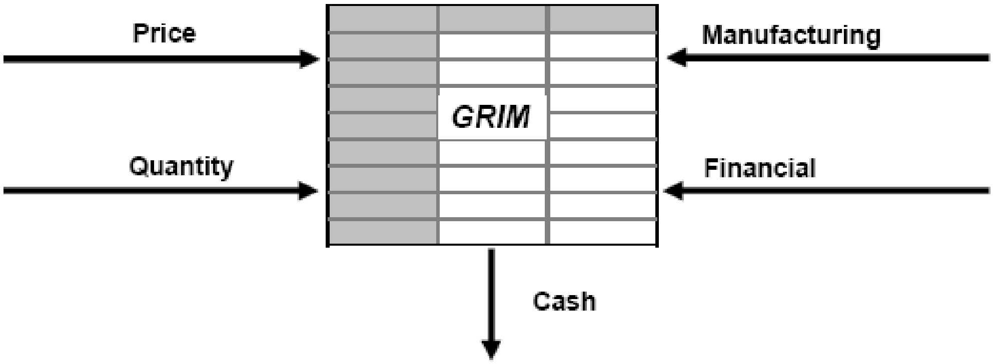

Figure 13.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard case scenario induced by new and amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the new and amended energy conservation standard on manufacturers. Appendix 13B provides more technical details and user information for the GRIM.

13.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

13.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers that manufacture metal halide lamp fixtures and ballasts, among other products. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies as its initial estimates of the financial parameters in the GRIM analysis. These figures were later revised using feedback from interviews to be representative of metal halide lamp fixture and ballast manufacturing. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital

- SG&A
- R&D
- Depreciation
- Capital expenditures
- Net PPE

13.4.2.2 Standard and Poor Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

13.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the NIA. The model relied on historical shipments data for metal halide fixtures. Chapter 10 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

13.4.2.4 Engineering Analysis

The engineering analysis establishes the relationship between manufacturer production cost (MPC) and energy efficiency for the products covered in this rulemaking. DOE has adopted an efficiency level approach paired with reverse engineering cost estimates to develop cost-efficiency curves. DOE began its analysis by conducting industry research to determine equipment classes, select baseline ballasts and fixtures, and select representative ballasts and fixtures for further testing and analysis. Next DOE determined efficiency levels based on the design options associated with the specific ballasts and fixtures studied and the maximum technologically feasible efficiency level. Lastly, DOE conducted a price analysis by generating a bill of materials (BOM) by tearing down representative ballasts and fixtures and developing a cost model that converts the BOMs for each efficiency level into MPCs. By applying derived manufacturer markups to the MPC, DOE calculated the manufacturer selling price (MSP) and constructed industry cost-efficiency curves. In cases where DOE was not able to generate a BOM for representative ballasts and fixtures, DOE estimated an MSP based on the relationship between teardown data and manufacturer-supplied MSPs. See chapter 5 for a complete discussion of the engineering analysis.

13.4.2.5 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of ballast and fixture manufacturers. DOE also interviewed manufacturers representing a significant portion of sales in every equipment class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- capital conversion costs (one-time investments in PPE);
- product conversion costs (one-time investments in research, product development, testing, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- possible profitability impacts; and
- cost-efficiency curves calculated in the engineering analysis.

13.4.3 Financial Parameters

Table 13.4.1 below provides financial parameters for six public companies engaged in manufacturing and selling metal halide lamp fixtures. Table 13.4.2 below provides financial parameters for four public companies engaged in manufacturing and selling metal halide lamp ballasts. The values listed are averages over an eight-year period (2003 to 2010).

Table 13.4.1 GRIM Metal Halide Fixure Financial Parameters Based on 2003–2010 Weighted Company Financial Data

Parameter	**Weighted Average**	**Manufacturer**					
		A	**B**	**C**	**D**	**E**	**F**
Tax Rate % of taxable income	25.5	14.0	43.5	26.6	33.7	19.8	27.3
Working Capital ***% of revenues***	6.0	-9.1	18.2	7.0	12.8	16.5	21.3
SG&A % of revenues	17.0	13.1	23.2	13.0	28.7	17.0	17.4
R&D % of revenues	3.3	2.8	4.6	5.2	1.6	2.0	0.4
Depreciation ***% of revenues***	3.0	2.2	4.3	3.9	1.9	2.5	2.6
Capital Expenditures ***% of revenues***	3.0	2.6	4.0	4.2	1.6	2.1	2.2
Net PPE % of revenues	19.7	20.9	28.6	13.0	16.6	13.2	13.8

Table 13.4.2 GRIM Metal Halide Ballast Financial Parameters Based on 2003–2010 Weighted Company Financial Data

Parameter	**Weighted Average**	**Manufacturer**			
		A	**B**	**C**	**D**
Tax Rate % of taxable income	30.3	14.0	20.7	26.6	56.4
Working Capital ***% of revenues***	6.6	-9.1	18.2	7.0	15.4
SG&A % of revenues	17.7	13.1	23.2	13.0	21.4
R&D % of revenues	4.0	2.8	4.6	5.2	4.1
Depreciation ***% of revenues***	3.4	2.2	4.3	3.9	3.9
Capital Expenditures ***% of revenues***	3.5	2.6	4.0	4.2	3.8
Net PPE % of revenues	20.9	20.9	28.6	13.0	19.5

During interviews, metal halide lamp fixture and ballast manufacturers were asked to provide their own figures for the parameters listed in Table 13.4.1 and Table 13.4.2. Where applicable, DOE adjusted the parameters in the GRIM using this feedback and data from publicly traded companies to reflect manufacturing metal halide lamp fixtures and ballasts. Table 13.4.3 presents the revised parameters for metal halide lamp fixture and ballast manufacturers.

Table 13.4.3 GRIM Revised Metal Halide Lamp Fixture and Ballast Industry Financial Parameters

Parameter	Fixture Revised Estimate	Ballast Revised Estimate
Tax Rate % of taxable income	28.7	33.2
Working Capital ***% of revenues***	8.3	6.5
SG&A % of revenues	18.7	17.6
R&D % of revenues	3.1	4.4
Depreciation ***% of revenues***	2.9	2.9
Capital Expenditures ***% of revenues***	3.0	3.2
Net PPE % of revenues	19.2	18.0

13.4.4 Corporate Discount Rate

DOE used the weighted-average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the metal halide ballast and fixture industries based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the metal halide fixture industry is 14.6 percent (Table 13.4.4) and the metal halide ballast industry is 13.4 percent (Table 13.4.5).

Table 13.4.4 Cost of Equity Calculation for Metal Halide Fixture Manufacturers

Parameter	Industry-Weighted Average %	Manufacturer					
		A	B	C	D	E	F
(1) Average Beta	1.53	1.68	1.38	1.58	1.34	1.55	1.14
(2) Yield on 10-Year T-Bill (1928-2010)	5.2	-	-	-	-		
(3) Market Risk Premium (1928-2010)	6.1	-	-	-	-		
Cost of Equity (2)+[(1)*(3)]	14.6	-	-	-	-		
Equity/Total Capital	79.9	92.7	84.2	62.5	66.3	69.3	71.1

Table 13.4.5 Cost of Equity Calculation for Metal Halide Ballast Manufacturers

Parameter	Industry-Weighted Average %	Manufacturer			
		A	B	C	D
(1) Average Beta	1.34	1.68	1.38	1.58	0.83
(2) Yield on 10-Year T-Bill (1928-2010)	5.2	-	-	-	-
(3) Market Risk Premium (1928-2010)	6.1	-	-	-	-
Cost of Equity (2)+[(1)*(3)]	13.4	-	-	-	-
Equity/Total Capital	82.3	92.7	84.2	62.5	79.9

Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company's cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate. DOE used this method to calculate the cost of debt for all four manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2010.

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for the four public manufacturers. DOE added the industry-weighted average spread to the average T-Bill rate. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 13.4.6 and Table 13.4.7 presents the derivation of the cost of debt and the capital structure of the metal halide lamp fixture and ballast industries respectively (*i.e.* the debt ratio (debt/total capital)).

Table 13.4.6 Cost of Debt Calculation for Metal Halide Lamp Fixture

Parameter	Industry-Weighted Average %	Manufacturer					
		A	B	C	D	E	F
S&P Bond Rating	--	AA	A-	A+	BBB	A	A
(1) Yield on 10-Year T-Bill (1928-2010)	5.2	-	-	-	-		
(2) Gross Cost of Debt	6.1	5.9	6.3	6.1	6.8	6.2	6.2
(3) Tax Rate	25.5	14.0	20.7	26.6	33.7	19.8	27.3
Net Cost of Debt (2) x (1-(3))	4.6	-	-	-	-	-	-
Debt/Total Capital	20.1	7.3	15.8	37.5	33.7	30.7	28.9

Table 13.4.7 Cost of Debt Calculation for Metal Halide Lamp Ballast

Parameter	Industry-Weighted Average %	Manufacturer			
		A	B	C	D
S&P Bond Rating	--	AA	A-	A+	A+
(1) Yield on 10-Year T-Bill (1928-2010)	5.2	-	-	-	-
(2) Gross Cost of Debt	6.1	5.9	6.3	6.1	6.1
(3) Tax Rate	30.3	14.0	20.7	26.6	56.4
Net Cost of Debt (2) x (1-(3))	4.2	-	-	-	-
Debt/Total Capital	17.7	7.3	15.8	37.5	20.1

Using public information for these six fixture companies, the initial estimate for the metal halide lamp fixture industry's WACC was approximately 12.6 percent and using public information for these four ballast companies, the initial estimate for the metal halide lamp ballast industry's WACC was approximately 11.8 percent. Subtracting an inflation rate of 3.1 percent between 1928 and 2010, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 9.5 percent for the fixture industry and 8.7 percent for the ballast industry. DOE also asked for feedback on the 9.5 percent and 8.7 discount during manufacturer interviews and used this feedback to determine that 9.5 and 8.9 percent was an appropriate discount rate for use in the fixture and ballast GRIM, respectively.

13.4.5 Trial Standard Levels

DOE developed the same TSLs for metal halide lamp fixtures and ballasts. Consistent with the engineering analysis, DOE analyzed ten equipment classes. Table 13.4.8 shows the TSLs for the equipment classes analyzed by DOE and presents the efficiency level (EL) at each TSL used in the GRIM.

Table 13.4.8 Trial Standard Levels for Metal Halide Lamp Fixtures

Rep. Wattage	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
70 W Indoor	EL1	EL2	EL2	EL2	EL4
150 W Indoor	EL1	EL2	EL4	EL4	EL4
250 W Indoor	EL1	EL2	EL2	EL2	EL4
400 W Indoor	EL1	EL2	EL2	EL2	EL4
1000 W Indoor	EL1 +DS	EL2 +DS	EL2 +DS	EL2 +DS	EL2 +DS
70 W Outdoor	EL1	EL2	EL2	EL3	EL4
150 W Outdoor	EL1	EL2	EL4	EL4	EL4
250 W Outdoor	EL1	EL2	EL2	EL2	EL4
400 W Outdoor	EL1	EL2	EL2	EL2	EL4
1000 W Outdoor	EL1 +DS	EL2 +DS	EL2 +DS	EL2 +DS	EL2 +DS

TSL 1 would set energy conservation standards at EL1 for all equipment classes. Standards included in TSL 1 typically can be satisfied by magnetic ballasts with mid-grade steel and copper windings. These ballasts are commercially available except for the 150 W indoor and outdoor and 400 W indoor ballasts which are modeled. TSL 1 includes a design standard for 1000 W indoor and outdoor fixtures that prohibits the sale of probe start ballasts in new fixtures. TSL 1 sets the same standards for indoor and outdoor representative equipment classes at the same wattage, except for the 400 W equipment classes.

TSL 2 would set energy conservation standards at EL2 for all equipment classes. Standards included in TSL 2 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings. These ballasts are modeled except for the 1000 W indoor and outdoor ballasts which are commercially available. TSL 2 includes a design standard for the 1000 W indoor and outdoor fixtures which prohibits the sale of probe start ballasts in new fixtures. TSL 2 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

TSL 3 would set energy conservation standards at EL4 for the 150 W indoor and outdoor fixtures and at EL2 for the remaining equipment classes (70 W indoor and outdoor, 250 W indoor and outdoor, 400 W indoor and outdoor, and 1000 W indoor and outdoor fixtures). Standards included in TSL 3 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings except for the 150 W indoor and outdoor fixtures which require high-grade electronic ballasts. These ballasts are modeled except for the 150 W indoor and outdoor and 1000 W indoor and outdoor ballasts which are commercially available. TSL 3 includes a design standard for 1000 W indoor and outdoor fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 3 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

TSL 4 would set energy conservation standards at EL4 for the 150 W indoor and outdoor fixtures, at EL3 for the 70 W outdoor fixtures, and at EL2 for the remaining equipment classes (70 W indoor, 250 W indoor and outdoor, 400 W indoor and outdoor, and 1000 W indoor and outdoor fixtures). Standards included in TSL 4 typically can be satisfied by fixtures that contain magnetic ballasts with high-grade core steel and copper windings except for the 70 W outdoor fixtures which require standard-grade electronic ballasts and the 150 W indoor and outdoor fixtures which require high-grade electronic ballasts. The 70 W outdoor, 150 W indoor and outdoor, and 1000 W indoor and outdoor ballasts are commercially available, while the 70 W indoor, 250 W indoor and outdoor, and 400 W indoor and outdoor ballasts are modeled. TSL 4 includes a design standard for 1000 W indoor and outdoor fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 4 sets the same standards for indoor and outdoor equipment classes of the same wattage except for the 70 W equipment classes.

TSL 5 represents all of the maximum technologically feasible (max tech) efficiency levels, which would set energy conservation standards at EL4 for the 70 W indoor and outdoor, 150 W indoor and outdoor, 250 W indoor and outdoor, and 400 W indoor and outdoor fixtures, and EL2 for the 1000 W indoor and outdoor fixtures. Standards included in TSL 5, require fixtures to contain the max tech electronic ballasts with high-grade electronic components for the 70 W indoor and outdoor, 150 W indoor and outdoor, 250 W indoor and outdoor, and 400 W indoor and outdoor fixtures. For the 1000 W indoor and outdoor fixtures standards at TSL 5 typically require fixtures that contain magnetic ballasts with high-grade core steel and copper windings. All ballasts are commercially available at TSL 5. TSL 5 would require high-frequency electronic ballasts for the 400 W indoor and outdoor fixtures. TSL 5 includes a design standard for 1000 W indoor and outdoor fixtures that prohibits the sale of probe-start ballasts in new fixtures. TSL 5 sets the same standards for indoor and outdoor representative equipment classes at the same wattage.

13.4.6 NIA Shipment Forecast

The GRIM estimates manufacturer revenues based on total-unit shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM used the NIA shipments forecasts under two scenarios: low- and high-shipments. In the low-shipment scenario, DOE reviewed trends in fixture replacement technologies and forecasted a decline in shipments over the analysis period. In the high scenario, the decline in metal halide lamp fixture shipments is not as large as in the low scenario. Manufacturers earn greater revenue under the high-shipment scenario compared to the low-shipment scenario. The assumptions and methodology that drive these scenarios and the details specific to each are described in chapter 10 of the NOPR TSD.

Only the shipments in 2013 and beyond have an impact on INPV because 2013 is the base year to which future cash flows are summed. Table 13.4.9 shows total shipments forecasted in the shipment analysis for metal halide lamp fixtures in 2016 and 2045 under each scenario.

Table 13.4.9 Total Base Case NIA Shipments Forecast in 2016 and 2045 under the Low- and High-Shipment Scenarios

Equipment Class	Total Industry Shipments			
	Low-Shipments		High-Shipments	
	2016	2045	2016	2045
70 W Indoor	236,773	53,579	239,600	155,803
150 W Indoor	120,183	27,196	121,618	79,084
250 W Indoor	255,930	61,044	258,985	177,512
400 W Indoor	319,912	76,306	323,732	221,890
1000 W Indoor	86,247	19,517	87,276	56,753
70 W Outdoor	710,319	150,021	718,799	436,249
150 W Outdoor	280,428	63,458	283,776	184,529
250 W Outdoor	597,170	142,437	604,299	414,195
400 W Outdoor	746,462	178,046	755,374	517,744
1000 W Outdoor	258,740	58,550	261,829	170,258

As part of the shipments analysis, DOE estimated the base case shipment distribution by efficiency level for each equipment class. In the standards case, DOE determined efficiency distributions for cases in which a potential standard applies for 2016 and beyond. DOE assumed that product efficiencies in the base case that did not meet the standard under consideration would move to meet the new standard in 2016 under a roll-up scenario. The roll-up scenario represents the case in which all shipments in the base case that do not meet the new standard roll up to meet the new standard level. Consumers in the base case who purchase fixtures above the standard level are not affected as they are assumed to continue to purchase the same fixture in the standards case. See chapter 10 of the NOPR TSD for more information on the ballasts standards case shipment scenarios.

13.4.7 Production Costs

Manufacturing a higher-efficiency product is typically more expensive than manufacturing a baseline product due to the use of components that are more costly than baseline components. The changes in the MPCs of the analyzed equipment can affect the revenues, gross margins, and cash flow of the manufacturer, making these equipment cost data key GRIM inputs for DOE’s analysis. DOE employed one of two methods to derive these per unit production costs. DOE was able to establish a BOM for those ballasts it tore down. DOE then converted the BOMs at each efficiency level into corresponding MPCs composed of labor, materials, and overhead expenses using its engineering cost model. When DOE was not able to generate a BOM for a given ballast, DOE estimated the per unit production costs based on the relationship between teardown data and manufacturer-supplied MSPs. DOE included a cost adder for indoor electronic ballasts to account for the additional cost of including a 120 V auxiliary tap in some models. DOE also developed fixture MPCs for several different fixture types using either a teardown analysis or retail price scaling. With these costs for several common fixture types, DOE created a single “hybrid” fixture for each of the five representative wattages, reflecting the weighted average of the common fixture types. DOE included a cost adder for all fixtures that use electronic ballasts to account for thermal management and a cost adder for outdoor fixtures that use electronic ballasts to account for voltage transient protection. In addition, DOE used teardown cost data to disaggregate the ballast and fixture MPCs into material, labor, and overhead costs.

Table 13.4.10 through Table 13.4.29 show the production cost estimates used in the GRIM for each equipment class for ballasts and fixtures.

Table 13.4.10 MPC Breakdown for 70 W Indoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$1.56	$15.83	$0.67	$0.80	$18.86	1.47	$27.72
EL1	$1.59	$16.18	$0.68	$0.82	$19.27	1.47	$28.33
EL2	$1.96	$19.93	$0.84	$1.00	$23.74	1.47	$34.90
EL3	$1.19	$19.87	$0.44	$0.95	$22.45	1.47	$33.00
EL4	$1.42	$23.88	$0.53	$1.14	$26.98	1.47	$39.66

Table 13.4.11 MPC Breakdown for 150 W Indoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.42	$24.52	$1.04	$1.24	$29.20	1.47	$42.93
EL1	$2.87	$29.11	$1.23	$1.47	$34.68	1.47	$50.98
EL2	$3.09	$31.32	$1.32	$1.58	$37.31	1.47	$54.84
EL3	$1.68	$28.24	$0.63	$1.35	$31.89	1.47	$46.89
EL4	$2.03	$33.99	$0.75	$1.62	$38.40	1.47	$56.44

Table 13.4.12 MPC Breakdown for 250 W Indoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.92	$29.67	$1.25	$1.50	$35.34	1.47	$51.95
EL1	$3.58	$36.32	$1.53	$1.83	$43.27	1.47	$63.60
EL2	$4.02	$40.74	$1.72	$2.05	$48.54	1.47	$71.35
EL3	$2.99	$50.16	$1.11	$2.40	$56.66	1.47	$83.29
EL4	$2.86	$48.00	$1.06	$2.29	$54.22	1.47	$79.70

Table 13.4.13 MPC Breakdown for 400 W Indoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.45	$24.83	$1.05	$1.25	$29.58	1.47	$43.48
EL1	$3.53	$35.76	$1.51	$1.80	$42.60	1.47	$62.62
EL2	$4.05	$41.07	$1.73	$2.07	$48.93	1.47	$71.93
EL3	$3.53	$59.28	$1.31	$2.83	$66.96	1.47	$98.43
EL4	$4.27	$71.63	$1.59	$3.42	$80.91	1.47	$118.93

Table 13.4.14 MPC Breakdown for 1000 W Indoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$3.09	$31.31	$1.32	$1.58	$37.30	1.47	$54.83
Baseline + DS	$3.70	$37.50	$1.58	$1.89	$44.68	1.47	$65.67
EL1	$4.26	$43.19	$1.82	$2.18	$51.45	1.47	$75.64
EL1 + DS	$4.87	$49.39	$2.09	$2.49	$58.83	1.47	$86.48
EL2	$4.65	$47.19	$1.99	$2.38	$56.21	1.47	$82.63
EL2 + DS	$5.26	$53.38	$2.25	$2.69	$63.59	1.47	$93.48

Table 13.4.15 MPC Breakdown for 70 W Outdoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$1.56	$15.83	$0.67	$0.80	$18.86	1.47	$27.72
EL1	$1.59	$16.18	$0.68	$0.82	$19.27	1.47	$28.33
EL2	$1.96	$19.93	$0.84	$1.00	$23.74	1.47	$34.90
EL3	$1.14	$19.19	$0.42	$0.92	$21.67	1.47	$31.86
EL4	$1.38	$23.20	$0.51	$1.11	$26.20	1.47	$38.52

Table 13.4.16 MPC Breakdown for 150 W Outdoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.42	$24.52	$1.04	$1.24	$29.20	1.47	$42.93
EL1	$2.87	$29.11	$1.23	$1.47	$34.68	1.47	$50.98
EL2	$3.09	$31.32	$1.32	$1.58	$37.31	1.47	$54.84
EL3	$1.64	$27.55	$0.61	$1.32	$31.12	1.47	$45.74
EL4	$1.99	$33.31	$0.74	$1.59	$37.62	1.47	$55.30

Table 13.4.17 MPC Breakdown for 250 W Outdoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.92	$29.67	$1.25	$1.50	$35.34	1.47	$51.95
EL1	$3.58	$36.32	$1.53	$1.83	$43.27	1.47	$63.60
EL2	$4.02	$40.74	$1.72	$2.05	$48.54	1.47	$71.35
EL3	$2.95	$49.47	$1.10	$2.36	$55.88	1.47	$82.15
EL4	$2.82	$47.31	$1.05	$2.26	$53.44	1.47	$78.56

Table 13.4.18 MPC Breakdown for 400 W Outdoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$2.45	$24.83	$1.05	$1.25	$29.58	1.47	$43.48
EL1	$3.53	$35.76	$1.51	$1.80	$42.60	1.47	$62.62
EL2	$4.05	$41.07	$1.73	$2.07	$48.93	1.47	$71.93
EL3	$3.49	$58.59	$1.30	$2.80	$66.18	1.47	$97.29
EL4	$4.23	$70.94	$1.57	$3.39	$80.13	1.47	$117.79

Table 13.4.19 MPC Breakdown for 1000 W Outdoor Ballasts (2012$)

EL	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$3.09	$31.31	$1.32	$1.58	$37.30	1.47	$54.83
Baseline + DS	$3.70	$37.50	$1.58	$1.89	$44.68	1.47	$65.67
EL1	$4.26	$43.19	$1.82	$2.18	$51.45	1.47	$75.64
EL1 + DS	$4.87	$49.39	$2.09	$2.49	$58.83	1.47	$86.48
EL2	$4.65	$47.19	$1.99	$2.38	$56.21	1.47	$82.63
EL2 + DS	$5.26	$53.38	$2.25	$2.69	$63.59	1.47	$93.48

Table 13.4.20 MPC Breakdown for 70 W Indoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC $	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$27.72	$16.83	$3.46	$36.58	$2.46	$2.04	$44.54	1.58	$70.38
EL1	$28.33	$45.15	$3.51	$37.08	$2.49	$2.07	$45.15	1.58	$71.34
EL2	$34.90	$51.72	$4.02	$42.48	$2.85	$2.37	$51.72	1.58	$81.72
EL3	$33.00	$53.19	$3.25	$44.85	$2.65	$2.44	$53.19	1.58	$84.05
EL4	$39.66	$59.85	$3.66	$50.46	$2.99	$2.74	$59.85	1.58	$94.57

Table 13.4.21 MPC Breakdown for 150 W Indoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC $	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$42.93	$29.01	$5.59	$59.08	$3.97	$3.30	$71.94	1.58	$113.66
EL1	$50.98	$78.96	$6.22	$65.69	$4.41	$3.67	$79.98	1.58	$126.38
EL2	$54.84	$83.85	$6.52	$68.86	$4.62	$3.84	$83.85	1.58	$132.48
EL3	$46.89	$81.69	$5.00	$68.88	$4.08	$3.75	$81.69	1.58	$129.08
EL4	$56.44	$91.25	$5.58	$76.93	$4.55	$4.18	$91.25	1.58	$144.18

Table 13.4.22 MPC Breakdown for 250 W Indoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC $	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$51.95	$41.19	$7.24	$76.49	$5.13	$4.27	$93.14	1.58	$147.16
EL1	$63.60	$103.37	$8.15	$86.06	$5.78	$4.80	$104.79	1.58	$165.57
EL2	$71.35	$112.53	$8.75	$92.42	$6.20	$5.16	$112.53	1.58	$177.81
EL3	$83.29	$132.71	$8.12	$111.89	$6.62	$6.09	$132.71	1.58	$209.69
EL4	$79.70	$129.12	$7.90	$108.86	$6.44	$5.92	$129.12	1.58	$204.02

Table 13.4.23 MPC Breakdown for 400 W Indoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC $	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$43.48	$63.79	$8.34	$88.10	$5.91	$4.92	$107.27	1.58	$169.48
EL1	$62.62	$124.22	$9.83	$103.81	$6.97	$5.80	$126.40	1.58	$199.72
EL2	$71.93	$135.71	$10.55	$111.46	$7.48	$6.22	$135.71	1.58	$214.43
EL3	$98.43	$174.97	$10.70	$147.52	$8.73	$8.02	$174.97	1.58	$276.46
EL4	$118.93	$195.48	$11.95	$164.81	$9.76	$8.96	$195.48	1.58	$308.86

Table 13.4.24 MPC Breakdown for 1000 W Indoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC $	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$54.83	$137.40	$14.94	$157.87	$10.60	$8.81	$192.23	1.58	$303.72
Baseline + DS	$65.67	$137.40	$15.79	$166.78	$11.19	$9.31	$203.07	1.58	$320.85
EL1	$75.64	$137.40	$16.56	$174.97	$11.74	$9.77	$213.04	1.58	$336.60
EL1 + DS	$86.48	$219.93	$17.40	$183.87	$12.34	$10.27	$223.88	1.58	$353.74
EL2	$82.63	$220.03	$17.11	$180.71	$12.13	$10.09	$220.03	1.58	$347.65
EL2 + DS	$93.48	$230.88	$17.95	$189.62	$12.73	$10.59	$230.88	1.58	$364.79

Table 13.4.25 MPC Breakdown for 70 W Outdoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC *$*	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$27.72	$16.83	$3.46	$36.58	$2.46	$2.04	$44.54	1.58	$70.38
EL1	$28.33	$45.11	$3.51	$37.08	$2.49	$2.07	$45.15	1.58	$71.34
EL2	$34.90	$51.72	$4.02	$42.48	$2.85	$2.37	$51.72	1.58	$81.72
EL3	$31.86	$71.70	$4.38	$60.45	$3.58	$3.29	$71.70	1.58	$113.29
EL4	$38.52	$78.36	$4.79	$66.06	$3.91	$3.59	$78.36	1.58	$123.81

Table 13.4.26 MPC Breakdown for 150 W Outdoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC *$*	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$42.93	$29.01	$5.59	$59.08	$3.97	$3.30	$71.94	1.58	$113.66
EL1	$50.98	$78.96	$6.22	$65.69	$4.41	$3.67	$79.98	1.58	$126.38
EL2	$54.84	$83.85	$6.52	$68.86	$4.62	$3.84	$83.85	1.58	$132.48
EL3	$45.74	$100.20	$6.13	$84.48	$5.00	$4.59	$100.20	1.58	$158.32
EL4	$55.30	$109.76	$6.71	$92.54	$5.48	$5.03	$109.76	1.58	$173.42

Table 13.4.27 MPC Breakdown for 250 W Outdoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC *$*	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$51.95	$41.19	$7.24	$76.49	$5.13	$4.27	$93.14	1.58	$147.16
EL1	$63.60	$103.45	$8.15	$86.06	$5.78	$4.80	$104.79	1.58	$165.57
EL2	$71.35	$112.53	$8.75	$92.42	$6.20	$5.16	$112.53	1.58	$177.81
EL3	$82.15	$151.22	$9.25	$127.49	$7.55	$6.93	$151.22	1.58	$238.93
EL4	$78.56	$147.63	$9.03	$124.47	$7.37	$6.77	$147.63	1.58	$233.26

Table 13.4.28 MPC Breakdown for 400 W Outdoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC *$*	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$43.48	$107.27	$8.34	$88.10	$5.91	$8.34	$107.27	1.58	$169.48
EL1	$62.62	$126.40	$9.83	$103.81	$6.97	$9.83	$126.40	1.58	$199.72
EL2	$71.93	$135.71	$10.55	$111.46	$7.48	$10.55	$135.71	1.58	$214.43
EL3	$97.29	$193.48	$11.83	$163.12	$9.66	$11.83	$193.48	1.58	$305.70
EL4	$117.79	$213.99	$13.09	$180.41	$10.68	$13.09	$213.99	1.58	$338.10

Table 13.4.29 MPC Breakdown for 1000 W Outdoor Fixtures (2012$)

EL	Ballast MSP $	Empty Fixture MPC *$*	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline	$54.83	$137.40	$14.94	$157.87	$10.60	$8.81	$192.23	1.58	$303.72
Baseline + DS	$65.67	$137.40	$15.79	$166.78	$11.19	$9.31	$203.07	1.58	$320.85
EL1	$75.64	$137.40	$16.56	$174.97	$11.74	$9.77	$213.04	1.58	$336.60
EL1 + DS	$86.48	$219.90	$17.40	$183.87	$12.34	$10.27	$223.88	1.58	$353.74
EL2	$82.63	$220.03	$17.11	$180.71	$12.13	$10.09	$220.03	1.58	$347.65
EL2 + DS	$93.48	$230.88	$17.95	$189.62	$12.73	$10.59	$230.88	1.58	$364.79

13.4.8 Product and Capital Conversion Costs

New and amended energy conservation standards will cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance. For the MIA, DOE classified these conversion costs into two major groups: (1) product conversion costs and (2) capital conversion costs. Product conversion costs are investments in research, development, testing, marketing, and other non-capitalized costs necessary to make product designs comply with the new and amended energy conservation standards. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new product designs can be fabricated and assembled.

Ballast Industry Conversion Costs. DOE's interviews with ballast manufacturers revealed that they expect the need to develop new and improved circuit designs—as opposed to the need to purchase new capital equipment—will account for most of the conversion costs at each TSL. Due to the flexible nature of most ballast production equipment and DOE's assumption that the stack height of magnetic ballasts will not increase, manufacturers do not expect new and amended standards to strand (make obsolete in advance of complete depreciation) a significant share of their production assets. As opposed to other more capital-intensive appliance manufacturers, much of the expenses required to achieve higher efficiency levels would occur through research and development, engineering, and testing efforts.

DOE based its estimates of the product conversion costs that would be required to meet each TSL on information obtained from manufacturer interviews and catalog data on the number and efficiency of models that each major manufacturer supports. DOE estimated the product development costs manufacturers would incur for each model that would need to be converted based on the necessary engineering and testing resources required to redesign each model. DOE assumed higher R&D and testing costs for levels requiring electronic ballasts compared to magnetic ballasts. Testing costs include internal testing, UL testing, additional certifications, pilot runs, and product training. DOE then multiplied these per-model cost estimates for each interviewed manufacturer by the total number of ballast models that would need to be converted at each efficiency level in each wattage bin, based on information from manufacturer catalogs and interviews, to estimate the total cost.

To separate total product conversion costs into indoor and outdoor equipment classes, DOE assigned costs based on the percentage of indoor or outdoor shipments in the NIA. DOE then scaled these costs to account for the market share of the companies not interviewed. Finally, DOE inflated the ballast conversion costs from 2010$ to 2012$ using the producer price index specific to NAICS code 335311, electric power and specialty transformer manufacturing. DOE decided this was the most appropriate index to use when updating the ballast conversion costs since metal halide ballast manufacturing is classified under this NAICS code.

As discussed above, DOE also estimated the capital conversion costs ballast manufacturers would incur to comply with the potential new and amended energy conservation standards represented by each TSL. During interviews, DOE asked manufacturers to estimate the capital expenditures required to expand the production of higher-efficiency products. These estimates included the required tooling and plant changes that would be necessary if product lines meeting the proposed standard did not currently exist.

DOE estimated capital conversion costs, like product conversion costs, based on interviews with manufacturers. Some manufacturers anticipated minimal to no conversion costs because of the flexibility of their existing equipment or because they source certain ballast types rather than produce them in-house. Other manufacturers expected greater capital conversion costs because they would need to acquire new stamping dies for higher efficiency magnetic ballasts and/or wave solder machines for electronic ballasts. In general, DOE's view is that significant changes to existing production lines and equipment would not be necessary in response to standards. It is therefore unlikely that most manufacturers would require high levels of capital expenditures compared to ordinary capital additions or replacements. DOE scaled its estimated conversion costs based on interviews to account for the market share of the companies not interviewed. DOE's estimates of the product and capital conversion costs for ballast manufacturers for each equipment class can be found in Table 13.4.30 through Table 13.4.39 below.

Fixture Industry Conversion Costs. To estimate conversion costs for fixture manufacturers, DOE again based its estimates on manufacturer interviews and its knowledge of the industry. DOE doubts that the stack height of magnetic ballasts will increase in response to standards. As such, DOE assumed that fixture manufacturers would be able to use higher efficiency magnetic ballasts without incurring redesign or capital costs. Even if higher efficiency levels can be met with magnetic ballasts, however, DOE expects manufacturers will incur one-time non-capital expenses at these levels associated with testing, literature changes, and marketing costs. These costs are included in DOE's product conversion cost estimates.

At efficiency levels requiring electronic ballasts, DOE expects fixture manufacturers may face more significant conversion costs. Manufacturers will have to consider thermal protection in their product designs because more efficient electronic ballasts have lower tolerances for high temperatures than magnetic ballasts. DOE estimated product conversion costs for fixture manufacturers by multiplying the number of product families in each wattage bin by the expected cost of fixture redesign and testing. DOE then multiplied these totals by the percentage of fixtures that would need to be redesigned at each efficiency level.

DOE employed a similar methodology to estimate fixture capital conversion costs at efficiency levels associated with electronic ballasts. Based on manufacturer interviews, DOE estimated platform tooling and equipment costs, such as costs for die castings, bracketing, and extrusions, and multiplied these costs by the number of fixtures affected by the standard.

To separate total product and capital conversion costs for fixture manufacturers into indoor and outdoor equipment classes, DOE assigned costs based on the percentage of indoor and outdoor fixtures each interviewed manufacturer offers. Finally, DOE inflated the fixture conversion costs from 2010$ to 2012$ using the producer price index specific to NAICS code 335122, nonresidential electric lighting fixture manufacturing. DOE decided this was the most appropriate index to use when updating the fixture conversion costs since metal halide fixture manufacturing is classified under this NAICS code.

DOE's estimates of the product and capital conversion costs for ballast and fixture manufacturers for each equipment class can be found in Table 13.4.30 through Table 13.4.39 below.

Table 13.4.30 Product and Capital Conversion Costs for 70 W Indoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$0.47	$0.66	$0.23	-
EL2	2, 3 ,4	$0.47	$0.66	$0.23	-
EL3	-	$0.72	$0.08	$2.03	$2.17
EL4	5	$1.02	$0.10	$2.68	$3.98

Table 13.4.31 Product and Capital Conversion Costs for 150 W Indoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$0.37	$0.46	$0.22	-
EL2	2	$0.40	$0.53	$0.22	-
EL3	-	$0.56	$0.08	$1.96	$2.22
EL4	3, 4, 5	$0.63	$0.08	$1.96	$2.38

Table 13.4.32 Product and Capital Conversion Costs for 250 W Indoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$0.56	$0.60	$0.26	-
EL2	2, 3, 4	$0.64	$1.02	$0.26	-
EL3	-	$0.94	$0.08	$3.74	$4.91
EL4	5	$1.19	$0.08	$6.17	$8.99

Table 13.4.33 Product and Capital Conversion Costs for 400 W Indoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$0.75	$0.70	$0.42	-
EL2	2, 3, 4	$0.81	$1.12	$0.42	-
EL3	-	$1.24	$0.08	$8.92	$10.6
EL4	5	$1.57	$0.08	$12.24	$16.4

Table 13.4.34 Product and Capital Conversion Costs for 1000 W Indoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
Baseline + DS	-	$0.03	-	$0.02	-
EL1	-	$0.41	$0.39	$0.09	-
EL1+ DS	1	$0.48	$0.39	$0.09	-
EL2	-	$0.97	$1.36	$0.09	-
EL2+ DS	2, 3, 4, 5	$1.04	$1.45	$0.09	-

Table 13.4.35 Product and Capital Conversion Costs for 70 W Outdoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$1.41	$1.97	$0.52	-
EL2	2, 3	$1.41	$1.97	$0.52	-
EL3	4	$2.17	$0.24	$4.60	$3.48
EL4	5	$3.07	$0.29	$6.08	$6.40

Table 13.4.36 Product and Capital Conversion Costs for 150 W Outdoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$0.86	$1.08	$0.48	-
EL2	2	$0.94	$1.24	$0.48	-
EL3	-	$1.30	$0.19	$4.24	$3.53
EL4	3, 4, 5	$1.46	$0.19	$4.24	$3.78

Table 13.4.37 Product and Capital Conversion Costs for 250 W Outdoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$1.31	$1.40	$0.40	-
EL2	2, 3, 4	$1.48	$2.39	$0.40	-
EL3	-	$2.20	$0.19	$5.69	$6.43
EL4	5	$2.77	$0.19	$9.39	$11.77

Table 13.4.38 Product and Capital Conversion Costs for 400 W Outdoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
EL1	1	$1.75	$1.64	$0.65	-
EL2	2, 3, 4	$1.88	$2.62	$0.65	-
EL3	-	$2.90	$0.19	$13.70	$13.9
EL4	5	$3.66	$0.19	$18.82	$21.5

Table 13.4.39 Product and Capital Conversion Costs for 1000 W Outdoor Ballasts and Fixtures

EL	TSL	Ballast Product Conversion Costs 2012$ millions	Ballast Capital Conversion Costs 2012$ millions	Fixture Product Conversion Costs 2012$ millions	Fixture Capital Conversion Costs 2012$ millions
Baseline + DS	-	$0.09	-	$0.03	-
EL1	-	$1.22	$1.17	$0.17	-
EL1+ DS	1	$1.44	$1.17	$0.17	-
EL2	-	$2.91	$4.08	$0.17	-
EL2+ DS	2, 3, 4, 5	$3.11	$4.35	$0.17	-

13.4.9 Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of new and amended energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all equipment classes. In the standards case, DOE modeled two markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of new and amended energy conservation standards: (1) a flat markup scenario, and (2) a 'preservation of operating profit' markup scenario. These scenarios lead to different markup values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

13.4.9.1 Flat Markup Scenario

The flat markup scenario assumes that the cost of goods sold for each product is marked up by a flat percentage to cover SG&A expenses, R&D expenses, and profit. The flat markup scenario uses the baseline manufacturer markup (1.47 for ballasts and 1.58 for fixtures, as discussed in chapter 5 of the TSD) for all equipment classes in both the base case and the standards case. This scenario represents the upper bound of industry profitability in the standards case because it is designed so that manufacturers can fully pass through additional costs due to standards to their customers. To derive the flat markup percentage, DOE evaluated publicly available financial information for manufacturers of metal halide ballasts or fixtures. DOE also requested feedback on this value during manufacturer interviews before arriving at the final values use in the analysis.

13.4.9.2 Preservation of Operating Profit Markup Scenario

During interviews, manufacturers expressed skepticism that they would be able to mark up higher equipment costs in the standards case to the same degree as in the base case. In recognition of this concern, DOE also modeled a scenario called the 'preservation of operating profit' markup scenario. In this scenario, markups in the standards case are lowered such that manufacturers are only able to maintain their total base case operating profit in absolute dollars, despite higher product costs and investment. This scenario represents the lower bound of industry profitability following new and amended energy conservation standards because the resulting higher production costs and investments do not yield any additional operating profit.

DOE implemented this scenario in the GRIM by lowering the manufacturer markups at each TSL to yield approximately the same earnings before interest and taxes in the standards case in 2017, as in the base case.

Table 13.4.40 through Table 13.4.59 lists equipment classes DOE analyzed with the corresponding markups at each TSL under the 'preservation of operating profit' markup scenario. The markups are presented with the low-shipment scenario, as this combination represents the lower bound for industry impacts. It is worth noting that in cases where the average MPC decreases at a higher efficiency level, this scenario yields a higher markup at the new baseline than in the base case.

Table 13.4.40 Preservation of Operating Profit Markups for 70 W Indoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.4700				
1.4700	1.4700			
1.4700	1.4700	1.4700		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4393

Table 13.4.41 Preservation of Operating Profit Markups for 150 W Indoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2	-	TSL 3, 4, 5
1.4700				
1.4700	1.4404			
1.4700	1.4700	1.4293		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4258

Table 13.4.42 Preservation of Operating Profit Markups for 250 W Indoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.4700				
1.4700	1.4372			
1.4700	1.4700	1.4204		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4147

Table 13.4.43 Preservation of Operating Profit Markups for 400 W Indoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.4700				
1.4700	1.4188			
1.4700	1.4700	1.4011		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.3668

Table 13.4.44 Preservation of Operating Profit Markups for 1000 W Indoor Ballasts

Markups by EL					
Baseline	**Baseline +DS**	**EL1**	**EL1 +DS**	**EL2**	**EL2 +DS**
-	-	-	TSL 1	-	TSL 2, 3, 4, 5
1.4700					
1.4700	1.4700				
1.4700	1.4700	1.4700			
1.4700	1.4700	1.4700	1.4027		
1.4700	1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4700	1.3983

Table 13.4.45 Preservation of Operating Profit Markups for 70 W Outdoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3	TSL 4	TSL 5
1.4700				
1.4700	1.4676			
1.4700	1.4700	1.4327		
1.4700	1.4700	1.4700	1.4471	
1.4700	1.4700	1.4700	1.4700	1.4186

Table 13.4.46 Preservation of Operating Profit Markups for 150 W Outdoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2	-	TSL 3, 4, 5
1.4700				
1.4700	1.4404			
1.4700	1.4700	1.4293		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4281

Table 13.4.47 Preservation of Operating Profit Markups for 250 W Outdoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.4700				
1.4700	1.4391			
1.4700	1.4700	1.4221		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4093

Table 13.4.48 Preservation of Operating Profit Markups for 400 W Outdoor Ballasts

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.4700				
1.4700	1.4184			
1.4700	1.4700	1.4008		
1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.3548

Table 13.4.49 Preservation of Operating Profit Markups for 1000 W Outdoor Ballasts

Markups by EL					
Baseline	**Baseline +DS**	**EL1**	**EL1 +DS**	**EL2**	**EL2 +DS**
-	-	-	TSL 1	-	TSL 2, 3, 4, 5
1.4700					
1.4700	1.4700				
1.4700	1.4700	1.4700			
1.4700	1.4700	1.4700	1.4023		
1.4700	1.4700	1.4700	1.4700	1.4700	
1.4700	1.4700	1.4700	1.4700	1.4700	1.3964

Table 13.4.50 Preservation of Operating Profit Markups for 70 W Indoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.5800				
1.5800	1.5800			
1.5800	1.5800	1.5800		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5681

Table 13.4.51 Preservation of Operating Profit Markups for 150 W Indoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2	-	TSL 3, 4, 5
1.5800				
1.5800	1.5698			
1.5800	1.5800	1.5655		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5465

Table 13.4.52 Preservation of Operating Profit Markups for 250 W Indoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.5800				
1.5800	1.5692			
1.5800	1.5800	1.5628		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5440

Table 13.4.53 Preservation of Operating Profit Markups for 400 W Indoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.5800				
1.5800	1.5662			
1.5800	1.5800	1.5600		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5274

Table 13.4.54 Preservation of Operating Profit Markups for 1000 W Indoor Fixtures

Markups by EL					
Baseline	**Baseline +DS**	**EL1**	**EL1 +DS**	**EL2**	**EL2 +DS**
-	-	-	TSL 1	-	TSL 2, 3, 4, 5
1.5800					
1.5800	1.5800				
1.5800	1.5800	1.5800			
1.5800	1.5800	1.5800	1.5659		
1.5800	1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5800	1.5642

Table 13.4.55 Preservation of Operating Profit Markups for 70 W Outdoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3	TSL 4	TSL 5
1.5800				
1.5800	1.5792			
1.5800	1.5800	1.5663		
1.5800	1.5800	1.5800	1.4770	
1.5800	1.5800	1.5800	1.5800	1.4761

Table 13.4.56 Preservation of Operating Profit Markups for 150 W Outdoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2	-	TSL 3, 4, 5
1.5800				
1.5800	1.5698			
1.5800	1.5800	1.5655		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.4976

Table 13.4.57 Preservation of Operating Profit Markups for 250 W Outdoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.5800				
1.5800	1.5698			
1.5800	1.5800	1.5634		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5041

Table 13.4.58 Preservation of Operating Profit Markups for 400 W Outdoor Fixtures

Markups by EL				
Baseline	**EL1**	**EL2**	**EL3**	**EL4**
-	TSL 1	TSL 2, 3, 4	-	TSL 5
1.5800				
1.5800	1.5661			
1.5800	1.5800	1.5599		
1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.4968

Table 13.4.59 Preservation of Operating Profit Markups for 1000 W Outdoor Fixtures

Markups by EL					
Baseline	**Baseline +DS**	**EL1**	**EL1 +DS**	**EL2**	**EL2 +DS**
-	-	-	TSL 1	-	TSL 2, 3, 4, 5
1.5800					
1.5800	1.5800				
1.5800	1.5800	1.5800			
1.5800	1.5800	1.5800	1.5658		
1.5800	1.5800	1.5800	1.5800	1.5800	
1.5800	1.5800	1.5800	1.5800	1.5800	1.5637

13.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the metal halide ballast and fixture industries. The following sections detail additional inputs and assumptions for metal halide ballasts and fixtures. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

13.5.1 Impacts on Industry Net Present Value

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's net present value, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The metal halide ballast and fixture GRIM estimates cash flows from 2013 to 2045. This timeframe models both the short-term impacts on the industry and a long-term assessment over the 30-year analysis period used in the NIA (2016 – 2045).

In the MIA, DOE compares the INPV of the base case (no new and amended energy conservation standards) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the metal halide ballast and fixture industries, DOE examined the two markup scenarios described above: the flat markup and the 'preservation of operating profit' markup. DOE also examined the high and low-shipment scenarios. This yields four sets of INPV results, bounded by the flat markup and high-shipments combination and the 'preservation of operating profit' markup and low-shipments combination. Table 13.5.1 through Table 13.5.4 provide the INPV estimates for the metal halide ballast and fixture industries.

Table 13.5.1 Changes in Industry Net Present Value for Metal Halide Ballasts (Flat Markup and High-Shipment Scenarios)

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	(2012$ millions)	123	123	126	127	127	159
Change in INPV	(2012$ millions)		0.8	3.3	4.5	4.7	36.5
	(%)		0.7	2.7	3.7	3.8	29.8

*For tables in section 13.5.1, values in parenthesis indicate negative numbers

Table 13.5.2 Changes in Industry Net Present Value for Metal Halide Ballasts (Preservation of Operating Profit Markup and Low-Shipment Scenarios)

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	(2012$ millions)	103	86	77	77	79	79
Change in INPV	(2011$ millions)		(17.1)	(26.8)	(25.9)	(24.8)	(24.1)
	(%)		-16.6%	-25.9	-25.0	-24.0	-23.3

Table 13.5.3 Changes in Industry Net Present Value for Metal Halide Lamp Fixtures (Flat Markup and High-Shipment Scenarios)

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	(2012$ millions)	630	667	694	695	703	741
Change in INPV	(2012$ millions)		37.0	63.9	64.8	73.6	111.3
	(%)		5.9%	10.2	10.3	11.7	17.7

Table 13.5.4 Changes in Industry Net Present Value for Metal Halide Lamp Fixtures (Preservation of Operating Profit Markup and Low-Shipment Scenarios)

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	(2012$ millions)	540	534	532	523	516	423
Change in INPV	(2012$ millions)		(6.1)	(8.1)	(17.3)	(23.8)	(116.9)
	(%)		-1.1%	-1.5	-3.2	-4.4	-21.6

13.5.2 Impacts on Annual Cash Flow

While INPV is useful for evaluating the long-term effects of new and amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture.

Annual cash flows are discounted to 2012 dollars. Between 2013 and 2016, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standards announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new and amended energy conservation standards. The more stringent the new and amended energy conservation standards, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in 2016 is driven by two competing factors. In addition to capital and product conversion costs, new and amended energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standards had not made them obsolete. In 2016, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the new and amended energy conservation standards. This one-time write-down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In 2016, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in 2016.

In the years after 2016, the impact on cash flow depends on the operating revenue. There is very little impact on cash flow from operations under the ‘preservation of operating profit’ scenario because this scenario is calibrated to have the same operating income in the standards case at each TSL as the base case in 2017. In this scenario, the industry value is impacted because production costs increase, but operating profit remains approximately equal to the base case which decreases profit margins as a percentage of revenue.

Figure 13.5.1 through Figure 13.5.4 present the annual net cash flows for the metal halide ballast and fixture industries.

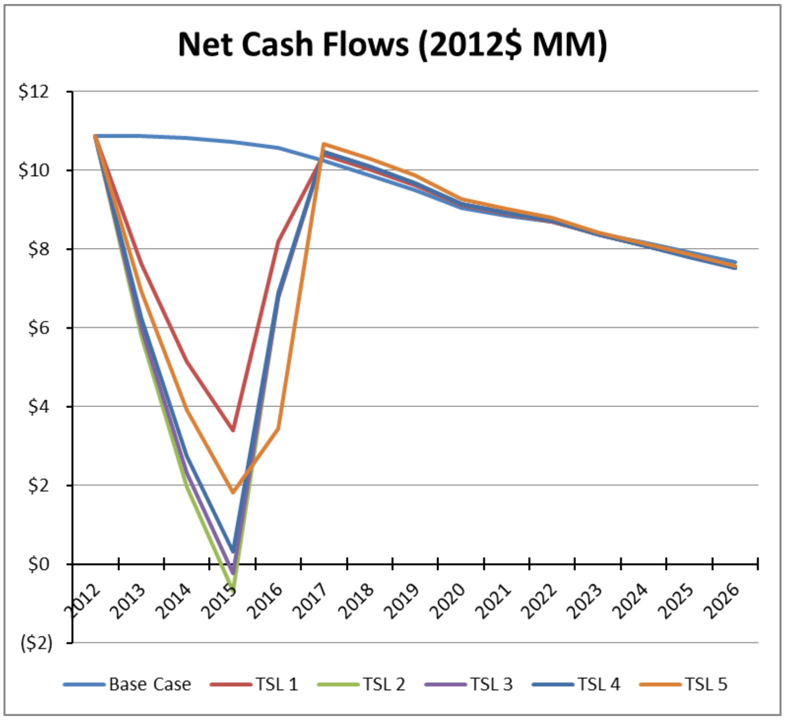

Figure 13.5.1 Annual Metal Halide Ballast Industry Net Cash Flows (Flat Markup and High-Shipment Scenarios)

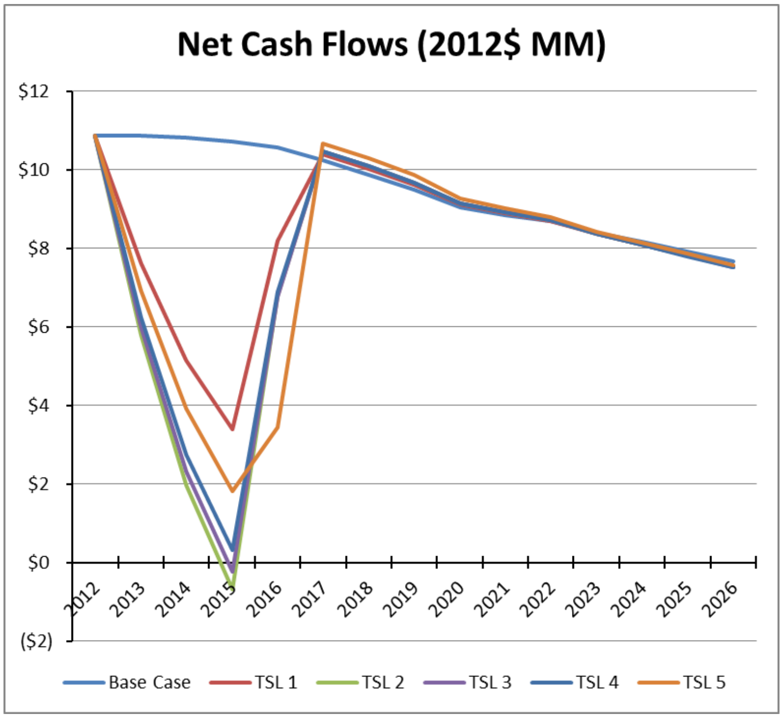

Figure 13.5.2 Annual Metal Halide Ballast Industry Net Cash Flows (Preservation of Operating Profit Markup and Low-Shipment Scenarios)

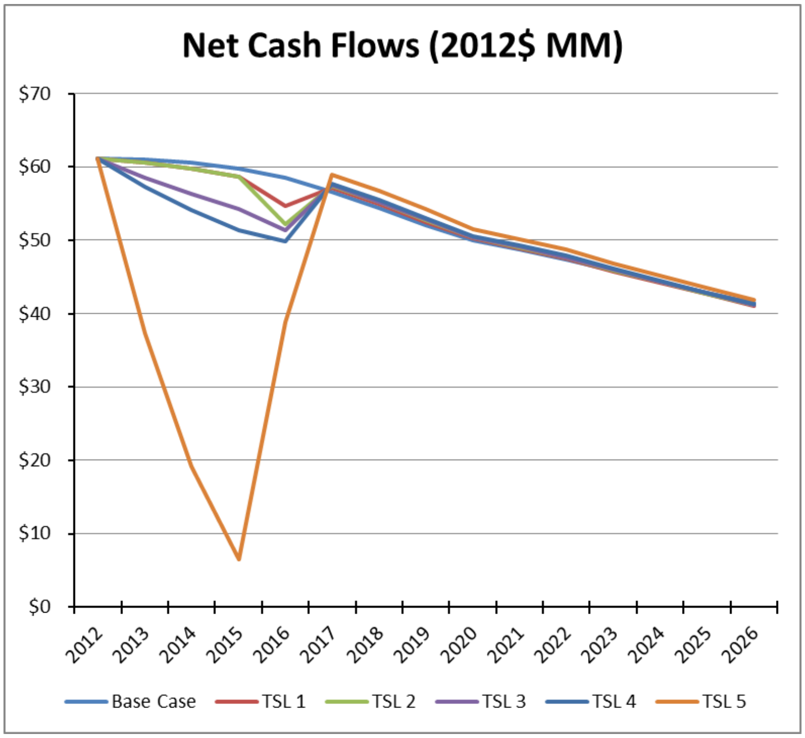

Figure 13.5.3 Annual Metal Halide Fixture Industry Net Cash Flows (Flat Markup and High-Shipment Scenarios)

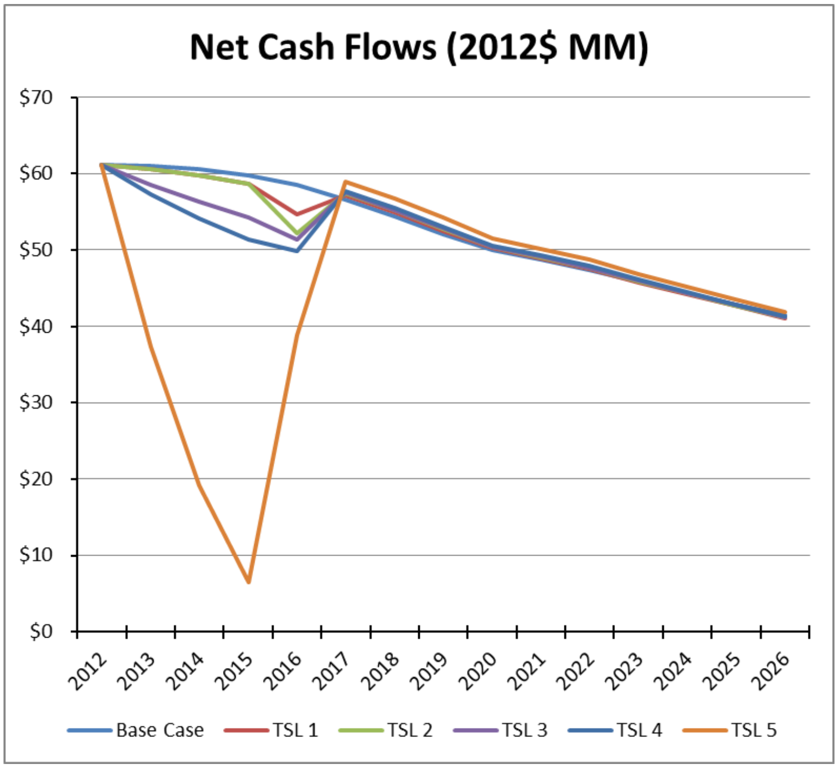

Figure 13.5.4 Annual Metal Halide Fixture Industry Net Cash Flows (Preservation of Operating Profit Markup and Low-Shipment Scenarios)

13.6 IMPACTS ON MANUFACTURER SUBGROUPS

As described in section 13.2.3.3 above, DOE identified one subgroup of metal halide ballast and fixture manufacturers: small business manufacturers. The results of this subgroup analysis are described below.

13.6.1 Impacts on Small Business Manufacturers

13.6.1.1 Description and Estimated Number of Small Entities Regulated

For manufacturers of metal halide ballasts and metal halide lamp fixtures, the Small Business Administration (SBA) has set a size threshold which defines those entities classified as "small businesses" for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. (65 FR 30836, 30850 (May 15, 2000), as amended at 65 FR 53533, 53545 (Sept. 5, 2000) and codified at 13 CFR part 121) The size standards are listed by North American Industry Classification System (NAICS) code and industry description and are available at http://www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf. Metal halide ballast manufacturing is classified under NAICS 335311, "Power, Distribution and Specialty Transformer Manufacturing." The SBA sets a threshold of 750 employees or less for an entity to be considered as a small business for this category. Metal halide lamp fixture manufacturing is classified under NAICS 335122, "Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing." The SBA sets a threshold of 500 employees or less for an entity to be considered as a small business for this category.

To estimate the number of companies that could be small business manufacturers of equipment covered by this rulemaking, DOE conducted a market survey using all available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (including NEMA), individual company websites, and market research tools (e.g., Dun and Bradstreet reports and Hoovers reports) to create a list of every company that manufactures or sells metal halide ballasts or fixtures covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE contacted companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered equipment. DOE screened out companies that did not offer equipment covered by this rulemaking, did not meet the definition of a "small business," or were foreign owned and operated.

DOE initially identified at least 25 potential manufacturers of metal halide ballasts sold in the U.S. DOE reviewed publicly available information on these 25 potential manufacturers and determined that 13 were either large manufacturers, manufacturers that were foreign owned and operated, or did not manufacture ballasts covered by this rulemaking. DOE then attempted to contact the remaining 12 companies that were potential small business manufacturers. DOE was able to determine that five companies meet the SBA's definition of a small business and likely manufacture ballasts covered by this rulemaking.

For metal halide lamp fixtures sold in the U.S., DOE initially identified at least 134 potential manufacturers. DOE reviewed publicly available information on these 134 potential manufacturers and determined that 66 were large manufacturers, manufacturers that were foreign owned and operated, or did not sell fixtures covered by this rulemaking. DOE then attempted to contact the remaining 68 companies that were potential small business manufacturers. Though many companies were unresponsive, DOE was able to determine that approximately 54 meet the SBA's definition of a small business and likely manufacture fixtures covered by this rulemaking.

Before issuing this NOPR, DOE attempted to contact the small business manufacturers of metal halide ballasts and fixtures it had identified. One small ballast manufacturer and two small fixture manufacturers consented to being interviewed. DOE also obtained information about small business impacts while interviewing large manufacturers.

Ballasts. Five major ballast manufacturers with limited domestic production supply the vast majority of the metal halide ballast market. None of the five major manufacturers is a small business. The remaining market share is held by a few smaller domestic companies, only one of which has significant market share. Nearly all metal halide ballast production occurs abroad.

The five large ballast manufacturers typically offer a much wider range of designs of metal halide ballasts than small manufacturers. Ballasts can vary by start method, input voltage, wattage, and ballast design. Often large ballast manufacturers will offer several different ballast options for each lamp wattage. Small manufacturers generally specialize in manufacturing only a handful of different ballast types and do not have the volume to support as wide a range of products as large manufacturers. Three of the five small ballast manufacturers specialize in high efficiency electronic ballasts and do not offer any magnetic ballasts. Some small ballast manufacturers offer a wide variety of lighting products, but others focus exclusively on metal halide ballasts.

Fixtures. The majority of the metal halide lamp fixture market is supplied by six major manufacturers with sizeable domestic production. None of these major manufacturers is a small business. The remaining market share is held by several smaller domestic and foreign manufacturers. Most of the small domestic manufacturers produce fixtures in the U.S. Although none of the small businesses holds a significant market share individually, collectively these small businesses account for a third of the market. See chapter 3 of the TSD for further details on the metal halide ballast and fixture markets.

The six large fixture manufacturers typically serve large-scale commercial lighting markets, while small fixture manufacturers tend to operate in niche lighting markets such as architectural and designer lighting. Small fixture manufacturers also frequently fill custom orders that are much smaller in volume than large fixture manufacturers' typical orders. Because small manufacturers typically offer specialized products and cater to individual customers' needs, they can command higher markups than most large manufacturers. Like large ballast manufacturers, large fixture manufacturers offer a wider range of metal halide lamp fixtures than small fixture manufacturers. A small fixture manufacturer may offer fewer than 50 models while a large manufacturer may typically offer several hundred models. Almost all small fixture manufacturers offer a variety of lighting products in addition to those covered by this rulemaking, such as fluorescent, incandescent, and LED fixtures.

13.6.1.2 Description and Estimate of Compliance Requirements

Ballasts. Because three of the five small ballast manufacturers offer only electronic ballasts that already meet the standards at TSL 3, the level proposed in today's notice, DOE does not expect any product or capital conversion costs for these small ballast manufacturers. The fourth small ballast manufacturer offers a wide range of magnetic and electronic ballasts, so DOE does not expect this manufacturer's conversion costs to differ significantly from those of the large manufacturers. The fifth small ballast manufacturer currently offers a large variety of lighting products but only two models of metal halide ballasts. Because it would likely invest in other parts of its business, this manufacturer stated to DOE that this rulemaking is unlikely to significantly affect it.

Fixtures. As stated above, DOE identified approximately 54 small fixture businesses affected by this rulemaking. Based on interviews with two of these manufacturers and examinations of product offerings on company websites, DOE believes that approximately one-fourth of these small businesses will not face any conversion costs because they offer very few metal halide lamp fixture models and would therefore focus on more substantial areas of their business. Of the remaining small businesses DOE identified, nearly two-thirds primarily serve the architectural or specialty lighting markets. Because these products command higher prices and margins compared to the typical product offered by a large manufacturer, DOE believes that these small fixture manufacturers will be able to pass on any necessary conversion costs to their customers without significantly impacting their businesses.

The remaining small fixture manufacturers (roughly 14 in number) could be differentially impacted by today's proposed standards. These manufacturers operate partially in industrial and commoditized markets in which it may be more difficult to pass on any disproportionate costs to their consumers. The impacts could be relatively greater for a typical small manufacturer because of the far lower production volumes and the relatively fixed nature of the R&D and capital resources required per fixture family.

Based on interviews, however, DOE anticipates that small manufacturers would take steps to mitigate the costs required to meet new and amended energy conservation standards. At TSL 3, DOE believes that under the proposed standards small fixture businesses would likely selectively upgrade existing product lines to offer products that are in high demand or offer strategic advantage. Small manufacturers could then spread out further investments over a longer time period by not upgrading all product lines prior to the compliance date.

13.7 OTHER IMPACTS

13.7.1 Employment

DOE assessed the impacts of potential new and amended energy conservation standards on direct employment in the sections that follow. Because of the limited number of estimated domestic production workers for metal halide ballasts, employment impacts on ballast manufacturers are described qualitatively, whereas a full quantitative assessment was performed for metal halide lamp fixtures.

13.7.1.1 Employment Impacts for Metal Halide Ballasts

Based on the U.S. Census Bureau's 2009 Annual Survey of Manufacturers (ASM) and interviews with manufacturers, DOE estimates that less than 40 domestic production workers would be involved in manufacturing metal halide ballasts in 2016, as the vast majority of metal halide ballasts are manufactured abroad. DOE's view is that manufacturers could face moderate positive impacts on domestic employment levels because increasing equipment costs at each TSL would result in higher labor expenditures per unit, causing manufacturers to hire more workers to meet demand for metal halide ballasts, assuming that production remains in domestic facilities. Many manufacturers, however, do not expect a significant change in total employment at their facilities. Although manufacturers are concerned that higher prices for metal halide ballasts will drive consumers to alternate technologies, most manufacturers offer these alternate technologies and can shift their employees from metal halide ballast production to production of other technologies in their facilities. Most manufacturers believe that domestic employment will only be significantly adversely affected if consumers shift to foreign imports, causing the total lighting market share of the major domestic manufacturers to decrease.

13.7.1.2 Employment Impacts for Metal Halide Lamp Fixtures

DOE quantitatively assessed the impacts of potential new and amended energy conservation standards on direct employment for metal halide lamp fixtures. DOE used the GRIM to estimate the domestic labor expenditures and number of domestic production workers in the base case and at each TSL from 2013 to 2045. DOE used statistical data from the 2009 ASM, the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures involved with the manufacture of the product are a function of the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time.

In the GRIM, DOE used the labor content of each product and the manufacturing production costs to estimate the annual labor expenditures in the industry. DOE used Census data and interviews with manufacturers to estimate the portion of the total labor expenditures that is attributable to domestic labor.

The production worker estimates in this section cover only workers up to the line-supervisor level who are directly involved in fabricating and assembling a product within an original equipment manufacturer (OEM) facility. Workers performing services that are closely associated with production operations, such as material handing with a forklift, are also included as production labor. DOE's estimates account for only production workers who manufacture the specific products covered by this rulemaking. For example, a worker on a fluorescent lamp ballast line would not be included with the estimate of the number of metal halide ballast or fixture workers.

The employment impacts shown in the tables below represent the potential production employment that could result following new and amended energy conservation standards. The upper bound of the results estimates the maximum change in the number of production workers that could occur after compliance with new and amended energy conservation standards when assuming that manufacturers continue to produce the same scope of covered products in the same production facilities. It also assumes that domestic production does not shift to lower-labor-cost countries. Because there is a real risk of manufacturers evaluating sourcing decisions in response to new and amended energy conservation standards, the lower bound of the employment results includes the estimated total number of U.S. production workers in the industry who could lose their jobs if all existing production were moved outside of the U.S. While the results present a range of employment impacts following 2016, the discussion below also includes a qualitative discussion of the likelihood of negative employment impacts at the various TSLs. Finally, the employment impacts shown are independent of the employment impacts from the broader U.S. economy, which are documented in chapter 14 of the TSD.

Using 2009 ASM data and interviews with manufacturers, DOE estimates that approximately 60 percent of the metal halide lamp fixtures sold in the United States are manufactured domestically. With this assumption, DOE estimates that in the absence of new and amended energy conservation standards, there would be between 519 and 525 domestic production workers involved in manufacturing metal halide lamp fixtures in 2016. The tables below show the range of the impacts of potential new and amended energy conservation standards on U.S. production workers in the metal halide lamp fixture industry.

Table 13.7.1 Potential Changes in the Total Number of Domestic Metal Halide Lamp Fixture Production Workers in 2016 (Flat Markup and High-Shipment Scenario)

	Base Case	Trial Standard Level				
		1	2	3	4	5
Total Number of Domestic Production Workers in 2016 (without changes in production locations)	525	588	626	625	630	684
Potential Changes in Domestic Production Workers in 2016*	-	63 - (525)	101 - (525)	100 - (525)	105 - (525)	159 - (525)

* DOE presents a range of potential employment impacts. Numbers in parentheses indicate negative numbers

Table 13.7.2 Potential Changes in the Total Number of Domestic Metal Halide Lamp Fixture Production Workers in 2016 (Preservation of Operating Profit Markup and Low-Shipment Scenario)

	Base Case	Trial Standard Level				
		1	2	3	4	5
Total Number of Domestic Production Workers in 2016 (without changes in production locations)	519	581	619	618	623	676
Potential Changes in Domestic Production Workers in 2016	-	62 - (519)	100 - (519)	99 - (519)	104 - (519)	157 - (519)

At the upper end of the range, all examined TSLs show slight to moderate positive impacts on domestic employment levels. The increased equipment cost at each TSL would result in higher labor expenditures per unit, causing manufacturers to hire more workers to meet demand levels of metal halide lamp fixtures, assuming that production remains in domestic facilities. Many manufacturers, however, do not expect a significant change in total employment at their facilities. Although manufacturers are concerned that higher prices for metal halide fixtures will drive consumers to alternate technologies, most manufacturers offer these alternate technologies and can shift their employees from metal halide lamp fixture production to production of other technologies in their facilities. As with ballasts manufacturers, most fixture manufacturers believe that domestic employment will only be significantly adversely affected if consumers shift to foreign imports, causing the total lighting market share of the major domestic manufacturers to decrease. Because of the potentially high cost of shipping fixtures from overseas, many manufacturers believe this shift is unlikely occur. This is particularly true for the significant portion of the market served by small manufacturers for whom the per-unit shipping costs of sourcing products would be even greater because of the lower volumes.

Based on the above, DOE does not expect the proposed energy conservation standards for the metal halide lamp fixtures, at TSL 3, to have a significant negative impact on direct domestic employment levels. DOE notes that domestic employment levels could be negatively affected in the event that small fixture businesses choose to exit the market due to standards. However, discussions with small manufacturers indicated that most small businesses will be able to adapt to new and amended regulations.

13.7.2 Production Capacity

Both ballast and fixture manufacturers stated that they do not anticipate any capacity constraints at efficiency levels that can be met with magnetic ballasts, which are the efficiency levels being proposed for eight of the 10 equipment classes in the NOPR, the two exceptions are the 150W indoor and outdoor equipment classes. If the production of higher efficiency magnetic ballasts decreases the throughput on production lines, manufacturers stated that they would be able to add shifts on existing lines and maintain capacity.

At efficiency levels that require electronic ballasts, however, manufacturers are concerned about the current worldwide shortage of electrical components. The components most affected by this shortage are high-efficiency parts, for which demand would increase even further following new and amended conservation standards. The increased demand could exacerbate the component shortage, thereby impacting manufacturing capacity in the near term, according to manufacturers. The only equipment classes requiring electronic ballasts that are being proposed in the NOPR are the 150W indoor and outdoor equipment classes. DOE does not anticipate a significant increase in demand for electronic components due to today's proposed energy conservation standards. While DOE recognizes that the premium component shortage is currently a significant issue for manufacturers, DOE views it as a relatively short term phenomenon to which component suppliers will ultimately adjust. According to several manufacturers, suppliers have the ability to ramp up production to meet ballast component demand, but those suppliers have hesitated to invest in additional capacity due to economic uncertainty and skepticism about the sustainability of demand. The state of the macroeconomic environment from now until after the compliance date will likely affect the duration of the premium component shortage. Potential mandatory standards, however, could create more certainty for suppliers about the eventual demand for these components. Additionally, the premium components at issue are not new technologies; rather, they have simply not historically been demanded in large quantities by ballast manufacturers.

13.7.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. For the cumulative regulatory burden analysis, DOE looks at other significant product-specific regulations that could affect metal halide ballast and fixture manufacturers that will take effect approximately 3 years prior to and 3 years after the compliance date of new and amended energy conservation standards for these products. In addition to the new and amended energy conservation regulations on metal halide lamp ballasts and fixtures, several other Federal regulations apply to these products and other equipment produced by the same manufacturers. While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, DOE also has described a number of other regulations in section 13.7.3.2 because it recognizes that these regulations also impact the products covered by this rulemaking.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be disproportionately affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new and amended regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

13.7.3.1 DOE Regulations for Other Products Produced by Metal Halide Lamp Ballast and Fixture Manufacturers

In addition to the new and amended energy conservation standards on metal halide lamp ballasts and fixtures, several other Federal regulations and pending regulations apply to other products produced by the same manufacturers. DOE recognizes that each regulation can significantly affect a manufacturer’s financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers’ profits and possibly cause an exit from the market. Table 13.7.3 lists the other DOE energy conservation standards that could also affect manufacturers of metal halide lamp ballasts and fixtures that are scheduled or estimated to go into effect between 2012 and 2018.

Table 13.7.3 Other DOE and Federal Actions Affecting the Metal Halide Ballast and Fixture Industries

Regulation	Approximate Compliance Date	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Total Industry Conversion Costs
Commercial Packaged Boilers	2012	0	N/A††
Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps	2012	1	$17.3 million (2007$)[b]
Cooking Products	2012	1	$22.6 million (2006$)[c]
Residential Boilers	2012	0	N/A†
General Service Fluorescent Lamps and Incandescent Reflector Lamps	2012	3	$363.1 million (2008$)[d]
Dehumidifiers	2012	1	N/A†
Refrigerated Beverage Vending Machines	2012	0	$14.5 million (2008$)[e]
Variable Refrigerant Flow Equipment	2012 & 2013	0	N/A††
Computer Room Air Conditioners	2012 & 2013	0	N/A††

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[b] Estimated industry conversion expenses were published in the TSD for the October 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule. 73 FR 58772 The TSD for the 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ptacs_pthps_final_tsd.html.

[c] Estimated industry conversion expenses were published in the TSD for the April 2009 residential cooking products final rule. 74 FR 16040 The TSD for the 2009 residential cooking products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/cooking_products_final_rule_tsd.html.

[d] Estimated industry conversion expenses were published in the TSD for the July 2009 general service fluorescent lamps and incandescent reflector lamps final rule. 74 FR 34080 The TSD for the 2009 lamps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule_tsd.html.

[e] Estimated industry conversion expenses were published in the TSD for the August 2009 refrigerated beverage vending machines final rule. 74FR44914 The TSD for the 2009 refrigerated beverage vending machines final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines_final_rule_tsd.html.

Commercial Clothes Washers	2013	1	$20.4 million (2008$)[f]
Residential Pool Heaters	2013	0	$0.3 million (2009$)[g]
Dishwashers	2013	1	$94.0 million (2010$)[h]
Battery Chargers and External Power Supplies	2013*	1	N/A**
Commercial Package Air-Conditioning and Heating Equipment	2013 & 2014	0	N/A††
Residential Furnaces & Residential Central Air Conditioners and Heat Pumps	2013 & 2015	0	$46 million (2009$)[i]
Direct Heating Equipment	2013 & 2015	1	$5.39 million (2009$)[j]
Residential Refrigerators and Freezers	2014	1	$1,243 million (2009$)[k]
Room Air Conditioners	2014	1	$171 million (2009$)[l]

[f] Estimated industry conversion expenses were published in the TSD for the January 2010 commercial clothes washers final rule. 75 FR 1122 The TSD for the 2010 commercial clothes washers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_ecs_final_rule_tsd.html.

[g] Estimated industry conversion expenses were published in the TSD for the April 2010 residential pool heaters final rule. 75 FR 20112 The TSD for the 2010 residential pool heaters final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

[h] Estimated industry conversion expenses were published in the TSD for the May 2012 dishwashers direct final rule. 77 FR 31918 The TSD for the 2012 dishwashers direct final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/dw_direct_final_rule_tsd.html.

[i] Estimated industry conversion expenses were published in the TSD for the June 2011 residential furnaces and residential central air conditioners and heat pumps direct final rule. 76 FR 37408 The TSD for the 2011 residential furnaces and residential central air conditioners and heat pumps direct final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

[j] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112 The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

[k] Estimated industry conversion expenses were published in the TSD for the September 2011 residential refrigerators and freezers final rule. 76 FR 57516 The TSD for the 2011 residential refrigerators and freezers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

[l] Estimated industry conversion expenses were published in the TSD for the April 2011 room air conditioners and clothes dryers final rule. 76 FR 22454 The TSD for the 2011 room air conditioners and clothes dryers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_clothes_dryers_room_ac_direct_final_rule_tsd.html.

Fluorescent Lamp Ballasts	2014	13	$82 million (2010$)[m]
Microwave Ovens	2014*	2	N/A[**]
ER, BR, and Small Diameter IRLs	2014*	3	N/A[**]
Small Electric Motors	2015	2	$51.2 million (2009$)[n]
Residential Water Heaters	2015	1	$95.9 million (2009$)[o]
Residential Clothes Dryers	2015	1	$95 million (2009$)[p]
Walk-In Freezers and Coolers	2015*	0	N/A[**]
Metal Halide Lamp Fixtures	2015*	3	N/A[**]
Commercial Electric Motors	2015*	1	N/A[**]
Residential Clothes Washers	2015 & 2018	1	$418.5 million (2010$)[q]
Commercial Distribution Transformers	2016*	4	N/A[**]
Commercial Refrigeration Equipment	2016*	0	N/A[**]
Furnace Fans	2016*	1	N/A[**]
HID Lamps	2017*	6	N/A[**]

* The dates listed are an approximation. The exact dates are pending final DOE action.

** For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.

† For minimum performance requirements prescribed by the Energy Independence and Security Act of 2007 (EISA 2007), DOE did not estimate total industry conversion costs because an MIA was not completed as part of a rulemaking. Pub. L. 110-140. EISA 2007 made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment.

[m] Estimated industry conversion expenses were published in the TSD for the November 2011 fluorescent lamp ballast final rule. 76 FR 70548 The TSD for the 2011 fluorescent lamp ballast final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/flb_ecs_finalrule_tsd.pdf.

[n] Estimated industry conversion expenses were published in the TSD for the March 2010 small motors final rule. 75 FR 10874 The TSD for the 2010 small motors final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/sem_finalrule_tsd.html.

[o] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112 The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

[p] Estimated industry conversion expenses were published in the TSD for the April 2011 room air conditioners and clothes dryers final rule. 76 FR 22454 The TSD for the 2011 room air conditioners and clothes dryers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_clothes_dryers_room_ac_direct_final_rule_tsd.html.

[q] Estimated industry conversion expenses were published in the TSD for the May 2012 residential clothes washers direct final rule. 77 FR 32308 The TSD for the 2012 residential clothes washers direct final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/rcw_direct_final_rule_tsd.html.

†† For certain ASHRAE products a complete MIA was not conducted. Therefore there are no estimated industry conversion costs for these rulemakings.

One regulation that could potentially have a significant impact on metal halide ballast and fixture manufacturers is an ongoing DOE standard for HID lamps. On July 1, 2010, DOE published a positive determination to establish coverage for HID lamps, including metal halide lamps. DOE is currently conducting rulemakings to establish a test procedure no later than January 1, 2013 and energy conservation standards no later than June 30, 2014. Many manufacturers of metal halide ballasts and fixtures also manufacture HID lamps and anticipated that this rulemaking could constitute a significant regulatory burden, depending on the stringency of standards set. DOE does not describe the quantitative impacts of standards that have not yet been finalized because any impacts would be speculative.

13.7.3.2 Other Regulations that Could Impact Metal Halide Ballast and Fixture Manufacturers

While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, in this section DOE has described a number of other regulations that could also impact the metal halide ballasts and fixtures covered by this rulemaking.

European Union Metal Halide Efficiency Standards.

The European Union Commission enacted Directive 2009/245/EC regarding the eco-design requirements for fluorescent lamps without integrated ballasts, for HID lamps, and for ballasts and luminaires able to operate such lamps. This directive sets a minimum lumens per watt efficiency metric for metal halide lamp fixtures and also sets a minimum ballast efficiency metric for metal halide ballasts. This directive was published in April 2010. The efficiency requirements for HID lamps are list in the table below.

Table 13.7.4 European Union HID Minimum Ballast Efficiency

Nominal Lamp Wattage (P) W	Minimum Ballast Efficiency %
$P \leq 30$	65
$30 < P \leq 75$	75
$75\ P \leq 105$	80
$105 < P \leq 405$	85
$P > 405$	90

These efficiency standards take effect three years after the implementing measure comes into force.

Optional Reporting Requirements

There are several optional reporting requirements that manufacturers have stated some or all of their products meet. These include ENERGY STAR certification, International Dark Sky certification, and several others.

Potential Congressional Outdoor Lighting Bill

Manufacturers have noted the possibility of an outdoor lighting bill being passed by Congress in the future. This bill could set an efficiency standard on the number of lumens per watt for outdoor lights, including metal halide lamps. DOE does not describe the quantitative impacts of regulations that have not yet been finalized because any impacts would be speculative.

Restriction of Hazardous Substances Directive

Metal halide ballasts and fixtures sold outside of the United States are subject to several international toxic materials regulations. In the EU, products are subject to the Restriction of Hazardous Substances Directive (RoHS). This regulation bans the sale of new equipment in the EU that contains more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and Polybrominated diphenyl ethers (PBDE) flame retardants. Although there is no Federal regulation on RoHS, California has passed SB 20: Electronic Waste Recycling Act of 2003. Under this law, California limits the amount of hazards substances included in the RoHS directive that can be sold in California. Most manufacturers stated the metal halide ballasts and fixtures they produce are already lead-free or were already planning on eliminating lead from their products.

13.8 CONCLUSION

The following sections summarize the impacts for the scenarios DOE believes are most likely to capture the range of impacts on metal halide ballast and fixture manufacturers as a result of new and amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances which cause manufacturers to experience impacts outside of this range.

13.8.1 Cash Flow Analysis Results For Metal Halide Lamp Ballasts

TSL 1 is EL1 for all ten equipment classes (the 70 W indoor and outdoor, 150 W indoor and outdoor, 250 W indoor and outdoor, 400 W indoor and outdoor, and 1000 W indoor and outdoor fixtures). At TSL 1, DOE estimates impacts on INPV range from $0.8 million to -$17.1 million, or a change in INPV of 0.7 percent to -16.6 percent. At TSL 1, industry free cash flow (operating cash flow minus capital expenditures) under the low-shipment scenario is estimated to decrease by approximately 68 percent to $3.4 million, compared to the base case value of $10.7 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 69 percent to $3.3 million, compared to the base case value of $10.6 million in 2015.

Impacts on INPV are slightly positive to moderately negative at TSL 1. TSL 1 requires the use of more efficient magnetic ballasts for the 70 W indoor and outdoor, 150 W indoor and outdoor, 250 W indoor and outdoor, 400 W indoor, and 1000 W indoor and outdoor equipment classes. DOE projects that in 2016 100 percent of 70 W indoor shipments, 5 percent of 150 W indoor shipments, 14 percent of 250 W indoor shipments, 23 percent of 400 W indoor shipments, 10 percent of 1000 W indoor shipments, 30 percent of 70 W outdoor shipments, zero percent of 150 W outdoor shipments, 10 percent of 250 W outdoor shipments, 10 percent of 400 W outdoor, and 6 percent of 1000 W outdoor shipments would meet TSL 1 or higher in the base case.

Conversion costs are expected to be moderate at TSL 1. DOE expects ballast manufacturers to incur $9 million in product conversion costs for model redesigns and testing and $10 million in capital conversion costs for equipment such as stamping dies to process more efficient steel cores.

At TSL 1, under the flat markup scenario the shipment-weighted average MPC increases by 25 percent relative to the base case MPC. Manufacturers are able to fully pass on this cost increase to customers under this scenario. Additionally, under the high-shipment scenario, shipments are 191 percent higher than shipments under the low-shipment scenario in the last year of the analysis period. Thus, manufacturers generate the most revenue under this combination (flat markup and high-shipment) of scenarios. The moderate price increase applied to a large quantity of shipments mitigates the impact of the $19 million in conversion costs estimated at TSL 1, resulting in slightly positive impacts at TSL 1 under the flat markup and high-shipment scenarios.

Under the ‘preservation of operating profit’ markup scenario, manufacturers earn the same operating profit as would be earned in the base case in 2017, but manufacturers do not earn additional profit from their investments. The 22 percent MPC increase is outweighed by a lower average markup of 1.44 in the ‘preservation of operating profit’ markup scenario (compared to the flat markup scenario markup of 1.47) and $19 million in conversion costs, resulting in greater negative impacts at TSL 1 under this scenario. On a percentage basis, the low-shipment scenario exacerbates these impacts relative to the high-shipment scenario because the base case INPV against which the absolute change in INPV is compared is 16 percent lower in the low shipment scenario compared to the high shipment scenario.

TSL 2 is EL2 for all ten equipment classes (the 70 W indoor and outdoor, 150 W indoor and outdoor, 250 W indoor and outdoor, 400 W indoor and outdoor, and 1000 W indoor and outdoor fixtures). At TSL 2, DOE estimates impacts on INPV to range from $3.3 million to -$26.8 million, or a change in INPV of 2.7 percent to -25.9 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 106 percent to -$0.7 million, compared to the base case value of $10.7 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 108 percent to -$0.8 million, compared to the base case value of $10.6 million in 2015.

TSL 2 is the highest efficiency level the engineering analysis assumes manufacturers can meet with magnetic ballasts for all equipment classes. DOE projects that in 2016, 100 percent of 70 W indoor shipments, 5 percent of 150 W indoor shipments, 10 percent of 250 W indoor, 15 percent of 400 W indoor, 5 percent of 1000 W indoor shipments, and 3 percent of 1000 W outdoor shipments would meet TSL 2 or higher in the base case. No shipments from the 70 W outdoor, 150 W outdoor, 250 W outdoor, and 400 W outdoor equipment classes would meet TSL 2 or higher in the base case. At TSL 2, product conversion costs rise to $12 million and capital conversion costs rise to $17 million as manufacturers need to purchase additional equipment and tooling to upgrade magnetic production lines.

At TSL 2, under the flat markup scenario the shipment-weighted average MPC increases 40 percent over the base case MPC. In this scenario INPV impacts are slightly positive because manufacturers' ability to pass on the higher equipment costs to customers outweighs the $30 million in conversion costs. Under the 'preservation of operating profit' markup scenario, the 35 percent MPC increase is outweighed by a lower average markup of 1.42 and $30 million in conversion costs, resulting in moderately negative INPV impacts at TSL 2.

TSL 3 includes, for the first time, EL4 for two equipment classes (the 150 W indoor and outdoor fixtures) and EL2 for the other eight equipment classes (the 70 W indoor and outdoor, 250 W indoor and outdoor, 400 W indoor and outdoor, and 1000 W indoor and outdoor fixtures). At TSL 3, DOE estimates impacts on INPV to range from $4.5 million to -$25.9 million, or a change in INPV of 3.7 percent to -25.0 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 102 percent to -$0.2 million, compared to the base case value of $10.7 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 104 percent to -$0.4 million, compared to the base case value of $10.6 million in 2015.

The technology changes from TSL 2 to TSL 3 are that manufacturers must use max-tech level electronic ballasts for the 150 W indoor and outdoor equipment classes at TSL 3. This has a negligible effect on total conversion costs, which slightly decreases to $29 million. DOE projects that no 150 W indoor or outdoor shipments would meet TSL 3 or higher in 2016 in the base case. DOE expects product conversion costs to increase slightly to $13 million and capital conversion costs to decrease slightly to $16 million.

At TSL 3, under the flat markup scenario the shipment-weighted average MPC increases 40 percent over the base case MPC. In this scenario the additional revenues earned from passing on these higher MPC costs outweigh the $29 million in conversion costs and higher working capital requirements, resulting in slightly positive INPV impacts. Under the 'preservation of operating profit' markup scenario, the 35 percent MPC increase is outweighed by a lower average markup of 1.42 and $29 million in conversion costs, resulting in INPV results remaining moderately negative at TSL 3.

TSL 4 is EL4 for two equipment classes (the 150 W indoor and outdoor fixtures), EL3 for one equipment class (the 70 W outdoor fixtures), and EL2 for the remaining seven equipment classes (the 70 W indoor fixtures, 250 W indoor and outdoor fixtures, 400 W indoor and outdoor fixtures, and 1000 W indoor and outdoor fixtures). At TSL 4, DOE estimates impacts on INPV to range from $4.7 million to -$24.8 million, or a change in INPV of 3.8 percent to -24.0 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 97 percent to $0.3 million, compared to the base case value of $10.7 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 98 percent to $0.2 million, compared to the base case value of $10.6 million in 2015.

The technology changes from TSL 3 to TSL 4 are that manufacturers must use electronic ballasts for the 70 W outdoor equipment class at TSL 4. DOE projects that no 70 W outdoor shipments would meet TSL 4 or higher in 2016 in the base case. Total conversion costs decrease from $29 million at TSL 3 to $28 million at TSL 4, because of the flexibility of electronic ballast production within the lighting manufacturing industry.

At TSL 4, under the flat markup scenario the shipment-weighted average MPC increases 39 percent over the base case MPC. In this scenario the additional revenues earned from passing on these higher MPC costs outweigh the $28 million in conversion costs, resulting in slightly positive impacts on INPV. Under the 'preservation of operating profit' markup scenario, the 34 percent MPC increase is outweighed by a lower average markup of 1.42 and $28 million in conversion costs, resulting in INPV results remaining moderately negative at TSL 4.

TSL 5 is EL4 for eight equipment classes (the 70 W indoor and outdoor fixtures, 150 W indoor and outdoor fixtures, 250 W indoor and outdoor fixtures, and 400 W indoor and outdoor fixtures) and EL2 for two equipment classes (the 1000 W indoor and outdoor fixtures). At TSL 5, DOE estimates impacts on INPV to range from $36.5 million to -$24.1 million, or a change in INPV of 29.8 percent to -23.3 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 83 percent to $1.8 million, compared to the base case value of $10.7 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 84 percent to $1.7 million, compared to the base case value of $10.6 million in 2015.

At TSL 5, the stringency of standards increases to max-tech ballasts for the 70 W indoor and outdoor, 250 W indoor and outdoor, and 400 W outdoor equipment classes compared to TSL 4. DOE projects that 1 percent of 70 W indoor shipments would meet TSL 5 or higher in 2016 in the base case. No shipments from the 70 W outdoor, 250 W indoor or outdoor, and 400 W indoor or outdoor equipment classes would meet TSL 5 or higher in the base case. As a result, product conversion costs increase to $20 million because of the need to redesign and test additional models, and capital conversion costs decrease to $7 million due to the flexibility of electronic ballast production.

At TSL 5, under the flat markup scenario the shipment-weighted average MPC increases 76 percent over the base case MPC. In this scenario the additional revenues earned from passing on these higher MPC costs outweigh the decreased conversion costs of $26 million, resulting in a significantly positive impact on INPV. Under the 'preservation of operating profit' markup scenario, the 67 percent MPC increase is outweighed by a lower average markup of 1.39 and $26 million in conversion costs, resulting in INPV results remaining moderately negative at TSL 5.

13.8.2 Cash Flow Analysis Results For Metal Halide Lamp Fixtures

At TSL 1, DOE estimates impacts on INPV to range from $37.0 million to -$6.1 million, or a change in INPV of 5.9 percent to -1.1 percent. At TSL 1, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 2 percent to $58.7 million, compared to the base case value of $59.8 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 2 percent to $58.0 million, compared to the base case value of $59.1 million in 2015.

DOE expects minimal conversion costs for fixture manufacturers at TSL 1. Fixture manufacturers would incur $3 million in product conversion costs for the testing of redesigned ballasts. Because the stack height of magnetic ballasts is not expected to change in response to the standards, fixture manufacturers would not incur any capital conversion costs at magnetic ballast levels such as TSL 1.

At TSL 1, under the flat markup scenario the shipment-weighted average MPC increases by 12 percent from the base case MPC. In this scenario manufacturers maximize revenue since they are able to fully pass on this cost increase to customers. The moderate price increase applied to a large quantity of shipments outweighs the impact of the $3 million in conversion costs for TSL 1, resulting in positive impacts at TSL 1 under the flat markup and high-shipment scenarios.

Under the ‘preservation of operating profit’ markup scenario, the 10 percent MPC increase is outweighed by a lower average markup of 1.56 (compared to the flat manufacturer markup of 1.58) and $3 million in conversion costs, resulting in slightly negative impacts at TSL 1. These impacts increase on a percentage basis under the low-shipment scenario relative to the high-shipment scenario because the base case INPV against which changes are compared is 14 percent lower.

At TSL 2, DOE estimates impacts on INPV to range from $63.9 million to -$8.1 million, or a change in INPV of 10.2 percent to -1.5 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 2 percent to $58.7 million, compared to the base case value of $59.8 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 2 percent to $58.0 million, compared to the base case value of $59.1 million in 2015.

At TSL 2, DOE expects conversion costs to remain low at $3 million for the testing of redesigned ballasts and catalog updates. Under the flat markup scenario the shipment-weighted average MPC increases 19 percent over the base case MPC. In this scenario the INPV impacts are positive because the ability to pass on the higher equipment costs to customers outweighs the $3 million in estimated conversion costs. Under the ‘preservation of operating profit’ markup scenario, the 15 percent MPC increase is outweighed by a lower average markup of 1.53 and $3 million in conversion costs, resulting in slightly negative INPV impacts at TSL 2.

At TSL 3, DOE estimates impacts on INPV to range from $64.8 million to -$17.3 million, or a change in INPV of 10.3 percent to -3.2 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 9 percent to $54.2 million, compared to the base case value of $59.8 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 9 percent to $53.5 million, compared to the base case value of $59.1 million in 2015. DOE expects product conversion costs to increase to $9 million because of the additional cost of redesigning fixtures for thermal protection to accommodate 150 W indoor and outdoor electronic ballasts. Manufacturers would also incur an estimated $6 million in capital costs for 150 W indoor fixture changes.

At TSL 3, the electronic fixture cost increases for the 150 W indoor and outdoor equipment classes because of fixture adders for thermal protection and voltage transient protection. Under the flat markup scenario, the shipment-weighted average MPC increases 21 percent over the base case MPC. This increase in revenue outweighs the increase of $15 million in conversion costs, resulting in positive impacts at TSL 3. Under the ‘preservation of operating profit’ markup scenario, the 17 percent MPC increase is outweighed by a lower average markup of 1.53 and $15 million in conversion costs, resulting in slightly negative INPV impacts at TSL 3.

At TSL 4, DOE estimates impacts on INPV to range from $73.6 million to -$23.8 million, or a change in INPV of 11.7 percent to -4.4 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 14 percent to $51.4 million, compared to the base case value of $59.8 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 14 percent to $50.7 million, compared to the base case value of $59.1 million in 2015.

The technology changes from TSL 3 to TSL 4 are that manufacturers must use electronic ballasts to meet the required efficiencies for the 70 W outdoor fixture class at TSL 4. This increases the product conversion costs from $9 million at TSL 3 to $13 million at TSL 4 and increases the capital conversion costs from $6 million at TSL 3 to $10 million at TSL 4.

At TSL 4, under the flat markup scenario the shipment-weighted average MPC increases 26 percent over the base case MPC. In this scenario the additional revenue results in slightly more positive impacts on INPV at TSL 4 compared to TSL 3. Under the ‘preservation of operating profit’ markup scenario the 21 percent MPC increase is outweighed by a lower average markup of 1.52 and $23 million in conversion costs, resulting in slightly more negative INPV impacts at TSL 4 compared to TSL 3.

At TSL 5, DOE estimates impacts on INPV to range from $111.3 million to -$116.9 million, or a change in INPV of 17.7 percent to -21.6 percent. At this proposed level, industry free cash flow under the low-shipment scenario is estimated to decrease by approximately 89 percent to $6.5 million, compared to the base case value of $59.8 million in 2015. Under the high-shipment scenario, industry free cash flow is estimated to decrease by approximately 90 percent to $5.8 million, compared to the base case value of $59.1 million in 2015.

At TSL 5, product conversion costs significantly increase to $62 million as manufacturers must redesign all equipment classes to accommodate the most efficient electronic ballasts. Capital conversion costs also significantly increase to $75 million because of the need for additional equipment and tooling, such as new castings, to incorporate thermal protection in all equipment classes.

At TSL 5, under the flat markup scenario the shipment-weighted average MPC increases 57 percent over the base case MPC. In this scenario the revenue increase from TSL 4 to TSL 5 outweighs the increase in conversion costs of $137 million, resulting in greater positive impacts on INPV at TSL 5 compared to TSL 4. Under the ‘preservation of operating profit’ markup scenario, the 46 percent MPC increase is outweighed by a lower average markup of 1.47 and $137 million in conversion costs, resulting in significantly more negative INPV impacts at TSL 5 compared to TSL 4.

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CHAPTER 14. EMPLOYMENT IMPACT ANALYSIS

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14.1 INTRODUCTION

The U.S. Department of Energy's (DOE's) employment impact analysis is designed to estimate indirect national job creation or elimination resulting from adopted standards, due to reallocation of the associated expenditures for purchasing and operating metal halide lamp fixtures (hereafter referred to as "fixtures"). DOE conducted this analysis as part of this notice of proposed rulemaking (NOPR).

14.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (*i.e.*, they may remain "saved"). The standards may increase the purchase price of fixtures, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see NOPR technical support document (TSD) chapter 13).

DOE notes that ImSET (Impact of Sector Energy Technologies) is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would overestimate the magnitude of actual job impacts over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore includes a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long-run employment impacts.

14.3 METHODOLOGY

DOE based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1,[2] as a successor to ImBuild,[3] a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity and so changes in the level of spending (*e.g.*, due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial building technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.*, changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input/output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy efficient appliances. The increased cost of appliances leads to higher employment in the appliance manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand, which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the fixture manufacturing sector estimated in the NOPR TSD chapter 13 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

14.4 SHORT-TERM RESULTS

The results in this section refer to impacts of fixture standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy and water costs, and changes in operations and maintenance costs. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors: the fixture production sector, the energy generation sector, and the general consumer goods sector (as mentioned above, ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of fixtures. This increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on electricity. The reduction in electricity demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on fixtures and reduced expenditures on electricity, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (as more workers are hired, they consume more goods, which generates more employment; the converse is true for workers laid off). Table 14.4.1 presents the modeled net employment impact from the rule in 2017 and 2020.

Table 14.4.1 Net National Short-Term Change in Employment

Analysis Period Year	Trial Standard Level	Net National Change in Jobs	
		Low Shipments	High Shipments
2017	1	10	8
	2	-30	-36
	3	76	73
	4	170	168
	5	352	346
2020	1	376	392
	2	511	530
	3	791	827
	4	1,091	1,142
	5	2,336	2,445

14.5 LONG-TERM RESULTS

Due to the short payback period of energy efficiency improvements mandated by this rule, over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in appliance costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for electricity to decline over time and demand for other goods to increase. Because the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation toward consumer goods. Note that in long-run equilibrium there is no net effect on total employment because wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will be negligible over time due to the small magnitude of the short-term effects presented in Table 14.4.1. The ImSET model projections, assuming no price or wage effects until 2020, are included in the third and fourth columns of Table 14.4.1.

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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15.1 INTRODUCTION

In the utility impact analysis, U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and generation that result for each trial standard level (TSL).

The utility impact analysis uses a variant of the DOE Energy Information Administration's (EIA's) National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *Annual Energy Outlook* (*AEO*). DOE uses a variant of this model, referred to as NEMS-BT,[b] to account for selected utility impacts of energy conservation standards. DOE's analysis consists of a comparison between model results for the most recent *AEO* Reference Case and for cases in which energy use is decremented to reflect the impact of standards. For the analysis of standards on metal halide lamp fixtures, DOE used the version of NEMS based on *AEO2013*.[1]

NEMS-BT has a number of advantages that have led to its use in the analysis of energy conservation standards:

- NEMS-BT uses a set of assumptions that are well known and fairly transparent, due to the exposure and scrutiny each *AEO* receives.
- NEMS-BT is updated each year, with each edition of the *AEO*, to reflect changes in energy prices, supply trends, regulations, etc.
- The comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors.

15.2 METHODOLOGY

DOE uses NEMS-BT to estimate the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of energy conservation standards. In practice, the numerical differences between marginal and average values may turn out to be smaller than the intrinsic uncertainties in the *AEO*.

NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the *AEO* Reference Case, in general there are three inter-

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[a] For more information on NEMS, refer to the DOE/EIA documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003.

[b] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed).

related effects: the annual generation (terawatt-hours (TWh)) from the stock of electric generating capacity changes, the total generation capacity itself (gigawatts (GW)) may change, and the mix of capacity by fuel type may change. Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use.

To model the impact of a standard, DOE inputs a reduction to annual energy demand for the corresponding end use in the appropriate start year. The NEMS-BT model is run with the decremented energy demand to determine the modified build-out of capacity and total generation. Regional effects of a standard can be accounted for by defining the energy demand decrement as a function of census division.

The output of the NEMS-BT analysis includes the effective marginal heat rate (ratio of the change in fuel consumption in quadrillion British thermal units (quads) to the change in generation in terawatt-hours), and the capacity reduction by fuel type for a given reduction in total generation. DOE uses the site energy savings multiplied by a transmission and distribution loss factor to estimate the reduction in generation for each TSL. The relationship between a reduction[c] in electricity generation (terawatt-hours) and the reduction in capacity (gigawatts) is estimated based on the output of NEMS-BT model runs using the end-use specific energy demand decrement. Details on the approach used may be found in Coughlin (2013).[2]

NEMS-BT provides output for the following capacity types: coal, nuclear, combined cycle (natural gas), renewable sources, oil and natural gas steam, combustion turbine/diesel, pumped storage, fuel cells, and distributed generation (natural gas). DOE grouped oil and natural gas steam and combustion turbine/diesel into a peaking category, and grouped pumped storage, fuel cells, and distributed generation (natural gas) into an "other" category.

In general, energy conservation standards impact primarily fossil combustion (coal, natural gas, and diesel) and renewables. Pumped storage and nuclear power are very insensitive to small changes in demand, while fuel cells and distributed generation make up a very small fraction (less than 1 percent) of the generation capacity base.

15.3 UTILITY IMPACT RESULTS

This section presents results of the analysis for all of the capacity types except "Other," for which the impacts are very small.

15.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Note that a negative number means an increase in capacity under a TSL.

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[c] These reductions are defined relative to the *AEO* Reference Case.

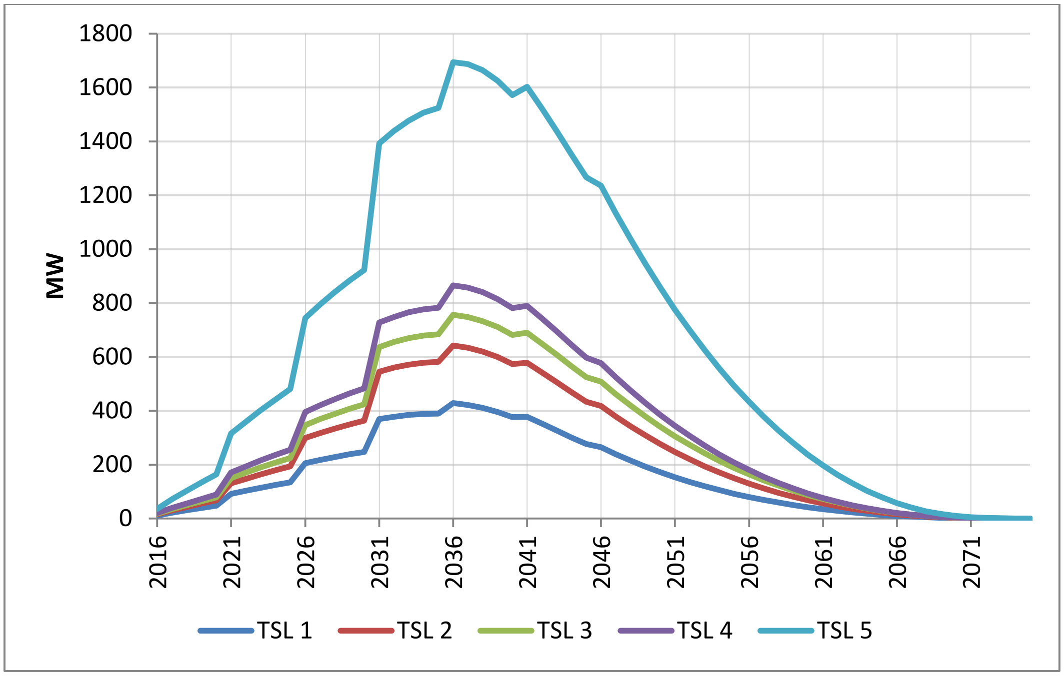

Figure 15.3.1 Metal Halide Lamp Fixtures: Total Capacity Reduction (Low Shipments)

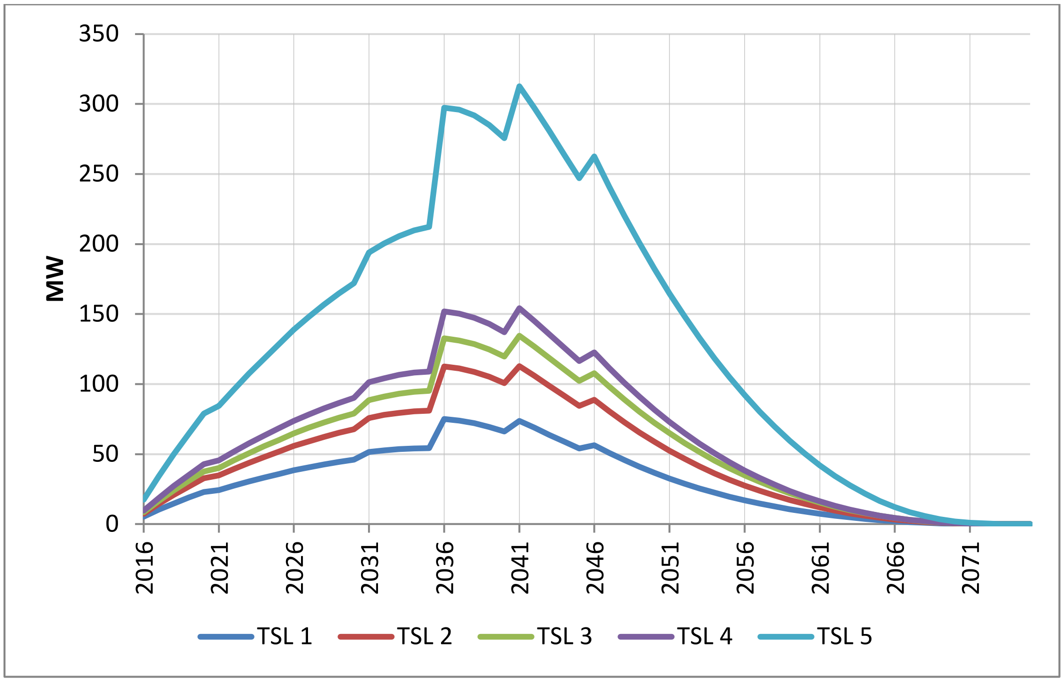

Figure 15.3.2 Metal Halide Lamp Fixtures: Coal Capacity Reduction (Low Shipments)

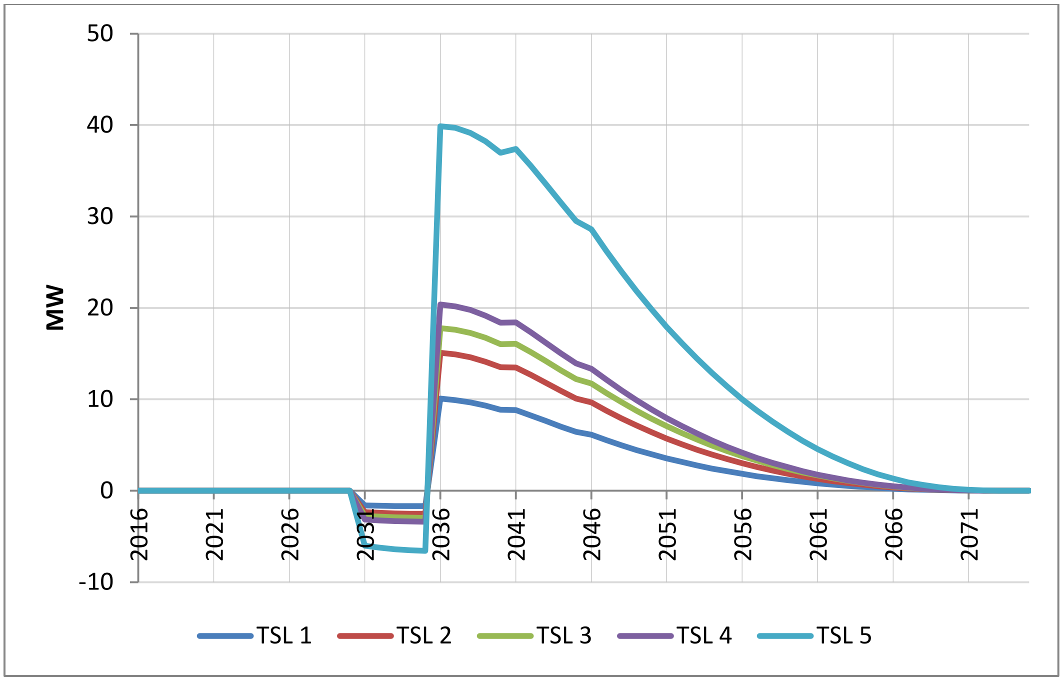

Figure 15.3.3 Metal Halide Lamp Fixtures: Nuclear Capacity Reduction (Low Shipments)

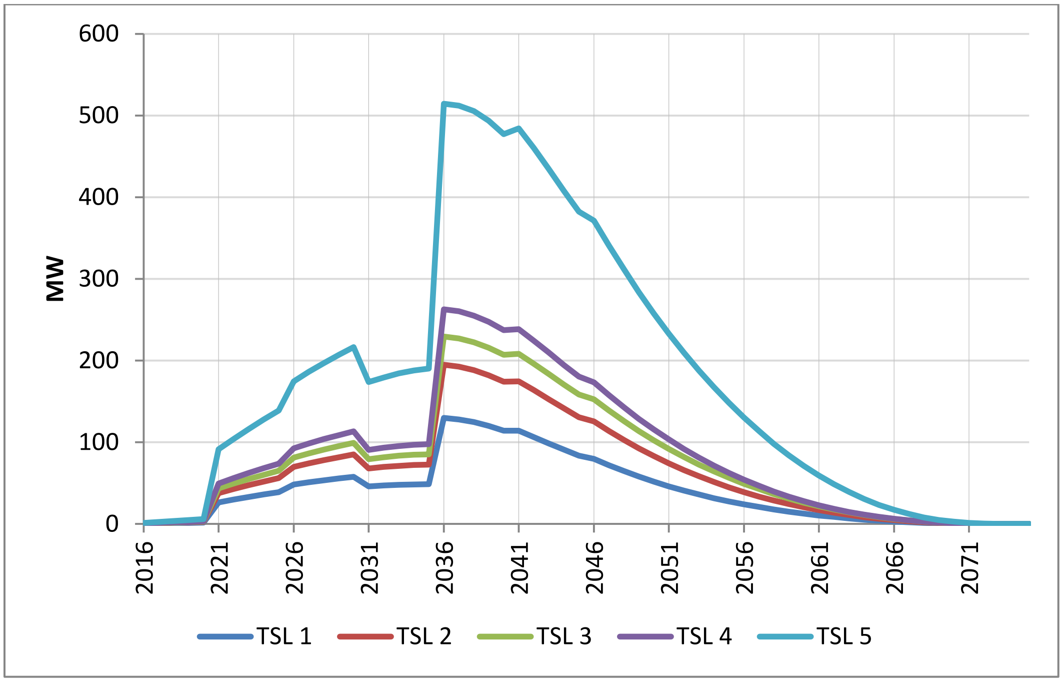

Figure 15.3.4 Metal Halide Lamp Fixtures: Gas Combined Cycle Capacity Reduction (Low Shipments)

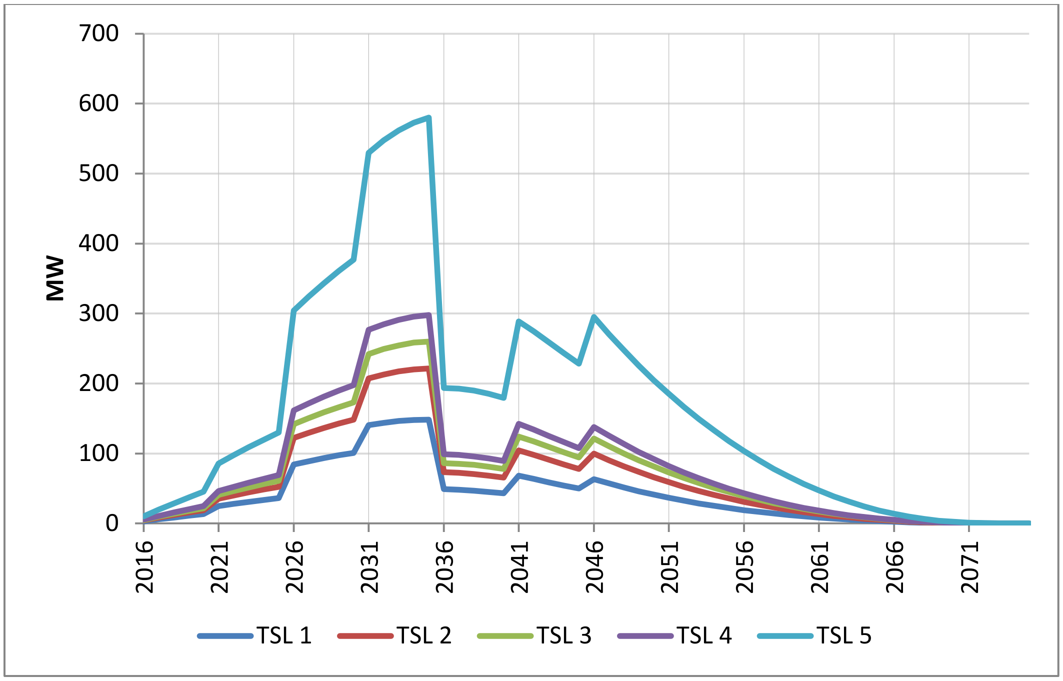

Figure 15.3.5 Metal Halide Lamp Fixtures: Peaking Capacity Reduction (Low Shipments)

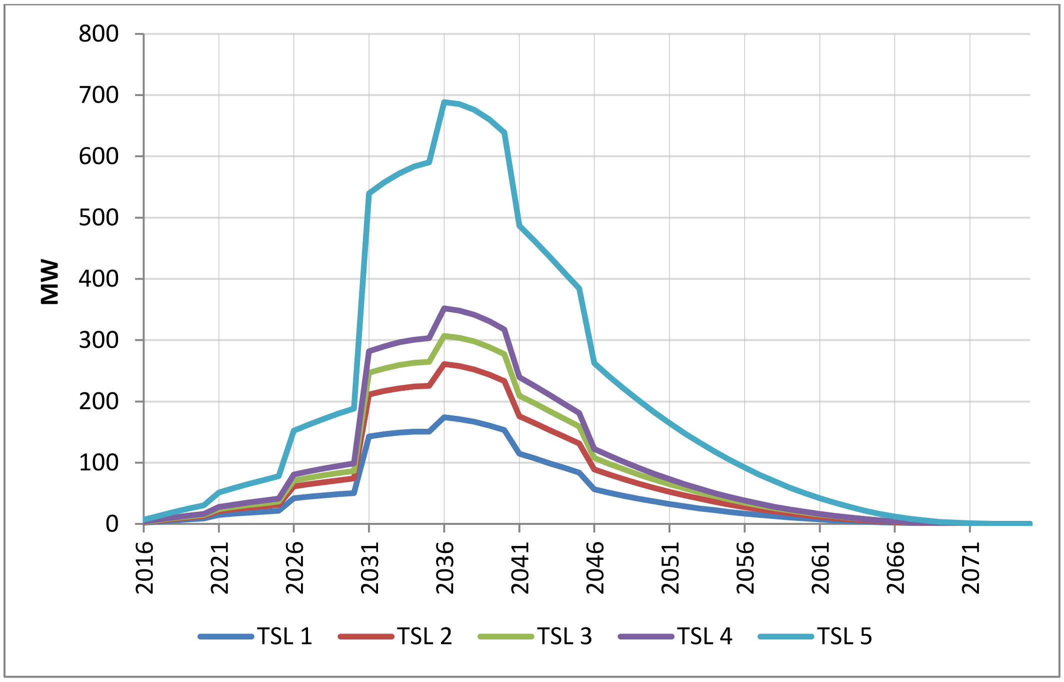

Figure 15.3.6 Metal Halide Lamp Fixtures: Renewables Capacity Reduction (Low Shipments)

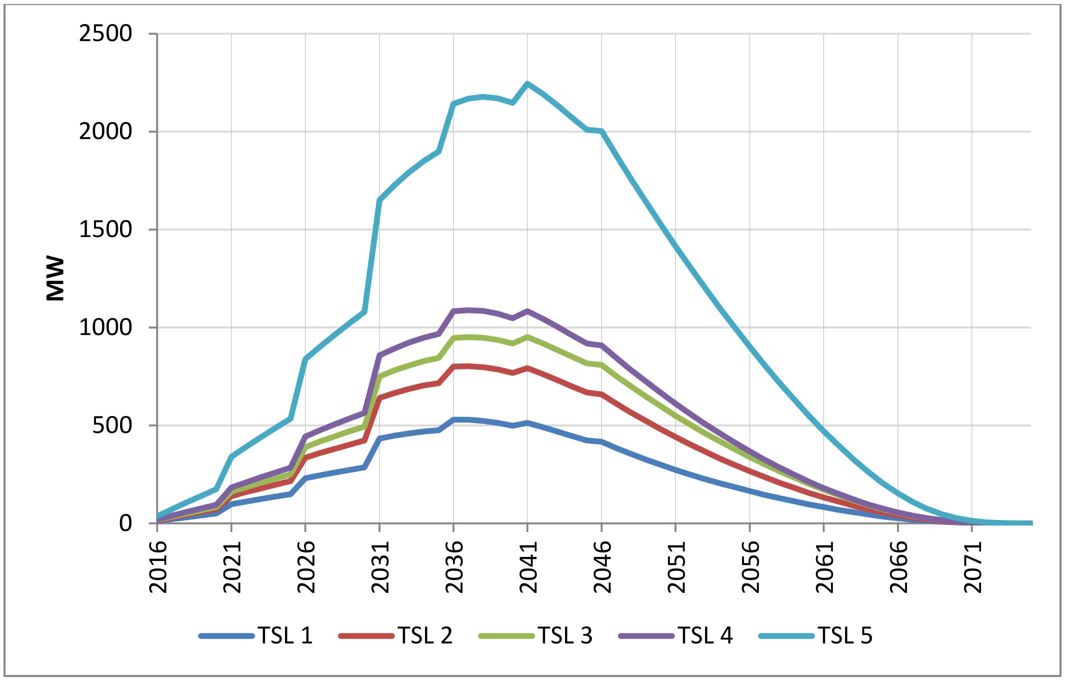

Figure 15.3.7 Metal Halide Lamp Fixtures: Total Capacity Reduction (High Shipments)

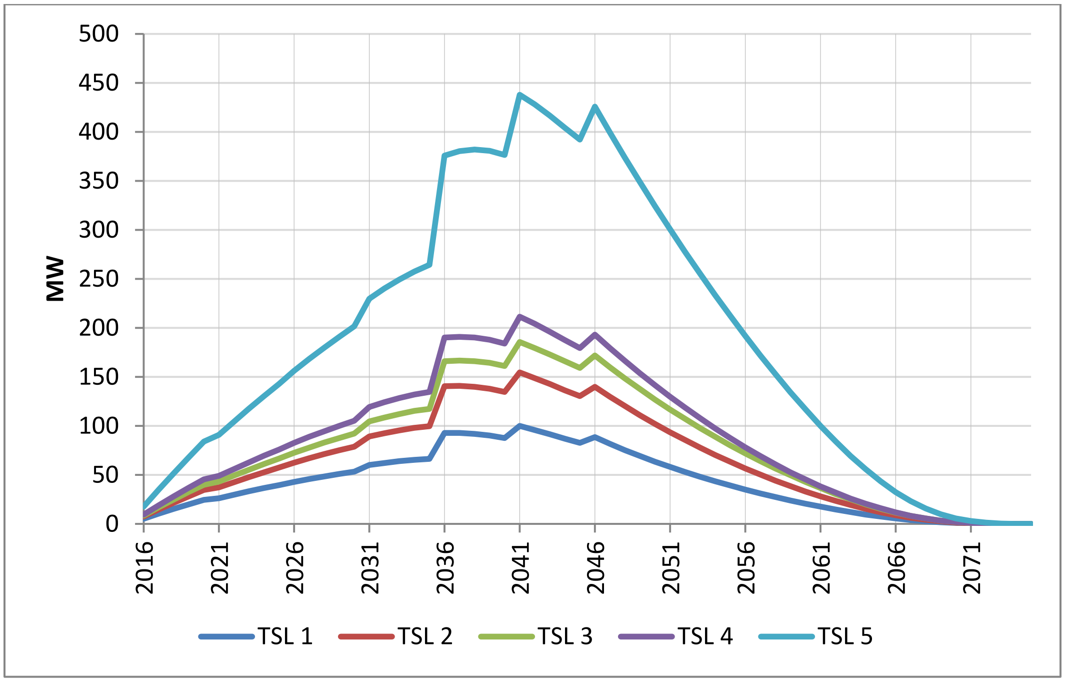

Figure 15.3.8 Metal Halide Lamp Fixtures: Coal Capacity Reduction (High Shipments)

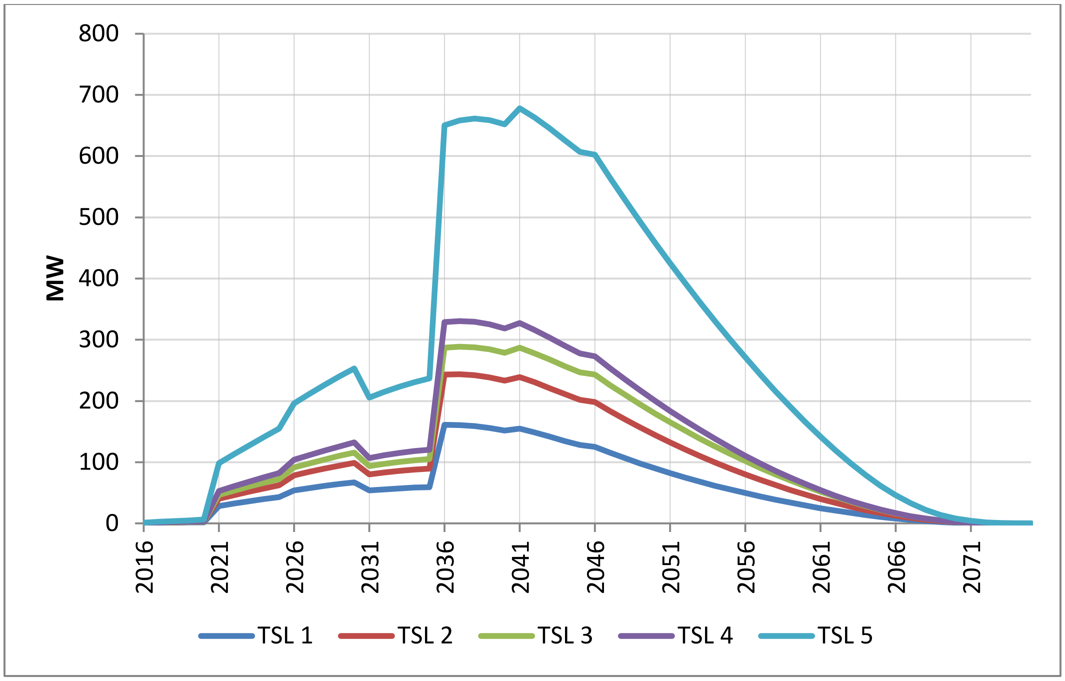

Figure 15.3.9 Metal Halide Lamp Fixtures: Gas Combined Cycle Capacity Reduction (High Shipments)

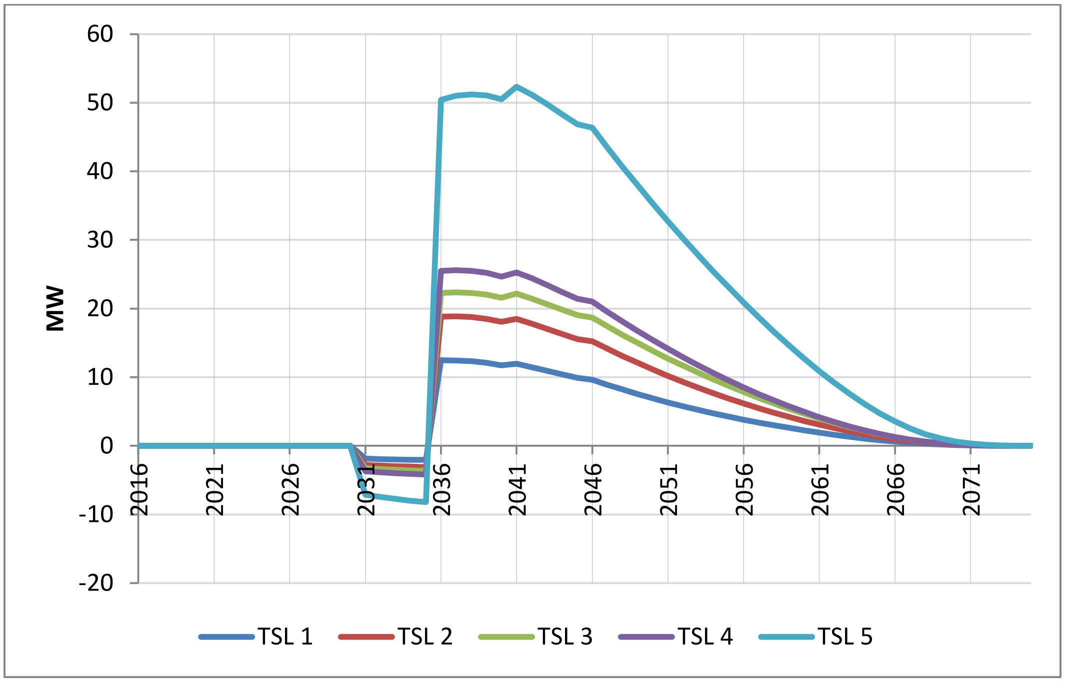

Figure 15.3.10 Metal Halide Lamp Fixtures: Nuclear Capacity Reduction (High Shipments)

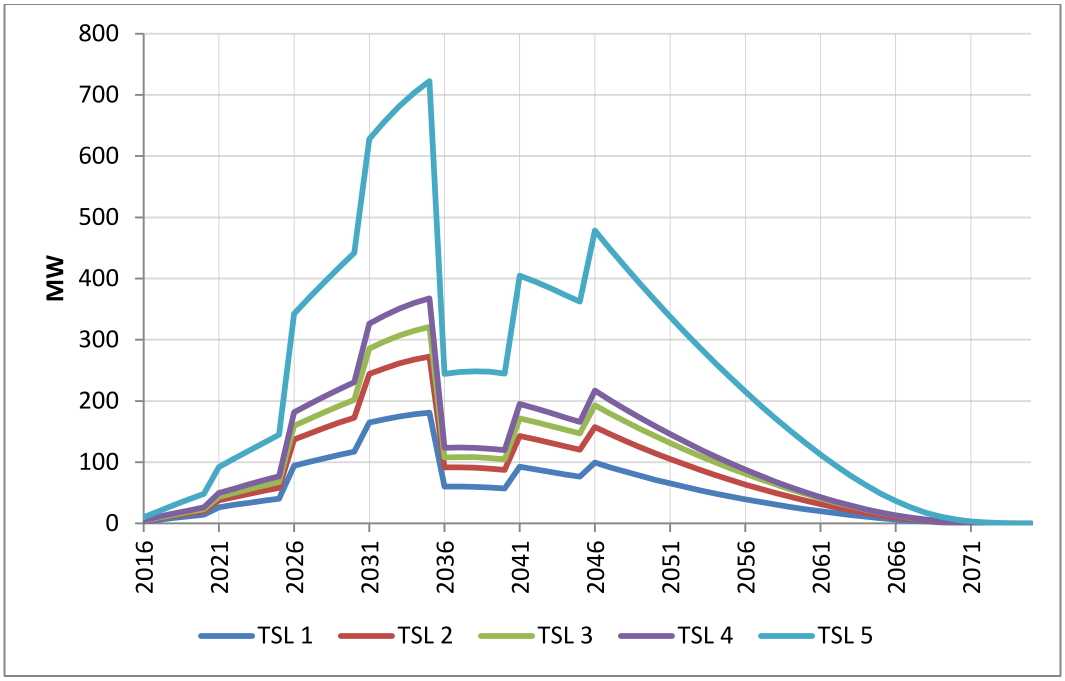

Figure 15.3.11 Metal Halide Lamp Fixtures: Peaking Capacity Reduction (High Shipments)

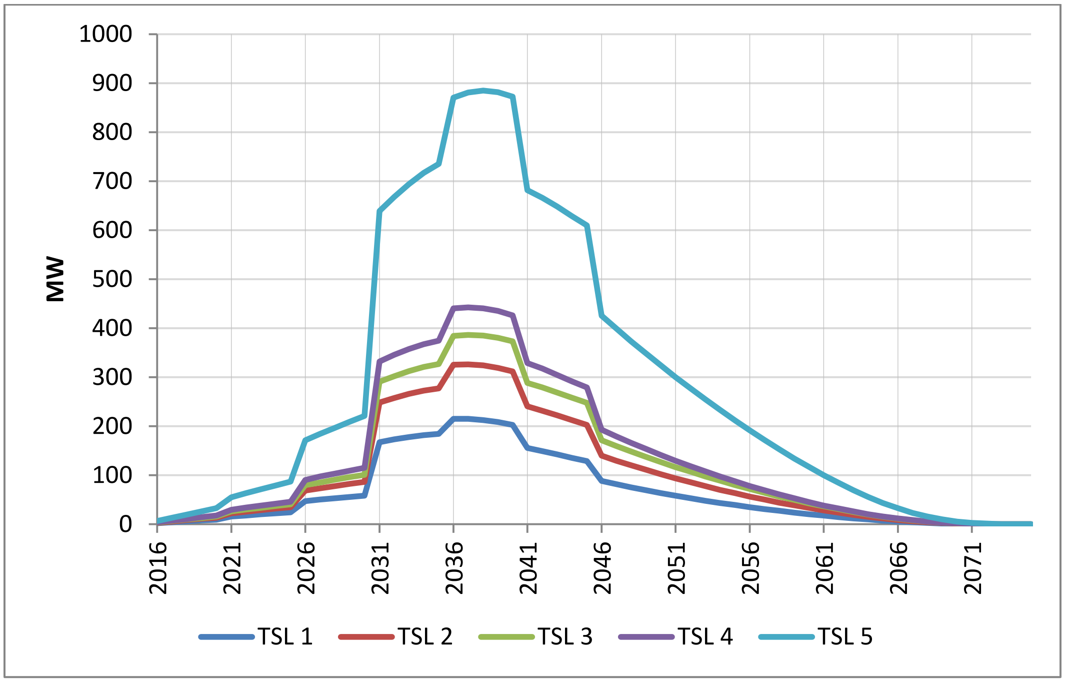

Figure 15.3.12 Metal Halide Lamp Fixtures: Renewables Capacity Reduction (High Shipments)

15.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by plant type. Coal-fired power plants account for most of the generation reduction. Note that a negative number means an increase in generation under a TSL.

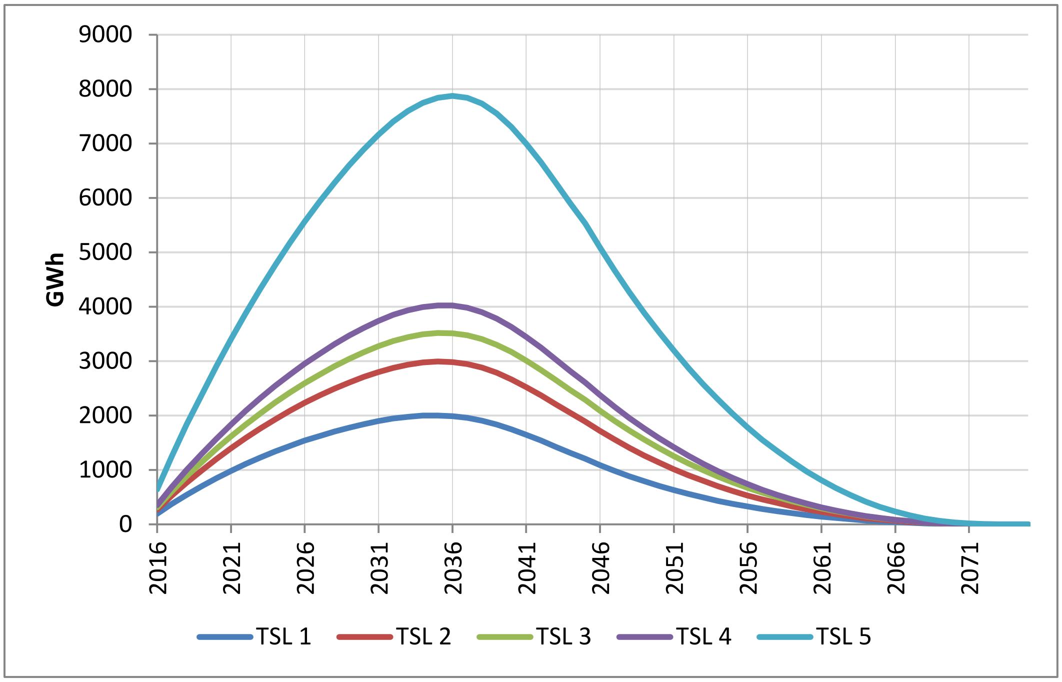

Figure 15.3.13 Metal Halide Lamp Fixtures: Total Generation Reduction (Low Shipments)

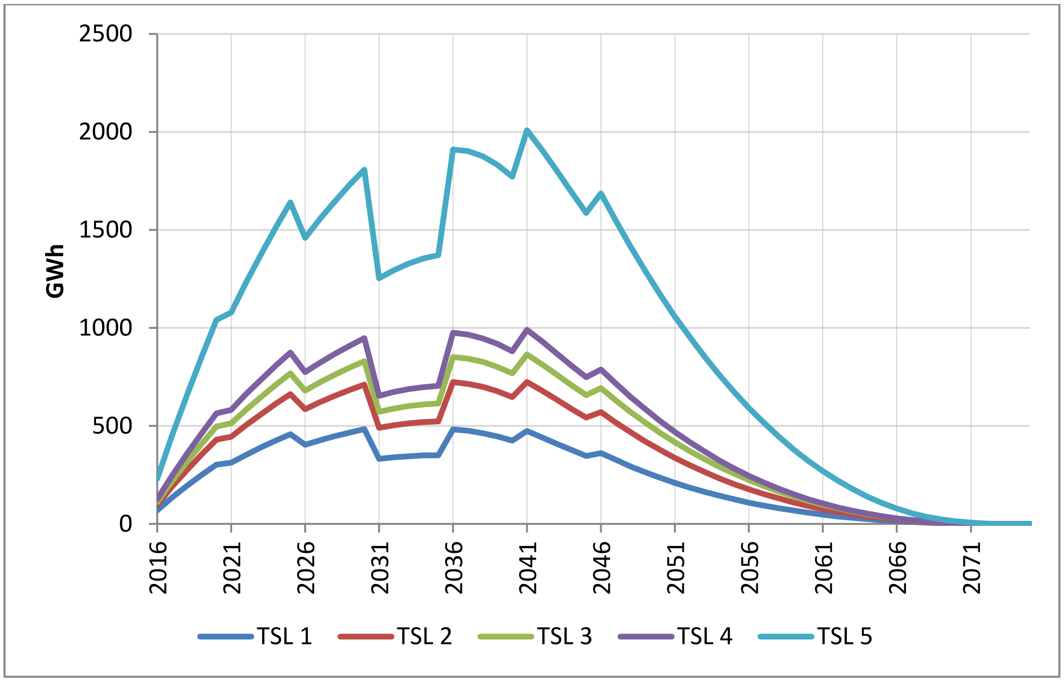

Figure 15.3.14 Metal Halide Lamp Fixtures: Coal Generation Reduction (Low Shipments)

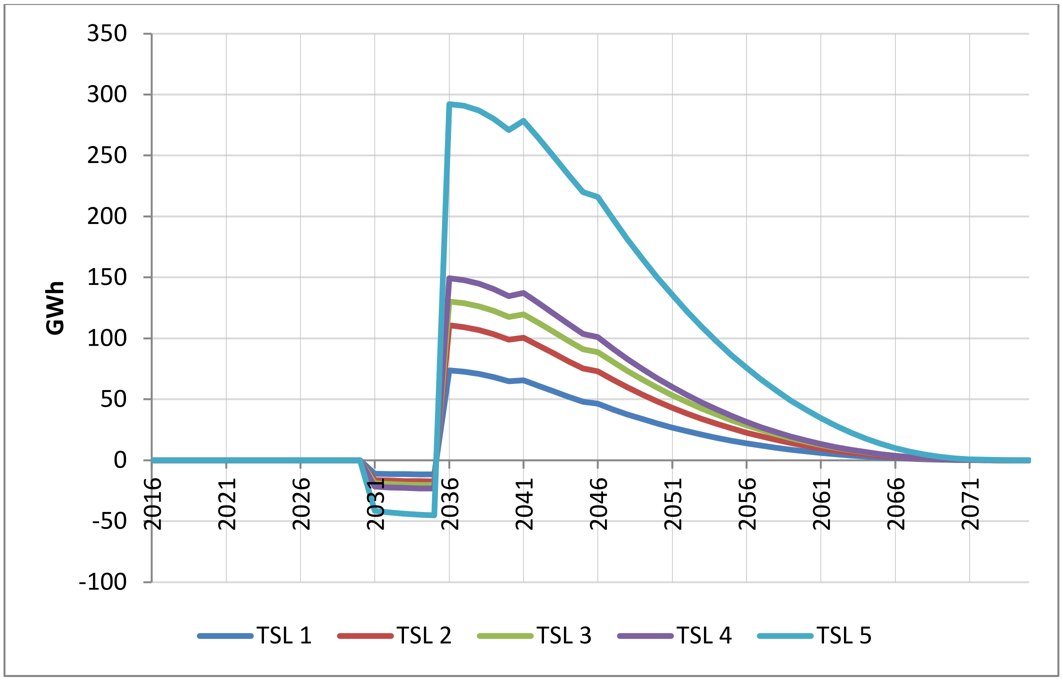

Figure 15.3.15 Metal Halide Lamp Fixtures: Nuclear Generation Reduction (Low Shipments)

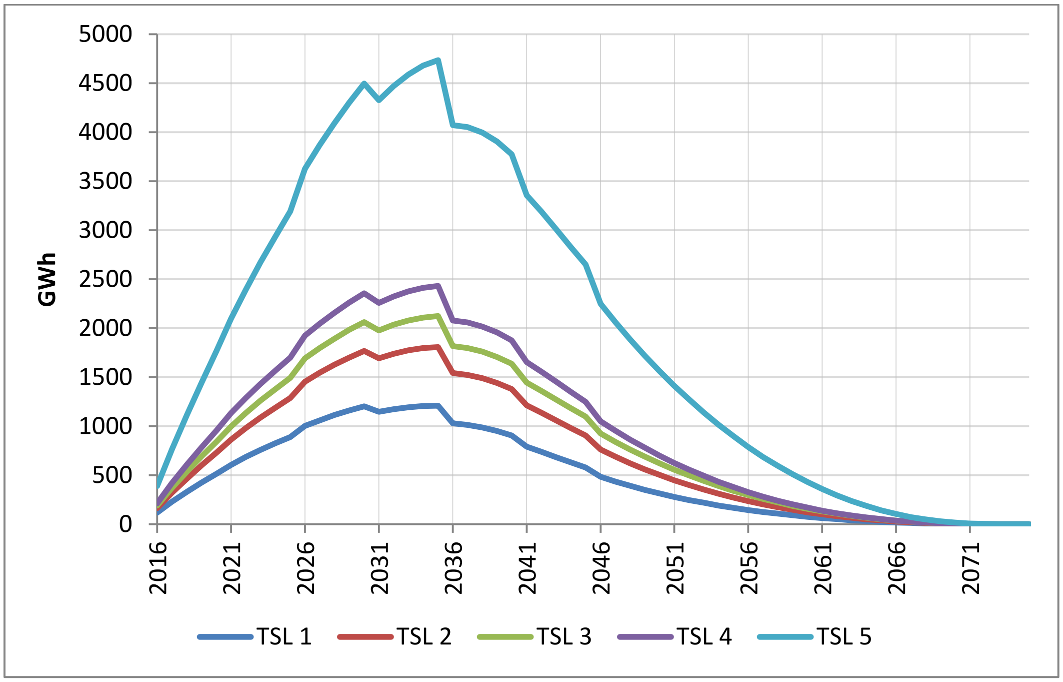

Figure 15.3.16 Metal Halide Lamp Fixtures: Gas Combined Cycle Generation Reduction (Low Shipments)

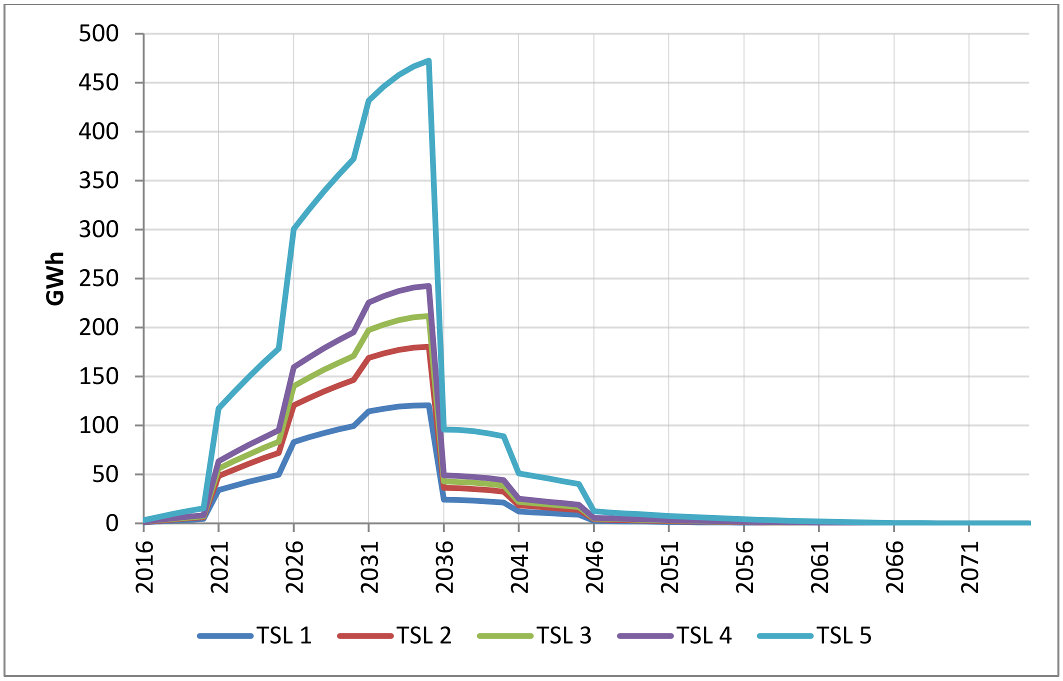

Figure 15.3.17 Metal Halide Lamp Fixtures: Peaking Generation Reduction (Low Shipments)

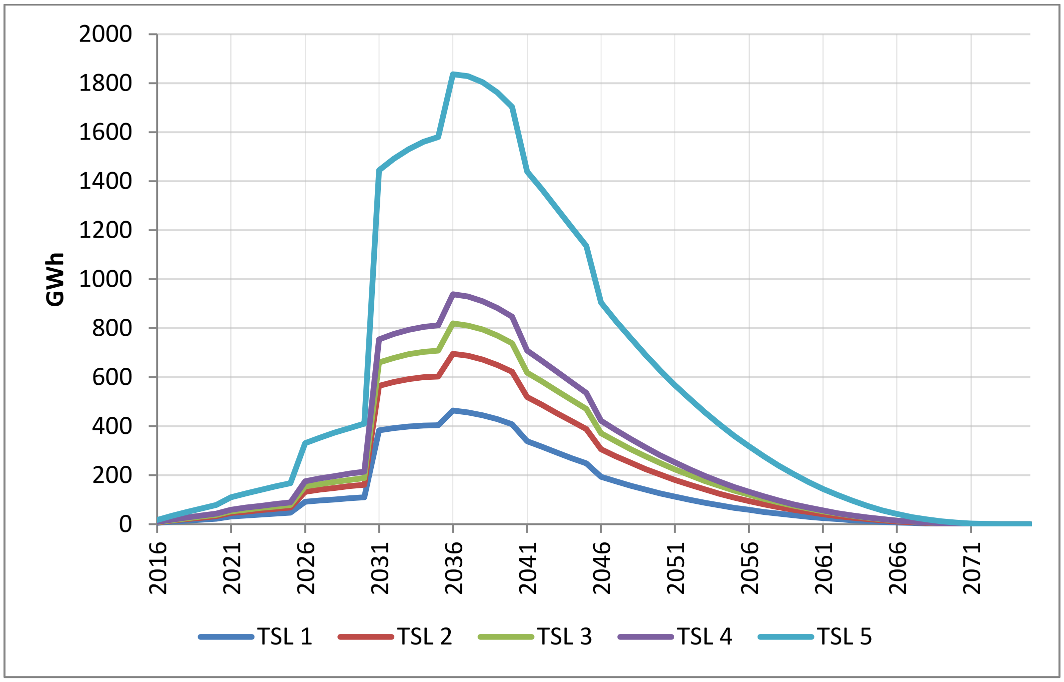

Figure 15.3.18 Metal Halide Lamp Fixtures: Renewables Generation Reduction (Low Shipments)

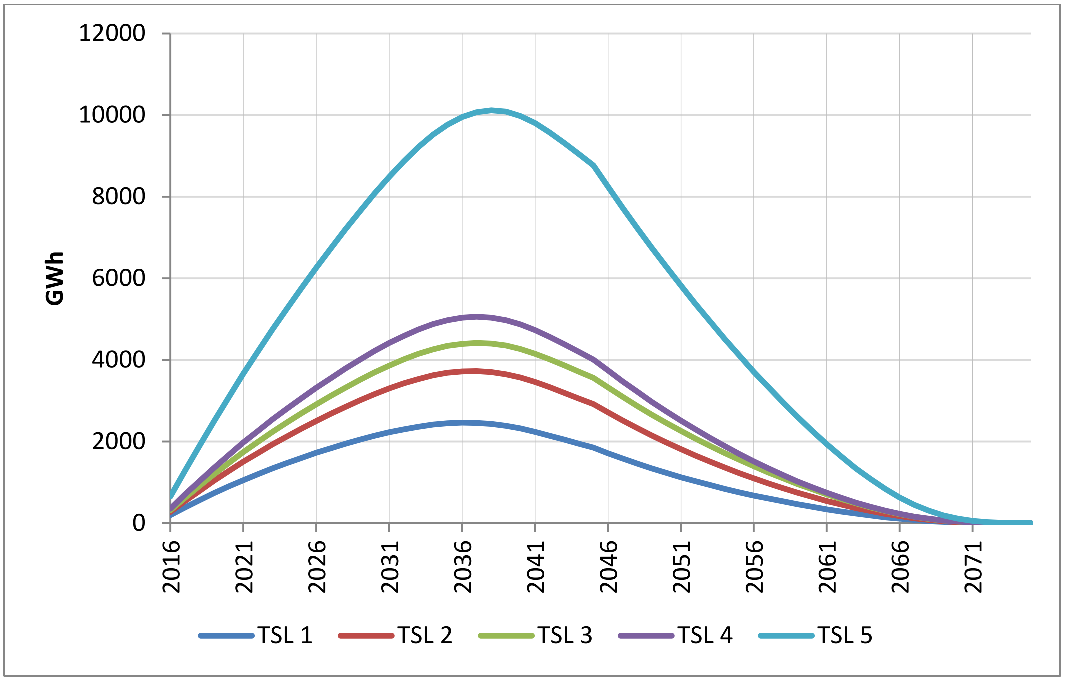

Figure 15.3.19 Metal Halide Lamp Fixtures: Total Generation Reduction (High Shipments)

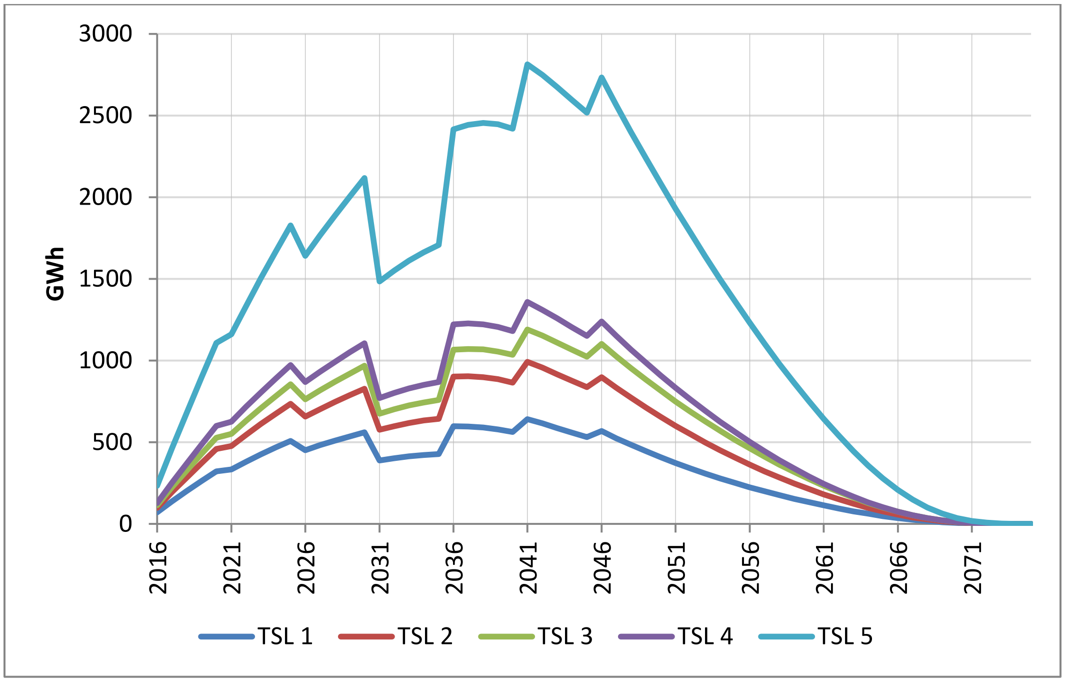

Figure 15.3.20 Metal Halide Lamp Fixtures: Coal Generation Reduction (High Shipments)

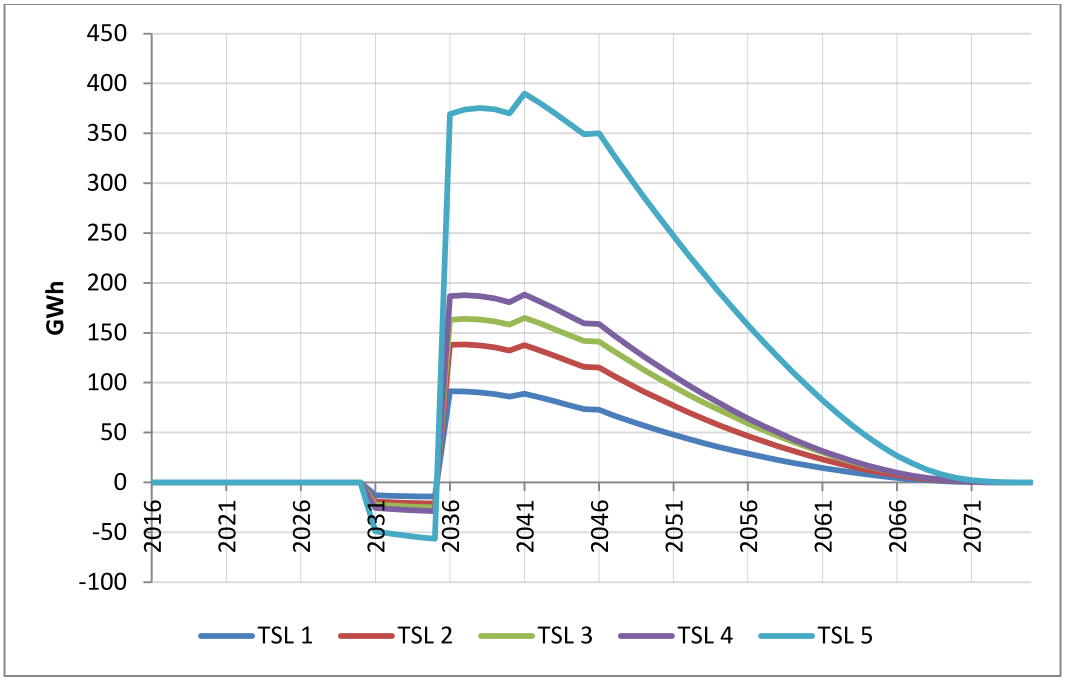

Figure 15.3.21 Metal Halide Lamp Fixtures: Nuclear Generation Reduction (High Shipments)

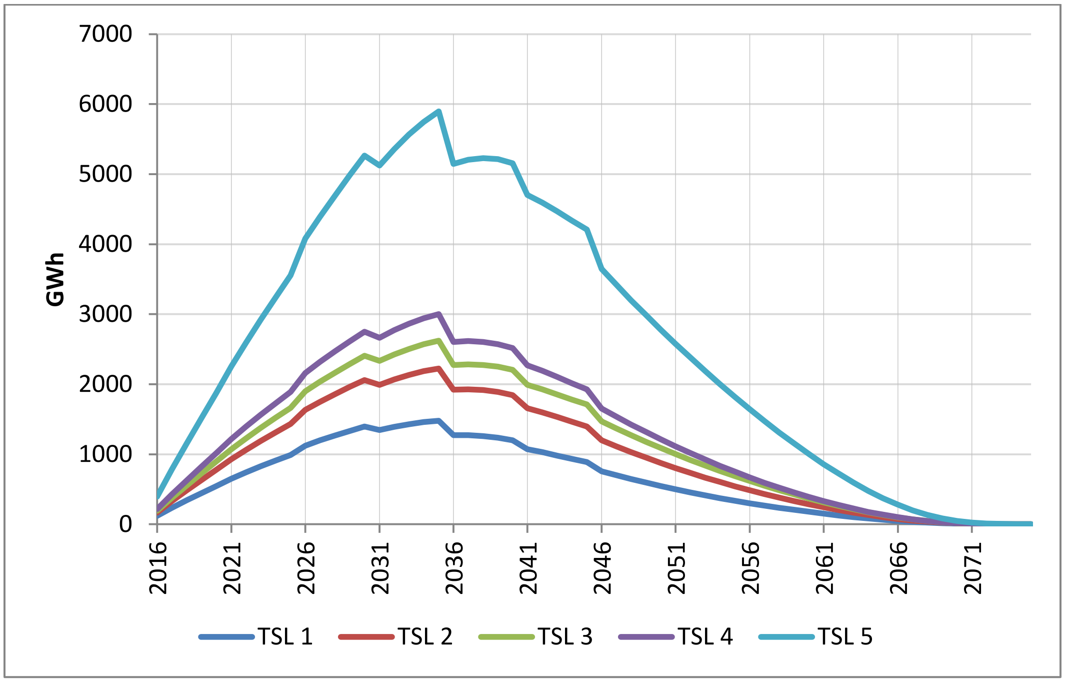

Figure 15.3.22 Metal Halide Lamp Fixtures: Gas Combined Cycle Generation Reduction (High Shipments)

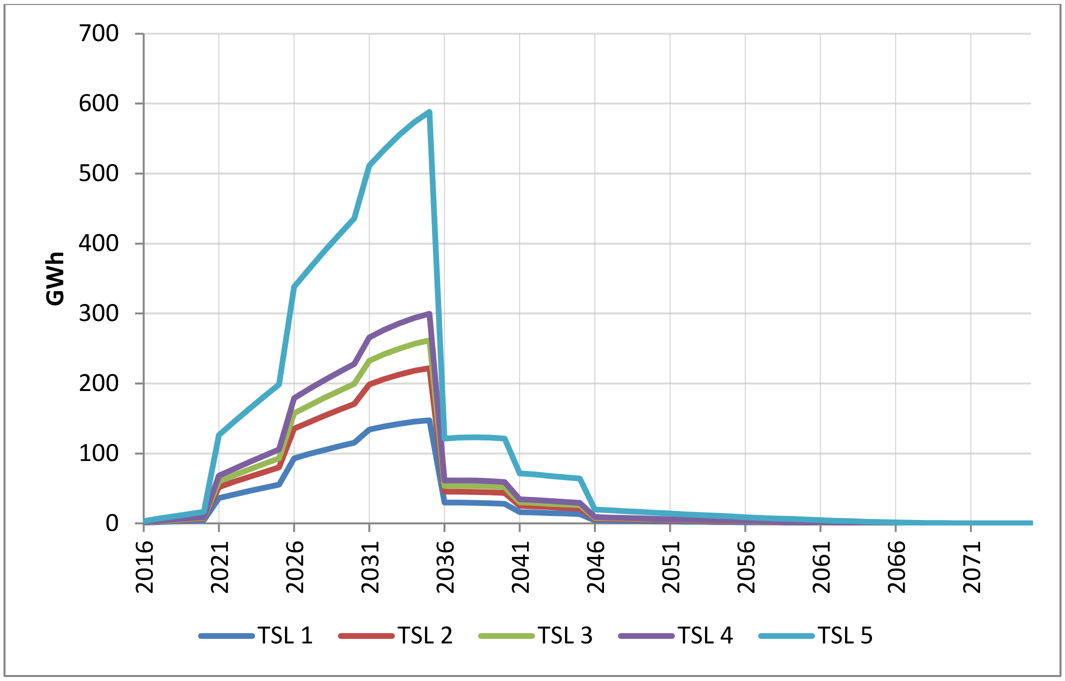

Figure 15.3.23 Metal Halide Lamp Fixtures: Peaking Generation Reduction (High Shipments)

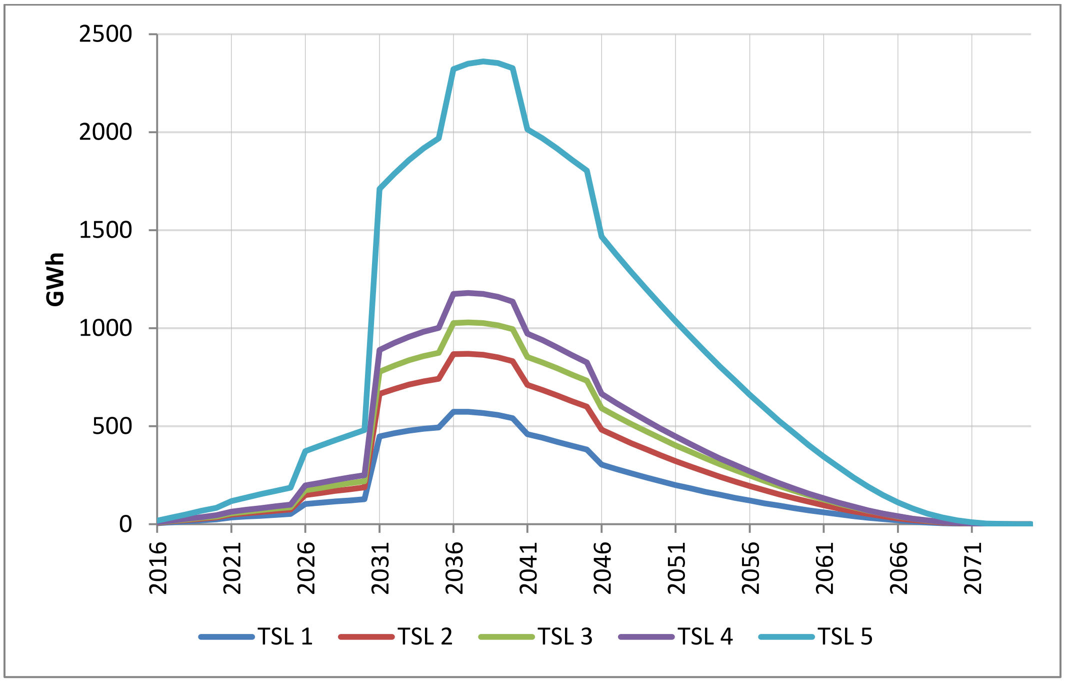

Figure 15.3.24 Metal Halide Lamp Fixtures: Renewables Generation Reduction (High Shipments)

15.3.3 Results Summary

Table 15.3.1 and Table 15.3.2 present a summary of the utility impact results for metal halide lamp fixtures.

Table 15.3.1 Metal Halide Lamp Fixtures: Summary of Utility Impact Results (Low Shipments)

	TSL				
	1	**2**	**3**	**4**	**5**
Installed Capacity Reduction ***MW***					
2020	47.74	67.83	78.23	88.71	163.88
2025	134.03	193.77	224.84	255.72	480.34
2030	246.69	362.87	423.55	483.46	922.70
2035	389.22	581.67	683.63	782.52	1,524.09
2040	376.56	573.69	681.77	781.28	1,571.32
Electricity Generation Reduction ***GWh***					
2020	846.05	1,202.09	1,386.46	1,572.23	2,904.38
2025	1,444.32	2,088.17	2,422.97	2,755.73	5,176.33
2030	1,843.30	2,711.40	3,164.80	3,612.45	6,894.55
2035	2,002.29	2,992.30	3,516.81	4,025.54	7,840.39
2040	1,749.74	2,665.72	3,167.92	3,630.32	7,301.36

Table 15.3.2 Metal Halide Lamp Fixtures: Summary of Utility Impact Results (High Shipments)

	TSL				
	1	**2**	**3**	**4**	**5**
Installed Capacity Reduction ***MW***					
2020	50.77	72.17	83.25	94.41	174.47
2025	148.82	215.47	250.14	284.56	535.23
2030	286.32	422.74	494.06	564.32	1,080.69
2035	475.76	716.05	844.09	966.50	1,898.32
2040	499.17	767.37	917.58	1,047.88	2,145.94
Electricity Generation Reduction ***GWh***					
2020	899.79	1,278.99	1,475.33	1,673.22	3,092.14
2025	1,603.75	2,322.01	2,695.59	3,066.56	5,767.91
2030	2,139.41	3,158.80	3,691.70	4,216.66	8,075.10
2035	2,447.46	3,683.58	4,342.28	4,971.95	9,765.53
2040	2,319.48	3,565.69	4,263.67	4,869.14	9,971.40

REFERENCES

1. U.S. Energy Information Administration. *Annual Energy Outlook 2013 with Projections to 2040*, 2013. Washington, DC. <www.eia.gov/forecasts/aeo/>.

2. Coughlin, K. 2013. Projections of Full-Fuel-Cycle Energy and Emissions Metrics. Lawrence Berkeley National Laboratory, Report Number LBNL-6025E.

CHAPTER 16. EMISSIONS IMPACT ANALYSIS

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CHAPTER 16. EMISSIONS IMPACT ANALYSIS

16.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with the U.S. Department of Energy's (DOE's) FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012).

The analysis of power sector emissions uses marginal emissions intensity factors derived from runs of DOE's National Energy Modeling System – Building Technologies (NEMS-BT) model, described in chapter 14. DOE used the version of NEMS based on the *Annual Energy Outlook 2013 (AEO2013).*[1] Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. *AEO2013* generally represents current Federal and State legislation and final implementation regulations in place as of the end of December 2012. Site emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[2]

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the U.S. Environmental Protection Agency (EPA), GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[3] The upstream emissions include both emissions from fuel combustion during extraction, processing, and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per megawatt-hours (MWh) or million British thermal units (MMBtu) of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

16.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous States and the District of Columbia (D.C.). SO_2 emissions from 28 eastern States and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR

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[a] www.epa.gov/climateleadership/guidance/ghg-emissions.html

was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), but parts of it remained in effect. See *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008); *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2011, EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (Aug. 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO2013* emissions factors used for today's notice of proposed rulemaking assume that CAIR remains a binding regulation through 2040.

The attainment of emissions caps is typically flexible among affected EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO_2 as a result of standards.

Beginning in 2015, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants, which were announced by EPA on December 21, 2011. 77 FR 9304 (Feb. 16, 2012).[b] In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO2013* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2015. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, NEMS shows a reduction in SO_2 emissions when electricity demand decreases (*e.g.*, as a result of energy efficiency standards). Emissions will be far below the cap that would be established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO_2 emissions in 2015 and beyond.

CAIR established a cap on NO_x emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NO_x emissions in those States covered by CAIR because excess NO_x emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_x emissions. However, standards would be expected to reduce NO_x emissions in the States not affected by CSAPR, so DOE estimated NO_x emissions reductions from potential standards for those States.

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[b] On July 20, 2012, EPA announced a partial stay, for a limited duration, of the effectiveness of national new source emission standards for hazardous air pollutants from coal- and oil-fired electric utility steam generating units. <www.epa.gov/airquality/powerplanttoxics/pdfs/20120727staynotice.pdf>

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reductions using the NEMS-BT based on *AEO2013*, which incorporates the MATS.

16.3 POWER SECTOR EMISSIONS FACTORS

The analysis of power sector emissions uses marginal emissions intensity factors derived from runs of DOE's NEMS-BT model, using the version updated to the *AEO2013.* To model the impact of a standard, DOE inputs a reduction to annual energy demand for the corresponding end use in the appropriate start year. The NEMS-BT model is run with the decremented energy demand to determine the modified build-out of capacity, fuel use, and power sector emissions. A marginal emissions intensity factor is defined by dividing the reduction in the total emissions of a given pollutant by the reduction in total generation (in billion kilowatt-hours). DOE uses the site energy savings multiplied by a transmission and distribution (T&D) loss factor to estimate the reduction in generation for each trial standard level (TSL). Details on the approach used may be found in Coughlin (2013).[3]

Table 16.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity to buildings. DOE used the commercial lighting end use load shape. The average factors for each year take into account the projected shares of each of the sources in total electricity generation.

The power plant emissions factor for NO_x is an average for the entire U.S. The marginal calculation based on the NEMS-BT model accounts for the fact that NO_x emissions are capped in some States.

Table 16.3.1 Power Plant Emissions Factors

	Unit	2017	2020	2025	2030	2035	2040
CO_2	kg/MWh	605	605	581	545	490	409
SO_2	g/MWh	563	563	721	801	512	616
NOx	g/MWh	372	372	357	304	222	225
Hg	g/MWh	0.0014	0.0014	0.0007	0.0012	0.0009	0.0010
N_2O	g/MWh	6.9	7.2	7.2	7.1	7.1	6.9
CH_4	g/MWh	48	50	50	50	49	48

16.4 UPSTREAM AND GREENHOUSE GAS EMISSIONS FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 11B. See also Coughlin (2013).[3] When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of CO_2 occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total CO_2 emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas, and coal production. Combustion emissions of CH_4 are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 16.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_x emissions do not apply to upstream combustion sources.

Table 16.4.1 Electricity Upstream Emissions Factors

	Unit	2015	2020	2025	2030	2035	2040
CO_2	kg/MWh	28.5	27.3	26.9	26.8	26.9	26.3
SO_2	g/MWh	4.9	5.3	5.3	5.2	5.1	5.1
NOx	g/MWh	361	340	334	333	336	329
Hg	g/MWh	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
N_2O	g/MWh	0.25	0.25	0.25	0.25	0.24	0.24
CH_4	g/MWh	2,142	2,025	2,008	2,025	2,057	1,199

16.5 EMISSIONS IMPACT RESULTS

Table 16.5.1 and Table 16.5.2 present the estimated cumulative emissions reductions for the lifetime of products sold in 2016−2045 for each TSL, for the low and high shipment scenarios, respectively.

Table 16.5.1 Cumulative Emissions Reduction for Potential Standards for Metal Halide Lamp Fixtures for Low Shipments

	Trial Standard Level				
	1	2	3	4	5
Power Sector Emissions					
CO_2 (million metric tons)	25.90	38.85	46.04	52.32	104.72
NO_x (thousand tons)	17.39	26.22	31.20	35.41	71.71
Hg (tons)	0.06	0.09	0.11	0.12	0.24
N_2O (thousand tons)	0.48	0.72	0.86	0.98	2.00
CH_4 (thousand tons)	2.90	4.37	5.18	5.89	11.86
SO_2 (thousand tons)	36.23	54.37	64.42	73.25	146.53
Upstream Emissions					
CO_2 (million metric tons)	1.40	2.11	2.50	2.84	5.70
NO_x (thousand tons)	19.27	28.98	34.37	39.08	78.45
Hg (tons)	0.001	0.001	0.001	0.002	0.003
N_2O (thousand tons)	0.01	0.02	0.03	0.03	0.06
CH_4 (thousand tons)	116.89	175.81	208.58	237.15	476.16
SO_2 (thousand tons)	0.30	0.45	0.54	0.61	1.22
Total Emissions					
CO_2 (million metric tons)	27.30	40.96	48.53	55.16	110.43
NO_x (thousand tons)	36.66	55.20	65.57	74.48	150.16
Hg (tons)	0.06	0.09	0.11	0.12	0.24
N_2O (thousand tons)	0.49	0.74	0.89	1.01	2.06
CH_4 (thousand tons)	119.79	180.18	213.76	243.04	488.01
SO_2 (thousand tons)	36.53	54.82	64.95	73.85	147.75

Table 16.5.2 Cumulative Emissions Reduction for Potential Standards for Metal Halide Lamp Fixtures for High Shipments

	Trial Standard Level				
	1	**2**	**3**	**4**	**5**
Power Sector Emissions					
CO_2 (million metric tons)	33.93	51.48	61.61	69.58	143.59
NO_X (thousand tons)	23.50	35.86	43.14	48.58	101.88
Hg (tons)	0.08	0.12	0.14	0.16	0.34
N_2O (thousand tons)	0.66	1.01	1.22	1.37	2.90
CH_4 (thousand tons)	3.85	5.87	7.04	7.95	16.50
SO_2 (thousand tons)	47.41	71.94	86.07	97.26	200.46
Upstream Emissions					
CO_2 (million metric tons)	1.85	2.81	3.37	3.81	7.88
NO_X (thousand tons)	25.44	38.69	46.36	52.37	108.39
Hg (tons)	0.001	0.002	0.002	0.002	0.004
N_2O (thousand tons)	0.02	0.03	0.03	0.04	0.08
CH_4 (thousand tons)	154.45	234.93	281.50	317.98	658.29
SO_2 (thousand tons)	0.40	0.60	0.72	0.82	1.69
Total Emissions					
CO_2 (million metric tons)	35.78	54.29	64.98	73.39	151.47
NO_X (thousand tons)	48.94	74.55	89.50	100.95	210.26
Hg (tons)	0.08	0.12	0.15	0.16	0.34
N_2O (thousand tons)	0.68	1.04	1.25	1.41	2.98
CH_4 (thousand tons)	158.30	240.80	288.54	325.92	674.79
SO_2 (thousand tons)	47.80	72.54	86.79	98.08	202.14

Figure 16.5.1 through Figure 16.5.12 show the annual reductions for total emissions for each type of emission from each TSL for the low and high shipment scenarios. The reductions reflect the lifetime impacts of products sold in 2016−2045.

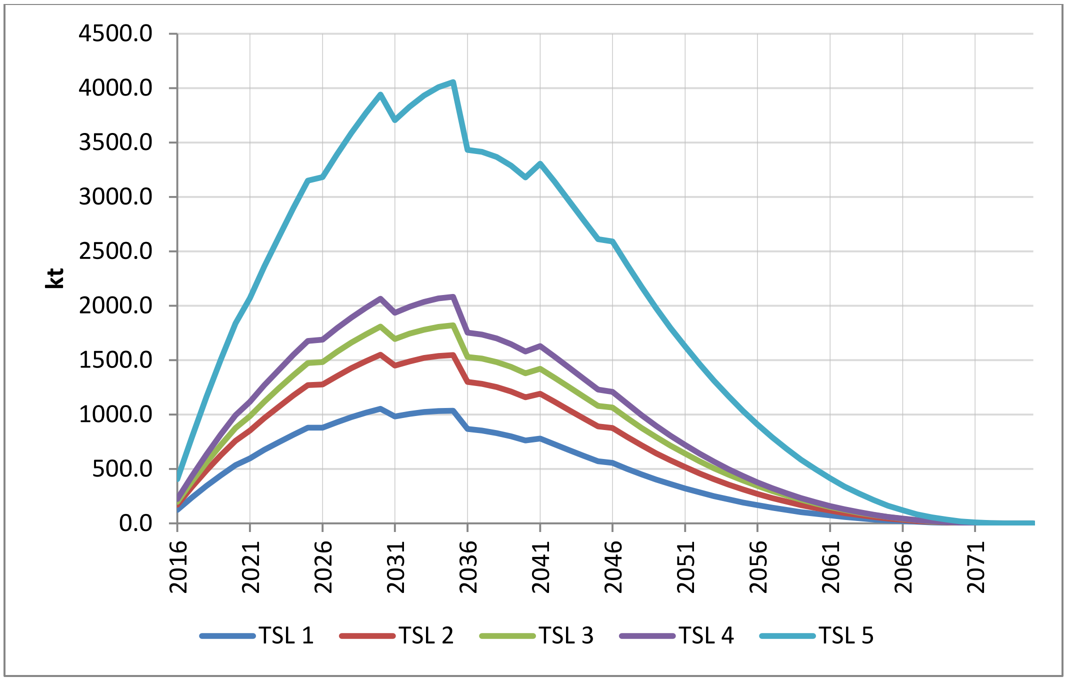

Figure 16.5.1 Metal Halide Lamp Fixtures: CO_2 Total Emissions Reduction for Low Shipments

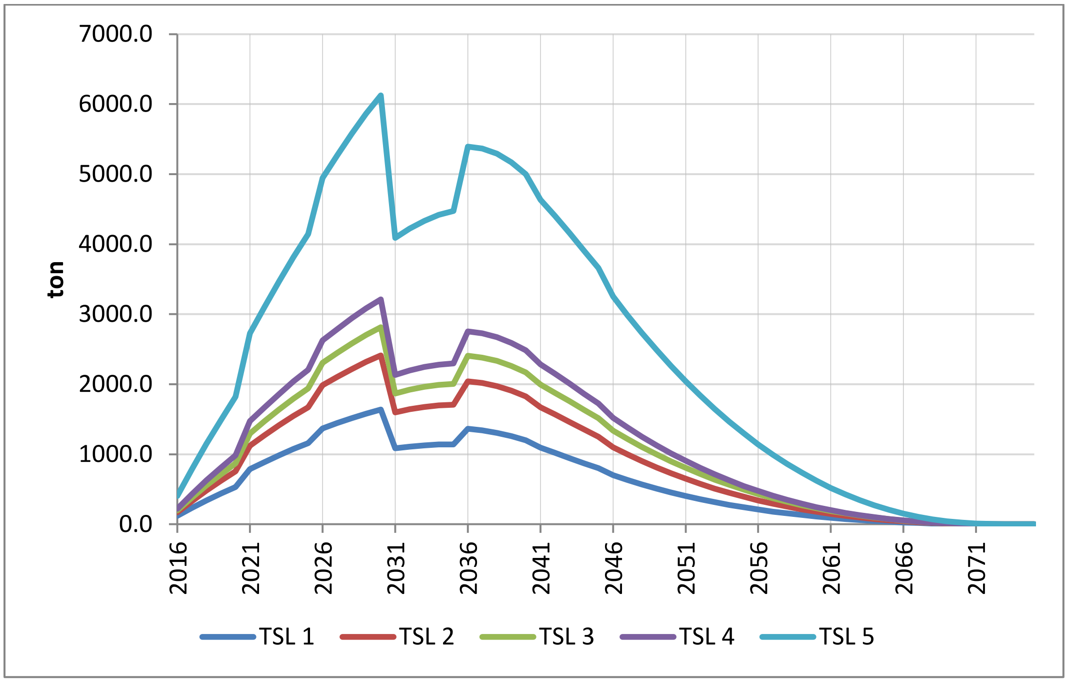

Figure 16.5.2 Metal Halide Lamp Fixtures: SO_2 Total Emissions Reduction for Low Shipments

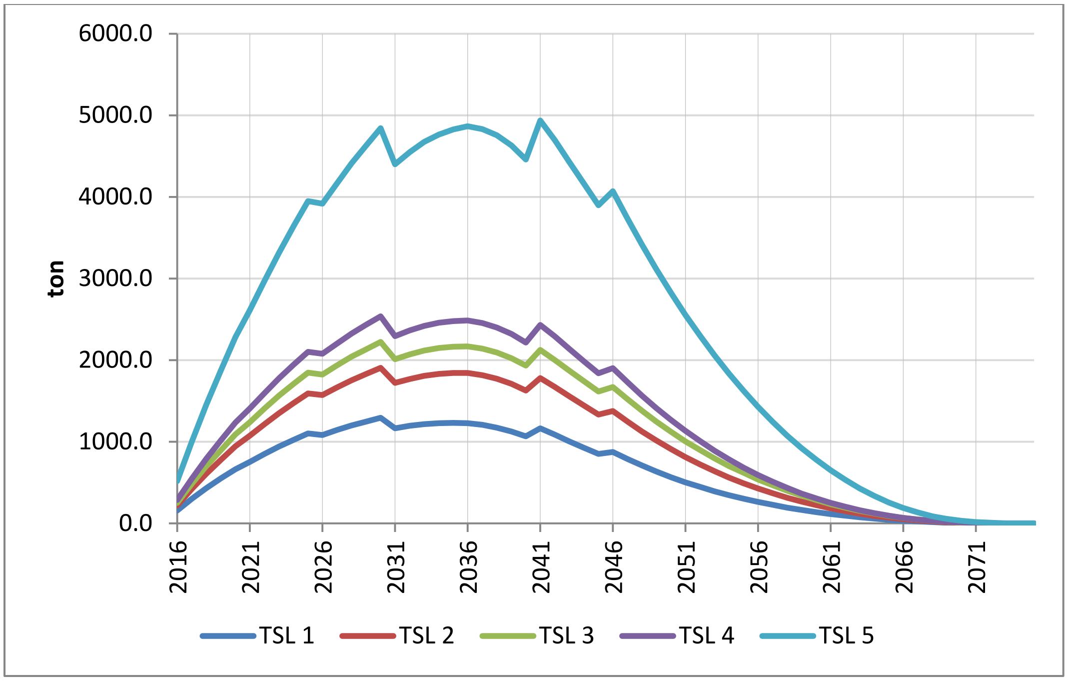

Figure 16.5.3 Metal Halide Lamp Fixtures: NO_x Total Emissions Reduction for Low Shipments

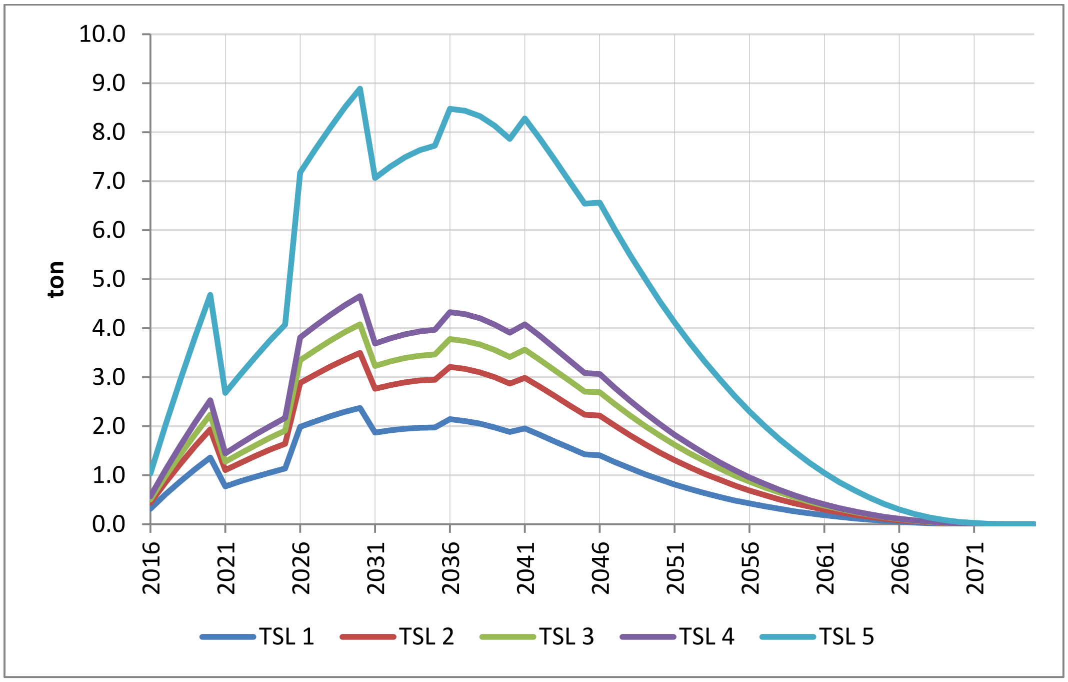

Figure 16.5.4 Metal Halide Lamp Fixtures: Hg Total Emissions Reduction for Low Shipments

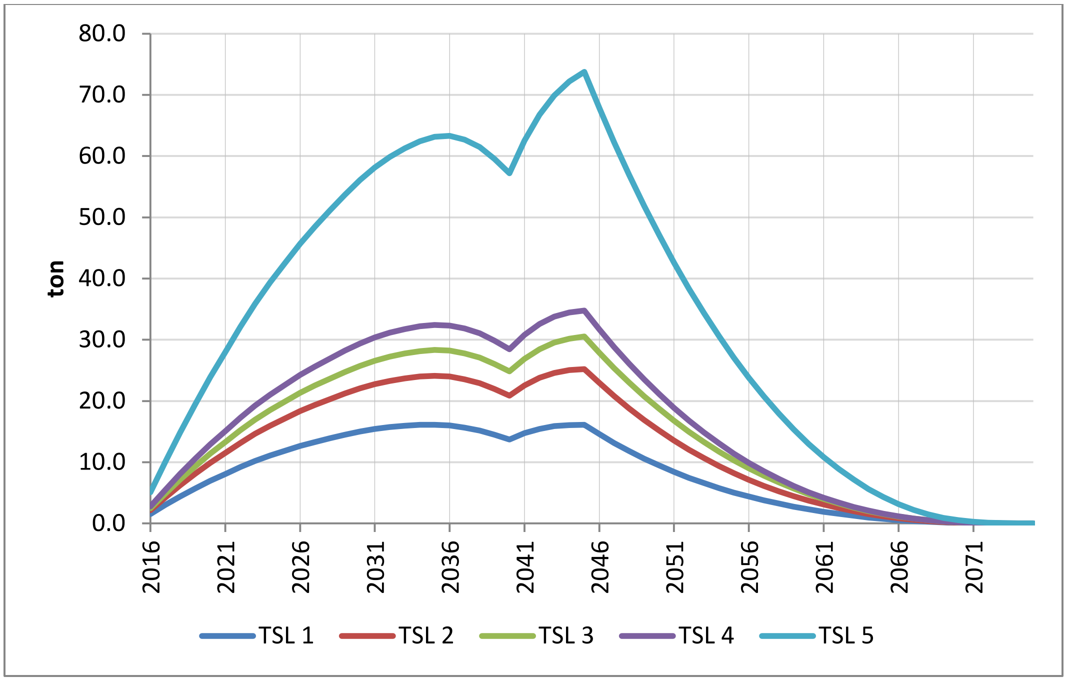

Figure 16.5.5 Metal Halide Lamp Fixtures: N_2O Total Emissions Reduction for Low Shipments

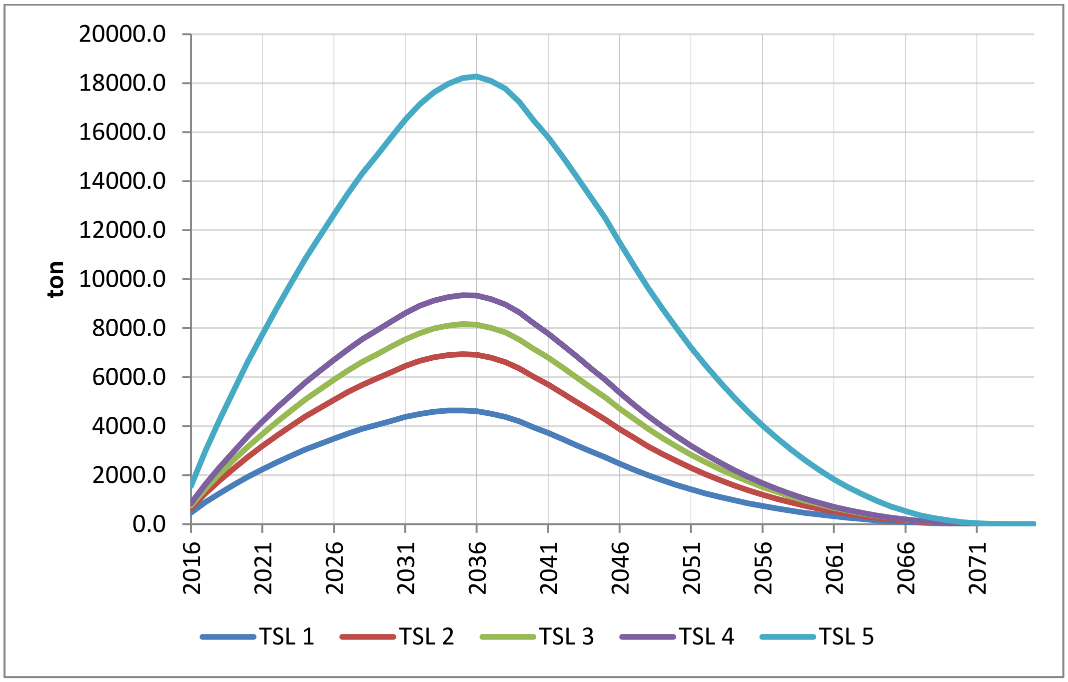

Figure 16.5.6 Metal Halide Lamp Fixtures: CH_4 Total Emissions Reduction for Low Shipments

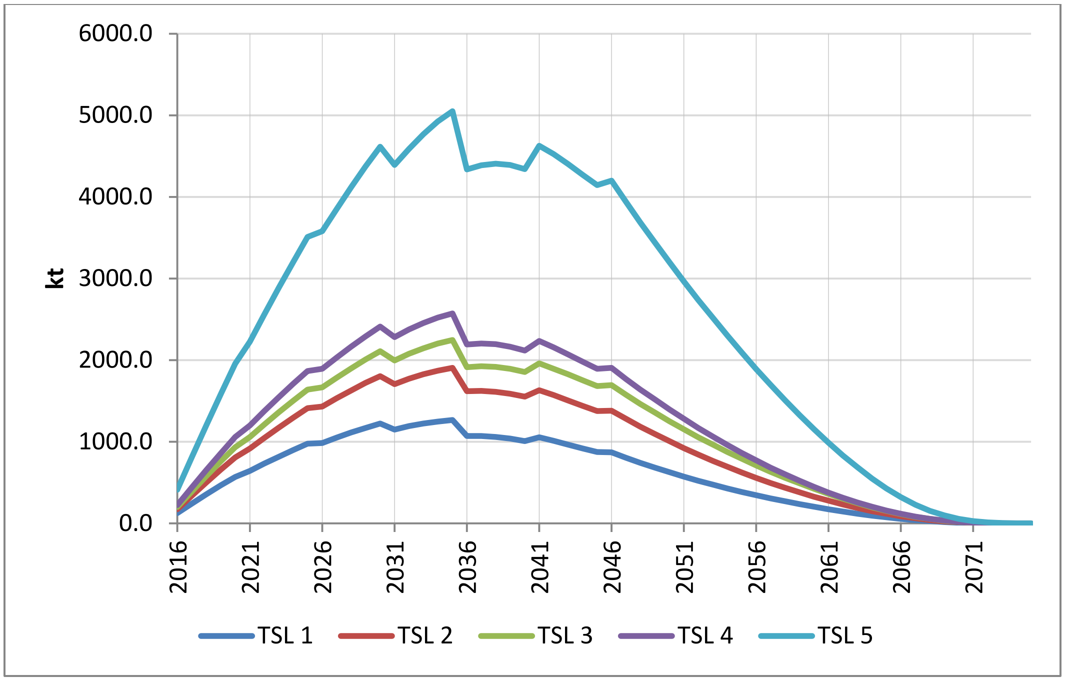

Figure 16.5.7 Metal Halide Lamp Fixtures: CO_2 Total Emissions Reduction for High Shipments

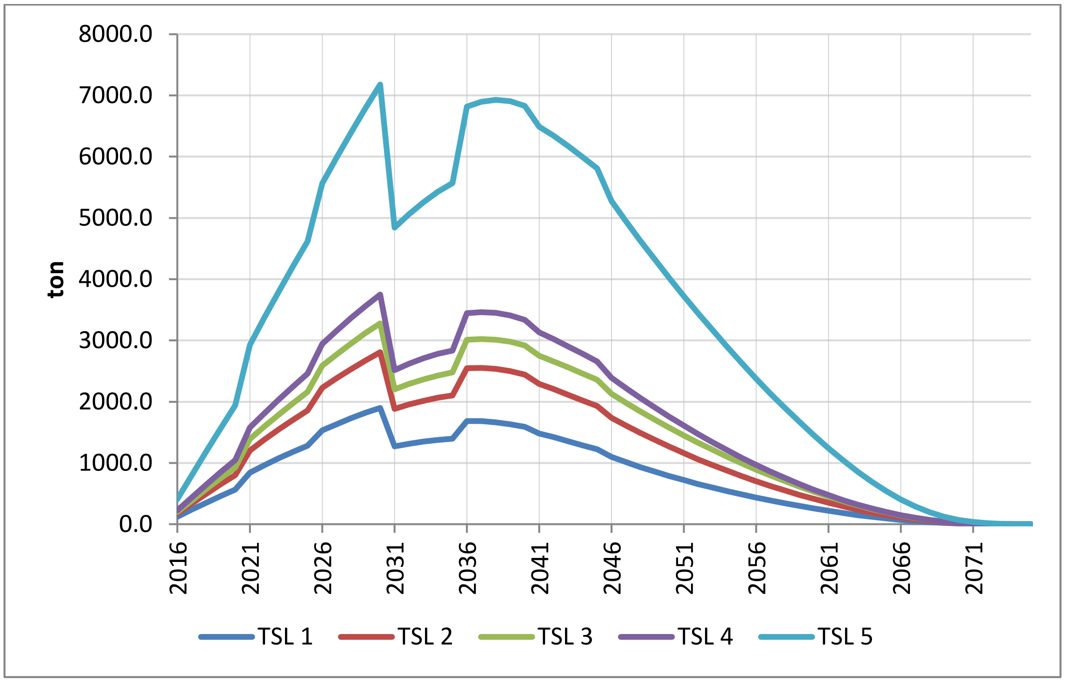

Figure 16.5.8 Metal Halide Lamp Fixtures: SO_2 Total Emissions Reduction for High Shipments

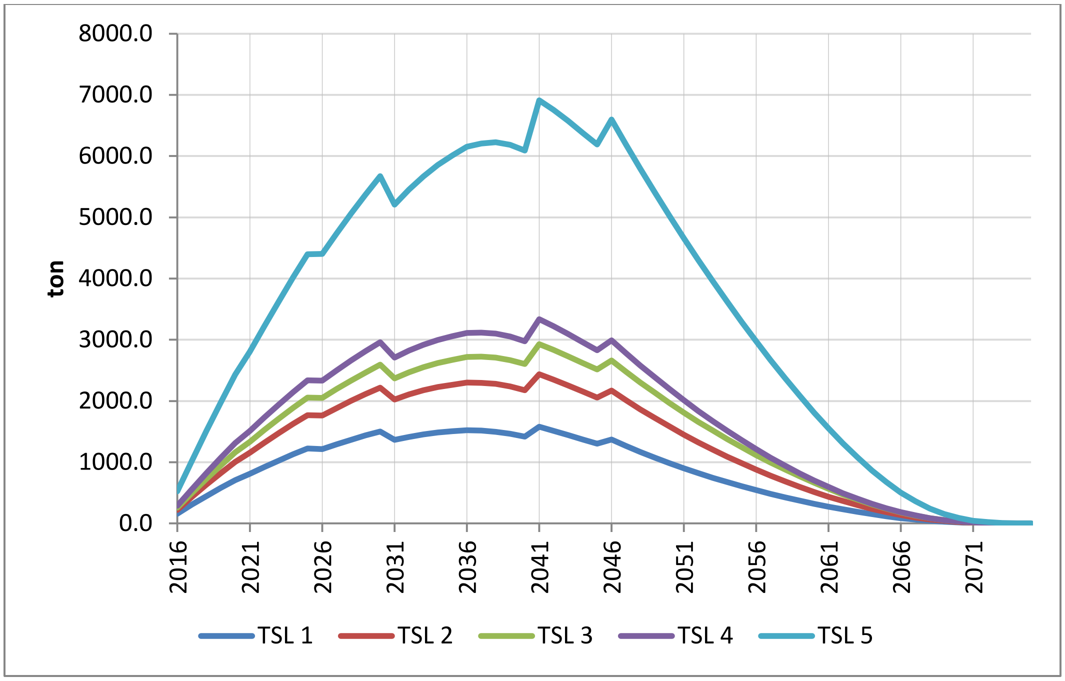

Figure 16.5.9 Metal Halide Lamp Fixtures: NO_x Total Emissions Reduction for High Shipments

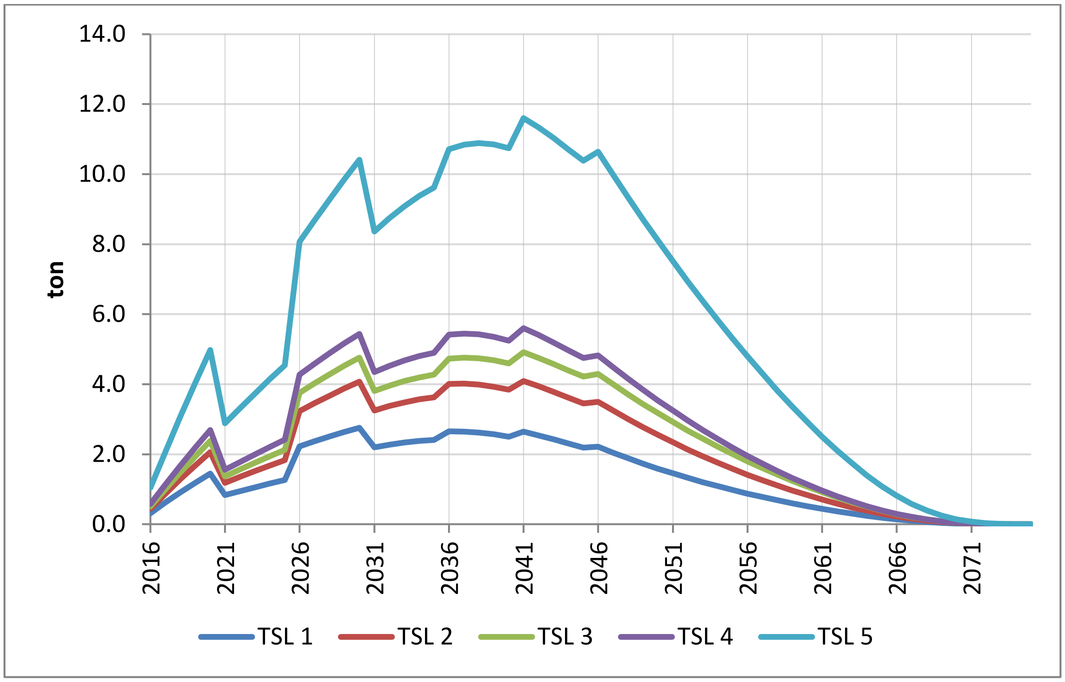

Figure 16.5.10 Metal Halide Lamp Fixtures: Hg Emissions Reduction for High Shipments

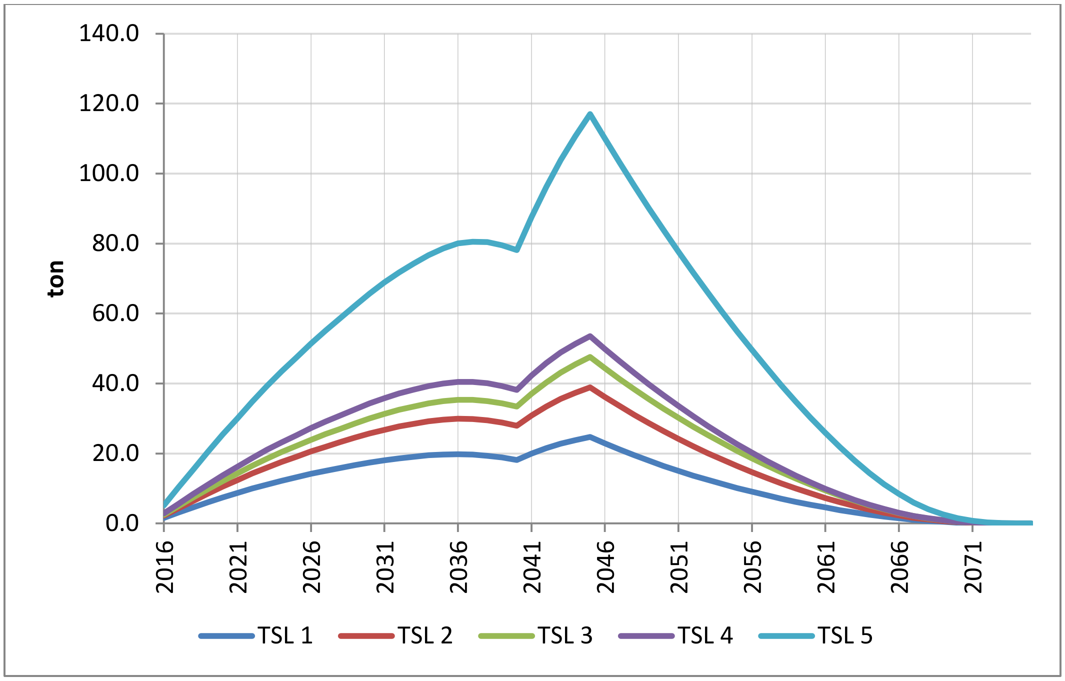

Figure 16.5.11 Metal Halide Lamp Fixtures: N_2O Total Emissions Reduction for High Shipments

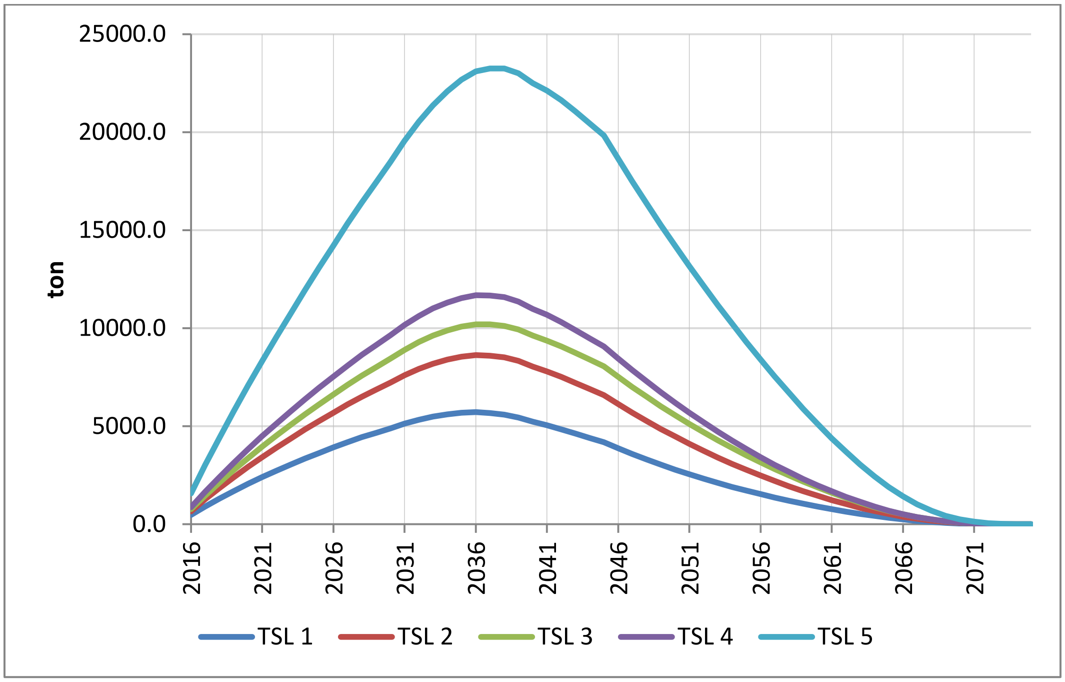

Figure 16.5.12 Metal Halide Lamp Fixtures: CH_4 Total Emissions Reduction for High Shipments

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CHAPTER 17. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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17.1 INTRODUCTION

As part of its assessment of energy conservation standards for metal halide lamp fixtures, the U.S. Department of Energy (DOE) estimated the monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) that are expected to result from each of the trial standard levels (TSLs) considered. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

17.2 MONETIZING CARBON DIOXIDE EMISSIONS

17.2.1 Social Cost of Carbon

The social cost of carbon (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 emissions, while a global SCC value is meant to reflect the value of damages worldwide.

Under section 1(b) of Executive Order 12866, agencies must, to the extent permitted by law, "assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to allow agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

17.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of CO_2 emissions, the analyst faces a number of serious challenges. A report from the National Research Council[1] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases; (2) the effects of past and future emissions on the climate system; (3) the impact of changes in climate on the physical and biological environment; and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions. For such policies, the agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global CO_2 emissions.

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing CO_2 emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of CO_2.[2] These interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules.

17.2.3 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates, which were considered for this proposed rule. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[a] These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in the SCC values that were developed. The SCC values used for in this notice of proposed rulemaking

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[a] The models are described in appendix 17A of the technical support document.

(NOPR) technical support document (TSD) were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature.[3]

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: (1) climate sensitivity; (2) socio-economic and emissions trajectories; and (3) discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socio-economic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3-percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. The values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing CO_2 emissions. Table 17.2.1 presents the values in the 2010 interagency group report,[b] which is reproduced in appendix 17A of the NOPR TSD.

The SCC values used for this analysis were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature.[c] Table 17.2.2 shows the updated sets of SCC estimates in 5-year increments from 2010 to 2050. The full set of annual SCC estimates between 2010 and 2050 is reported in appendix 17B of the NOPR TSD. The central value that emerges is the average SCC across models at the 3-percent discount rate. However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SCC values. For the years after 2050, DOE applied the average annual growth rate of the SCC estimates in 2040−2050 associated with each of the four sets of values.

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[b] *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Interagency Working Group on Social Cost of Carbon, United States Government, February 2010. www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[c] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Interagency Working Group on Social Cost of Carbon, United States Government*. May 2013. www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf

Table 17.2.1 Annual SCC Values from 2010 Interagency Report, 2010–2050 (in 2007$ per metric ton)

Year	Discount Rate %			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

Table 17.2.2 Annual SCC Values from 2013 Interagency Update, 2010–2050 (in 2007$ per metric ton CO_2)

Year	Discount Rate %			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned above points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC. The interagency group intends to periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2013 interagency report, escalated to 2012$ using the GDP price deflator. For each of the four cases specified, the values used for emissions in 2015 are $12.9, $40.8, $62.2, and $117 per metric ton avoided.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year in each of the four cases. To calculate a present value of the stream of monetary values, the interagency report notes that damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency. Thus, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SCC values in each case.

17.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefit of reduced NO_X emissions from the TSLs it considered. As noted in chapter 13, new or amended energy conservation standards would reduce NO_x emissions in those States that are not affected by caps. DOE estimated the monetized value of NO_x emissions reductions resulting from each of the TSLs considered based on environmental damage estimates found in the relevant scientific literature. Available estimates suggest a very wide range of monetary values, ranging from $468 to $4,809 per ton (in 2012$).[4] In accordance with Office of Management and Budget (OMB) guidance, DOE calculated a range of monetary benefits using each of the economic values for NO_x and real discount rates of 3 percent and 7 percent.[5]

DOE is still evaluating appropriate values to use to monetize avoided SO_2 and Hg emissions. It did not monetize these emissions for this analysis.

17.4 RESULTS

Table 17.4.1 and Table 17.4.2 present the global values of CO_2 emissions reductions for each considered TSL for low and high shipments respectively. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values for low and high shipments respectively, and these results are presented in Table 17.4.3 and Table 17.4.4.

Table 17.4.1 Estimates of Global Present Value of CO_2 Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for Low Shipments

TSL	SCC Case*			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	Million 2012$			
Primary Energy Emissions				
1	180.6	824.4	1,309.4	2,521.8
2	268.6	1,230.7	1,956.1	3,766.3
3	316.6	1,453.6	2,311.6	4,449.4
4	360.3	1,653.5	2,629.2	5,061.5
5	709.1	3,276.7	5,218.2	10,037.1
Upstream Emissions				
1	9.6	44.2	70.3	135.5
2	14.3	66.2	105.3	202.8
3	16.9	78.3	124.6	239.9
4	19.3	89.1	141.8	273.0
5	38.0	177.1	282.3	543.0
Total Emissions				
1	190.2	868.7	1,379.7	2,657.2
2	283.0	1,296.9	2,061.5	3,969.1
3	333.5	1,531.9	2,436.2	4,689.3
4	379.5	1,742.6	2,771.0	5,334.5
5	747.2	3,453.8	5,500.6	10,580.1

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 17.4.2 Estimates of Global Present Value of CO_2 Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for High Shipments

TSL	SCC Case*			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	Million 2012$			
Primary Energy Emissions				
1	226.5	1,052.4	1,678.3	3,225.1
2	340.4	1,587.8	2,534.4	4,868.3
3	404.3	1,891.8	3,021.8	5,802.1
4	458.2	2,141.2	3,418.9	6,566.6
5	924.3	4,359.1	6,975.4	13,379.6
Upstream Emissions				
1	12.2	56.9	90.9	174.7
2	18.3	86.1	137.6	264.4
3	21.8	102.8	164.3	315.5
4	24.7	116.3	185.9	357.1
5	50.1	237.6	380.6	730.0
Total Emissions				
1	238.7	1,109.3	1,769.2	3,399.8
2	358.7	1,674.0	2,672.0	5,132.7
3	426.2	1,994.6	3,186.1	6,117.6
4	482.9	2,257.5	3,604.9	6,923.7
5	974.3	4,596.7	7,356.0	14,109.6

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 17.4.3 Estimates of Domestic Present Value of CO_2 Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for Low Shipments

TSL	SCC Case*			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	Million 2012$			
Primary Energy Emissions				
1	12.6 to 41.5	57.7 to 189.6	91.7 to 301.2	176.5 to 580.0
2	18.8 to 61.8	86.1 to 283.1	136.9 to 449.9	263.6 to 866.2
3	22.2 to 72.8	101.8 to 334.3	161.8 to 531.7	311.5 to 1023.4
4	25.2 to 82.9	115.7 to 380.3	184.0 to 604.7	354.3 to 1164.1
5	49.6 to 163.1	229.4 to 753.6	365.3 to 1200.2	702.6 to 2308.5
Upstream Emissions				
1	0.7 to 2.2	3.1 to 10.2	4.9 to 16.2	9.5 to 31.2
2	1.0 to 3.3	4.6 to 15.2	7.4 to 24.2	14.2 to 46.6
3	1.2 to 3.9	5.5 to 18.0	8.7 to 28.7	16.8 to 55.2
4	1.3 to 4.4	6.2 to 20.5	9.9 to 32.6	19.1 to 62.8
5	2.7 to 8.8	12.4 to 40.7	19.8 to 64.9	38.0 to 124.9
Total Emissions				
1	13.3 to 43.8	60.8 to 199.8	96.6 to 317.3	186.0 to 611.2
2	19.8 to 65.1	90.8 to 298.3	144.3 to 474.1	277.8 to 912.9
3	23.3 to 76.7	107.2 to 352.3	170.5 to 560.3	328.2 to 1078.5
4	26.6 to 87.3	122.0 to 400.8	194.0 to 637.3	373.4 to 1226.9
5	52.3 to 171.9	241.8 to 794.4	385.0 to 1265.1	740.6 to 2433.4

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 17.4.4 Estimates of Domestic Present Value of CO_2 Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for High Shipments

TSL	SCC Case*			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	Million 2012$			
Primary Energy Emissions				
1	15.9 to 52.1	73.7 to 242.1	117.5 to 386.0	225.8 to 741.8
2	23.8 to 78.3	111.1 to 365.2	177.4 to 582.9	340.8 to 1119.7
3	28.3 to 93.0	132.4 to 435.1	211.5 to 695.0	406.1 to 1334.5
4	32.1 to 105.4	149.9 to 492.5	239.3 to 786.4	459.7 to 1510.3
5	64.7 to 212.6	305.1 to 1002.6	488.3 to 1604.3	936.6 to 3077.3
Upstream Emissions				
1	0.9 to 2.8	4.0 to 13.1	6.4 to 20.9	12.2 to 40.2
2	1.3 to 4.2	6.0 to 19.8	9.6 to 31.7	18.5 to 60.8
3	1.5 to 5.0	7.2 to 23.6	11.5 to 37.8	22.1 to 72.6
4	1.7 to 5.7	8.1 to 26.8	13.0 to 42.8	25.0 to 82.1
5	3.5 to 11.5	16.6 to 54.6	26.6 to 87.5	51.1 to 167.9
Total Emissions				
1	16.7 to 54.9	77.7 to 255.1	123.8 to 406.9	238.0 to 781.9
2	25.1 to 82.5	117.2 to 385.0	187.0 to 614.6	359.3 to 1180.5
3	29.8 to 98.0	139.6 to 458.8	223.0 to 732.8	428.2 to 1407.1
4	33.8 to 111.1	158.0 to 519.2	252.3 to 829.1	484.7 to 1592.4
5	68.2 to 224.1	321.8 to 1057.2	514.9 to 1691.9	987.7 to 3245.2

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 17.4.5 and Table 17.4.6 present the present value of cumulative NO_x emissions reductions for each TSL, calculated using the average dollar-per-ton values and 7-percent and 3-percent discount rates.

Table 17.4.5 Estimates of Present Value of NO_x Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for Low Shipments

TSL	3% discount rate	7% discount rate
	Million 2012$	
Power Sector Emissions		
1	24.4	12.3
2	36.3	18.1
3	42.8	21.2
4	48.7	24.1
5	96.3	46.6
Upstream Emissions		
1	27.2	13.6
2	40.5	20.0
3	47.7	23.4
4	54.3	26.6
5	106.9	51.4
Total Emissions		
1	51.6	25.9
2	76.8	38.1
3	90.6	44.6
4	103.0	50.8
5	203.2	98.1

Table 17.4.6 Estimates of Present Value of NO_x Emissions Reduction under Metal Halide Lamp Fixtures Trial Standard Levels for High Shipments

TSL	3% discount rate	7% discount rate
	Million 2012$	
Power Sector Emissions		
1	30.9	14.7
2	46.5	21.8
3	55.4	25.7
4	62.7	29.1
5	127.3	57.2
Upstream Emissions		
1	34.1	16.2
2	51.3	24.0
3	60.9	28.3
4	69.0	32.1
5	139.1	63.0
Total Emissions		
1	65.0	30.9
2	97.8	45.8
3	116.3	53.9
4	131.7	61.2
5	266.4	120.3

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CHAPTER 18. REGULATORY IMPACT ANALYSIS

18.1 INTRODUCTION

Under the Process Rule (*Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products*, 61 FR 36974 (July 15, 1996)), the U.S. Department of Energy (DOE) is committed to continually explore non-regulatory alternatives to standards. DOE will prepare a draft regulatory impact analysis pursuant to E.O. 12866, *Regulatory Planning and Review*, which will be subject to review under the Executive Order by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735 (Sept. 30, 1993).

The U.S. Department of Energy (DOE) has determined that energy conservation standards for metal halide lamp fixtures constitute an "economically significant regulatory action" under Executive Order (E.O.) 12866, "Regulatory Planning and Review." 58 FR 51735, 51735. (Oct. 4, 1993). This regulatory impact analysis (RIA), which DOE has prepared pursuant to E.O. 12866, evaluates potential non-regulatory alternatives, comparing the costs and benefits of each to those of the proposed standards. 58 FR 51741 (Oct. 4, 1993). As noted in E.O. 12866, this RIA is subject to review by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51740 (Oct. 4, 1993).

For this notice of proposed rulemaking (NOPR), DOE identified six major, non-regulatory alternatives to standards as representing feasible policy options to achieve potentially similar improvements in metal halide lamp fixture energy efficiency:

1. No New Regulatory Action
2. Customer Rebates
3. Customer Tax Credits
4. Manufacturer Tax Credits
5. Voluntary Energy Efficiency Programs
6. Bulk Government Purchases

DOE evaluated each alternative that applies to the metal halide lamp fixtures covered by this proposed rule in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each alternative to that of the proposed standards. The following sections discuss the analysis method used, the non-regulatory alternatives considered, and the energy savings calculated.

18.2 METHODOLOGY

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the six non-regulatory policy alternatives (excluding the alternative of no new regulatory action) for the identified metal halide lamp fixtures. This section also describes the assumptions underlying the analysis.

DOE used integrated national impact analysis-regulatory impact analysis (NIA-RIA) spreadsheet models to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 11 of the NOPR technical support document (TSD) describes the NIA spreadsheet models.

DOE quantified the effect of each alternative on the purchase of equipment that meets *target levels*, which are defined as the efficiency levels in the proposed standards. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet models. The primary model input revised was market shares of equipment meeting target efficiency levels. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed that the proposed standards would affect 100 percent of the shipments of equipment that did not meet target levels in the base case, whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy.

Increasing equipment's efficiency often increases its average installed cost but generally decreases its operating costs because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the proposed standards. Because DOE assumed that customers would re-pay credits and rebates in some way (such as additional taxes), DOE did not include rebates or tax credits as a customer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the effect of each alternative:

- NES, given in quadrillion British thermal units (quads), describes the cumulative national primary energy savings for equipment sold in 2016-2045.
- NPV represents the value in 2012$ (discounted to 2013) of net monetary savings from equipment sold in 2016-2045.
- DOE calculated the NPV as the difference between the present value of installed equipment cost and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the equipment.

DOE quantified the market penetration of each alternative, *i.e.*, what percent of customers below the target efficacy level would migrate to the higher efficacy equipment, and revised its inputs to the NIA-RIA spreadsheet models. With these modifications, DOE calculated the NES and NPV of each non-regulatory alternative and compared it to that of the proposed standards, which correspond with trial standard level (TSL) 3.

DOE's analyses indicated that the proposed standards at TSL 3 would save a significant amount of energy—with cumulative NES estimated at 0.80–1.08 quads for fixtures shipped in 2016–2045. The corresponding cumulative NPV of total customer costs and savings of the proposed standards for metal halide lamp fixtures, in 2012$, ranges from $0.95 billion (at a 7-percent discount rate) to $3.2 billion (at a 3-percent discount rate).

DOE calculated the effects of each regulatory policy separately from those of the other policies. In actual practice, certain policies are often most effective when implemented in combination to provide incentives, such as customer and manufacturer credits. DOE attempted to make conservative assumptions to avoid double-counting policy effects. Therefore, the policy effects reported below are not additive; the combined effect of several or all of the policies may not be inferred from adding the results together.

For all non-regulatory policies considered, DOE assumed a shift from the baseline to efficiency level (EL) 1 for all equipment classes. In all equipment classes, EL1 represents real equipment—for some equipment classes certain ELs are not currently commercially available. For the 150 W, 250 W, and the 400 W equipment classes, EL 3 and EL 4 represent electronic ballasts. For many of these fixtures, converting from the baseline to the higher EL incurs fixture redesign costs. DOE assumes that without regulation, manufacturers would not convert to these higher ELs en masse.

18.3 NON-REGULATORY POLICIES

The following subsections describe DOE's analysis of the effects of the six non-regulatory policy alternatives to chosen standards for metal halide lamp fixtures. Because the alternative of No New Regulatory Action has no energy or NPV impacts, essentially representing the NIA base case, DOE did not perform additional analysis for that alternative. DOE developed estimates of the market penetration of high-efficiency equipment with each of the non-regulatory policy alternatives and compared them to the NIA base case.

18.3.1 No New Regulatory Action

The base case is the one in which no new regulatory action is taken with regard to the energy efficiency of metal halide lamp fixtures, as described in the NOPR TSD chapter 11. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

18.3.2 Customer Rebates

Customer rebates cover a portion of the difference in incremental equipment price between equipment meeting baseline efficiency levels and those meeting higher efficiency levels, resulting in a higher percentage of customers purchasing more efficient models and decreased aggregated energy use compared to the base case. For metal halide lamp fixtures, DOE assumed a rebate that paid 25 percent of the incremental equipment price, based on its research from *Database of State Incentives and Renewable Energy* (DSIRE)[1] focusing on existing utility rebate programs for replacing mercury vapor; probe-start metal halide or high-pressure sodium systems with pulse-start metal halide.

DOE's previous research showed that for the rebate amount that was equal to the full incremental cost, customer response rate was about 25 percent (2000 Fluorescent Lamp Ballast Rule[2]). DOE reviewed the incentives from energy efficiency programs and utilities across the country from the *DSIRE.* Appendix 18A details each of the programs, the amount of the incentive, and in a limited sense the parameters of the incentive. Many programs have limitations that the incentive can only be a portion of the total cost (*e.g.*, 70 percent). Therefore a customer response of 25 percent is unlikely. DOE compared the average cost of each efficiency level for each metal halide lamp fixture per equipment class to the average applicable incentive from the DSIRE data.

Table 18.3.1 compares the average metal halide lamp fixture cost to the average incentive for the 70 W and 150 W equipment classes. For the 70 W equipment class, the average incentive is roughly one-third the average cost of the fixture. It should be noted that the standard deviation of the incentive is two-thirds the average, indicating there is significant variation of the incentives. Incentives for fixtures in the 150 W equipment class are roughly 30 percent of the average fixture price.

Table 18.3.2 compares the average metal halide lamp fixture cost to the average incentive for the 250 W, 400 W, and 1000 W equipment classes. For the 250 W and 400 W equipment classes, the average incentive is roughly one-quarter the average cost of the fixture. For the 1000 W equipment class, the average incentive is only 15 percent of the average fixture cost.

Metal halide lamp fixtures are used mostly in commercial sectors, and DOE considers commercial customers more likely to be aware of, and take advantage of customer rebates. DOE assumed a response rate of 10 percent, and estimated a corresponding shift of 10 percent in market shares toward more efficient equipment, with no change in total shipments.

Table 18.3.1 Comparison of Incentives and Fixture Costs

	70 W		**150 W**	
	Indoor	Outdoor	Indoor	Outdoor
Average	$113.77	$117.59	$182.87	$180.57
Std. Dev	$12.31	$29.33	$13.58	$28.85
Average	$41.76	$42.11	$53.73	$54.21
Std. Dev	$27.08	$27.28	$41.43	$41.89
% of Fixture Cost	36.70%	35.81%	29.38%	30.02%

Table 18.3.2 Comparison of Incentives and Fixture Costs

	250 W		**400 W**		**1000 W**	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Average	$263.96	$284.22	$323.50	$311.15	$483.25	$440.41
Std. Dev	$32.32	$84.37	$70.66	$85.70	$40.14	$38.45
Average	$59.80	$60.70	$77.29	$77.39	$73.68	$74.10
Std. Dev	$44.47	$45.19	$76.51	$77.02	$49.39	$49.63
% of Fixture Cost	22.66%	21.36%	23.89%	24.87%	15.25%	16.82%

Although the rebate program reduces the total installed cost to the customer, it is financed by tax revenues. Therefore, from a societal perspective, the installed cost at any efficiency level does *not* change with the rebate program; rather, part of the cost is transferred from the customer to taxpayers as a whole. Consequently, DOE assumed that equipment costs in the rebates scenario were identical to the NIA base case.

18.3.3 Customer Tax Incentives

Customer tax deductions are considered a viable non-regulatory market transformation program, as shown by the inclusion of Federal customer tax deductions in the Energy Policy Act of 2005 (EPAct 2005) Section 179D. The tax deductions are provided if a commercial building reaches a lighting power density (LPD) 25 percent (50 percent for warehouses) lower than ANSI/ASHRAE/IES Standard 90.1-2001 minimum requirements and incorporates bi-level switching. These deductions are applicable for interior applications – note the Internal Revenue Service has issued a bulletin that parking structures are interior spaces except for the top floors that are not covered. Metal halide lamp fixtures are sparsely used in interior applications because metal halide lamps have longer warm-up time and it is difficult to dim these lamps and incorporate bi-level switching. The incentive is not focused on ballast efficiency, but it should be assumed that more efficient ballasts help reduce the lighting power density. Because this deduction is not explicitly directed toward metal halide lamp fixtures, given the low proportion of metal halide fixtures installed indoors (roughly 25 percent), and given that in a 2009 survey 82 percent of owners were not aware of the tax deduction,[3] DOE estimated a response rate of 5 percent for customer tax deductions as of 2012. However, the 179D tax provisions were only extended to December 31, 2013 by the Emergency Economic Stabilization Act of 2008 (Pub. L. 110-343). As of the summer of 2013, the future of the tax incentive is unknown for the start of the analysis period (2016). Therefore, DOE assumes an actual response rate of 0 percent for customer tax deductions.

18.3.4 Manufacturer Tax Credits

Manufacturer tax credits are considered a viable non-regulatory market transformation program, as shown by the inclusion of Federal tax credits in EPAct 2005 for manufacturers of residential appliances. Those manufacturer tax credits were in effect for models produced in 2006 and 2007 and reinstated under the American Recovery and Reinvestment Act (ARRA) for 2009 and 2010. DOE was unable to locate data from the IRS or other sources on manufacturer response to the Federal credits. Manufacturer tax credits would effectively result in lower equipment prices for customers by an amount that covers part of the incremental price difference between equipment meeting baseline efficiency levels and those meeting targeted efficiency levels.

DOE assumed that this incentive policy would help reimburse manufacturers for retooling costs. Because these tax credits would go to manufacturers instead of customers, DOE assumed that manufacturers would pass the reduced costs on to customers. Only these “direct price effects” would be visible to the customer, with the tax credit program itself visible only to affected manufacturers. The effect of manufacturer tax credits is differentiated into direct price effects, which arise from the customer cost savings, and “announcement effects” that establish credibility of a particular technology by its inclusion in an incentive program. DOE assumed that these effects split the overall response rate equally.[4]

Therefore, the response rate for manufacturer tax credits is assumed to be a half of that for customer tax incentives (when a viable, current tax incentive is offered), or 2.5 percent. As discussed above, DOE assumed that total installed costs will remain unchanged from the NIA base case, with no change in total shipments.

18.3.5 Voluntary Energy Efficiency Programs

DOE estimated the effect of voluntary energy efficiency programs by reviewing the historical and projected market transformation performance of past and current ENERGY STAR® programs. DOE and the U.S. Environmental Protection Agency (EPA) developed ENERGY STAR specifications for residential light fixtures and solid-state lighting (SSL). In 2011, ENERGY STAR finalized the luminaire specification (V1.2) that covers all light sources, but is more focused on residential applications than commercial applications.[5] Qualification is limited to luminaires below a total input power of 250 watts. ENERGY STAR also limits coverage for luminaires using high-intensity discharge (HID) sources (which include metal halide) to outdoor luminaires only.

For residential non-directional luminaires using HID sources, until September 1, 2013, the lamp-ballast platform shall have a source efficacy of ≥ 65 lumens per watt (lm/W). After September 1, 2013 the lamp-ballast platform shall have an efficacy of ≥ 70 lm/W. Although ballast efficiency does factor into lamp-ballast platform, it is possible to use a better performing lamp to achieve the lamp-ballast platform efficacy requirements. Indoor non-directional luminaires (fixtures) includes: bath vanity; ceiling and close-to-ceiling mounted; chandeliers; decorative pendants; linear strips; wall sconces; wrapped lens' ventilation fan lights; and portable luminaires (as previously stated, not applicable to HID luminaires for ENERGY STAR). Outdoor non-directional luminaires includes: ceiling and close-to-ceiling mount; porch (wall-mounted); pendant; and security. ENERGY STAR sets luminaire efficacy[a] requirements for directional residential outdoor wall, porch, pendant, or post-mounted luminaires of 35 lm/W.

For the most recent year in which ENERGY STAR collected unit shipment data (2006), roughly 11 million residential light fixtures[b] were shipped.[6] ENERGY STAR had an 84 percent response rate from partners. Of these responses, 4 percent of ENERGY STAR residential light fixtures were "indoor" and 11 percent were "outdoor."

Therefore, because previous ENERGY STAR efforts yielded 4 percent for indoor shipments and 11 percent for outdoor shipments; and only a small portion of the comprehensive ENERGY STAR luminaire specification are applicable to metal halide lamp fixtures; and the wattage limit of ENERGY STAR is 250 W, DOE assumes that voluntary energy efficiency programs have little effect (1 percent).

18.3.6 Bulk Government Purchases

In this policy alternative, "bulk government purchases" refers to programs that encourage Federal, state, and local governments to purchase equipment meeting applicable energy conservation standards. The motivations for this policy are that (1) aggregating public sector demand could provide a market signal to manufacturers and vendors that some of their largest customers seek suppliers with equipment that meet efficiency targets at competitive prices; and (2) this could induce "market pull" impacts through the effects of manufacturers and vendors achieving economies of scale for high-efficiency equipment.

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[a] Total initial light output of the luminaire (fixture) divided by the total input power

[b] Residential Light Fixtures was one of the previous ENERGY STAR specifications before ENERGY STAR consolidated the various specifications into one comprehensive fixture specification.

DOE estimates that bulk government purchases have low yield.

DOE reviewed existing federal, state, and local government programs and found most of them focusing on other lighting technologies besides metal halide. DOE's Federal Energy Management Program has a new initiative focusing on SSL in the federal sector. DOE also has a program focusing on SSL for municipalities. Government programs are currently focusing on non-HID technologies for bulk purchases. Therefore, DOE assumes that bulk government purchases will have a very low market-pull effect (2.5 percent) for metal halide lamp fixtures.

18.4 SUMMARY OF RESULTS FOR NON-REGULATORY ALTERNATIVES

Table 18.4.1 and Table 18.4.2 show the NES and NPV for the non-regulatory alternatives analyzed. The case in which no regulatory action is taken with regard to metal halide lamp fixtures constitutes the base case (or "No New Regulatory Action") scenario. Since this is the base case, energy savings and NPV are zero by definition. For comparison, the table includes the results of the NES and NPV for TSL 2 associated with the proposed energy conservation standard. Energy savings expressed in quads in terms of primary or source energy, which includes generation and transmission losses from electricity utility sector. The NES and NPVs shown in the tables are computed only for roll-up scenario for the low and high shipments scenarios addressed in the NIA. These scenarios better reflect market behavior, because only customers of below the target efficiency levels are affected. This is the same target group that non-regulatory alternatives aim to influence.

Table 18.4.1 Cumulative NES of Non-Regulatory Alternatives Compared to the Proposed Standards for Metal Halide Lamp Fixtures

Policy Alternatives	**Cumulative NES** *quads*	
	Low Shipments	**High Shipments**
No New Regulatory Action	0.00	0.00
Customer Rebates	0.05	0.07
Customer Tax Incentive	0.00	0.00
Manufacturer Tax Credits	0.01	0.02
Voluntary Energy Efficiency Programs	0.00	0.01
Bulk Government Purchases	0.01	0.02
Proposed Standards (TSL 3)	0.80	1.08

Table 18.4.2 Cumulative NPV of Non-Regulatory Alternatives Compared to the Proposed Standards for Metal Halide Lamp Fixtures

Policy Alternatives	**Cumulative NPV** *billion 2012$*			
	Low Shipments		**High Shipments**	
	7% Discount	**3% Discount**	**7% Discount**	**3% Discount**
No New Regulatory Action	0.00	0.00	0.00	0.00
Customer Rebates	0.07	0.15	0.08	0.20
Customer Tax Incentives	0.00	0.00	0.00	0.00
Manufacturer Tax Credits	0.01	0.04	0.02	0.05
Voluntary Energy Efficiency Programs	0.00	0.02	0.01	0.02
Bulk Government Purchases	0.01	0.04	0.02	0.05
Proposed Standards (TSL 3)	0.95	2.45	1.18	2.93

As shown above, none of the policy alternatives DOE examined would save as much energy as and have a higher NPV than the proposed standards level of TSL 3. Also, several alternatives would require legislation, such as commercial customer or federal tax credits, because there is currently no authority to carry out those alternatives.

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

8A.1 INTRODUCTION

The results obtained for the life-cycle cost (LCC) and payback period (PBP) analysis can be examined and reproduced using the Microsoft Excel spreadsheet available on the U.S. Department of Energy (DOE) Building Technologies website at: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16.

There is one spreadsheet covering all combinations of metal halide lamp fixture (MHLF or fixture) system equipment classes. The spreadsheet posted on the DOE website represents the latest version that has been tested with both Microsoft Excel 2007 and 2010. The LCC and PBP spreadsheet performs calculations to forecast the change in LCC from an energy conservation standard and the PBP that such a change implies. These concepts are explained in the main body of the notice of proposed rulemaking (NOPR) technical support document (TSD) chapter 8.

To operate the spreadsheet, a user chooses values of interest in the LCC&PBP tab. Analysis Mode, Subgroup, Fixture Environment, and Economic Growth Scenarios are all selected via drop-down menus. Any market and energy price behavior can be set by adjusting the named ranges embedded throughout the LCC/PBP spreadsheet model. Therefore, strictly speaking, no "instructions" are necessary to operate the spreadsheet. Rather, in this appendix, DOE describes the model in case users wish to examine DOE's assumptions and methods or to test alternative assumptions.

8A.2 MODEL CONVENTIONS

Both of the model's primary outputs, LCC savings and PBP, are calculated on the LCC worksheet by using base case and standards case fixtures as inputs (*e.g.*, the LCC savings for a particular MHLF system is calculated by subtracting the LCC associated with that unit from the LCC associated with a unit of the same equipment class at a baseline efficiency).

In general, logic flows from the data sources and assumption worksheets (assembled as the right-most worksheets) toward outputs (produced in the left-most worksheets). Data carried from one sheet and reproduced in another are generally presented in a box on the upper-left side of a worksheet.

8A.3 INDIVIDUAL WORKSHEETS

The LCC/PBP spreadsheet or workbook consists of the following worksheets.

Instructions	Contains notes from the model developer for spreadsheet users.
LCC&PBP	Presents LCC savings and PBP results by MHLF type to produce the results that DOE provides in the NOPR TSD chapter 8 and the NOPR text for the *Federal Register*. Also condenses the

	information from the Lifetime Costs worksheet, for user ease of use.
Lifetime Costs	Compiles data from several other worksheets to calculate the actual LCC of each fixture. This worksheet also contains assumptions for labor costs, some equipment prices, and mark-up values.
Discount Rate	Derives discount rates for commercial, industrial, and outdoor stationary sector fixtures.
Operating Hours	Provides the data and calculations used to develop operating hours for commercial, industrial, and outdoor stationary sectors.
Electricity and Tax Rates	Contains data and calculations for electricity prices over time, and sales tax rates. Also contains economic growth scenario information.
Information Hub	Contains the engineering summary data, and many important quantities that pertain to each equipment class and representative piece of equipment.
Monte Carlo	Contains distributions of many different components of LCC computations, for use in the Monte Carlo analysis.
Output to NIA	Contains a few calculated values for easy output to the national impacts analysis (NIA) model.

APPENDIX 8B. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR METAL HALIDE LAMP FIXTURES

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APPENDIX 8B. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR METAL HALIDE LAMP FIXTURES

8B.1 INTRODUCTION

In developing the proposed standards, the U.S. Department of Energy (DOE) assumed that the manufacturer costs and retail prices of products meeting various efficiency levels remained fixed, in real terms, after 2010 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. In its notice of data availability (NODA), 76 FR 9696 (Feb. 22, 2011), DOE stated that it may consider improving regulatory analysis by addressing equipment price trends. Consistent with the NODA, DOE examined historical producer price indices (PPI) for metal halide lamp fixtures and found both positive and negative real price trends depending on the time period examined. Therefore, in the absence of a definitive trend, DOE decided to use price deflators from the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2011* (*AEO2011*) to adjust fixture prices over the analysis period.

The following paragraphs briefly describe the experience curve approach and deflator approach and the reasons why the latter was adopted.

8B.2 EXPERIENCE CURVE APPROACH

DOE stated in the NODA that examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, overestimate long-term appliance and equipment price trends. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves, or alternatively that the price trends for certain sectors of the U.S. economy may be different than the price trends for the economy as a whole. A draft paper, "Using the Experience Curve Approach for Appliance Price Forecasting," posted on the DOE website at http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/experience_curve_appliance_price_forecasting_3-16-11.pdf, provides a summary of the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[a] In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a manufactured product. A common functional relationship used to model the evolution of production costs in this case is:

$$Y = aX^{-b}$$

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[a] In addition to the draft paper mentioned above, see Weiss, M., H.M. Junginger, M.K. Patel, and K. Blok. A Review of Experience Curve Analyses for Energy Demand Technologies. *Technological Forecasting & Social Change*. 2010. 77:411-428.

where a is an initial price (or cost), b is a positive constant known as the learning rate parameter, X is cumulative production, and Y is the price as a function of cumulative production. Thus, as experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (LR), given by:

$$LR = 1 - 2^{-b}$$

In typical learning curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost).

DOE examined historical prices using the Bureau of Labor Statistics' (BLS) PPI and gross domestic product (GDP) deflator, available from the Bureau of Economic Analysis (BEA). The PPI data for industrial-type electric lighting fixtures, including parts and accessories, is available for 1987–2010 and is used to represent aggregate industrial lighting system prices. Figure 8B.2.1 shows this PPI data series.

Inflation-adjusted price indices were calculated by dividing the PPI series by the GDP deflator for the same years. The GDP deflator was used as opposed to the Consumer Price Index (CPI) because nearly all metal halide lamp fixtures are shipped to commercial and industrial customers.

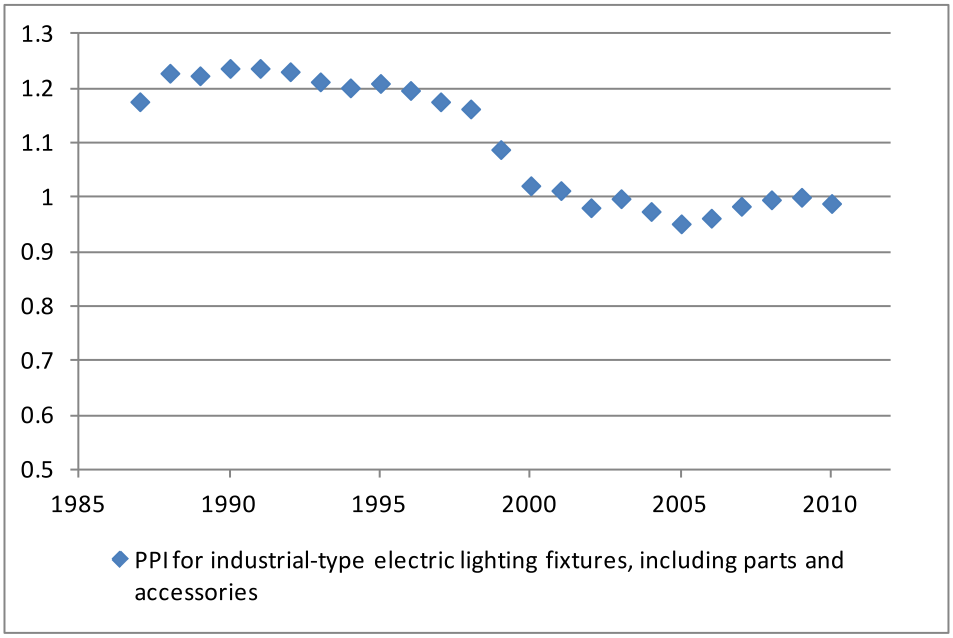

Figure 8B.2.1 PPI Data for Metal Halide Lamp Fixtures

Figure 8B.2.1 shows an apparent price trend in lighting fixtures that is trending downward from 1987 to 2005, but shows an increase in the real PPI from 2005 to 2010. Given the presence of both positive and negative real price trends, DOE elected to not use the experience curve approach to adjust fixture prices.

8B.3 *AEO* PRICE TREND APPROACH

For this proposed rule, DOE instead used the *AEO* price trend approach. DOE has access to the forecasted price indexes used by EIA to develop *AEO2011*. The price index projections used in the EIA model are called deflators. The narrowest index that includes metal halide lamp fixtures—the series "Non-residential investment – Other equipment"—was used. This index was inflation-adjusted by dividing by the "GDP Deflator" index, also available from *AEO2011*. The resulting factor was reset to 1 in 2011—the year for which the prices were developed.

The *AEO* price indexes begin in 1990 and extend to 2035. Because the *AEO* time series does not extend to the end of the analysis period, the forecasted trend was extrapolated for 2035–2074. Table 8B.3.1 presents the resulting price factors used in the national impact analysis and all downstream analyses for this proposed rule.

Table 8B.3.1 Price Factors for Metal Halide Lamp Fixtures

Year	Price Factor
2011	1.000
2012	1.001
2013	1.005
2014	1.005
2015	1.000
2016	0.997
2017	0.990
2018	0.983
2019	0.976
2020	0.967
2021	0.957
2022	0.948
2023	0.938
2024	0.929
2025	0.919
2026	0.909
2027	0.898
2028	0.886
2029	0.875
2030	0.864
2031	0.852
2032	0.841
2033	0.829
2034	0.817
2035	0.804
2036	0.799
2037	0.795
2038	0.790
2039	0.785
2040	0.780
2041	0.776
2042	0.771
2043	0.766
2044	0.762
2045	0.757

Table 8.B.3.1 (cont)

Year	Price Factor
2046	0.753
2047	0.748
2048	0.744
2049	0.739
2050	0.735
2051	0.730
2052	0.726
2053	0.722
2054	0.717
2055	0.713
2056	0.709
2057	0.705
2058	0.700
2059	0.696
2060	0.692
2061	0.688
2062	0.684
2063	0.680
2064	0.675
2065	0.671
2066	0.667
2067	0.663
2068	0.659
2069	0.655
2070	0.651
2071	0.648
2072	0.644
2073	0.640
2074	0.636

APPENDIX 11A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

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APPENDIX 11A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

11A.1 INTRODUCTION

The results obtained for the shipments analysis and national impact analysis (NIA) can be examined and reproduced using Microsoft Excel spreadsheets available on the U.S. Department of Energy (DOE) Building Technologies website at: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/23. The spreadsheets posted represent the latest versions that have been tested with both Microsoft Excel 2007 and 2010.

There is one spreadsheet for both the shipments and the NIA model. This spreadsheet performs calculations to forecast shipments during the analysis period (2016–2074), the national energy savings (NES, *i.e.*, the change in national energy use from the base to standards cases), and the net present value (NPV) from an energy conservation standard. Furthermore, this model contains numerous macros and spreadsheets required for calculating and outputting ROCIS tables and other tables of interest.

The energy use and associated costs for a given trial standard level (TSL) are determined first by calculating the shipments and then calculating the energy use and costs for all equipment shipped under that TSL. The differences between the standards and base cases can then be compared, and the overall NES and NPV determined.

11A.2 INDIVIDUAL SHIPMENTS MODEL WORKSHEETS

There are several shipment worksheets in the NIA workbook, as listed and described below.

Instructions	This worksheet contains instructions for navigating through the NIA workbook.
NIA_Controls	This worksheet contains user-selected values, shipments/NIA results, and NIA calculations. This worksheet allows users to toggle the following values. • Low/High Shipments Scenario • Trial Standard Level • Discount Rate • Discount Year • Extend NPV benefits past the end of the analysis period • Constant or *AEO* Deflator pricing • Indoor or Outdoor fixture location Shipment values are input from the shipments worksheets, and NIA (NES and NPV) values are calculated in this worksheet.

W70	This worksheet contains historical and projected shipments for all efficiency levels within the 70 W equipment class. All possible market scenarios are computed, and the NIA worksheet selects the appropriate sets of values to use.
W150	This worksheet contains historical and projected shipments for all efficiency levels within the 150 W equipment class. All possible market scenarios are computed, and the NIA worksheet selects the appropriate sets of values to use.
W250	This worksheet contains historical and projected shipments for all efficiency levels within the 250 W equipment class. All possible market scenarios are computed, and the NIA worksheet selects the appropriate sets of values to use.
W400	This worksheet contains historical and projected shipments for all efficiency levels within the 400 W equipment class. All possible market scenarios are computed, and the NIA worksheet selects the appropriate sets of values to use.
W1000	This worksheet contains historical and projected shipments for all efficiency levels within the 1000 W equipment class. All possible market scenarios are computed, and the NIA worksheet selects the appropriate sets of values to use.
Lifetimes	This worksheet contains lifetime assumptions, calculations, and plots for all equipment classes in this analysis.
LCC Inputs	This worksheet contains the Information Hub values and other important quantities from the "Output to NIA" worksheet in the LCC model. This worksheet also contains lookup values for trial standard levels.
Shipments	This worksheet contains shipments for all equipment classes and efficiency levels. These shipment values feed into the individual equipment class worksheets, where fixture stocks and market behaviors are addressed.
Employment Results	This worksheet contains results from the NIA, which are used as inputs for the employment analysis.
[Remaining Worksheets]	There are many worksheets whose tabs are not colored. These worksheets include calculations and results for ROCIS tables and other downstream results.

11A.3 BASIC INSTRUCTIONS

Below are basic instructions for operating the NIA workbook:

1. Once the spreadsheet file is downloaded, open the file using Excel, and begin with the “Instructions” worksheet. This worksheet gives further descriptions of each worksheet within the workbook.

2. In the “NIA_Controls” worksheet, the user can change the model parameters listed in the upper-left corner of the worksheet as follows:
    a. Shipment Scenario: Select low or high shipments projections, which give lower and upper bounds on energy savings and NPV, respectively.
    b. Trial Standard Level: Select desired trial standard level from the drop-down menu.
    c. Fixture Location: Determine whether to analyze indoor or outdoor fixtures.
    d. Discount Year: Select the year the NIA model discounts future expenditures to, using the drop-down menu.
    e. Analysis Period Start: Choose the first year in which the analysis period starts.
    f. Pricing Scenario: Use a constant across time price for fixtures, or use an *AEO* deflator index.

    There are many other values that can be modified by users in cells A140:G200 in the NIA_Controls worksheet.

3. The NIA results are automatically updated and reported for each equipment class in the NIA_Controls worksheet when users select values for the quantities described in (a) through (g) above. Shipments and NIA results are displayed by equipment class in the NIA_Controls worksheet.

APPENDIX 11B. FULL-FUEL-CYCLE MULTIPLIERS

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APPENDIX 11B. FULL-FUEL-CYCLE MULTIPLIERS

11B.1 INTRODUCTION

This appendix summarizes the methods used to calculate full-fuel-cycle (FFC) energy savings expected to result from potential standards. The FFC measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. The U.S. Department of Energy's (DOE's) traditional approach encompassed only site energy and the energy losses associated with generation, transmission, and distribution of electricity. Per DOE's 2011 *Statement of Policy for Adopting Full Fuel Cycle Analyses*, DOE now uses FFC measures of energy use and emissions in its energy conservation standards analyses. 76 FR 51281 (Aug. 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012). This appendix summarizes the methods used to incorporate the FFC impacts into the analysis.

This analysis uses several different terms to reference energy use. The physical sources of energy are the primary fuels such as coal, natural gas, liquid fuels, etc. Primary energy is equal to the heat content (British thermal units) of the primary fuels used to provide an end-use service. Site energy use is defined as the energy consumed at the point-of-use in a building or industrial process. Where natural gas and petroleum fuels are consumed at the site (for example, in a furnace), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed. For electricity, site energy is measured in kilowatt-hours. In this case, the primary energy is equal to the quadrillion British thermal units (quads) of primary energy required to generate and deliver the site electricity. This primary energy is calculated by multiplying the site kilowatt-hours by the site-to-power plant energy use factor*,* given in chapter 11. For the FFC analysis, the upstream energy use is defined as the energy consumed in extracting, processing, and transporting or distributing primary fuels. FFC energy use is the sum of primary plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in fuel cycle analysis must distinguish between electricity generated by fossil fuels and uranium, and electricity generated from renewable fluxes (wind, solar, and hydro). For the former, the upstream fuel cycle impacts are derived from the amount of fuel consumed at the power plant. For the latter, no fuel *per se* is used, so there is no upstream component.

11B.2 METHODOLOGY

The mathematical approach is discussed in the paper *A Mathematical Analysis of Full Fuel Cycle Energy Use*,[1] and details on the fuel production chain analysis are presented in the paper *Projections of Full Fuel Cycle Energy and Emissions Metrics*.[2] The text below provides a brief summary of the methods used to calculate FFC energy.

When all energy quantities are normalized to the same units, the FFC energy use can be represented as the product of the primary energy use and an *FFC multiplier*. The FFC multiplier is defined mathematically as a function of a set of parameters representing the energy intensity and material losses at each production stage. These parameters depend only on physical data, so the calculations do not require any assumptions about prices or other economic data. While in general these parameter values may vary by geographic region, for this analysis national averages are used.

In the notation below, the indices x and y are used to indicate fuel type, with x=c for coal, x=g for natural gas, x=p for petroleum fuels, x=u for uranium, and x=r for renewable fluxes. The fuel cycle parameters are:

- a_x is the quantity of fuel x burned per unit of electricity output, on average, for grid electricity. The calculation of a_x includes a factor to account for transmission and distribution system losses.
- b_y is the amount of grid electricity used in production of fuel y, in megawatt-hours per physical unit of fuel y.
- c_{xy} is the amount of fuel x consumed in producing one unit of fuel y.
- q_x is the heat content of fuel x (million British thermal units/physical unit)
- $z_x(s)$ is the emissions intensity for fuel x (mass of pollutant s per physical unit of x)

The parameters are calculated as a function of time with an annual time step; hence, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period. Fossil fuel quantities are converted to energy units using the heat content factors qx. To convert electricity in kilowatt-hours to primary energy units, on-site electricity consumption is multiplied by the site-to-power plant energy use factor. The site-to-power plant energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quads) divided by the total electricity generation in each year.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. A multiplier is also calculated for electricity reflecting the fuel mix used in its generation. The multipliers are dimensionless numbers that are applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

For DOE's appliance standards energy savings estimates, the fuel cycle analysis methodology is designed to make use of data and projections published in the *Annual Energy Outlook* (*AEO*). Table 11B.2.1 provides a summary of the *AEO* data used as inputs to the different parameter calculations. The *AEO* does not provide all the information needed to estimate total energy use in the fuel production chain. Reference [2] describes the additional data sources used to complete the analysis. However, the time dependence in the FFC multipliers arises exclusively from variables taken from the *AEO*. The FFC analysis for MHLF used data from *AEO2013*.[3]

Table 11B.2.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter	Fuel	*AEO* Table	Variables
qx	all	Conversion Factors	MMBtu per physical unit
ax	all	Electricity Supply, Disposition, Prices, and Emissions	Generation by fuel type
		Energy Consumption by Sector and Source	Electric power sector energy consumption
bc, cnc, cpc	coal	Coal Production by Region and Type	Production by coal type and sulfur content
bp, cnp, cpp	petroleum	Refining Industry Energy Consumption	Refining only energy use
		Liquid Fuels Supply and Disposition	Crude supply by source
		International Liquids Supply and Disposition	Crude oil imports
		Oil and Gas Supply	Crude oil domestic production
cnn	natural gas	Oil and Gas Supply	US dry gas production
		Natural Gas Supply, Disposition and Prices	Pipeline, lease and plant fuel
zx	all	Electricity Supply, Disposition, Prices and Emissions	Power sector emissions

11B.3 FULL-FUEL-CYCLE ENERGY MULTIPLIERS

FFC energy multipliers are presented in Table 11B.3.1 for selected years. To extend the analysis period beyond 2040, the last year in the *AEO2013* projection, the multipliers are assumed constant through the final year of the analysis period. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation over the forecast period.

Table 11B.3.1 Full Fuel Cycle Energy Multipliers (Based on *AEO2013*)

	2015	2020	2025	2030	2035	2040
Electricity (power plant primary energy use)	1.042	1.041	1.040	1.040	1.041	1.041
Natural Gas (site)	1.103	1.103	1.100	1.099	1.098	1.097
Petroleum Fuels (site)	1.141	1.145	1.151	1.161	1.170	1.179

REFERENCES

1. Coughlin, K. A Mathematical Analysis of Full Fuel Cycle Energy Use. *Energy*, 2012. 37(1): pp. 698-708. (Last accessed July 8, 2013.) <www.sciencedirect.com/science/article/pii/S0360544211006803>.

2. Coughlin, K. 2013. *Projections of Full-Fuel-Cycle Energy and Emissions Metrics*. Lawrence Berkeley National Laboratory, Berkeley, CA. Report No. LBNL-6025E.

3. U.S. Department of Energy − Energy Information Administration. *Annual Energy Outlook 2013 with Projections to 2040*. April 2013. Washington, D.C. <www.eia.gov/forecasts/aeo/pdf/0383%282012%29.pdf>.

APPENDIX 13A MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDES

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13A.1 METAL HALIDE LAMP BALLAST MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Manufacturer Impact Analysis Interview Guide
Metal Halide Lamp Ballasts

Spring 2011

The U.S. Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA) as part of the rulemaking process to set energy conservation standards for metal halide lamp fixtures (MHLFs). In this analysis, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1 Key Impacts on Your Company

1.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

1.2 Do any of these issues become particularly significant at a specific efficiency level or for a specific equipment class?

2 Test Procedure

DOE defines ballast efficiency (in accordance with ANSI C82.6) as ballast output power divided by ballast input power, as measured during stable operation of a lamp. That definition will be used in this guide.

2.1 **(Input Voltage)** Although many ballasts operate at a range of input voltages, the current test procedure does not specify which to use for efficiency testing. Since tested efficiency can vary with input voltage, this presents the opportunity for operation at a voltage that does not meet standards. DOE is currently considering defining efficiency to be the average of all rated input voltages. Are there drawbacks to doing so? Is there a better way to be thorough? If DOE only required testing at one input voltage, which voltage would be the most commonly used (i.e., most representative of use in the field)?

2.2 **(Efficiency Variance)** What is the typical variation in ballast efficiency due to testing (instrumentation, materials, procedure)? What is the typical variation due to manufacturing variability (within multiple samples of the same model number)? Do you have any test data that you can provide to illustrate this variation?

2.3 **(High Frequency)** Commenters at the preliminary analysis meeting suggested that high-frequency testing was more prone to inaccuracy. Do you agree? If so, what is a reasonable accuracy? Is there equipment that can test reliably at frequencies on the order of 100 kHz? How does your company test its high-frequency ballasts, if any?

3 Scope of Coverage

3.1 **(Wattage)** DOE is considering limiting scope of coverage to fixtures with ballasts of rated wattage 50 and above on the basis that ballasts above and below this range consume very little energy. What fraction of your sales of metal halide lighting falls outside this range?

3.2 **(Fixture Metrics)** DOE did not find the proposed alternative metrics (*i.e.*, TER and FTE) appropriate for amending metal halide lamp fixture standards. Do you know the current status of NEMA's OPD metric development and its applicability to metal halide lamp fixtures?

3.3 **(Lamp/Ballast Metric)** Setting a lamp/ballast standard (*i.e.*, one that prescribed a certain number of lumens and ballast input watts) might allow system-level optimization not possible with ballast standards alone. Do you support that approach? Why or why not? Do any systems that you sell currently represent this system level optimization? Please provide the performance specifications if so.

3.4 Would a system approach confer competitive advantage to manufacturers of both ballasts and lamps?

3.5 **(Lamp/Ballast Compatibility)** Lamp/ballast incompatibility was also cited as a reason why the system approach to standards was beneficial. Can you describe the technical reasons for lamp/ballast incompatibility? Are high frequency or electronic ballasts the only source of incompatibility? Are certain lamp types more susceptible to this incompatibility?

3.6 **(Standard Lamps)** One way of allowing compliance with a lamp/ballast-level standard might be to use a table of "standard lamps," with lamp efficacy values. Would you support such an approach? Why or why not? If so, what would be appropriate values to use at each analyzed wattage (70, 150, 250, 400, 1000)? Please fill in the table, which asks for efficacy values for different grades of lamps.

Table 3.1 Standard Lamps

Wattage	"Cheap" Lamp Efficacy (Mean Lumens per Watt)	"Cheap" Lamp Cost ($)	Typical Lamp Efficacy (Mean Lumens per Watt)	Typical Lamp Cost ($)	Expensive Lamp Efficacy (Mean Lumens per Watt)	Expensive Lamp Cost ($)
70						
150						
250						
400						
1000						

3.7 **(California Title 20 System Approach)** DOE may consider a design standard similar to the one in California's Title 20. Do you have data on the representative operating profiles (e.g., percentages of full-output versus dimmed operation) for occupancy-based and daylight-based dimming metal halide applications? Are reduced wattage MH lamps (e.g., 320 W in place of 400 W) typically more efficacious, and if so, how much more? Are there any other issues with California's approach?

3.8 **(Fixture Controls)** For the various types of fixture controls discussed (photosensors, dimming, occupancy-based, etc.), what are the impacts to manufacturer selling price (MSP)? What are the specific mechanisms for achieving controllability? Please populate Table 3.2 with changes to fixture selling price.

Table 3.2 Manufacturer Selling Price Changes for Various Lighting Controls

Control Type	**70 W Fixture**	**150 W Fixture**	**250 W Fixture**	**400 W Fixture**	**1000 W Fixture**	**Comments**
Dimming						
Photosensor						
Occupancy-based						
Other (specify)						
Other (specify)						

3.9 **(150 W Exemption)** If DOE eliminated the exemption for 150-W-only fixtures rated for wet locations and containing ballasts rated to operate in ambient air temperature higher than 50 °C, how would your company respond? Should DOE maintain or eliminate this exemption?

3.10 **(480 V Electronic)** DOE knows of no electronic ballasts able to operate at 480 V. What stands in the way of creating such a ballast? Are the challenges technical? Is expected demand low?

4 Engineering

4.1 **(Equipment Classes)** Based on comments received and the engineering analysis, DOE proposes ≥50 W and <150 W as the lowest wattage bin range for the equipment classes. Should this range be further divided based on wattage? If so, what should these additional divisions be?

4.2 (**Wattage Bins)** Are wattage bins the best method for setting standards for the equipment classes as listed in the previous table? Would any particular wattage bin require the use of an equation to accurately represent the relationship between wattage and efficiency? In general, would you support the use of an equation?

4.3 **(Probe Replacement)** A consumer wishing to replace his or her probe-start lighting (*e.g.*, 400 W) with pulse-start lighting might use the same number of reduced-wattage ballasts (*e.g.*, 320 W), or the same number of full-wattage ballasts. How often might each scenario occur? Why?

4.4 **(Design Standard)** DOE is considering setting a design standard for MHLFs, which could be used to ban probe starting, particularly at wattages above 500. What are the potential issues with the elimination of probe-start ballasts? Are the issues wattage-specific?

4.5 **(Potting)** DOE is aware that some manufacturers use various potting materials in electronic ballasts, both to add mechanical stability and manage temperature. Which models use potting? What materials are used?

4.6 **(Thermal Management)** DOE understands that electronic metal halide ballasts have lower tolerances for high temperatures than magnetic ballasts. This susceptibility can be mitigated with technology such as heat sinks or fixture redesign. However, DOE has limited information and limited ability to estimate the costs of these measures for different wattages and fixture applications, what percentage cost increase would be required to permit electronic ballasts? Similarly, what would be the increased cost of fixtures to permit higher efficiency magnetic? Please indicate the driver for the increased cost (e.g., additional aluminum for heat sinking, reengineering costs passed onto consumer).

Table 4.1 Expected Cost Increases for Thermal Management

Application	Equipment Class (Wattage)	Percentage MSP Increase	Thermal Management Details
e.g. outdoor pole mounted	*400*	*10%*	

4.7 **(Voltage Transients)** DOE also understands that electronic metal halide ballasts have lower tolerances of voltage transients than magnetic ballasts. For fixtures under threat of high-voltage surges and spikes, an electronic ballast can be coupled with a transient arrestor. What are the typical applications in which transients over 6kV are a particular concern? How is the protection implemented? Are there situations where the addition of an arrestor would not adequately protect an electronic ballast? What are the costs of adding inline transient protection at the 70, 150, 250, and 400 W levels? Are there specific sources of reliability concerns (relative to magnetic ballasts) for electronic ballasts that cannot be mitigated through the use of external equipment or devices? Please see Table 4.2 below.

4.8 **(120 V Tap)** Many multi-tap ballasts can run 120 V equipment (e.g., auxiliary lighting) from their lowest taps. In practice, what proportion of ballasts are used this way? Is this ever a reason to choose a magnetic ballast over an electronic ballast? What is the manufacturer selling price increase of enabling an electronic ballast to output 120 V power if it doesn't initially? Please see Table 4.2 below.

Table 4.2 Expected Manufacturer Selling Price Increases for Transient Protection and 120 V Output

Wattage	Transient Protection ($ Increase)	120 V Electronic Output ($ Increase)
70		
150		
250		
400		
1000		

4.9 **(Efficiency and Input Voltage)** Through comparing 1000 W ballast average test results, DOE found that quad-input-voltage ballasts (ballasts able to operate at 120, 208, 240, and 277 V) were 1.2% more efficient than dedicated 480 V units. DOE also found that the quad-input-voltage ballasts were 0.4% more efficient than quint-input-voltage ballasts (ballasts that are able to operate at 120, 208, 240, 277, and 480 V). Do these results seem accurate? Why or why not?

4.10 **(Cost and Input Voltage)** How does cost change across quad- and quint-input-voltage ballasts of similar efficiency? Dedicated 480 V units?

4.11 **(Engineering Summary)** Table 4.3 (below) shows DOE's preliminary engineering results for each equipment class (LFE is low-frequency electronic, HFE is high frequency electronic, and M is magnetic). Are the MSPs appropriate for the efficiency levels? Would empty fixture price vary with efficiency as a result of such concerns as increased weight, volume, or heat dissipation? Where do your products fall?

Table 4.3 Costs and Efficiencies of Draft CSLs

Watts	CSL	Type	Eff.	Input Watts	Ballast MSP	Empty Fixture MSP	Total Fixture MSP	Products Available
70	Baseline	M	72.3%	96.8	$27.63	$23.90	$51.53	
	1	M	76.1%	92.0	$28.33	$23.90	$52.23	
	2	LFE	89.3%	78.4	$30.79	$23.90	$54.69	
	3	LFE	91.1%	76.8	$37.22	$23.90	$61.12	
250	Baseline	M	88.0%	284.1	$47.88	$58.50	$106.38	
	1	M	90.5%	276.2	$53.99	$58.50	$112.49	
	2	M	91.5%	273.2	$60.67	$58.50	$119.17	
	3	LFE	93.2%	268.1	$79.38	$58.50	$137.88	
	4	HFE	93.6%	267.1	$75.91	$58.50	$134.41	
400	Baseline	M	88.0%	454.5	$45.10	$90.62	$135.72	
	1	M	90.0%	444.4	$57.62	$90.62	$148.24	
	2	M	91.7%	436.2	$66.10	$90.62	$156.72	
	3	LFE	92.7%	431.5	$94.01	$90.62	$184.63	
	4	HFE	93.9%	426.0	$113.82	$90.62	$204.44	
1000	Baseline	M	91.9%	1088.1	$58.83	$195.17	$254.00	
	1	M	92.6%	1079.9	$68.01	$195.17	$263.18	
	2	M	93.3%	1071.8	$72.51	$195.17	$267.68	

4.12 **(Max-Tech)** Can the efficiency of magnetic and electronic ballasts be increased beyond the commercially available levels identified in Table 4.4? What is the maximum technologically feasible efficiency at each wattage for both magnetic and electronic ballasts? What are the associated costs and design pathways required?

Table 4.4 Max Tech Levels for Representative Product Classes

Equipment Class	Wattage	Maximum Commercially Available Efficiency Analyzed	Potential Efficiency Improvement	Design Pathway	Associated MSP increase
1	70	91.1			
2	250	93.6			
3	400	93.9			
4	1000	93.3			

4.13 **(Intellectual Property)** Do any of the CSLs listed in the previous table require the use of a proprietary technology?

4.14 **(Equipment Lifetime)** How would the average lifetimes of fixtures, ballasts, and lamps vary within the representative equipment classes? Between CSLs?

4.15 **(Electronic 1000 W)** The max-tech for a 1000 W metal halide fixture currently incorporates a magnetic ballast. Are 1000 W electronic metal halide ballasts technologically feasible? Are there technical challenges, or is anticipated demand low? What is the potential for this technology to emerge in the future?

4.16 **(High Frequency)** For its third (400 W) equipment class, DOE used a high frequency ballast as representative. Is this appropriate based on compatibility concerns? Is the level achievable with low-frequency units?

4.17 **(Amorphous)** Is using amorphous steel to reduce magnetic losses feasible? Why is it possible to incorporate amorphous steel in other equipment (e.g., transformers) but not in metal halide ballasts? Is there something unique about the manufacturing process? What would be the expected increases in cost and efficiency?

4.18 **(Magnetic Modeling)** Can you describe the amounts and grades of electrical steel and the amounts and types of conductor you would use to produce magnetic ballasts of the following efficiencies and wattages with no increase in footprint size? If footprint size would increase, or if a particular efficiency would be impossible to produce, please indicate so.

Table 4.5 Magnetic Ballast Efficiency

Wattage	Efficiency (%)	Steel Grade	Stack Height (in.)	Footprint	Conductor Type	Conductor Mass (lbs.)	Conductor Gauge
70	74						
	76						
	78						
	80						
	82						
150	80						
	84						
	86						
	88						
	90						
250	88						
	90						
	91						
	92						
	93						
400	88						
	90						
	92						
	93						
	94						
1000	91						
	92						
	93						
	94						
	95						

4.19 **(Materials Prices)** To model magnetic ballast cost, DOE used materials prices as reported by a variety of manufacturers of different products. Please comment on whether these five-year average prices are appropriate and, if not, what values should be used.

Table 4.6 Material Prices

Material	Five-Year Average Price ($/lb)	Correct Price ($/lb)
M36 Steel	0.59	
M19 Steel	0.63	
M18 Steel	0.70	
M15 Steel	1.09	
M12 Steel	1.12	
M6 Steel	1.54	
Copper Conductor – 10 AWG	3.53	
Aluminum Conductor – 10 AWG	3.85	

4.20 **(150 W Representative Wattage)** Based on feedback in the preliminary analysis public meeting, DOE may consider 150 W ballasts as a new representative wattage. What are typical ballast efficiencies, design pathways, incremental costs, and manufacturer selling prices for 150 W electronic ballasts?

Table 4.7 Commercially Available 150 W Electronic Ballasts

#	Ballast Type	Input Power	Ballast Efficiency	Defining Design Characteristics	Incr. Cost (over Std. Ballast) per Imp.	Total Mfr. Unit Selling Price to OEM Fixture Mfr.
0	Standard, Electronic Ballast	150				
1	High Efficiency, Electronic Ballast	150				
2	Maximum Electronic Ballast	150				

5 Markups and Profitability

One of the primary objectives of the MIA is to assess the impact of energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how energy conservation standards would impact your company's markup structure and profitability.

DOE estimated the manufacturer production costs for four equipment classes of metal halide lamp fixtures and metal halide lamp ballasts. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. It does not reflect a "profit margin."

The manufacturer production cost times the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but does not include additional costs along the distribution channels.

DOE estimated a baseline markup of 1.47 for metal halide lamp ballasts and fixtures in the preliminary analysis. For the NOPR, DOE is considering using a 1.47 markup for metal halide ballasts and a baseline markup of 1.58 for metal halide lamp fixtures.

5.1 Is the 1.47 baseline markup representative of an average industry markup for metal halide lamp **ballasts**?

5.2 Please comment on the baseline markup DOE calculated as compared to your company's baseline markups for metal halide lamp ballasts. Does this markup vary by lamp wattage?

5.3 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Is this markup different than the markup applied to higher efficiency metal halide lamp ballasts? If yes, please provide information about the markups at higher efficiencies.

5.4 What factors besides efficiency affect the profitability of metal halide lamp ballasts?

5.5 Would you expect changes in your estimated profitability following an energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5.6 Do the representative MSPs listed in Table 4.3 seem reasonable? Do you have fixture pricing data or typical markups that DOE may use to verify its pricing assumptions?

5.7 DOE is aware that fixtures are sometimes sold with the poles on which they are mounted. Would ballasts at different CSLs require different poles resulting in different MSPs? What percentage of fixtures rated for each 70, 250, 400, and 1000 W are sold this way? How many fixtures are typically mounted on a pole?

5.8 DOE derives fixture MSPs by adding ballast and empty fixture MPCs and applying a single markup. Is this appropriate in the cases of fixture manufacturers that do not produce ballasts? Should those ballasts be marked up twice (i.e., once for the ballast manufacturer and once as part of the whole fixture)? If so, what respective markups are appropriate for the ballast and for the fixture?

5.9 In the preliminary analysis, DOE used a markup for contractors installing metal halide lamp fixtures of 13%. Is that figure generally representative? If not, what would be better?

6 Company Overview and Organizational Characteristics

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to metal halide lamp fixture and/or metal halide lamp ballast production. However, the context within which the plant operates and the details of plant production and costs are not always readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical. Understanding the organizational setting around the metal halide lamp fixture and/or metal halide lamp ballast industry profit center will help DOE understand the probable future of the manufacturing activity with and without energy conservation standards.

6.1 Do you have a parent company, and/or any subsidiaries relevant to the metal halide lamp fixture and/or metal halide lamp ballast industry?

6.2 What is your company's approximate market share of the metal halide lamp **ballast** market? Does this vary significantly for any particular equipment class that you manufacture?

6.3 Do you manufacture any products other than metal halide lamp ballasts? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to metal halide lamp **ballasts**?

6.4 Please complete Table 6.1 to the best of your ability for your company. If possible, please express revenue in both dollar amount and in percentage of metal halide lamp ballast sales. Additionally, please express shipments in both volume and percentage of all metal halide lamp ballast shipments. Because the rulemaking covers only new fixtures, please note the fraction of sales to fixture original equipment manufacturers. Please indicate if you do not manufacturer products in any given equipment class.

Table 6.1 Metal Halide Lamp Ballast Revenue and Shipment Volumes

Rated Lamp Wattage Grouping	**2010 Revenue**		**2010 Shipments**		**Fraction of Sales, by Revenue, to Fixture OEMs**
	($)	***(%)***	***(volume)***	***(%)***	
≥50 W and <150 W					
≥150 W and ≤250 W					
>250 W and ≤500 W					
>500 W					

6.5 Please describe your distribution channel. Who are your main customers for metal halide lamp ballasts?

7 Shipment Projections

Energy conservation standards can change overall shipments by altering product attributes, marketing approaches, product availability, and prices. The industry revenue calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent energy conservation standards) and the standards case shipments (i.e., total industry shipments with new energy conservation standards). In its shipment scenarios, DOE intends to model the effect of emerging technologies on the metal halide market.

7.1 Do you have historical fixture shipment data that you could provide?

7.2 EISA 2007 set standards for ballasts shipped in new fixtures with lamps of 150-500 W. Does your company sell ballasts of that range outside of fixtures below EISA standard levels? What percentage of shipped ballasts in the covered wattage range meet EISA standards?

7.3 If DOE were to set higher standards for the 150-500 W range, or any standards for other wattages, would your company produce less-efficient ballasts for sale outside of new fixtures? Or would economies-of-scale make that too costly? What standard level, for each wattage, would force manufacturers to produce multiple efficiency levels?

7.4 If available, please estimate industry wide shipments of metal halide lamp fixtures and metal halide lamp ballasts over the past 2 years. Please describe any trends in these shipments. Because the rulemaking covers only new fixtures, please note the fraction of sales (by revenue) to fixture original equipment manufacturers.

Table 7.1 Metal Halide Lamp Fixture Industry Shipment Volumes

Rated Lamp Wattage Grouping	2010	2009
<50 W		
≥50 W and <150 W		
≥150 W and ≤250 W		
>250 W and ≤500 W		
>500 W		

Table 7.2 Metal Halide Lamp Ballast Industry Shipment Volumes

Rated Lamp Wattage Grouping	2010	2009	Fraction of Sales, by Revenue, to Fixture OEMs
<50 W			
≥50 W and <150 W			
≥150 W and ≤250 W			
>250 W and ≤500 W			
>500 W			

7.5 What is the proportion of domestically consumed metal halide lamp fixtures and metal halide lamp ballasts shipped by NEMA companies versus non-NEMA companies? Please fill in the table below.

Table 7.3 Percentage of Shipments from NEMA v. Non-NEMA Companies

Product	NEMA Shipments %	Non-NEMA Shipment %	Total
Metal Halide Lamp Fixtures			100%
Metal Halide Lamp Ballasts			100%

7.6 In the July 2009 Lamps Rule and other lighting rulemakings, DOE assumes that revised standards that increase purchase price do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes? Does it vary with equipment class?

7.7 Do you expect characteristics of metal halide lamp ballasts to change in response to the standards?

7.8 Would you expect your market share to change when higher energy conservation standards take effect?

7.9 Please quantify what percent of the market might shift to fixtures outside of the scope of coverage (<50 W) in response to standards.

7.10 At DOE's Preliminary Analysis public meeting of April 18, 2011, several parties commented that DOE's fixture shipment projections were too high. Those projections assumed 1.5% annual growth in HID lamps from the present until 2016, and 1.5% annual decline thereafter. In response, DOE is considering projecting no growth until 2016 and a 1.5% annual decline thereafter, or simply a 1.5% annual decline starting at the present. Are either of these scenarios likely? If not, what is more realistic?

8 Financial Parameters

Navigant Consulting, Inc. has developed a "strawman" model of the metal halide lamp fixtures and metal halide lamp ballasts industry financial performance called the Government Regulatory Impact Model (GRIM) using publicly available data. However, this public information might not be reflective of manufacturing at the metal halide lamp fixtures or metal halide lamp ballasts profit center. This section attempts to understand the financial parameters for metal halide lamp fixture and ballast manufacturing and how your company's financial situation could differ from the industry aggregate picture.

8.1 In order to accurately collect information about metal halide lamp ballast manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 8.1 Financial Parameters for Metal Halide Lamp Ballast Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	30.3%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	8.7%	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.6%	
Net PPE	Net plant property and equipment (percentage of revenues)	20.9%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	17.7%	
R&D	Research and development expenses (percentage of revenues)	4.0%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.4%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.5%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	68.0%	

8.2 Do any of the financial parameters in Table 8.1 change significantly based on equipment class? Please describe any differences.

8.3 Do any of the financial parameters in Table 8.1 change for a particular subgroup of manufacturers? Please describe any differences.

8.4 How would you expect an energy conservation standard to impact any of the financial parameters for the industry?

8.5 Could you please provide the breakdown in the total production costs for metal halide lamp ballasts by the percentage for labor, materials, overhead, and depreciation by filling in Table 8.2 below?

Table 8.2 Breakdown of Total Production Costs for Metal Halide Lamp Ballasts

Labor % of full production costs	Materials % of full production costs	Overhead % of full production costs	Depreciation % of full production costs	Total % of full production costs
				100%

9 Conversion Costs

DOE understands that new energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical part of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers two types of conversion costs:

- ***Capital conversion costs*** *are one-time investments in plant, property, and equipment (PPE) necessitated by new energy conservation standards. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.*

- ***Product conversion costs*** *are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by new energy conservation standards.*

Table 4.3 shows the CSLs and efficiencies DOE is analyzing for the equipment classes covered by this rulemaking. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs. Please refer to Table 4.3 when considering your response to the following questions.

9.1 At your manufacturing facilities, would the design pathways you would choose to meet these CSLs be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

9.2 Are there certain design pathways that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different equipment classes? Please describe these changes qualitatively.

9.3 For each of the equipment classes shown in Table 9.1, which CSLs could be achieved within existing platform designs and which would result in major product redesigns?

9.4 Please provide estimates for your capital conversion costs for metal halide lamp **ballasts** by equipment class in Table 9.1 below. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, etc., that would be required to implement the specified design changes.

9.5 What level of product development and other product conversion costs would you expect to incur to achieve each of these efficiency levels for each equipment class for metal halide lamp **ballasts**? Please provide your estimates in Table 9.1 considering such expenses as product development expenses, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

Table 9.1 Expected Product and Capital Conversion Costs for Metal Halide Lamp Ballasts

Ref #	Equipment class	CSL	Total Product Conversion Costs	Total Capital Conversion Costs	Description
1	**≥50 W and <150 W**	Baseline			
		1			
		2			
		3			
2	**≥150 W and ≤250 W**	Baseline			
		1			
		2			
		3			
		4			
3	**>250 W and ≤500 W**	Baseline			
		1			
		2			
		3			
		4			
4	**>500 W**	Baseline			
		1			
		2			

9.6 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

10 Cumulative Regulatory Burden

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

10.1 Below is a list of regulations that could affect manufacturers of metal halide lamp fixtures or metal halide lamp ballasts. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table 10.1 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for IRL and GSFL	July 14, 2012		
DOE's Energy Conservation Standards for Fluorescent Lamp Ballasts	June 2014		
EISA 2007 Standards for General Service Incandescent Lamps (GSIL)	2012		
International Energy Efficiency Standards			
Restriction of Hazardous Substances (RoHS)			

10.2 Are there any other recent or impending regulations that metal halide lamp fixture or ballast manufacturers face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

10.3 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with new energy conservation standards?

10.4 DOE research has not identified any production tax credits for manufacturers of metal halide lamp fixtures or metal halide lamp ballasts. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient metal halide lamp fixtures or metal halide lamp ballasts? If so, please describe.

10.5 Are there any voluntary programs (e.g., ENERGY STAR, DesignLights) that could affect the impact of DOE's energy conservation standard rulemaking?

11 Direct Employment Assessment

The impact of energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in metal halide lamp fixture and metal halide lamp ballast employment and solicit manufacturer *views on how domestic employment patterns might be affected by new energy conservation standards.*

11.1 Where are your facilities that produce metal halide lamp **ballasts** for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's metal halide lamp ballast or metal halide lamp fixture manufacturing at each location by equipment class. Please also provide employment levels at each of these facilities.

Table 11.1 Metal Halide Lamp Ballast Manufacturing Facilities

Facility	Location	Equipment Types Manufactured	Employees	Annual Shipments
Example	*Jackson, TN*	*Equipment Class 1, 2*	*650*	*300,000 for EC 1, 200,000 for EC 2*
1				
2				
3				
4				
5				

11.2 Would your domestic employment levels be expected to change significantly under energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

11.3 Would the workforce skills necessary under energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

11.4 Would energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of energy conservation standards?

12 Manufacturing Capacity and Non-US Sales

12.1 How would energy conservation standards impact your company's manufacturing capacity?

12.2 For any design changes that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business? Are there any design changes that could not be implemented before the compliance date of the final rule for certain equipment classes?

12.3 What percentage of your domestic metal halide lamp **ballast** sales are produced in the United States?

12.4 What percentage of your U.S. production of metal halide lamp ballasts is exported?

12.5 Are there any foreign companies with North American production facilities?

13 Impact on Competition

Energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an energy conservation standard.

13.1 How would industry competition change as a result of energy conservation standards? How would energy conservation standards affect your ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

13.2 Do any firms hold intellectual property that gives them a competitive advantage following energy conservation standards?

14 Impacts on Small Business

14.1 The Small Business Administration (SBA) denotes a small business in the metal halide lamp **fixture** manufacturing industry as having less than 500 total employees, including the parent company and all subsidiaries. The SBA denotes a small business in the metal halide lamp **ballast** manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[1] By this definition, is your company considered a small business?

14.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

14.3 To your knowledge, are there any small businesses for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

14.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

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[1] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a commercial, industrial, and institutional electric lighting fixture manufacturer and its affiliates may employ a maximum of 500 employees. To be categorized as a small business, a power, distribution, and specialty transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 500 and 750 employee thresholds include all employees in a business's parent company and any other subsidiaries.

13A.2 METAL HALIDE LAMP FIXTURE MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Manufacturer Impact Analysis Interview Guide
Metal Halide Lamp Fixtures

Spring 2011

The U.S. Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA) as part of the rulemaking process to set energy conservation standards for metal halide lamp fixtures (MHLFs). In this analysis, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1 Key Impacts on Your Company

1.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

1.2 Do any of these issues become particularly significant at a specific efficiency level or for a specific equipment class?

2 Scope of Coverage

2.1 **(Wattage)** DOE is considering limiting scope of coverage to fixtures with ballasts of rated wattage 50 and above on the basis that ballasts above and below this range consume very little energy. What fraction of your sales of metal halide lighting fall outside this range?

2.2 **(Fixture Metrics)** DOE did not find the proposed alternative metrics (*i.e.*, TER and FTE) appropriate for amending metal halide lamp fixture standards. Do you know the current status of NEMA's OPD metric development and its applicability to metal halide lamp fixtures?

2.3 **(Fixture Efficiency)** What are the primary ways of increasing fixture optical efficiency? Does it vary by application? Are fixtures ever sold on the basis of efficiency?

2.4 **(Lamp/Ballast Metric)** Setting a lamp/ballast standard (*i.e.*, one that prescribed a certain number of lumens and ballast input watts) might allow system-level optimization not possible with ballast standards alone. Do you support that approach? Why or why not? Do any systems that you sell currently represent this system level optimization? Please provide the performance specifications if so.

2.5 **(Lamp/Ballast Compatibility)** Lamp/ballast incompatibility was also cited as a reason why the system approach to standards was beneficial. Can you describe the technical reasons for lamp/ballast incompatibility? Are high frequency or electronic ballasts the only source of incompatibility? Are certain lamp types more susceptible to this incompatibility?

2.6 **(Standard Lamps)** One way of allowing compliance with a lamp/ballast-level standard might be to use a table of "standard lamps," with lamp efficacy values. Would you support such an approach? Why or why not? If so, what would be appropriate values to use at each analyzed wattage (70, 150, 250, 400, 1000)? Please fill in the table, which asks for efficacy values for different grades of lamps.

Table 2.1 Standard Lamps

Wattage	"Cheap" Lamp Efficacy (Mean Lumens per Watt)	"Cheap" Lamp Cost ($)	Typical Lamp Efficacy (Mean Lumens per Watt)	Typical Lamp Cost ($)	Expensive Lamp Efficacy (Mean Lumens per Watt)	Expensive Lamp Cost ($)
70						
150						
250						
400						
1000						

2.7 **(California Title 20 System Approach)** DOE may consider a design standard similar to the one in California's Title 20. Do you have data on the representative operating profiles (e.g., percentages of full-output versus dimmed operation) for occupancy-based and daylight-based dimming metal halide applications? Are reduced wattage MH lamps (e.g., 320 W in place of 400 W) typically more efficacious, and if so, how much more? Are there any other issues with California's approach?

2.8 **(Fixture Controls)** For the various types of fixture controls discussed (photosensors, dimming, occupancy-based, etc.), what are the impacts to manufacturer selling price (MSP)? What are the specific mechanisms for achieving controllability? Please populate Table 2.2 with changes to fixture selling price.

Table 2.2 Manufacturer Selling Price Changes for Various Lighting Controls

Control Type	70 W Fixture	150 W Fixture	250 W Fixture	400 W Fixture	1000 W Fixture	Comments
Dimming						
Photosensor						
Occupancy-based						
Other (specify)						
Other (specify)						

2.9 **(150 W Exemption)** If DOE eliminated the exemption for 150-W-only fixtures rated for wet locations and containing ballasts rated to operate in ambient air temperature higher than 50 °C, how would your company respond? Should DOE maintain or eliminate this exemption?

3 Engineering

3.1 **(Probe Replacement)** A consumer wishing to replace his or her probe-start lighting (*e.g.*, 400 W) with pulse-start lighting might use the same number of reduced-wattage ballasts (*e.g.*, 320 W), or the same number of full-wattage ballasts. How often might each scenario occur? Why?

3.2 **(Design Standard)** DOE is considering setting a design standard for MHLFs, which could be used to ban probe starting, particularly at wattages above 500. What are the potential issues with the elimination of probe-start ballasts? Are the issues wattage-specific?

3.3 **(Thermal Management)** DOE understands that electronic metal halide ballasts have lower tolerances for high temperatures than magnetic ballasts. This susceptibility can be mitigated with technology such as heat sinks or fixture redesign. However, DOE has limited information and limited ability to estimate the costs of these measures For different wattages and fixture applications, what percentage cost increase would be required to permit electronic ballasts? Similarly, what would be the increased cost of fixtures to permit higher efficiency magnetic? Please indicate the driver for the increased cost (e.g., additional aluminum for heat sinking, reengineering costs passed onto consumer).

Table 3.1 Expected Cost Increases for Thermal Management

Application	Equipment Class (Wattage)	Percentage MSP Increase	Thermal Management Details
e.g. outdoor pole mounted	*400*	*10%*	

3.4 **(Voltage Transients)** DOE also understands that electronic metal halide ballasts have lower tolerances of voltage transients than magnetic ballasts. For fixtures under threat of high-voltage surges and spikes, an electronic ballast can be coupled with a transient arrestor. What are the typical applications in which transients over 6kV are a particular concern? How is the protection implemented? Are there situations where the addition of an arrestor would not adequately protect an electronic ballast? What are the costs of adding inline transient protection at the 70, 250, and 400 W levels? Are there specific sources of reliability concerns (relative to magnetic ballasts) for electronic ballasts that cannot be mitigated through the use of external equipment or devices? Please see Table 3.2 below.

Table 3.2 Expected Manufacturer Selling Price Increases for Transient Protection and 120 V Output

Wattage	Transient Protection ($ Increase)
70	
150	
250	
400	
1000	

3.5 **(Efficiency and Input Voltage)** Through comparing 1000 W ballast average test results, DOE found that quad-input-voltage ballasts (ballasts able to operate at 120, 208, 240, and 277 V) were 1.2% more efficient than dedicated 480 V units. DOE also found that the quad-input-voltage ballasts were 0.4% more efficient than quint-input-voltage ballasts (ballasts that are able to operate at 120, 208, 240, 277, and 480 V). Do these results seem accurate? Why or why not?

3.6 **(Cost and Input Voltage)** How does cost change across quad- and quint-input-voltage ballasts of similar efficiency? Dedicated 480 V units?

3.7 **(Engineering Summary)** Table 3.3 (below) shows DOE's preliminary engineering results for each equipment class (LFE is low-frequency electronic, HFE is high frequency electronic, and M is magnetic). Are the MSPs appropriate for the efficiency levels? Would empty fixture price vary with efficiency as a result of such concerns as increased weight, volume, or heat dissipation? Where do your products fall?

Table 3.3 Costs and Efficiencies of Draft CSLs

Watts	CSL	Type	Eff.	Input Watts	Ballast MSP	Empty Fixture MSP	Total Fixture MSP	Products Available
70	Baseline	M	72.3%	96.8	$27.63	$23.90	$51.53	
	1	M	76.1%	92.0	$28.33	$23.90	$52.23	
	2	LFE	89.3%	78.4	$30.79	$23.90	$54.69	
	3	LFE	91.1%	76.8	$37.22	$23.90	$61.12	
250	Baseline	M	88.0%	284.1	$47.88	$58.50	$106.38	
	1	M	90.5%	276.2	$53.99	$58.50	$112.49	
	2	M	91.5%	273.2	$60.67	$58.50	$119.17	
	3	LFE	93.2%	268.1	$79.38	$58.50	$137.88	
	4	HFE	93.6%	267.1	$75.91	$58.50	$134.41	
400	Baseline	M	88.0%	454.5	$45.10	$90.62	$135.72	
	1	M	90.0%	444.4	$57.62	$90.62	$148.24	
	2	M	91.7%	436.2	$66.10	$90.62	$156.72	
	3	LFE	92.7%	431.5	$94.01	$90.62	$184.63	
	4	HFE	93.9%	426.0	$113.82	$90.62	$204.44	
1000	Baseline	M	91.9%	1088.1	$58.83	$195.17	$254.00	
	1	M	92.6%	1079.9	$68.01	$195.17	$263.18	
	2	M	93.3%	1071.8	$72.51	$195.17	$267.68	

3.8 **(Equipment Lifetime)** How would the average lifetimes of fixtures, ballasts, and lamps vary within the representative equipment classes? Between CSLs?

3.9 **(Market)** To generate a representative fixture prices for each wattage level, DOE tears down fixtures of applications common to that wattage. Please comment on which fixture types are common at each wattage, and what percentage of the market they account for.

Table 3.4 Market Percentage

Wattage	Most Common Application	Percentage of Market at the Wattage	Second Most Common Application	Percentage of Market at the Wattage	Third Most Common Application	Percentage of Market at the Wattage
70						
150						
250						
400						
1000						

4 Markups and Profitability

One of the primary objectives of the MIA is to assess the impact of energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how energy conservation standards would impact your company's markup structure and profitability.

DOE estimated the manufacturer production costs for four equipment classes of metal halide lamp fixtures and metal halide lamp ballasts. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. It does not reflect a "profit margin."

The manufacturer production cost times the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but does not include additional costs along the distribution channels.

DOE estimated a baseline markup of 1.47 for metal halide lamp ballasts and fixtures in the preliminary analysis. For the NOPR, DOE is considering using a 1.47 markup for metal halide ballasts and a baseline markup of 1.58 for metal halide lamp fixtures.

4.1 Is the 1.58 baseline markup representative of an average industry markup for metal halide lamp **fixtures**?

4.2 Please comment on the baseline markup DOE calculated as compared to your company's baseline markups for metal halide lamp fixtures. Does this markup vary by lamp wattage?

4.3 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Is this markup different than the markup applied to higher efficiency metal halide lamp ballasts or higher efficiency metal halide lamp fixtures? If yes, please provide information about the markups at higher efficiencies.

4.4 What factors besides efficiency affect the profitability of metal halide lamp fixtures?

4.5 Would you expect changes in your estimated profitability following an energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

4.6 Do the representative MSPs listed in Table 3.3 seem reasonable? Do you have fixture pricing data or typical markups that DOE may use to verify its pricing assumptions?

4.7 DOE is aware that fixtures are sometimes sold with the poles on which they are mounted. Would ballasts at different CSLs require different poles resulting in different MSPs? What percentage of fixtures rated for each 70, 250, 400, and 1000 W are sold this way? How many fixtures are typically mounted on a pole?

4.8 DOE derives fixture MSPs by adding ballast and empty fixture MPCs and applying a single markup. Is this appropriate in the cases of fixture manufacturers that do not produce ballasts? Should those ballasts be marked up twice (i.e., once for the ballast manufacturer and once as part of the whole fixture)? If so, what respective markups are appropriate for the ballast and for the fixture?

4.9 In the preliminary analysis, DOE used a markup for contractors installing metal halide lamp fixtures of 13%. Is that figure generally representative? If not, what would be better?

5 Company Overview and Organizational Characteristics

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to metal halide lamp fixture and/or metal halide lamp ballast production. However, the context within which the plant operates and the details of plant production and costs are not always readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical. Understanding the organizational setting around the metal halide lamp fixture and/or metal halide lamp ballast industry profit center will help DOE understand the probable future of the manufacturing activity with and without energy conservation standards.

5.1 Do you have a parent company, and/or any subsidiaries relevant to the metal halide lamp fixture and/or metal halide lamp ballast industry?

5.2 What is your company’s approximate market share of the metal halide lamp **fixture** market? Does this vary significantly for any particular equipment class that you manufacture?

5.3 Do you manufacture any products other than metal halide lamp fixtures? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to metal halide lamp **fixtures**?

5.4 Please complete Table 5.1 to the best of your ability for your company. If possible, please express revenue in both dollar amount and in percentage of total metal halide lamp fixture sales. Additionally, please express shipments in both volume and percentage of all metal halide lamp fixture shipments. Because the rulemaking covers only new fixtures, please note the fraction of sales to fixture original equipment manufacturers. Please indicate if you do not manufacturer products in any given equipment class.

Table 5.1 Metal Halide Lamp Fixture Revenue and Shipment Volumes

Rated Lamp Wattage Grouping	**2010 Revenue** ***($)***	***(%)***	**2010 Shipments** ***(volume)***	***(%)***
≥50 W and <150 W				
≥150 W and ≤250 W				
>250 W and ≤500 W				
>500 W				

5.5 Please describe your distribution channel. Who are your main customers for metal halide lamp fixtures?

6 Shipment Projections

Energy conservation standards can change overall shipments by altering product attributes, marketing approaches, product availability, and prices. The industry revenue calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent energy conservation standards) and the standards case shipments (i.e., total industry shipments with new energy conservation standards). In its shipment scenarios, DOE intends to model the effect of emerging technologies on the metal halide market.

6.1 Do you have historical fixture shipment data that you could provide?

6.2 If available, please estimate industry wide shipments of metal halide lamp fixtures over the past 2 years. Please describe any trends in these shipments. Because the rulemaking covers only new fixtures, please note the fraction of sales (by revenue) to fixture original equipment manufacturers.

Table 6.1 Metal Halide Lamp Fixture Industry Shipment Volumes

Rated Lamp Wattage Grouping	**2010**	**2009**
<50 W		
≥50 W and <150 W		
≥150 W and ≤250 W		
>250 W and ≤500 W		
>500 W		

6.3 What is the proportion of domestically consumed metal halide lamp fixtures and metal halide lamp ballasts shipped by NEMA companies versus non-NEMA companies? Please fill in the table below.

Table 6.2 Percentage of Shipments from NEMA v. Non-NEMA Companies

Product	**NEMA Shipments %**	**Non-NEMA Shipment %**	**Total**
Metal Halide Lamp Fixtures			100%
Metal Halide Lamp Ballasts			100%

6.4 In the July 2009 Lamps Rule and other lighting rulemakings, DOE assumes that revised standards that increase purchase price do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes? Does it vary with equipment class?

6.5 Do you expect characteristics of metal halide lamp fixtures or metal halide lamp ballasts to change in response to the standards?

6.6 Would you expect your market share to change when higher energy conservation standards take effect?

6.7 Please quantify what percent of the market might shift to fixtures outside of the scope of coverage (<50 W) in response to standards.

6.8 At DOE's Preliminary Analysis public meeting of April 18, 2011, several parties commented that DOE's fixture shipment projections were too high. Those projections assumed 1.5% annual growth in HID lamps from the present until 2016, and 1.5% annual decline thereafter. In response, DOE is considering projecting no growth until 2016 and a 1.5% annual decline thereafter, or simply a 1.5% annual decline starting at the present. Are either of these scenarios likely? If not, what is more realistic?

7 Financial Parameters

Navigant Consulting, Inc. has developed a "strawman" model of the metal halide lamp fixtures and metal halide lamp ballasts industry financial performance called the Government Regulatory Impact Model (GRIM) using publicly available data. However, this public information might not be reflective of manufacturing at the metal halide lamp fixtures or metal halide lamp ballasts profit center. This section attempts to understand the financial parameters for metal halide lamp fixture and ballast manufacturing and how your company's financial situation could differ from the industry aggregate picture.

7.1 In order to accurately collect information about metal halide lamp fixture manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 7.1 Financial Parameters for Metal Halide Lamp Fixture Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	25.5%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	9.5%	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.0%	
Net PPE	Net plant property and equipment (percentage of revenues)	19.7%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	17.0%	
R&D	Research and development expenses (percentage of revenues)	3.3%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.0%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.0%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	63.3%	

7.2 Do any of the financial parameters in Table 7.1 change significantly based on equipment class? Please describe any differences.

7.3 Do any of the financial parameters in Table 7.1 change for a particular subgroup of manufacturers? Please describe any differences.

7.4 How would you expect an energy conservation standard to impact any of the financial parameters for the industry?

7.5 Could you please provide the breakdown in the total production costs for metal halide lamp fixtures by the percentage for labor, materials, overhead, and depreciation by filling in Table 7.2 below?

Table 7.2 Breakdown of Total Production Costs for Metal Halide Lamp Fixtures

Labor % of full production costs	Materials % of full production costs	Overhead % of full production costs	Depreciation % of full production costs	Total % of full production costs
				100%

8 Conversion Costs

DOE understands that new energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical

part of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers two types of conversion costs:

- ***Capital conversion costs*** *are one-time investments in plant, property, and equipment (PPE) necessitated by new energy conservation standards. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.*

- ***Product conversion costs*** *are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by new energy conservation standards.*

Table 3.3 shows the CSLs and efficiencies DOE is analyzing for the equipment classes covered by this rulemaking. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs. Please refer to Table 3.3 when considering your response to the following questions.

8.1 At your manufacturing facilities, would the design pathways you would choose to meet these CSLs be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

8.2 Are there certain design pathways that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different equipment classes? Please describe these changes qualitatively.

8.3 For each of the equipment classes shown in Table 3.3, which CSLs could be achieved within existing platform designs and which would result in major product redesigns?

8.4 Would increasing the efficiency of the metal halide lamp ballasts to the levels presented in Table 3.3 result in any capital conversion costs for metal halide lamp **fixtures**? If so, please describe quantitatively and qualitatively.

8.5 Would fixture redesign costs (due to use of more efficient ballasts) be passed through to the consumer? Would the portion of redesign costs passed to the consumer change over time?

8.6 Would increasing the efficiency of the metal halide lamp ballasts to the levels presented in Table 3.3 result in any product conversion costs for metal halide lamp **fixtures**? If so, please describe quantitatively and qualitatively.

8.7 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

9 Cumulative Regulatory Burden

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

9.1 Below is a list of regulations that could affect manufacturers of metal halide lamp fixtures or metal halide lamp ballasts. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table 9.1 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for IRL and GSFL	July 14, 2012		
DOE's Energy Conservation Standards for Fluorescent Lamp Ballasts	June 2014		
EISA 2007 Standards for General Service Incandescent Lamps (GSIL)	2012		
International Energy Efficiency Standards			
Restriction of Hazardous Substances (RoHS)			

9.2 Are there any other recent or impending regulations that metal halide lamp fixture or ballast manufacturers face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

9.3 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with new energy conservation standards?

9.4 DOE research has not identified any production tax credits for manufacturers of metal halide lamp fixtures or metal halide lamp ballasts. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient metal halide lamp fixtures or metal halide lamp ballasts? If so, please describe.

9.5 Are there any voluntary programs (e.g., ENERGY STAR, DesignLights) that could affect the impact of DOE's energy conservation standard rulemaking?

10 Direct Employment Assessment

The impact of energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in metal halide lamp fixture and metal halide lamp ballast employment and solicit manufacturer *views on how domestic employment patterns might be affected by new energy conservation standards.*

10.1 Where are your facilities that produce metal halide lamp **fixtures** for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's metal halide lamp fixture manufacturing at each location by equipment class. Please also provide employment levels at each of these facilities.

Table 10.1 Metal Halide Lamp Fixture Manufacturing Facilities

Facility	Location	Equipment Types Manufactured	Employees	Annual Shipments
Example	*Jackson, TN*	*Equipment Class 1, 2*	*650*	*300,000 for EC 1, 200,000 for EC 2*
1				
2				
3				
4				
5				

10.2 Would your domestic employment levels be expected to change significantly under energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

10.3 Would the workforce skills necessary under energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

10.4 Would energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of energy conservation standards?

11 Manufacturing Capacity and Non-US Sales

11.1 How would energy conservation standards impact your company's manufacturing capacity?

11.2 For any design changes that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business? Are there any design changes that could not be implemented before the compliance date of the final rule for certain equipment classes?

11.3 What percentage of your domestic metal halide lamp **fixture** sales are produced in the United States?

11.4 What percentage of your U.S. production of metal halide lamp fixtures is exported?

11.5 Are there any foreign companies with North American production facilities?

12 Impact on Competition

Energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an energy conservation standard.

12.1 How would industry competition change as a result of energy conservation standards? How would energy conservation standards affect your ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

12.2 Do any firms hold intellectual property that gives them a competitive advantage following energy conservation standards?

13 Impacts on Small Business

13.1 The Small Business Administration (SBA) denotes a small business in the metal halide lamp **fixture** manufacturing industry as having less than 500 total employees, including the parent company and all subsidiaries. The SBA denotes a small business in the metal halide lamp **ballast** manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[2] By this definition, is your company considered a small business?

13.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

13.3 To your knowledge, are there any small businesses for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

13.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

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[2] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a commercial, industrial, and institutional electric lighting fixture manufacturer and its affiliates may employ a maximum of 500 employees. To be categorized as a small business, a power, distribution, and specialty transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 500 and 750 employee thresholds include all employees in a business's parent company and any other subsidiaries.

13A.3 SMALL BUSINESS METAL HALIDE LAMP BALLAST MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Small Business
Manufacturer Impact Analysis Interview Guide
Metal Halide Lamp Ballasts

Spring 2011

The U.S. Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA) as part of the rulemaking process to set energy conservation standards for metal halide lamp fixtures (MHLFs) by setting standards on the ballast used in fixtures. In this analysis, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1 Introduction

1.1 Are you aware of DOE's ongoing rulemaking to set new and amended national minimum energy conservation standards for metal halide lamp fixtures? If you are not already in it, would you like to be added to DOE's email database for updates relating to this rulemaking?

1.2 We are assessing the impacts of a potential energy conservation standard on small businesses. Is your company a small business (defined as less than 750 employees by the US Small Business Administration (SBA), including all subsidiaries and parent companies, and employees in all countries where you operate)?

1.3 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under adopted energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

1.4 To your knowledge, are there any small businesses for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

1.5 Table 1.1 (below) shows DOE's preliminary engineering results for each equipment class (LFE is low-frequency electronic, HFE is high frequency electronic, and M is magnetic). Are the MSPs appropriate for the efficiency levels? Where do your products fall?

Table 1.1 Costs and Efficiencies of Draft CSLs

Watts	CSL	Type	Eff.	Input Watts	Ballast MSP	Products Available
70	Baseline	M	72.3%	96.8	$27.63	
	1	M	76.1%	92.0	$28.33	
	2	LFE	89.3%	78.4	$30.79	
	3	LFE	91.1%	76.8	$37.22	
250	Baseline	M	88.0%	284.1	$47.88	
	1	M	90.5%	276.2	$53.99	
	2	M	91.5%	273.2	$60.67	
	3	LFE	93.2%	268.1	$79.38	
	4	HFE	93.6%	267.1	$75.91	
400	Baseline	M	88.0%	454.5	$45.10	
	1	M	90.0%	444.4	$57.62	
	2	M	91.7%	436.2	$66.10	
	3	LFE	92.7%	431.5	$94.01	
	4	HFE	93.9%	426.0	$113.82	
1000	Baseline	M	91.9%	1088.1	$58.83	
	1	M	92.6%	1079.9	$68.01	
	2	M	93.3%	1071.8	$72.51	

2 Key Impacts on Your Company

2.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

2.2 Do any of these issues become particularly significant at a specific efficiency level or for a specific equipment class?

3 Company Overview and Organizational Characteristics

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to metal halide lamp ballast production. However, the context within which the plant operates and the details of plant production and costs are not always readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical. Understanding the organizational setting around the metal halide lamp ballast industry profit center will help DOE understand the probable future of the manufacturing activity with and without energy conservation standards.

3.1 Do you have a parent company, and/or any subsidiaries relevant to the metal halide lamp ballast industry?

3.2 What is your company's approximate market share of the metal halide lamp ballast market? Does this vary significantly for any particular equipment class that you manufacture?

3.3 Do you manufacture any products other than metal halide lamp ballasts? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to metal halide lamp ballasts?

3.4 Please complete Table 3.1 to the best of your ability for your company. If possible, please express revenue in both dollar amount and in percentage of metal halide lamp ballast sales. Additionally, please express shipments in both volume and percentage of all metal halide lamp ballast shipments. Because the rulemaking covers only new fixtures, please note the fraction of sales to fixture original equipment manufacturers. Please indicate if you do not manufacturer products in any given equipment class.

Table 3.1 Metal Halide Lamp Ballast Revenue and Shipment Volumes

Rated Lamp Wattage Grouping	**2010 Revenue**		**2010 Shipments**		**Fraction of Sales, by Revenue, to Fixture OEMs**
	($)	***(%)***	***(volume)***	***(%)***	
≥50 W and <150 W					
≥150 W and ≤250 W					
>250 W and ≤500 W					
>500 W					

3.5 Please describe your distribution channel. Who are your main customers for metal halide lamp ballasts?

4 Markups and Profitability

One of the primary objectives of the MIA is to assess the impact of energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how energy conservation standards would impact your company's markup structure and profitability.

DOE estimated the manufacturer production costs for four equipment classes of metal halide lamp fixtures and metal halide lamp ballasts. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. It does not reflect a "profit margin."

The manufacturer production cost times the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but does not include additional costs along the distribution channels.

DOE estimated a baseline markup of 1.47 for metal halide lamp ballasts.

4.1 Is the 1.47 baseline markup representative of an average industry markup for metal halide lamp ballasts?

4.2 Please comment on the baseline markup DOE calculated as compared to your company's baseline markups for metal halide lamp ballasts. Does this markup vary by lamp wattage?

4.3 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Is this markup different than the markup applied to higher efficiency metal halide lamp ballasts? If yes, please provide information about the markups at higher efficiencies.

4.4 What factors besides efficiency affect the profitability of metal halide lamp ballasts?

4.5 Would you expect changes in your estimated profitability following an energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5 Financial Parameters

Navigant Consulting, Inc. has developed a "strawman" model of the metal halide lamp ballasts industry financial performance called the Government Regulatory Impact Model (GRIM) using publicly available data. However, this public information might not be reflective of manufacturing at the metal halide lamp ballasts profit center. This section attempts to understand the financial parameters for metal halide lamp ballast manufacturing and how your company's financial situation could differ from the industry aggregate picture.

5.1 In order to accurately collect information about metal halide lamp ballast manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 5.1 Financial Parameters for Metal Halide Lamp Ballast Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	30.3%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	8.7%	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.6%	
Net PPE	Net plant property and equipment (percentage of revenues)	20.9%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	17.7%	
R&D	Research and development expenses (percentage of revenues)	4.0%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.4%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.5%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	68.0%	

5.2 Do any of the financial parameters in Table 5.1 change significantly based on equipment class? Please describe any differences.

5.3 Do any of the financial parameters in Table 5.1 change for a particular subgroup of manufacturers? Please describe any differences.

5.4 How would you expect an energy conservation standard to impact any of the financial parameters for the industry?

5.5 Could you please provide the breakdown in the total production costs for metal halide lamp ballasts by the percentage for labor, materials, overhead, and depreciation by filling in Table 5.2 below?

Table 5.2 Breakdown of Total Production Costs for Metal Halide Lamp Ballasts

Labor % of full production costs	Materials % of full production costs	Overhead % of full production costs	Depreciation % of full production costs	Total % of full production costs
				100%

6 Conversion Costs

DOE understands that new energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical

part of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers two types of conversion costs:

- ***Capital conversion costs** are one-time investments in plant, property, and equipment (PPE) necessitated by new energy conservation standards. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.*

- ***Product conversion costs** are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by new energy conservation standards.*

Table 1.1 shows the CSLs and efficiencies DOE is analyzing for the equipment classes covered by this rulemaking. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs. Please refer to Table 1.1 when considering your response to the following questions.

6.1 At your manufacturing facilities, would the design pathways you would choose to meet these CSLs be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

6.2 Are there certain design pathways that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different equipment classes? Please describe these changes qualitatively.

6.3 For each of the equipment classes shown in Table 1.1, which CSLs could be achieved within existing platform designs and which would result in major product redesigns?

6.4 Please provide estimates for your capital conversion costs for metal halide lamp ballasts by equipment class in Table 6.1 below. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, etc., that would be required to implement the specified design changes.

6.5 What level of product development and other product conversion costs would you expect to incur to achieve each of these efficiency levels for each equipment class for metal halide lamp ballasts? Please provide your estimates in Table 6.1 considering such expenses as product development expenses, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

Table 6.1 Expected Product and Capital Conversion Costs for Metal Halide Lamp Ballasts

Ref #	Equipment class	CSL	Total Product Conversion Costs	Total Capital Conversion Costs	Description
1	**≥50 W and <150 W**	Baseline			
		1			
		2			
		3			
2	**≥150 W and ≤250 W**	Baseline			
		1			
		2			
		3			
		4			
3	**>250 W and ≤500 W**	Baseline			
		1			
		2			
		3			
		4			
4	**>500 W**	Baseline			
		1			
		2			

6.6 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

7 Direct Employment Assessment

The impact of energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in metal halide lamp ballast employment and solicit manufacturer views on how domestic employment patterns might be affected by new energy conservation standards.

7.1 Where are your facilities that produce metal halide lamp ballasts for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's metal halide lamp ballast or metal halide lamp fixture manufacturing at each location by equipment class. Please also provide employment levels at each of these facilities.

Table 7.1 Metal Halide Lamp Ballast Manufacturing Facilities

Facility	Location	Equipment Types Manufactured	Employees	Annual Shipments
Example	*Jackson, TN*	*Equipment Class 1, 2*	*650*	*300,000 for EC 1,* *200,000 for EC 2*
1				
2				
3				
4				
5				

7.2 Would your domestic employment levels be expected to change significantly under energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

13A.4 SMALL BUSINESS METAL HALIDE LAMP FIXTURE MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Small Business
Manufacturer Impact Analysis Interview Guide
Metal Halide Lamp Fixtures

Spring 2011

The U.S. Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA) as part of the rulemaking process to set energy conservation standards for metal halide lamp fixtures (MHLFs). In this analysis, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1 Introduction

1.1 Are you aware of DOE's ongoing rulemaking to set new and amended national minimum energy conservation standards for metal halide lamp fixtures? If you are not already in it, would you like to be added to DOE's email database for updates relating to this rulemaking?

1.2 We are assessing the impacts of a potential energy conservation standard on small businesses. Is your company a small business (defined as less than 500 employees by the US Small Business Administration (SBA), including all subsidiaries and parent companies, and employees in all countries where you operate)?

1.3 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under adopted energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

1.4 To your knowledge, are there any small businesses for which the adoption of energy conservation standards would have a particularly severe impact? If so, why?

1.5 Table 1.1 (below) shows DOE's preliminary engineering results for each equipment class (LFE is low-frequency electronic, HFE is high frequency electronic, and M is magnetic). Are the MSPs appropriate for the efficiency levels? Would empty fixture price vary with efficiency as a result of such concerns as increased weight, volume, or heat dissipation? Where do your products fall?

Table 1.1 Costs and Efficiencies of Draft CSLs

Watts	CSL	Type	Eff.	Input Watts	Ballast MSP	Empty Fixture MSP	Total Fixture MSP	Products Available
70	Baseline	M	72.3%	96.8	$27.63	$23.90	$51.53	
	1	M	76.1%	92.0	$28.33	$23.90	$52.23	
	2	LFE	89.3%	78.4	$30.79	$23.90	$54.69	
	3	LFE	91.1%	76.8	$37.22	$23.90	$61.12	
250	Baseline	M	88.0%	284.1	$47.88	$58.50	$106.38	
	1	M	90.5%	276.2	$53.99	$58.50	$112.49	
	2	M	91.5%	273.2	$60.67	$58.50	$119.17	
	3	LFE	93.2%	268.1	$79.38	$58.50	$137.88	
	4	HFE	93.6%	267.1	$75.91	$58.50	$134.41	
400	Baseline	M	88.0%	454.5	$45.10	$90.62	$135.72	
	1	M	90.0%	444.4	$57.62	$90.62	$148.24	
	2	M	91.7%	436.2	$66.10	$90.62	$156.72	
	3	LFE	92.7%	431.5	$94.01	$90.62	$184.63	
	4	HFE	93.9%	426.0	$113.82	$90.62	$204.44	
1000	Baseline	M	91.9%	1088.1	$58.83	$195.17	$254.00	
	1	M	92.6%	1079.9	$68.01	$195.17	$263.18	
	2	M	93.3%	1071.8	$72.51	$195.17	$267.68	

2 Key Impacts on Your Company

2.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

2.2 Do any of these issues become particularly significant at a specific efficiency level or for a specific equipment class?

3 Company Overview and Organizational Characteristics

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to metal halide lamp fixture production. However, the context within which the plant operates and the details of plant production and costs are not always readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical. Understanding the organizational setting around the metal halide lamp fixture industry profit center will help DOE understand the probable future of the manufacturing activity with and without energy conservation standards.

3.1 Do you have a parent company, and/or any subsidiaries relevant to the metal halide lamp fixture industry?

3.2 What is your company's approximate market share of the metal halide lamp fixture market? Does this vary significantly for any particular equipment class that you manufacture?

3.3 Do you manufacture any products other than metal halide lamp fixtures? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to metal halide lamp fixtures?

3.4 Please complete Table 3.1 to the best of your ability for your company. If possible, please express revenue in both dollar amount and in percentage of total metal halide lamp fixture sales. Additionally, please express shipments in both volume and percentage of all metal halide lamp fixture shipments. Please indicate if you do not manufacturer products in any given equipment class.

Table 3.1 Metal Halide Lamp Fixture Revenue and Shipment Volumes

Rated Lamp Wattage Grouping	**2010 Revenue**		**2010 Shipments**	
	($)	***(%)***	***(volume)***	***(%)***
≥50 W and <150 W				
≥150 W and ≤250 W				
>250 W and ≤500 W				
>500 W				

3.5 Please describe your distribution channel. Who are your main customers for metal halide lamp fixtures?

4 Markups and Profitability

One of the primary objectives of the MIA is to assess the impact of energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how energy conservation standards would impact your company's markup structure and profitability.

DOE estimated the manufacturer production costs for four equipment classes of metal halide lamp fixtures. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. It does not reflect a "profit margin."

The manufacturer production cost times the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but does not include additional costs along the distribution channels.

For the NOPR, DOE is considering using a baseline markup of 1.58 for metal halide lamp fixtures.

4.1 Is the 1.58 baseline markup representative of an average industry markup for metal halide lamp fixtures?

4.2 Please comment on the baseline markup DOE calculated as compared to your company's baseline markups for metal halide lamp fixtures. Does this markup vary by lamp wattage?

4.3 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Is this markup different than the markup applied to higher efficiency metal halide lamp fixtures? If yes, please provide information about the markups at higher efficiencies.

4.4 What factors besides efficiency affect the profitability of metal halide lamp fixtures?

4.5 Would you expect changes in your estimated profitability following an energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5 Financial Parameters

Navigant Consulting, Inc. has developed a "strawman" model of the metal halide lamp fixtures industry financial performance called the Government Regulatory Impact Model (GRIM) using publicly available data. However, this public information might not be reflective of manufacturing at the metal halide lamp fixtures profit center. This section attempts to understand the financial parameters for metal halide lamp fixture manufacturing and how your company's financial situation could differ from the industry aggregate picture.

5.1 In order to accurately collect information about metal halide lamp fixture manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 5.1 Financial Parameters for Metal Halide Lamp Fixture Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	25.5%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	9.5%	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.0%	
Net PPE	Net plant property and equipment (percentage of revenues)	19.7%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	17.0%	
R&D	Research and development expenses (percentage of revenues)	3.3%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.0%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.0%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	63.3%	

5.2 Do any of the financial parameters in Table 5.1 change significantly based on equipment class? Please describe any differences.

5.3 Do any of the financial parameters in Table 5.1 change for a particular subgroup of manufacturers? Please describe any differences.

5.4 How would you expect an energy conservation standard to impact any of the financial parameters for the industry?

5.5 Could you please provide the breakdown in the total production costs for metal halide lamp fixtures by the percentage for labor, materials, overhead, and depreciation by filling in Table 5.2 and below?

Table 5.2 Breakdown of Total Production Costs for Metal Halide Lamp Fixtures

Labor % of full production costs	Materials % of full production costs	Overhead % of full production costs	Depreciation % of full production costs	Total % of full production costs
				100%

6 Conversion Costs

DOE understands that new energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical

part of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers two types of conversion costs:

- ***Capital conversion costs** are one-time investments in plant, property, and equipment (PPE) necessitated by new energy conservation standards. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.*

- ***Product conversion costs** are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by new energy conservation standards.*

Table 1.1 shows the CSLs and efficiencies DOE is analyzing for the equipment classes covered by this rulemaking. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs. Please refer to Table 1.1 when considering your response to the following questions.

6.1 At your manufacturing facilities, would the design pathways you would choose to meet these CSLs be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

6.2 Are there certain design pathways that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different equipment classes? Please describe these changes qualitatively.

6.3 For each of the equipment classes shown in Table 1.1, which CSLs could be achieved within existing platform designs and which would result in major product redesigns?

6.4 Would increasing the efficiency of the metal halide lamp ballasts to the levels presented in Table 1.1 result in any capital conversion costs for metal halide lamp fixtures? If so, please describe quantitatively and qualitatively.

6.5 Would fixture redesign costs (due to use of more efficient ballasts) be passed through to the consumer? Would the portion of redesign costs passed to the consumer change over time?

6.6 Would increasing the efficiency of the metal halide lamp ballasts to the levels presented in Table 1.1 result in any product conversion costs for metal halide lamp fixtures? If so, please describe quantitatively and qualitatively.

6.7 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

7 Direct Employment Assessment

The impact of energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in metal halide lamp fixture employment and solicit manufacturer views on how domestic employment patterns might be affected by new energy conservation standards.

7.1 Where are your facilities that produce metal halide lamp fixtures for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's metal halide lamp fixture manufacturing at each location by equipment class. Please also provide employment levels at each of these facilities.

Table 7.1 Metal Halide Lamp Fixture Manufacturing Facilities

Facility	Location	Equipment Types Manufactured	Employees	Annual Shipments
Example	*Jackson, TN*	*Equipment Class 1, 2*	*650*	*300,000 for EC 1, 200,000 for EC 2*
1				
2				
3				
4				
5				

7.2 Would your domestic employment levels be expected to change significantly under energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

APPENDIX 13B GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

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13B.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers(s) following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (TSLs) (*i.e.*, the standards case).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

13B.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the printout of the output sheet (see section 13B.3).

Unit Sales: Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

Revenues: Annual revenues - computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup;

Labor: The portion of cost of goods sold (COGS) that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time;

Material: The portion of COGS that includes materials;

Overhead: The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, depreciation, property taxes, and insurance related to assets. While included in overhead, the depreciation is shown as a separate line item;

Depreciation: The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Annual depreciation computed as a percentage of ***COGS.*** While included in overhead, the depreciation is shown as a separate line item;

Stranded Assets: In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for;

Standard SG&A: Selling, general, and administrative costs are computed as a percentage of ***Revenues (2)***;

R&D: GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (2)***;

Product Conversion Costs: Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making products designs comply with the amended energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Earnings Before Interest and Taxes (EBIT): Includes profits before deductions for interest paid and taxes;

EBIT as a Percentage of Sales (EBIT/Revenues): GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

Taxes: Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in Major Assumptions by ***EBIT (11)***.

Net Operating Profits After Taxes (NOPAT): Computed by subtracting Cost of Goods Sold ((3) to (6)), SG&A (8), R&D (9), Product Conversion Costs (10), and Taxes (13) from Revenues (2).

NOPAT repeated: NOPAT is repeated in the Statement of Cash Flows;

Depreciation repeated: Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they are non-cash expenses;

Change in Working Capital: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

Cash Flow From Operations: Calculated by taking ***NOPAT (15)***, adding back non-cash items such as a ***Depreciation (16)***, and subtracting the ***Change in Working Capital (17)***;

Ordinary Capital Expenditures: Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (2)***;

Capital Conversion Costs: Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation; the GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Capital Investment: Total investments in property, plant, and equipment are computed by adding ***Ordinary Capital Expenditures (19)*** and ***Capital Conversion Costs (20)***;

Free Cash Flow: Annual cash flow from operations and investments; computed by subtracting ***Capital Investment (21)*** from ***Cash Flow from Operations (18)***;

Terminal Value: Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at the beginning of 2045 at a constant rate in perpetuity;

Present Value Factor: Factor used to calculate an estimate of the present value of an amount to be received in the future;

Discounted Cash Flow: Free Cash Flows (22) multiplied by the ***Present Value Factor (24)***. For the end of 2045, the discounted cash flow includes the discounted ***Terminal Value (23)***; and

Industry Value thru the end of 2045: The sum of Discounted Cash Flows (25).

13B.3 DETAILED CASH FLOW EXAMPLE

Industry Income Statement	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Revenues	$ 571.3	$ 565.8	$ 559.0	$ 552.5	$ 545.2	$ 537.5	$ 530.3	$ 523.1	$ 516.4	$ 512.0	$ 502.7	$ 496.6	$ 490.4	$ 484.8
- Materials	$ 297.2	$ 294.5	$ 291.0	$ 287.7	$ 283.9	$ 279.9	$ 276.2	$ 272.5	$ 269.0	$ 266.8	$ 262.0	$ 258.8	$ 255.6	$ 252.7
- Labor	$ 27.9	$ 27.6	$ 27.2	$ 26.8	$ 26.4	$ 26.0	$ 25.7	$ 25.3	$ 25.0	$ 24.7	$ 24.2	$ 23.9	$ 23.6	$ 23.4
- Depreciation	$ 16.6	$ 16.4	$ 16.2	$ 16.0	$ 15.8	$ 15.6	$ 15.4	$ 15.2	$ 15.0	$ 14.9	$ 14.6	$ 14.4	$ 14.2	$ 14.1
- Overhead	$ 19.9	$ 19.7	$ 19.4	$ 19.2	$ 18.9	$ 18.6	$ 18.4	$ 18.1	$ 17.9	$ 17.7	$ 17.4	$ 17.2	$ 17.0	$ 16.8
- Standard SG&A	$ 106.9	$ 105.9	$ 104.6	$ 103.4	$ 102.0	$ 100.6	$ 99.2	$ 97.9	$ 96.6	$ 95.8	$ 94.1	$ 92.9	$ 91.8	$ 90.7
- R&D	$ 17.5	$ 17.3	$ 17.1	$ 16.9	$ 16.7	$ 16.4	$ 16.2	$ 16.0	$ 15.8	$ 15.6	$ 15.4	$ 15.2	$ 15.0	$ 14.8
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 85.3	$ 84.5	$ 83.5	$ 82.5	$ 81.4	$ 80.3	$ 79.2	$ 78.1	$ 77.2	$ 76.5	$ 75.1	$ 74.2	$ 73.3	$ 72.4
EBIT/Revenues	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*	*14.9%*
- Taxes	$ 24.5	$ 24.3	$ 24.0	$ 23.7	$ 23.4	$ 23.1	$ 22.8	$ 22.5	$ 22.2	$ 22.0	$ 21.6	$ 21.3	$ 21.1	$ 20.8
Net Operating Profit after Taxes (NOPAT)	**$ 60.8**	**$ 60.2**	**$ 59.5**	**$ 58.8**	**$ 58.0**	**$ 57.2**	**$ 56.5**	**$ 55.7**	**$ 55.0**	**$ 54.5**	**$ 53.5**	**$ 52.9**	**$ 52.2**	**$ 51.6**
Cash Flow Statement														
NOPAT	$ 60.8	$ 60.2	$ 59.5	$ 58.8	$ 58.0	$ 57.2	$ 56.5	$ 55.7	$ 55.0	$ 54.5	$ 53.5	$ 52.9	$ 52.2	$ 51.6
+ Depreciation	$ 16.6	$ 16.4	$ 16.2	$ 16.0	$ 15.8	$ 15.6	$ 15.4	$ 15.2	$ 15.0	$ 14.9	$ 14.6	$ 14.4	$ 14.2	$ 14.1
+ Change in Working Capital	$ -	$ 0.5	$ 0.6	$ 0.5	$ 0.6	$ 0.6	$ 0.6	$ 0.6	$ 0.6	$ 0.4	$ 0.8	$ 0.5	$ 0.5	$ 0.5
Cash Flows from Operations	$ 77.4	$ 77.1	$ 76.3	$ 75.4	$ 74.5	$ 73.5	$ 72.4	$ 71.5	$ 70.5	$ 69.7	$ 68.9	$ 67.8	$ 67.0	$ 66.1
- Ordinary Capital Expenditures	$ 16.9	$ 16.7	$ 16.5	$ 16.3	$ 16.1	$ 15.9	$ 15.6	$ 15.4	$ 15.2	$ 15.1	$ 14.8	$ 14.7	$ 14.5	$ 14.3
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 60.5**	**$ 60.4**	**$ 59.8**	**$ 59.1**	**$ 58.4**	**$ 57.6**	**$ 56.8**	**$ 56.0**	**$ 55.3**	**$ 54.6**	**$ 54.0**	**$ 53.1**	**$ 52.5**	**$ 51.8**
Discounted Cash Flow														
Free Cash Flow	$ 60.5	$ 60.4	$ 59.8	$ 59.1	$ 58.4	$ 57.6	$ 56.8	$ 56.0	$ 55.3	$ 54.6	$ 54.0	$ 53.1	$ 52.5	$ 51.8
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*1.000*	*0.913*	*0.834*	*0.761*	*0.695*	*0.635*	*0.579*	*0.529*	*0.483*	*0.441*	*0.403*	*0.368*	*0.336*
Discounted Cash Flow	**$ -**	**$ 60.4**	**$ 54.6**	**$ 49.3**	**$ 44.4**	**$ 40.0**	**$ 36.0**	**$ 32.5**	**$ 29.2**	**$ 26.4**	**$ 23.8**	**$ 21.4**	**$ 19.3**	**$ 17.4**
INPV at Baseline $ 629.8														
Net PPE	$ 109.9	$ 108.8	$ 107.5	$ 106.3	$ 104.9	$ 103.4	$ 102.0	$ 100.6	$ 99.3	$ 98.5	$ 96.7	$ 95.5	$ 94.3	$ 93.3
Net PPE as % of Sales	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%	19.2%
Net Working Capital	$ 47.4	$ 47.0	$ 46.4	$ 45.9	$ 45.3	$ 44.6	$ 44.0	$ 43.4	$ 42.9	$ 42.5	$ 41.7	$ 41.2	$ 40.7	$ 40.3
Return on Invested Capital (ROIC)	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%
Weighted Average Cost of Capital (WACC)	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%
Return on Sales (EBIT/Sales)	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%	14.9%

APPENDIX 17A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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APPENDIX 17A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

Prepared by
Interagency Working Group on Social Cost of Carbon, United States Government

With participation by

Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

17A.1 EXECUTIVE SUMMARY

Under Executive Order (E.O.) 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include but is not limited to changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures.

In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC values for use in regulatory analyses (Table 17A.1.1. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 17A.1.1 Social Cost of CO_2, 2010–2050 (2007$)

Year	Discount Rate %			
	5	3	2.5	3
	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

17A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The "social cost of carbon" (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include but is not limited to changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. We report estimates of the social cost of carbon in dollars per metric ton of CO_2 throughout this document.[a]

When attempting to assess the incremental economic impacts of CO_2 emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases; (2) the effects of past and future emissions on the climate system; (3) the impact of changes in climate on the physical and biological environment; and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. Under E.O. 12866, agencies

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[a] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

are required, to the extent permitted by law, “to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small or “marginal” impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global CO_2 emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$4.7, \$21.4, \$35.1, and \$64.9 (2007\$). The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020. See Appendix A for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within 2 years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

17A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing CO_2 emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a “domestic” SCC value of $2 per ton of CO_2 and a “global” SCC value of $33 per ton of CO_2 for 2007 emission reductions (2007$), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at $80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of $7 per ton CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of $0-$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of $0 to $20 per ton CO_2 for 2007 emission reductions (2007$). In addition, EPA’s 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as “very preliminary” SCC estimates subject to revision. EPA’s global mean values were $68 and $40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (2006$ for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing CO_2 emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of $55, $33, $19, $10, and $5 per ton of $CO_{2.}$ The $33 and $5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The $55 and $10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The $19 value was chosen as a central value between the $5 and $33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

17A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

17A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[b] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-

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[b] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (*e.g.*, Tol 2002a, Tol 2002b, Anthoff *et al.* 2009, Tol 2009).

form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socio-economic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and economic processes (*e.g.*, the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socio-economic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socio-economic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (*e.g.*, the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

17A.4.1.1 The DICE Model

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric CO_2 concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, CO_2 emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren *et al*., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[c]

17A.4.1.2 The PAGE Model

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (*i.e.*, a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2 °C for developed countries and 0 °C for developing countries for economic impacts, and 0 °C for all regions for non-economic impacts), but adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2 °C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

17A.4.1.3 The FUND Model

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on the absolute temperature change but also on the rate of temperature change and level of regional

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[c] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20%, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

income.[d] In the forestry and agricultural sectors, economic damages also depend on CO_2 concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as “big unknowns:” for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, “Exactly what would cause these sorts of changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues.”

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from CO_2 fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of CO_2 fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

17A.4.1.4 Damage Functions

To generate revised SCC values, we rely on the IAM modelers’ current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. Given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figure 17A.4.1 and Figure 17A.4.2, using the modeler’s default scenarios and mean input assumptions. There are significant differences between the three models both at lower (Figure 17A.4.1) and higher (Figure 17A.4.2) increases in global-average temperature.

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[d] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren *et al*. 2006).

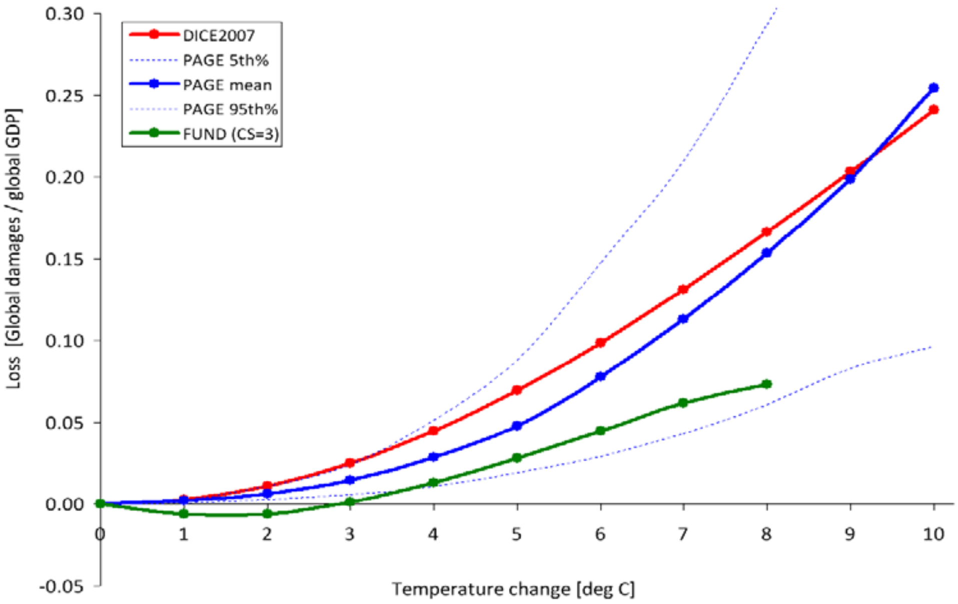

Figure 17A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE Models[e]

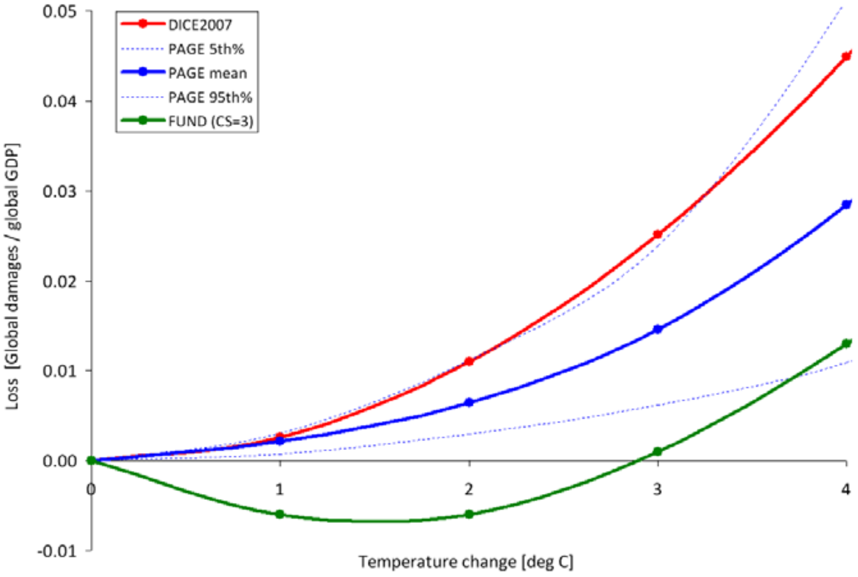

Figure 17A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

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[e] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socio-economic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figure 17A.4.1 and Figure 17A.4.2are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

17A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[f]

17A.4.2.1 Global SCC

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these

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[f] It is true that Federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (*e.g.*, Anthoff *et al*. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[g] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

17A.4.2.2 Domestic SCC

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7–10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[h]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no *a priori* reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not account for how damages in other regions could affect the United States (*e.g.*, global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

17A.4.3 Valuing Non-CO_2 Emissions

While CO_2 is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide,

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[g] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.

[h] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (*i.e.*, radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, CO_2 emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of CO_2 fertilization. Thus, transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases.

In light of these limitations, and the significant contributions of non-CO_2 emissions to climate change, further research is required to link non-CO_2 emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-CO_2 greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for CO_2 emissions.

17A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[i] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

> Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity,' is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.[j]
>
> For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally

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[i] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100–200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (*e.g.*, Hansen *et al.* 2007).

[j] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut *et al.* 2007). "Very likely" indicates a greater than 90 percent probability.

> worse for those high values than for values in the 2 °C to 4.5 °C range. (Meehl *et al*. 2007, p. 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 17A.4.1 gives summary statistics for the four calibrated distributions.

Table 17A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions

Rank	Roe & Baker	Log-Normal	Gamma	Weibull
Pr(ECS < 1.5 °C)	0.013	0.050	0.070	0.102
Pr(2 °C < ECS < 4.5 °C)	0.667	0.667	0.667	0.667
5th Percentile	1.72	1.49	1.37	1.13
10th Percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th Percentile	5.86	5.14	4.93	4.69
95th Percentile	7.14	5.97	5.59	5.17

Each distribution was calibrated by applying three constraints from the IPCC:

(1) a median equal to 3 °C, to reflect the judgment of "a most likely value of about 3 °C;"[k]
(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0 °C or greater than 10 °C (Hegerl *et al.* 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007; Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

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[k] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3 °C, rather than the mode or mean, gave a 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3 °C produced 95th percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3 °C than is the mode for the truncated distributions selected by the IPCC (Hegerl *et al*. 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl *et al*. 2006) than are the 95th percentiles of the three other calibrated distributions (5.2–6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5 °C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 17A.4.3 overlays it on Figure 17A.9.2 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[1]

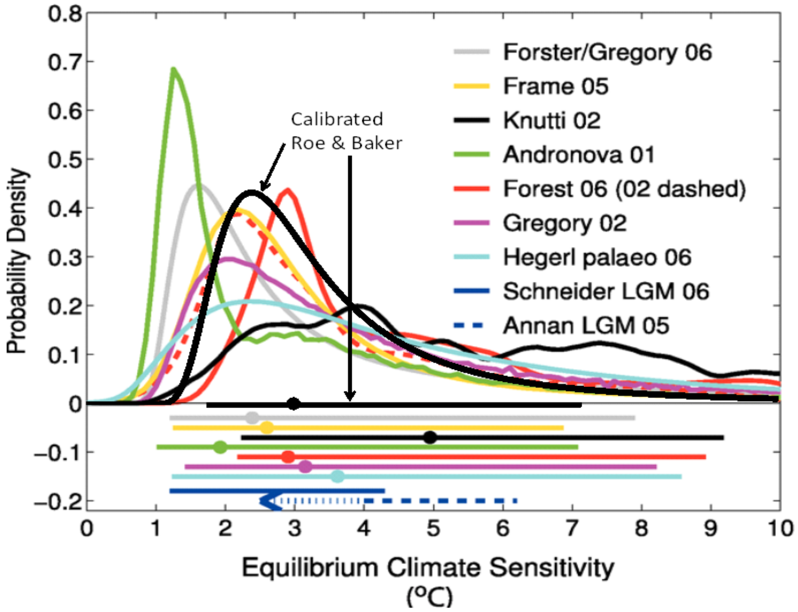

Figure 17A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity

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[1] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest *et al*. (2006; solid line, anthropogenic and natural forcings), Gregory *et al*. (2002), Knutti *et al*. (2002), Frame *et al*. (2005), and Forster and Gregory (2006). Hegerl *et al*. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5–95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan *et al*. 2005; solid, Schneider von Deimling *et al*. 2006), which are based on models with different structural properties.

17A.4.5 Socio-Economic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socio-economic and emissions parameters for use in PAGE, DICE, and FUND. Socio-economic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, CO_2 emissions, and non-CO_2 radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (*e.g.*, SRES 2000, CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22, which uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socio-economic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (Table 17A.4.2). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (*i.e.*, CO_2-only concentrations of 425–484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[m] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

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[m] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

Table 17A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios

Reference Fossil and Industrial CO_2 Emissions ***$GtCO_2$/yr***						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8
Reference GDP ***market exchange rates in trillion 2005$***[n]						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9
Global Population ***billions***						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socio-economic pathways.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the

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[n] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP), which takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (*e.g.*, Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (*i.e.*, using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

most likely outcome span a wide range, from the more optimistic (*e.g.*, abundant low-cost, low-carbon energy) to more pessimistic (*e.g.*, constraints on the availability of nuclear and renewables).[o] Second, the socio-economic trajectories associated with a 550 ppm CO_2e concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (*e.g.*, MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[p] We chose not to include socio-economic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 *Annual Energy Outlook* projected that global CO_2 emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be \$51.8, \$71.0 and \$93.9 trillion (2005\$ using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use CO_2 emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (*e.g.*, aerosols and other gases). See the Appendix for greater detail.

17A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because CO_2 emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of CO_2 emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

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[o] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.

[p] For example, MiniCAM projects if all non-US OECD countries reduce CO_2 emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path CO_2 concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow *et al.* (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled "descriptive" and "prescriptive." The descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices—*e.g.*, savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use" (Arrow *et al*. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (*e.g.*, Just *et al*. 2004). As some have noted, the word "potentially" is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—*e.g.*, how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is "ethically indefensible" to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above; Arrow *et al*. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

17A.4.6.1 Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (Lind 1990, Arrow *et al.*, 1996, Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," *i.e.*, the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[q] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's recommendation to use 3 percent to represent the consumption rate of interest.[r] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes yields a real rate of roughly 5 percent.[s]

17A.4.6.2 The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting

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[q] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.

[r] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.

[s] Cambell *et al*. (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950–2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20–40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[t] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[u] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta \cdot g$, will be equal to the rate of return to capital, *i.e.*, the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors articulate whether their choice is based on prescriptive or descriptive reasoning.[v] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, since η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than $\rho = 0$ would unjustly discriminate against future generations (*e.g.*, Arrow *et al.* 1996, Stern 2006). However, even in an inter-generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socio-economic scenarios used for this exercise, the EMF models assume that g is about 1.5–2 percent to 2100.

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[t] The parameter ρ measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[u] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

[v] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff *et al.* (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern (2006) applies this perspective through his choice of $\rho = 0.1$ percent per year, $\eta = 1$ and $g = 1.3$ percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[w]

Recently, Stern (2008) revisited the values used in Stern (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with $\eta = 1$). Using Stern's assumption that $\rho = 0.1$ percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate greater 2 percent.

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

17A.4.6.3 Accounting for Uncertainty in the Discount Rate

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Panipoulou *et al.* (2004) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (*e.g.*, the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Panipoulou *et al.* (2004); Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Panipoulou *et al.* (2004), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and variation in the level of persistence over time.

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[w] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

While Newell and Pizer (2003) and Panipoulou *et al.* (2004) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (*e.g.*, Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[x] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[y]

17A.4.6.4 The Discount Rates Selected for Estimating SCC

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value (3 percent) is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

The low value (2.5 percent) is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[z] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

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[x] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31–75; 2.5 percent for years 76–125; 2 percent for years 126–200; 1.5 percent for years 201–300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.

[y] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity, utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.

[z] Calculations done by Pizer *et al.* using the original simulation program from Newell and Pizer (2003).

17A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMS, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

    a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.

    b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.

    c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t*. (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10 year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Appendix.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no integrated assessment model or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socio-economic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Appendix.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 17A.5.1**,** we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

Table 17A.5.1 Disaggregated Social Cost of CO2 Values by Model, Socio-Economic Trajectory, and Discount Rate for 2010 (2007$)

	Discount rate:	**5%**	**3%**	**2.5%**	**3%**
Model	*Scenario*	Avg	Avg	Avg	95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[aa]

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Further, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 17A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

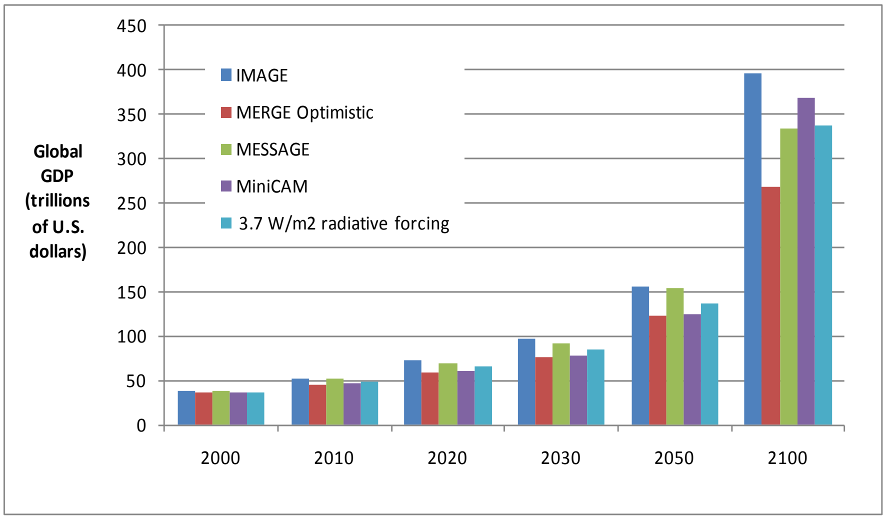

Figure 17A.5.1 Level of Global GDP Across EMF Scenarios

Table 17A.5.2 shows the four selected SCC values in 5-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

[aa] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC estimates for values of $\rho = 0$, 1, and 3 in many recent papers (*e.g.*, Anthoff *et al*. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

Table 17A.5.2 Social Cost of CO_2, 2010–2050 (2007$)

Discount Rate	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 17A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Appendix.

Table 17A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate	5%	3%	2.5%	3.0%
Year Range	Avg	Avg	Avg	95th
2010–2020	3.6	2.1	1.7	2.2
2020–2030	3.7	2.2	1.8	2.2
2030–2040	2.7	1.8	1.6	1.8
2040–2050	2.1	1.4	1.1	1.3

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—*i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[bb]

17A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic,

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[bb] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats and additional observations in the following section are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. It is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold "are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-impact low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures. The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (*e.g.*, DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change. Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning, so much so that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[cc] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs under or overstate the likely damages.

Risk aversion. A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability but lower-impact damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

Assuming a risk-neutral representative agent is consistent with OMB's Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that "emphasis on these expected values is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume 'risk neutrality' in [their] analysis."

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff *et al.* (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that "the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon." Since Circular A-4 allows for a different

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[cc] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

17A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models' functional forms may not adequately capture: (1) potentially discontinuous "tipping point" behavior in Earth systems; (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming; and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

17A.7.1 Extrapolation of Climate Damages to High Levels of Warming

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic "tipping points" at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (*e.g.*, Lenton *et al.* 2008, Kriegler *et al.* 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton *et al.* 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler *et al.* (2009); results from this study are highlighted in Table 17A.7.1. Ranges of probability are averaged across core experts on each topic.

Table 17A.7.1 Probabilities of Various Tipping Points from Expert Elicitation

Possible Tipping Points	**Duration before effect is fully realized**	**Additional Warming by 2100** **%**		
	years	**0.5–1.5 C**	**1.5–3.0 C**	**3–5 C**
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0–18	6–39	18–67
Greenland Ice Sheet Collapse	at least 300	8–39	33–73	67–96
West Antarctic Ice Sheet Collapse	at least 300	5–41	10–63	33–88
Dieback of Amazon rainforest	about 50	2–46	14–84	41–94
Strengthening of El Niño-Southern Oscillation	about 100	1–13	6–32	19–49
Dieback of Boreal Forests	about 50	13–43	20–81	34–91
Shift in Indian Summer Monsoon	about 1	not formally assessed		
Release of Methane from Melting Permafrost	less than 100	not formally assessed		

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (*i.e.*, ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (Figure 16-A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95th percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socio-economic and emission trajectories of \$113 per ton of CO_2 is almost double the value estimated by DICE, \$58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (*i.e.*, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler *et al.* (2009) estimate a probability of at least 16–36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2–4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

17A.7.2 Failure to Incorporate Inter-Sectoral and Inter-Regional Interactions

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (*e.g.*, Campbell *et al.* 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3–6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling *et al.* 2007; Campbell *et al*. 2007).

17A.7.3 Imperfect Substitutability of Environmental Amenities

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400–900 miles in the range of plants (Wing *et al.* 2005), and dwarfing of both land mammals (Gingerich 2006) and soil fauna (Smith *et al.* 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy *et al.* 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace. Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs (Sterner and Persson 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

17A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$4.7, \$21.4, \$35.1, and \$64.9 (2007\$). The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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17A.9 ANNEX

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300, and shows the full distribution of 2010 SCC estimates by model and scenario combination. Annual SCC values for the next 40 years are provided in Table 17A.9.1.

Table 17A.9.1 Annual SCC Values: 2010–2050 (2007$)

Discount Rate	5%	3%	2.5%	3%
Year	**Avg**	**Avg**	**Avg**	**95th**
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

17A.9.1 Other (non-CO_2) Gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (*e.g.*, aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[dd] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (*e.g.*, DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_2O, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

PAGE: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors,[ee] decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_2O, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was 0.48 + 0.16 + 0.34 = 0.98 W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

[dd] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).

[ee] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

> (1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter, and
>
> (2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.[ff]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, Figure 17A.9.1 shows that the sulfur dioxide emissions peak over the short-term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[gg] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[hh] The lower bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

[ff] AR4 Synthesis Report, p. 44, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[gg] See Smith, S.J., R. Andres, E. Conception, and J. Lurz. 2004. "Historical sulfur dioxide emissions, 1850-2000: methods and results." Joint Global Research Institute, College Park, 14 pp.

[hh] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda. 2002. "Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate." *Environmental Science and Technology* 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen. 2001. "Recent reductions in China's greenhouse gas emissions." *Science* 294(5548):1835-1837.

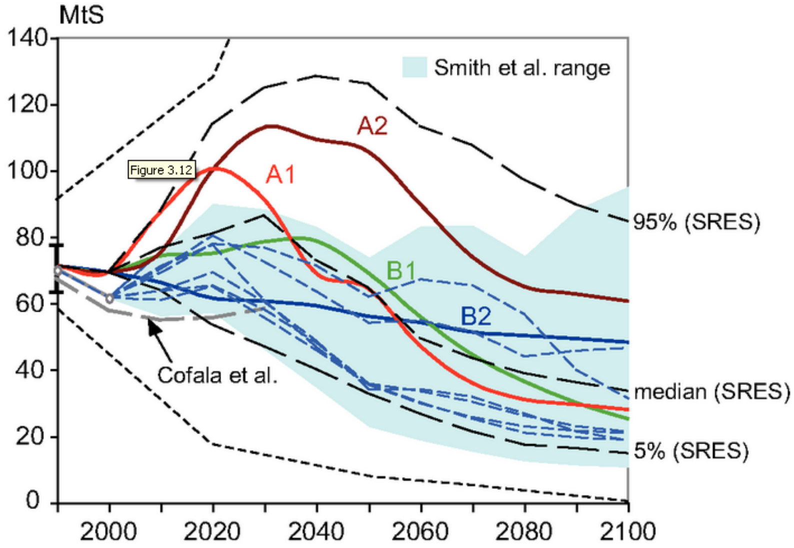

Figure 17A.9.1 Sulphur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th and 95th percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith *et al.* (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2, http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6–7 percent (or $0.50–$3), depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

17A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in 2300.

3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use CO_2 emissions decline linearly, reaching zero in 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[ii] The resulting range of EMF population trajectories (Figure A2) also encompass the UN medium scenario forecasts through 2300 – global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090–2100 carbon intensity growth rate (*i.e.*, CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

Figure 17A.9.2 through Figure 17A.9.8 show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

[ii] United Nations. 2004. *World Population to 2300.* http://www.un.org/esa/population/publications/longrange2/worldpop2300final.pdf.

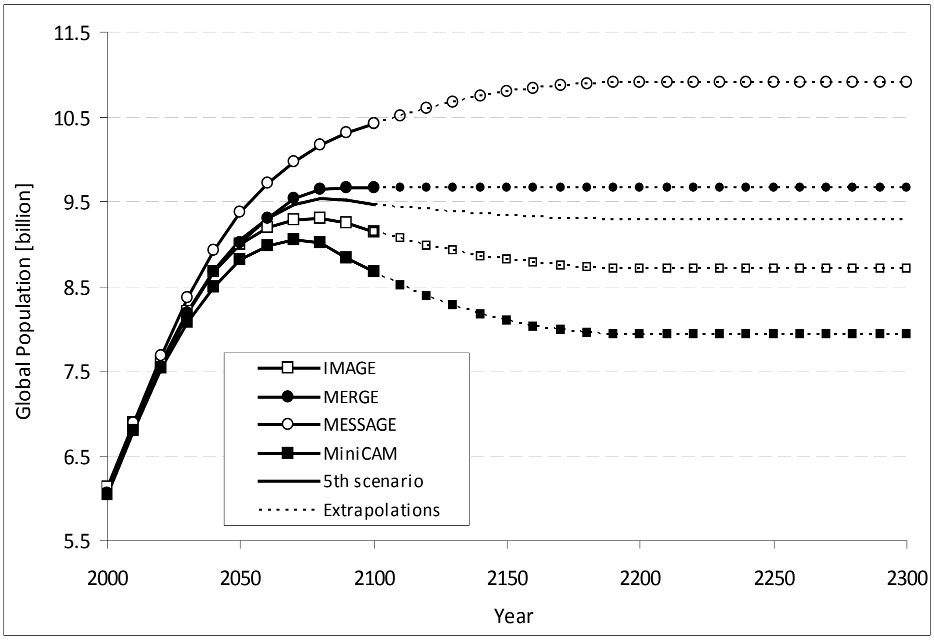

Figure 17A.9.2 Global Population, 2000–2300 (post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200)

Note: In the fifth scenario, 2000–2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

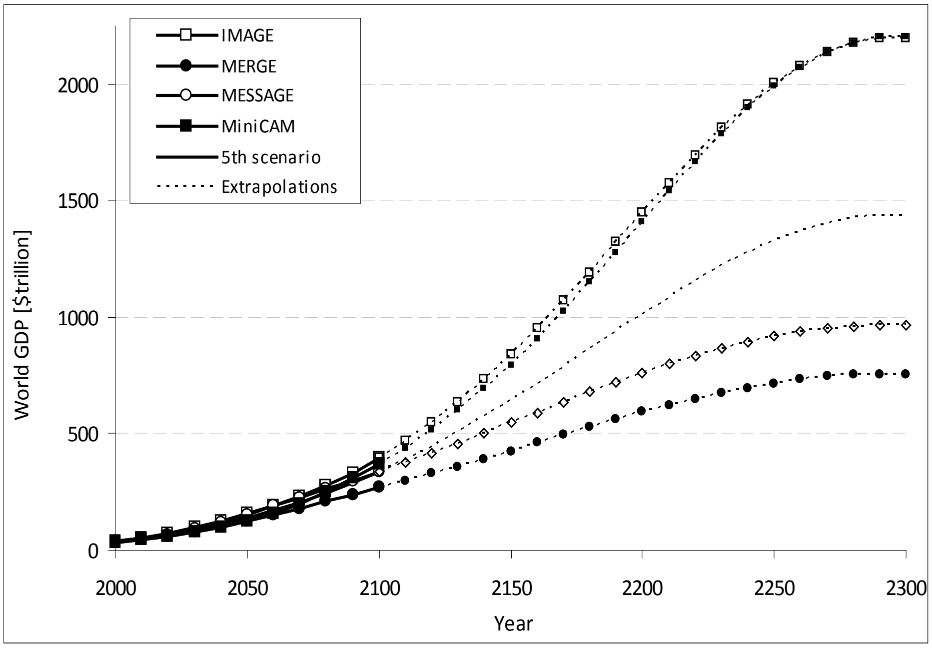

Figure 17A.9.3 World GDP, 2000-2300 (post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in 2300)

Note: In the fifth scenario, 2000–2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

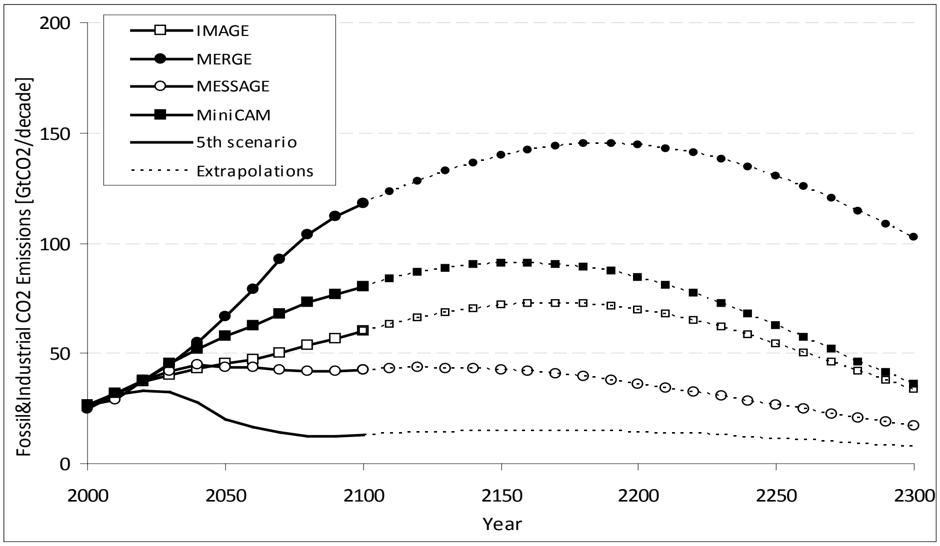

Figure 17A.9.4 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090–2100 is maintained through 2300)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

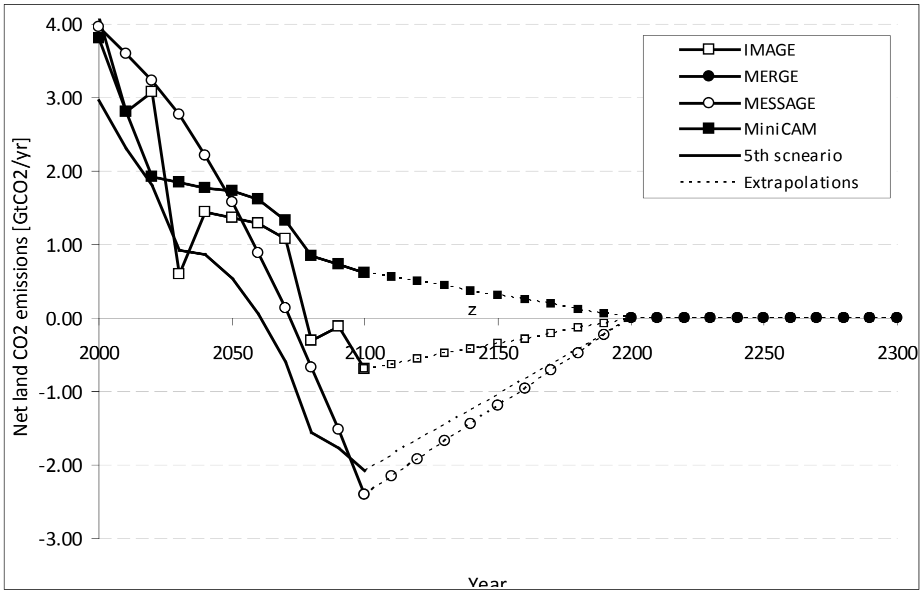

Figure 17A.9.5 Global Net Land Use CO_2 Emissions, 2000–2300 (post-2100 extrapolations assume emissions decline linearly, reaching zero in 2200)[jj]

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[jj] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).

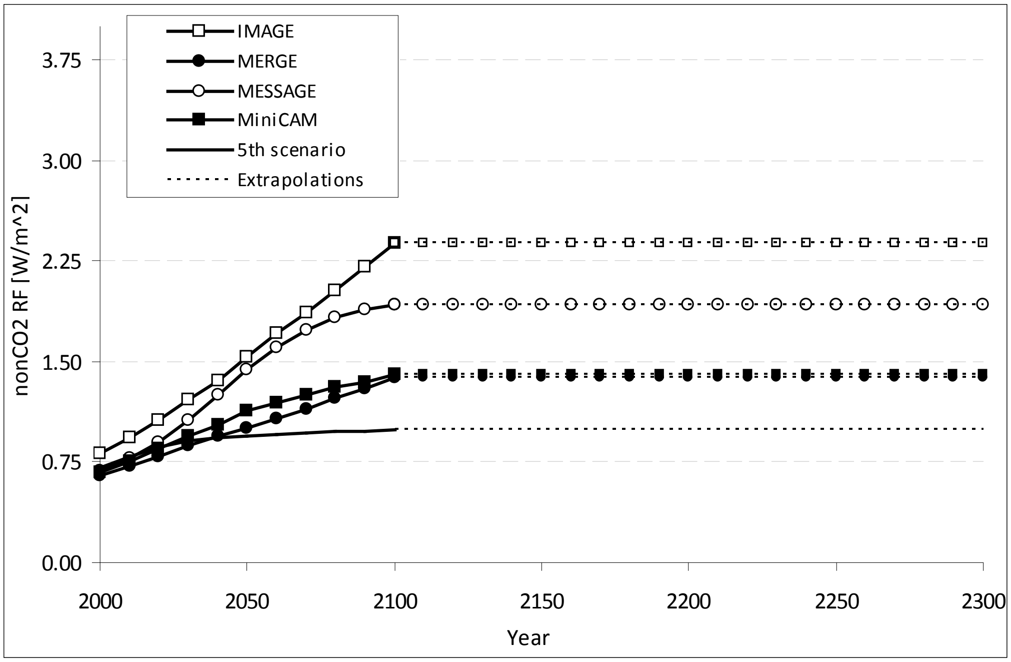

Figure 17A.9.6 Global Non-CO_2 Radiative Forcing, 2000–2300 (post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

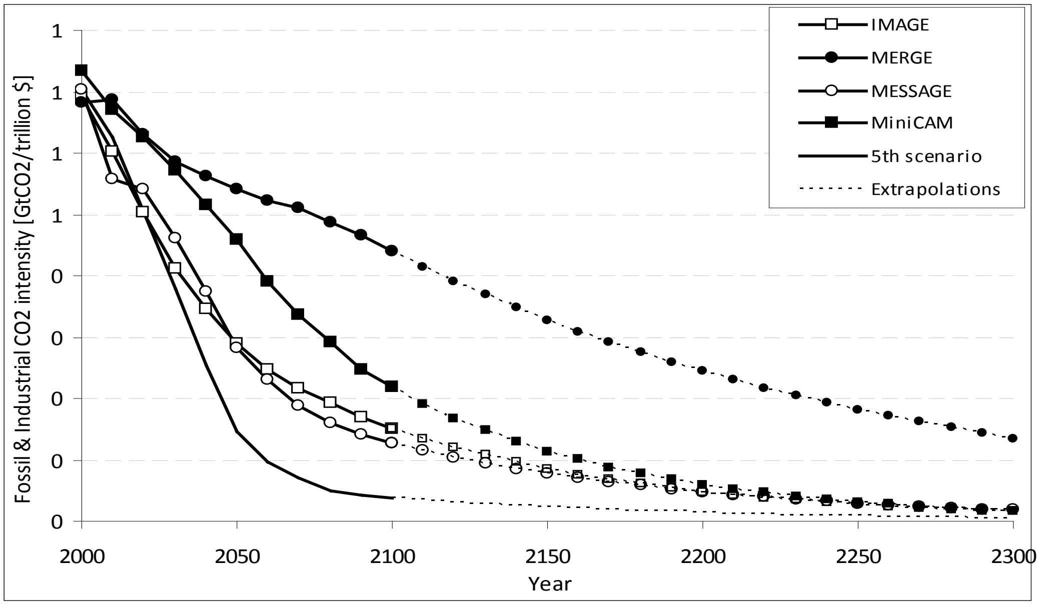

Figure 17A.9.7 Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000–2300 (post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090–2100 is maintained through 2300)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 17A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	3.3	5.9	8.1	13.9	28.8	65.5	68.2	147.9	239.6	563.8
MERGE optimistic	1.9	3.2	4.3	7.2	14.6	34.6	36.2	79.8	124.8	288.3
Message	2.4	4.3	5.8	9.8	20.3	49.2	50.7	114.9	181.7	428.4
MiniCAM base	2.7	4.6	6.4	11.2	22.8	54.7	55.7	120.5	195.3	482.3
5th scenario	2.0	3.5	4.7	8.1	16.3	42.9	41.5	103.9	176.3	371.9
Scenario	DICE									
IMAGE	16.4	21.4	25	33.3	46.8	54.2	69.7	96.3	111.1	130.0
MERGE optimistic	9.7	12.6	14.9	19.7	27.9	31.6	40.7	54.5	63.5	73.3
Message	13.5	17.2	20.1	27	38.5	43.5	55.1	75.8	87.9	103.0
MiniCAM base	13.1	16.7	19.8	26.7	38.6	44.4	56.8	79.5	92.8	109.3
5th scenario	10.8	14	16.7	22.2	32	37.4	47.7	67.8	80.2	96.8
Scenario	FUND									
IMAGE	-33.1	-18.9	-13.3	-5.5	4.1	19.3	18.7	43.5	67.1	150.7
MERGE optimistic	-33.1	-14.8	-10	-3	5.9	14.8	20.4	43.9	65.4	132.9
Message	-32.5	-19.8	-14.6	-7.2	1.5	8.8	13.8	33.7	52.3	119.2
MiniCAM base	-31.0	-15.9	-10.7	-3.4	6	22.2	21	46.4	70.4	152.9
5th scenario	-32.2	-21.6	-16.7	-9.7	-2.3	3	6.7	20.5	34.2	96.8

Table 17A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	2.0	3.5	4.8	8.1	16.5	39.5	41.6	90.3	142.4	327.4
MERGE optimistic	1.2	2.1	2.8	4.6	9.3	22.3	22.8	51.3	82.4	190.0
Message	1.6	2.7	3.6	6.2	12.5	30.3	31	71.4	115.6	263.0
MiniCAM base	1.7	2.8	3.8	6.5	13.2	31.8	32.4	72.6	115.4	287.0
5th scenario	1.3	2.3	3.1	5	9.6	25.4	23.6	62.1	104.7	222.5
Scenario	DICE									
IMAGE	11.0	14.5	17.2	22.8	31.6	35.8	45.4	61.9	70.8	82.1
MERGE optimistic	7.1	9.2	10.8	14.3	19.9	22	27.9	36.9	42.1	48.8
Message	9.7	12.5	14.7	19	26.6	29.8	37.8	51.1	58.6	67.4
MiniCAM base	8.8	11.5	13.6	18	25.2	28.8	36.9	50.4	57.9	67.8
5th scenario	7.9	10.1	11.8	15.6	21.6	24.9	31.8	43.7	50.8	60.6
Scenario	FUND									
IMAGE	-25.2	-15.3	-11.2	-5.6	0.9	8.2	10.4	25.4	39.7	90.3
MERGE optimistic	-24.0	-12.4	-8.7	-3.6	2.6	8	12.2	27	41.3	85.3
Message	-25.3	-16.2	-12.2	-6.8	-0.5	3.6	7.7	20.1	32.1	72.5
MiniCAM base	-23.1	-12.9	-9.3	-4	2.4	10.2	12.2	27.7	42.6	93.0
5th scenario	-24.1	-16.6	-13.2	-8.3	-3	-0.2	2.9	11.2	19.4	53.6

Table 17A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	0.5	0.8	1.1	1.8	3.5	8.3	8.5	19.5	31.4	67.2
MERGE optimistic	0.3	0.5	0.7	1.2	2.3	5.2	5.4	12.3	19.5	42.4
Message	0.4	0.7	0.9	1.6	3	7.2	7.2	17	28.2	60.8
MiniCAM base	0.3	0.6	0.8	1.4	2.7	6.4	6.6	15.9	24.9	52.6
5th scenario	0.3	0.6	0.8	1.3	2.3	5.5	5	12.9	22	48.7
Scenario	DICE									
IMAGE	4.2	5.4	6.2	7.6	10	10.8	13.4	16.8	18.7	21.1
MERGE optimistic	2.9	3.7	4.2	5.3	7	7.5	9.3	11.7	12.9	14.4
Message	3.9	4.9	5.5	7	9.2	9.8	12.2	15.4	17.1	18.8
MiniCAM base	3.4	4.2	4.7	6	7.9	8.6	10.7	13.5	15.1	16.9
5th scenario	3.2	4	4.6	5.7	7.6	8.2	10.2	12.8	14.3	16.0
Scenario	FUND									
IMAGE	-11.7	-8.4	-6.9	-4.6	-2.2	-1.3	0.7	4.1	7.4	17.4
MERGE optimistic	-10.6	-7.1	-5.6	-3.6	-1.3	-0.3	1.6	5.4	9.1	19.0
Message	-12.2	-8.9	-7.3	-4.9	-2.5	-1.9	0.3	3.5	6.5	15.6
MiniCAM base	-10.4	-7.2	-5.8	-3.8	-1.5	-0.6	1.3	4.8	8.2	18.0
5th scenario	-10.9	-8.3	-7	-5	-2.9	-2.7	-0.8	1.4	3.2	9.2

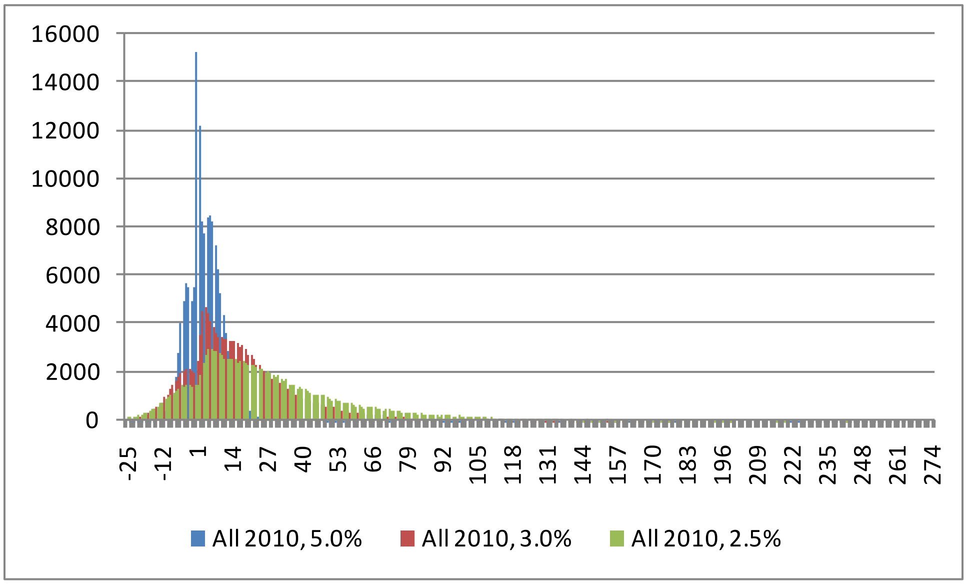

Figure 17A.9.8 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by Discount Rate*

* The distribution of SCC values ranges from -$5,192 to $66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

Table 17A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates

Discount Rate	**5%**				**3%**				**2.5%**			
Scenario	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis
DICE	9.0	13.1	0.8	0.2	28.3	209.8	1.1	0.9	42.2	534.9	1.2	1.1
PAGE	6.5	136.0	6.3	72.4	29.8	3,383.7	8.6	151.0	49.3	9,546.0	8.7	143.8
FUND	-1.3	70.1	28.2	1,479.0	6.0	16,382.5	128.0	18,976.5	13.6	150,732.6	149.0	23,558.3

APPENDIX 17B. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866: TECHNICAL MODEL UPDATE

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APPENDIX 17B. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866: TECHNICAL MODEL UPDATE

17B.1 PREFACE

The following text is reproduced almost verbatim from the draft (Feb. 13, 2013) report of the Interagency Working Group on the Social Cost of Carbon of the United States Government, titled "Technical Model Update for the Social Cost of Carbon (SCC)." Minor changes were made to the working group's report to make it more consistent with the rest of this technical support document.

17B.2 PURPOSE

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in CO_2 emissions are quantified.

Section II summarizes the major updates relevant to SCC estimation that are contained in the new versions of the integrated assessment models released since the 2010 interagency report. Section III presents the updated schedule of SCC estimates for 2010 – 2050 based on these versions of the models. Section IV provides a discussion of recent workshops to support improvements in SCC estimation.

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[a] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67.

[b] http://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf

[c] See p. 1, 3, 4, 29, and 33 (Interagency Working Group on Social Cost of Carbon 2010).[1]

17B.3 SUMMARY OF MODEL UPDATES

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

17B.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

17-B.3.1.1 Carbon Cycle Parameters

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2][d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each

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[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

17-B.3.1.2 Sea Level Dynamics

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4] [f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 ^{o}C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

17-B.3.1.3 Re-calibrated Damage Function

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested

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[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: http://nordhaus.econ.yale.edu/documents/SLR_021910.pdf.

[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

in the physical capital stock to support future production, so each period's climate damages will reduce consumption in that period and in all future periods due to the lost investment. The fraction of output in each period that is lost due to climate change impacts is represented as one minus a fraction, which is one divided by a quadratic function of the temperature anomaly, producing a sigmoid ("S"-shaped) function. The loss function in DICE2010 has been expanded by adding a quadratic function of SLR to the quadratic function of temperature. In DICE2010 the temperature anomaly coefficients have been recalibrated to avoid double-counting damages from sea level rise that were implicitly included in these parameters in DICE2007.

The aggregate damages in DICE2010 are illustrated by Nordhaus (2010 p 3),[3] who notes that "…damages in the uncontrolled (baseline) [i.e., reference] case … in 2095 are $12 trillion, or 2.8 percent of global output, for a global temperature increase of 3.4 ^{o}C above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 ^{o}C in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

17B.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

17-B.3.2.1 Space Heating

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled

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[g] http://www.fund-model.org/. This report uses version 3.8 of the FUND model, which represents a modest update to the most recent version of the model to appear in the literature (version 3.7) (Anthoff and Tol, 2013).[7] For the purpose of computing the SCC, the relevant changes are associated with improving consistency with IPCC AR4 by adjusting the atmospheric lifetimes of CH4 and N2O and incorporating the indirect forcing effects of CH4, along with making minor stability improvements in the sea wall construction algorithm.

[h] The other damage sectors (water resources, space cooling, land loss, migration, ecosystems, human health, and extreme weather) were not the subject of significant updates.

based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND 3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an unbounded convex function of the temperature anomaly. In FUND 3.8, the form of the scaling has been modified to ensure that the function is everywhere concave, meaning that for every simulation there will exist an upper bound on the benefits a region may receive from reduced space heating needs. The new formulation approaches a value of two in the limit as the temperature anomaly increases, or in other words, assuming no decrease in vulnerability, the reduced expenditures on space heating at any level of warming will not exceed two times the reductions experienced at one degree of warming. Since the reduced need for space heating represents a benefit of climate change in the model, or a negative damage, this change will increase the estimated SCC. This update accounts for a significant portion of the difference in the expected SCC estimates reported by the two versions of the model when run probabilistically.

17-B.3.2.2 Sea Level Rise and Land Loss

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

17-B.3.2.3 Agriculture

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector's value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector's value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector's value "lost" approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the "lost" value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

17-B.3.2.4 Temperature Response Model

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year's increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year's level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

17-B.3.2.5 Methane

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

17B.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

17-B.3.3.1 Sea Level Rise

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

17-B.3.3.2 Revised Damage Function to Account for Saturation

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

17-B.3.3.3 Regional Scaling Factors

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

17-B.3.3.4 Probability of a Discontinuity

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated either with or without a discontinuity occurring, rather than as an expected value. A large-scale discontinuity becomes possible when the temperature rises beyond some threshold value between 2 and 4°C. The probability that a discontinuity will occur beyond this threshold then increases by between 10 and 30 percent for every 1°C rise in temperature beyond the threshold. If a discontinuity occurs, the EU loses an additional 5 to 25 percent of its GDP (drawn from a triangular distribution with a mean of 15 percent) in addition to other damages, and other regions lose an amount determined by the regional scaling factor. The threshold value for a possible discontinuity is lower than in

PAGE2002, while the rate at which the probability of a discontinuity increases with the temperature anomaly and the damages that result from a discontinuity are both higher than in PAGE2002. The model assumes that only one discontinuity can occur and that the impact is phased in over a period of time, but once it occurs, its effect is permanent.

17-B.3.3.5 Adaptation

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

17-B.3.3.6 Other Noteworthy Changes

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased CO_2 absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the CO_2 emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

17B.4 REVISED SCC ESTIMATES

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, “the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate” (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 16A.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 17B.4.1 Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per ton of CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The SCC estimates using the updated versions of the models are higher than those reported in the TSD due to the changes to the models outlined in the previous section. Figure 16A.4.2 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

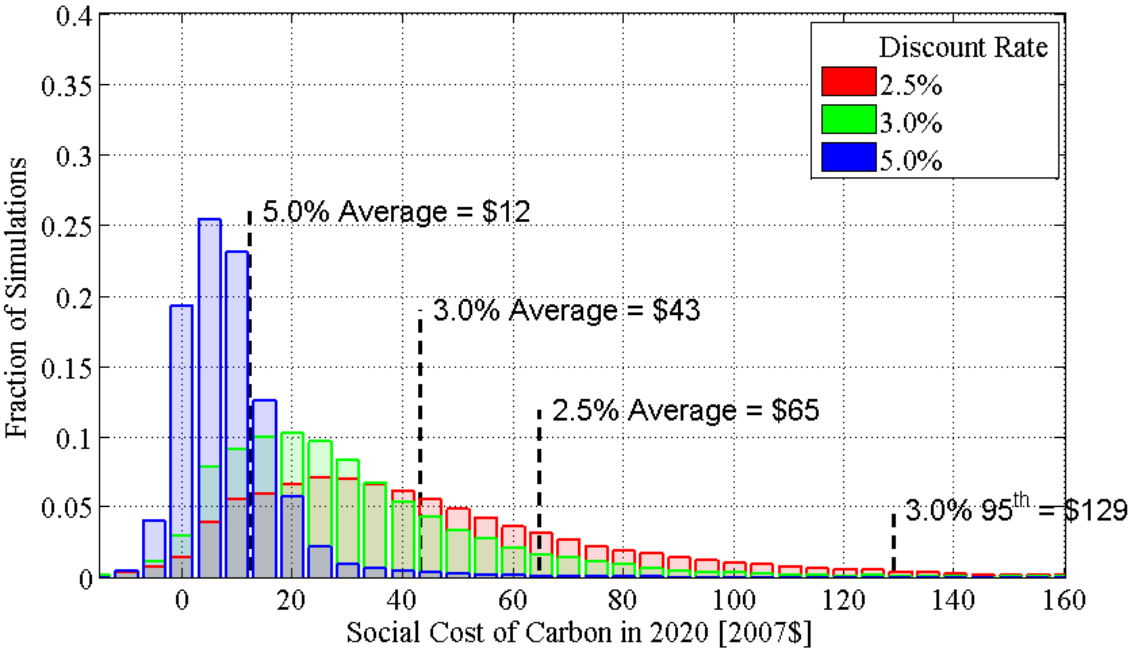

Figure 17B.4.2 Distribution of SCC Estimates for 2020 (in 2007$ per ton CO_2)

As was the case in the original TSD, the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the interagency group is to allow the growth rate to be determined endogenously by the models through running them for a set of perturbation years out to 2050. Table 16A.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

Table 17B.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.2%	2.4%	4.3%
2020-2030	3.4%	2.1%	1.7%	2.4%
2030-2040	3.0%	1.8%	1.5%	2.0%
2040-2050	2.6%	1.6%	1.3%	1.5%

The future monetized value of emission reductions in each year (the SCC in year t multiplied by the change in emissions in year t) must be discounted to the present to determine its total net present value for use in regulatory analysis. As previously discussed in the original TSD, damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency – i.e., future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate.

17B.5 OTHER MODEL LIMITATIONS OR RESEARCH GAPS

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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ANNEX

Table 17B.5.1 Annual SCC Values: 2010-2050 (2007$/ton CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2011	11	34	54	94
2012	11	35	55	98
2013	11	36	56	102
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
2025	14	48	70	144
2026	15	49	71	147
2027	15	49	72	150
2028	15	50	73	153
2029	16	51	74	156
2030	16	52	76	159
2031	17	53	77	163
2032	17	54	78	166
2033	18	55	79	169
2034	18	56	80	172
2035	19	57	81	176
2036	19	58	82	179
2037	20	59	84	182
2038	20	60	85	185
2039	21	61	86	188
2040	21	62	87	192
2041	22	63	88	195
2042	22	64	89	198
2043	23	65	90	200
2044	23	65	91	203
2045	24	66	92	206
2046	24	67	94	209
2047	25	68	95	212
2048	25	69	96	215
2049	26	70	97	218
2050	27	71	98	221

Table 17B.5.2 202 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	6	11	15	27	58	129	139	327	515	991
MERGE	4	6	9	16	34	78	82	196	317	649
MESSAGE	4	8	11	20	42	108	107	278	483	918
MiniCAM Base	5	9	12	22	47	107	113	266	431	872
5th Scenario	2	4	6	11	25	85	68	200	387	955

Scenario	DICE									
IMAGE	25	31	37	47	64	72	92	123	139	161
MERGE	14	18	20	26	36	40	50	65	74	85
MESSAGE	20	24	28	37	51	58	71	95	109	221
MiniCAM Base	20	25	29	38	53	61	76	102	117	135
5th Scenario	17	22	25	33	45	52	65	91	106	126

Scenario	FUND									
IMAGE	-17	-1	5	17	34	44	59	90	113	176
MERGE	-7	2	7	16	30	35	49	72	91	146
MESSAGE	-19	-4	2	12	27	32	46	70	87	135
MiniCAM Base	-9	1	8	18	35	45	59	87	108	172
5th Scenario	-30	-12	-5	6	19	24	35	57	72	108

Table 17B.5.3 SCC Estimates at 3 Percent Discount Rate (2007$/ton CO2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	4	7	10	18	38	91	95	238	385	727
MERGE	2	4	6	11	23	56	58	142	232	481
MESSAGE	3	5	7	13	29	75	74	197	330	641
MiniCAM Base	3	5	8	14	30	73	75	184	300	623
5th Scenario	1	3	4	7	17	58	48	136	264	660

Scenario	DICE									
IMAGE	16	21	24	32	43	48	60	79	90	102
MERGE	10	13	15	19	25	28	35	44	50	58
MESSAGE	14	18	20	26	35	40	49	64	73	83
MiniCAM Base	13	17	20	26	35	39	49	65	73	85
5th Scenario	12	15	17	22	30	34	43	58	67	79

Scenario	FUND									
IMAGE	-14	-3	1	9	20	25	35	54	69	111
MERGE	-8	-1	3	9	18	22	31	47	60	97
MESSAGE	-16	-5	-1	6	16	18	28	43	55	88
MiniCAM Base	-9	-1	3	10	21	27	35	53	67	107
5th Scenario	-22	-10	-5	2	10	13	20	33	42	63

Table 17B.5.4 2020 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	1	2	2	5	10	28	27	71	123	244
MERGE	1	1	2	3	7	17	17	45	75	153
MESSAGE	1	1	2	4	9	24	22	60	106	216
MiniCAM Base	1	1	2	3	8	21	21	54	94	190
5th Scenario	0	1	1	2	5	18	14	41	78	208

Scenario	DICE									
IMAGE	6	8	9	11	14	15	18	22	25	27
MERGE	4	5	6	7	9	10	12	15	16	18
MESSAGE	6	7	8	10	12	13	16	20	22	25
MiniCAM Base	5	6	7	8	11	12	14	18	20	22
5th Scenario	5	6	6	8	10	11	14	17	19	21

Scenario	FUND									
IMAGE	-9	-5	-3	-1	2	3	6	11	15	25
MERGE	-6	-3	-2	0	3	4	7	12	16	27
MESSAGE	-10	-6	-4	-1	2	2	5	9	13	23
MiniCAM Base	-7	-3	-2	0	3	4	7	11	15	26
5th Scenario	-11	-7	-5	-2	0	0	3	6	8	14

APPENDIX 18A. NON-REGULATORY INCENTIVE PROGRAMS

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APPENDIX 18A. NON-REGULATORY INCENTIVE PROGRAMS

This section summarizes existing business and industry incentive programs offered by States to reduce energy use from lighting technologies. Incentives may be offered for new construction, facility expansion, and retrofitting lighting technologies with more energy efficient alternatives. Incentives are summarized and links to the corresponding internet sites are given. This information was compiled during June 2013 and is subject to change. The following abbreviations are used:

- CFL: compact fluorescent lamp
- CMH: ceramic metal halide
- HB: high-bay
- HID: high intensity discharge
- HO: high output
- HPS: high pressure sodium
- IR: infrared
- LED: light emitting diode
- MH: metal halide (probe start)
- MV: mercury vapor
- PMH: pulse-start metal halide
- VHO: very high output

18A.1 CALIFORNIA INCENTIVE PROGRAMS

Alameda Municipal Power (AMP) offers rebates for its commercial customers to install energy-efficient lighting. The AMP site offers rebates in two programs, the Commercial Lighting Pilot Program 2 and the LED Advanced Technologies program. Customized rebates are also available for retrofitting basic T8 lamps and electronic ballasts with high-performance T8 lamps and electronic ballasts. The Commercial Lighting program incentivizes the replacement of existing incandescent, mercury vapor, T12/HO, T12/VHO, standard Metal Halide or High Pressure Sodium fixtures in a 12′ or greater high bay application one-for-one with T8, T5 or T5HO lamps. Existing fixtures with systems wattage of 400W or more must be replaced with 244W or less for a $125 per fixture rebate; and fixtures with system wattage of 250W or more must be replaced with 170W or less for a rebate of $100 per fixture. A $20 per lamp rebate is available for electronically ballasted metal halide lamps that replace existing HID lamps if the new lamps have 20,000 or more rated average life hours and a CRI of 70 or greater.

AMP's Advanced Technologies Rebates offers rebates for advanced technologies such as light emitting diodes (LEDs). The program goal is to encourage use of high-efficiency technologies in the early stages of commercialization and provides rebates of $0.20/kWh of reduced energy usage for LED retrofits. The custom lighting retrofit program covers other energy efficient lighting retrofits not specifically otherwise covered and offers $0.10/kWh of reduced energy usage.

More information: http://www.alamedamp.com/save-energy/commercial-savings.

Anaheim Public Utilities not only offers rebates on certain lighting equipment, they actually give away equipment for free. As part of their Dusk-to-Dawn Lighting Program, residents can receive a 70W HPS or fluorescent fixture (details not provided) for free. In addition to the fixture, residents receive a photosensor for automatic on/off dusk-to-dawn operation.

The Lighting Incentives Program provides incentives of $0.075 per kWh of reduced lighting energy use or $200 per kW of reduced on peak demand up to $50,000 per project or 50% of labor and materials, whichever is less. The Program targets replacement of T12 fluorescent lamps with T8 lamps, as well as converting HID systems to either a T8 or T5 lighting system. APU's New Construction Incentives Program will contribute up to $15,000 for design assistance to find the most cost-effective, energy efficient options for a business, and provides rebates for energy efficient lighting up to $50,000 per measure and $200,000 per facility. When APU is not giving away lighting equipment, they are performing lighting audits and making recommendations for improvements. At the end of the audits, APU provides specific rebates.

More information: http://www.anaheim.net/article.asp?id=990.

City of Palo Alto Utilities (CPAU), through the Commercial Advantage Program, offers several incentives for their commercial customers to replace old equipment with new, more efficient equipment. Rebates for interior linear fluorescent fixtures or compact fluorescent fixtures replacing incandescent, T12 high output (HO) fluorescent, T12 very high output (VHO) fluorescent are no longer available. Customers should contact CPAU for details. Rebates are available for any HID fixture (including MV, standard MH pulse-start MH, or HPS) with new interior T8, T5, Super T8, T8 VHO, or T5HO fixtures qualifies for a rebate depending on wattage as shown below:

CPAU offers rebates through its Commercial Advantage Program on complete new PMH fixtures or retrofit kits replacing existing incandescent, MV, probe-start MH or HPS fixtures. Replacements must be equipped with PMH or CMH lamps and electronic ballasts. New fixtures must replace, one for one, existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, MH, or HPS fixtures in interior installations. Rebates are available based on lamp wattages. The same incentives are applicable for exterior applications as well. To qualify for the 400W and > 400W categories, fixtures must be installed at a height over 12' above the finished floor. The incentives are as follows:

Pulse start metal halide fixtures - interior

- $20/fixture for replacing a < 100W lamp, up to 70W replacement fixture

- $35/fixture for replacing a 101-175W lamp, up to 125W replacement fixture
- $40fixture for replacing a 176-399W lamp, up to 175W replacement fixture
- $75/fixture for replacing a 400W lamp, up to 250W replacement fixture
- $90/fixture for replacing a >400W or more lamp, up to 750W replacement fixture$150/fixture for replacing >400W or more lamp, up to 600W replacement fixture

Pulse start metal halide fixtures - exterior

- $15/fixture for replacing a < 100W lamp, up to 70W replacement fixture
- $20/fixture for replacing a 101-175W lamp, up to 100W replacement fixture
- $25/fixture for replacing a 176-200W lamp, up to 125W replacement fixture
- $25/fixture for replacing a 201-399W lamp, up to 175W replacement fixture
- $45/fixture for replacing a >400W lamp, up to 250W replacement fixture (Tier 2)
- $75/fixture for replacing a >400W lamp, up to 750W replacement fixture

Interior and exterior induction fixtures are eligible for rebates. Only complete new induction fixtures qualify. Fixtures must be equipped with induction lamps and drivers. New fixtures must replace, one-for-one, existing incandescent, T12HO fluorescent, T12VHO fluorescent, or any HID fixture (MV, standard MH, pulse-start MH, or HPS) in interior installations. To qualify for the 400W category, fixtures must be installed at a height over 12' above the finished floor. Rebates are dependent on wattage as follows:

Induction fixtures - interior

- $35/fixture for replacing a 100W lamp, up to 70W replacement fixture
- $60/fixture for replacing a 101-175W lamp, up to 120W replacement fixture
- $75/fixture for replacing a 176-399W lamp, up to 180W replacement fixture
- $60/fixture for replacing a 400W lamp, up to 360W replacement fixture (Tier 2)
- $125/fixture for replacing a 400W lamp, up to 250W replacement fixture (Tier 1)

Induction fixtures – exterior

- $25/fixture for replacing a 100W lamp, up to 70W replacement fixture
- $45/fixture for replacing a 101-175W lamp, up to 100W replacement fixture

- $50/fixture for replacing a 176-399W lamp, up to 120W replacement fixture
- $50/fixture for replacing a 201-399W lamp, up to 180W replacement fixture
- $100/fixture for replacing a 400W lamp, up to 250W replacement fixture (Tier 1)

Rebates are available for integrated ballast ceramic metal halide (CMH) parabolic reflector (PAR) lamps that replace existing reflector-type incandescent, PAR halogen, or PAR halogen IR infrared (IR) lamps or fixtures. Accent lighting, flood lighting, or down lighting in interior installations qualify. Rebate amounts are $12.50 per lamp and $45 per fixture.

CPAU also offers rebates for lighting upgrades through its Right Lights+ Program that claims to provide instant average rebates of 81% of installed costs with energy cost reductions up to 50%.

More information:
http://www.cityofpaloalto.org/gov/depts/utl/business/rebates/default.asp

The Modesto Irrigation Department (MID) Business Rebates offers rebates on various types of energy efficient lighting upgrades as summarized below. All rebates replacing T12 fixtures expire 6/30/2013.

Linear fluorescent/LED/induction fixtures – hardwired, interior

Only complete new T8 or T5 or T5HO LED, or induction hardwired fixtures qualify. New fixtures must replace existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, MH, or HPS fixtures in interior installations. Fixtures with 400W and greater must be installed at a height over 12' above the finished floor. All lamps must be rated > 20,000 hours average lamp life based on 3 hours per start when operated on a program start ballast. T5 HO and T8 VHO lamps must have Color Rendering Index (CRI) that is equal or greater than 82. All 32 Watt T8 lamps must be HP T8 or Super T8 lamps. All T8 ballasts must be NEMA premium. LED fixtures must be listed as DesignLights Consortium (DLC) qualified. Existing fixtures with T12 lamps and magnetic ballasts apply under the "T8 or T5 Linear Fluorescent Lamps with Electronic Ballast" category. Useful life period for hardwired linear fluorescent / LED / induction fixtures is defined as 11 years. Additional lamp qualification requirements may apply. Exterior fixtures do not qualify.

- $150/fixture for replacing a >400W lamp, up to 600W replacement fixture
- $75/fixture for replacing a 400W lamp, up to 244W replacement fixture
- $38/fixture for replacing a 400W lamp, with 245-360W replacement fixture
- $38/fixture for replacing a 176-399W lamp, up to 192W replacement fixture
- $27/fixture for replacing 101-175Wlamp, up to 128W replacement fixture
- $19/fixture for replacing ≤ 100W lamp, up to 64W replacement fixture

Linear fluorescent /LED/induction fixtures – hardwired, exterior

Only complete new T8 or T5 or T5HO or LED or induction hardwired fixtures qualify. New fixtures must replace existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, MH, or HPS fixtures in exterior installations. All lamps must be rated > 20,000 hours average lamp life based on 3 hours per start when operated on a program start ballast. T5 HO and T8 VHO lamps must have Color Rendering Index (CRI) that is equal or greater than 82. All 32 Watt T8 lamps must be HP T8 or Super T8 lamps. All T8 ballasts must be NEMA premium. LED fixtures must be listed as DesignLights Consortium (DLC) qualified. Existing fixtures with T12 lamps and magnetic ballasts apply under the "T8 or T5 Linear Fluorescent Lamps with Electronic Ballast" category. Useful life period for hardwired linear fluorescent / LED / induction fixtures is defined as 11 years. Additional lamp qualification requirements may apply. Only fixtures operating during non-daylight hours qualify.

- $85/fixture for replacing a >400W lamp, up to 600W replacement fixture
- $40/fixture for replacing a 400W lamp, up to 244W replacement fixture
- $20/fixture for replacing a 400W lamp, with 245-360W replacement fixture
- $20/fixture for replacing a 176-399W lamp, up to 192W replacement fixture
- $15/fixture for replacing a 101-175W lamp, up to 128W replacement fixture
- $10/fixture for replacing a ≤ 100W lamp, up to 64W replacement fixture

Compact fluorescent fixtures – hardwired

Fixtures must be equipped with compact fluorescent lamps (CFLs) and electronic ballasts. CFL ballasts must be Programmed-start or Programmed Rapid-start with a Power Factor (PF) of ≥ 0.90 and Total Harmonic Distortion (THD) of <20%. New fixtures must replace existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, standard MH, or HPS fixtures in interior installations. Exterior installations qualify for existing lamps ≤ 100W only. Existing PMH installations do not qualify. To qualify for the ≥ 400W category, fixtures must be installed at a height over 12' above the finished floor. Useful life period for hardwired compact fluorescent fixtures is defined as 12 years.

- $35/fixture for replacing interior ≥ 400W lamp, up to 360W replacement fixture
- $30/fixture for replacing interior 176-399W lamp, up to 192W replacement fixture
- $27/fixture for replacing Interior 101-175W lamp, up to 128W replacement fixture
- $15/fixture for replacing interior ≤ 100W lamp , up to 70W replacement fixture
- $13/fixture for replacing exterior ≤ 100W lamp , up to 70W replacement fixture

PMH fixtures - hardwired, interior

Complete new PMH fixtures or retrofit kits qualify as replacements. Retrofit kits may be used on existing MV, standard MH or HPS fixtures only. Replacements must be equipped with PMH lamps and either magnetic or electronic ballasts. Lamp wattages below 175W do not qualify under this category. New fixtures must replace existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, standard MH, or HPS fixtures in interior installations. Exterior installations do not qualify. Fixtures may qualify for an occupancy sensor rebate under the occupancy sensor category, provided all requirements are met. To qualify for the 400W and > 400W categories, fixtures must be installed at a height over 12' above the finished floor. Useful life period for hardwired pulse start metal halide fixtures is defined as 16 years.

- $75/fixture for replacing >400W lamp, up to 820W replacement fixture
- $40/fixture for replacing >400W lamp, up to 821-950W replacement fixture
- $35/fixture for replacing 400W lamp, up to 400W replacement fixture
- $30/fixture for replacing 176-399W lamp, up to 275W replacement fixture
- $7.50/fixture for replacing 175W lamp, up to 190W replacement fixture

PMH fixtures – hardwired, exterior

Complete new PMH fixtures or retrofit kits qualify as replacements. All installations for this measure are for exterior applications only. New fixtures must replace existing incandescent, MV, T12HO fluorescent, T12VHO fluorescent, standard MH, or HPS fixtures. Retrofit kits may be used on existing MV, standard MH, or HPS fixtures only. Replacements must be equipped with PMH lamps and either magnetic or electronic ballasts. Lamp wattages below 175W do not qualify under this category. To qualify for the 400W and > 400W categories, fixtures must be installed at a height of over 12' above the finished floor. Useful life period for hardwired pulse start metal halide fixtures is defined as 16 years.

- $75/fixture for replacing >400W lamp, up to 820W replacement fixture
- $40/fixture for replacing >400W lamp, up to 821-950W replacement fixture
- $35/fixture for replacing 400W lamp, up to 400W replacement fixture
- $30/fixture for replacing 176-399W lamp, up to 275W replacement fixture
- $7.50/fixture for replacing 175W lamp, up to 190W replacement fixture

ENERGY STAR LED Lamps – interior canister or track lighting – screw-in

Only ENERGY STAR qualified LED lamps for downlighting applications are eligible for rebates. Must replace incandescent, PAR, R, and/or reflector flood lamps. Interior applications only. Must provide +/- 10% of existing lumen output. Useful life period for ENERGY STAR LED lamps is defined as 16 years.

- $6 per lamp for 100-150W lamp basecase, up to 40W replacement lamp
- $4 per lamp for 45-99W lamp basecase, up to 25W replacement lamp

Accent/directional lighting – interior

Limitation: Must replace existing reflector-type incandescent, PAR halogen, or PAR halogen IR lamps or fixtures. Accent lighting, flood lighting, or down lighting in interior installations qualify.

Integrated ballast CMH PAR lamps

Minimum 24W integrated ballast CMH PAR lamps with a rated lamp life of 10,500 hours or greater are eligible.

- $13/fixture for replacing integrated ballast CMH PAR lamps

CMH directional lighting fixtures

Only CMH directional light fixtures with nominal lamp wattage of 39W or lower qualify.

- $35/fixture for replacing CMH directional lighting fixtures

New construction rebate programs and custom rebate programs are also available.

More information: http://www.mid.org/rebates/commercial/default.html and http://www.mid.org/rebates/commercial/documents/CommLightingSpecs.pdf

The Los Angeles Department of Water and Power (LADWP) manages the Commercial Lighting Efficiency Offer (CLEO). CLEO was temporarily suspended for 90 days effective April 7, 2012. This program seeks to promote energy-efficient lighting retrofits. High-bay T8/T5 fixtures replacing ≥400W fixtures that result in a ≥45% energy savings are eligible for a $100 per fixture rebate. In applications replacing fixtures less than 400W, there is a $50 rebate. Installations where induction lamps and fixtures replace fixtures with incandescent, MH, HPS, or MV lamps are also eligible for rebates - $35 per 55W to 100W lamp and $50 for lamps greater than 100W. >100W MH interiors or PMH in exterior applications replacing incandescent, HPS, or MV have rebates of $40 per fixture. Incentives for CMH are both lamp and fixture focused. $40 per CMH fixture ≥35W and $15 per CMH lamp that is less than 35W are offered.

The Custom Performance Program offers incentives for the installation of energy saving measures and offers incentives of $0.05/kWh of annualized energy saved for lighting.

More information: https://www.ladwp.com/ladwp/faces/wcnav_externalId/c-sm-lighting?_adf.ctrl-state=t78quzmqn_4&_afrLoop=217847636066000.

Pacific Gas and Electric (PG& E) jointly manages a statewide program called Express Efficiency with Southern California Edison. The program is quite comprehensive, not only in lighting, but in many other areas. Rebates for lighting upgrades are summarized below:

Compact fluorescent fixtures

Requirements: Only complete, new compact fluorescent fixtures qualify. New fixture wattage is the total system wattage (lamp and ballast). Ballasts must have a power factor greater than or equal to 0.9. Rebates are based on a one-for-one replacement of incandescent or any HID fixture. HID fixtures include MV, HPS, and standard MH or PMH. Existing lamp wattage is used rather than total fixture wattage. New exterior installations qualify if existing lamps are 100W or less. Exterior installations and applications are typically operating during non-peak hours and therefore do not qualify under this interior fixture category.

- $75/fixture for replacing interior 400W lamp, up to 244W (Tier 1) replacement fixture
- $45/fixture for replacing interior 400W lamp, up to 360W (Tier 2) replacement
- $40/fixture for replacing interior 176-399W lamp, up to 192W replacement
- $35/fixture for replacing interior 101-175W lamp, up to 128W replacement
- $20/fixture for replacing interior <100W lamp, up to 70W replacement
- $17/fixture for replacing exterior <100W lamp, up to 70W replacement

Interior linear fluorescent fixtures

Requirements: Only complete, new High Performance (HP) T8/T5, Super T8, T8VHO, or T5HO interior linear fluorescent fixtures qualify. New fixture wattage is the total system wattage (lamp and ballast). Rebates are based on a one-for-one replacement of incandescent, MV, HPS, and standard MH or PMH. Existing lamp wattage is used rather than total fixture wattage. Exterior installations do not qualify.

- $200/fixture for replacing >400W lamp, up to 600W replacement fixture
- $100/fixture for replacing 400W lamp, up to 244W (Tier 1) replacement
- $50/fixture for replacing 400W lamp, with 245-360W (Tier 2) replacement
- $50/fixture for replacing 176-399W lamp, up to 192W replacement
- $35/fixture for replacing 101-175W lamp, up to 128W replacement
- $25/fixture for replacing <100W lamp, up to 64W replacement

Interior induction fixtures

Requirements: Only complete, new induction fixtures or retrofit kits. New lamp wattage is the total lamp only wattage. Rebates are based on a one-for-one replacement of incandescent, MV, HPS, standard MH or PMH. Existing lamp wattage is used rather than total fixture wattage.

Exterior installations and applications are typically operating during non-peak hours and therefore do not qualify under this interior fixture category.

- • $125/fixture for replacing 400W lamp, up to 250W (Tier 1) replacement
- • $60/fixture for replacing 400W lamp, up to 360W (Tier 2) replacement
- • $75/fixture for replacing 176-399W lamp, up to 180W replacement
- • $60/fixture for replacing 101-175W lamp, up to 120W replacement
- • $35/fixture for replacing <100W lamp, up to 70W replacement

Exterior induction fixtures

Requirements: Only complete, new induction fixtures or retrofit kits. New lamp wattage is the total lamp only wattage. Rebates are based on a one-for-one replacement of incandescent, MV, HPS, standard MH or PMH. Existing lamp wattage is used rather than total fixture wattage. Street and roadway installations do not qualify; refer to PG&E's Street Light Program. For details refer to www.pge.com/led. PMH does not qualify.

- $100/fixture for replacing 400W lamp, up to 250W replacement
- $50/fixture for replacing 201-399W lamp, up to 180W replacement
- $50/fixture for replacing 176-200W lamp, up to 120W replacement
- $45/fixture for replacing 101-175W lamp, up to 100W replacement
- $25/fixture for replacing <100W lamp, up to 70W replacement

Interior HID fixtures w/electronic ballasts

Requirements: Only complete, new PMH fixtures or retrofit kits with Electronic HID Ballasts qualify. Retrofit kits and new fixtures must be equipped with PMH or CMH lamps and electronic ballasts that are compatible with controls and capable of dimming or bi-level functionality. New lamp wattage is the total lamp only wattage. Rebates are based on a one-for-one replacement of incandescent, MV, HPS, standard MH or PMH. Existing lamp wattage is used rather than total fixture wattage. Exterior installations and applications that are typically operating non-peak hours do not qualify.

- $150/fixture for replacing >400W lamp, up to 600W (Tier 1) replacement
- $90/fixture for replacing >400W lamp, up to 750W (Tier 2) replacement
- $75/fixture for replacing 400W lamp, up to 250W replacement
- $40/fixture for replacing 176-399W lamp, up to 175W replacement

- $35/fixture for replacing 101-175W lamp, up to 125W replacement
- $20/fixture for replacing <100W lamp, up to 70W replacement

Exterior HID fixtures w/ electronic ballasts

Requirements: Only complete, new PMH or CMH fixtures or retrofit kits with Electronic HID Ballasts qualify. Retrofit kits and new fixtures must be equipped with CMH or PMH lamps and electronic ballasts that are compatible with controls and capable of Dimming or Bi-Level functionality. New lamp Wattage is the total lamp only Wattage. Rebates are based on a one-for-one replacement of incandescent, MV, HPS, standard MH or PMH. Existing lamp Wattage used rather than total fixture Wattage. Street and roadway installations do not qualify.

- $75/fixture for replacing >400W lamp, up to 750W replacement
- $45/fixture for replacing 400W lamp, up to 250W replacement
- $25/fixture for replacing 201-399W lamp, up to 175W replacement
- $25/fixture for replacing 176-200W lamp, up to 125W replacement
- $20/fixture for replacing 101-175W lamp, up to 100W replacement
- $15/fixture for replacing <100W lamp, up to 70W replacement

Accent/Directional Lighting: Integrated Ballast CMH PAR Lamps

Requirements: Only 25W or less, integrated ballast, CMH PAR lamps with a rated lamp life of 12,000 hours or greater. $17.50/lamp rebate.

CMH directional lighting fixtures

Requirements: Only those fixtures with a lamp wattage of 39W or less. $45/fixture rebate.

Customized retrofit incentives of $0.05/kWh of energy savings realized are offered to install energy-saving equipment as part of a retrofit project.

Savings By Design (SBD) is a statewide program offered by PG&E to encourage high-performance new building design and construction for commercial buildings. Funding can be obtained for projects that exceed California's Title 24 energy efficiency standards. Other support includes design assistance, design team incentives, owner incentives and educational resources.

LED street light fixtures

The LED Street Light Program Turnkey Replacement Service offers the following rebates for switching to LEDs:

- $200/fixture for replacing 400W fixture with new LED fixture

- $175/fixture for replacing 310W fixture with new LED fixture
- $150/fixture for replacing 250W fixture with new LED fixture
- $125/fixture for replacing 200W fixture with new LED fixture
- $100/fixture for replacing 150W fixture with new LED fixture
- $75/fixture for replacing 100W fixture with new LED fixture
- $50/fixture for replacing 70W fixture with new LED fixture

More information on the LED Street Light Program: http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ref/lighting/lightemittingdiodes/ledturnkey/.

More information on other programs: http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ (PG&E) or https://www.sce.com/wps/portal/home/business/savings-incentives/express-solutions (SCE)

The Silicon Valley Power lighting fixture replacement rebates have been recently changed from one-to-one prescriptive rebates for various types of eligible fixtures to an incentive based on calculated annual energy savings. The energy savings is based on comparing the energy use of a proposed system to the energy use of a minimally compliant system (based on California's Title 24 energy code, as the replacement of fixtures triggers Title 24). The exising wattage is only used as the baseline if it is already below the W/SF lighting power density allowed by Title 24 for a particular space use type. Default wattage tables are used by the calculator for determining the existing and proposed fixture wattages, and default (DEER) annual hours of operation for each space use type are used to calculate annual energy savings. If a customer's annual hours of operation deviate considerably from the DEER default hours, the program administrator can modify the hours of operation used in the energy savings calculation. The incentive level is $0.15 per annual kWh of energy savings.

This program allows the installation of high performance T8, reduced wattage T8, T5, pulse start metal halide, induction, and compact fluorescent fixtures. Probe start metal halide fixtures are not included. Additional fixtures will be added as appropriate. LED rebates are still offered on a one-to-one prescriptive basis for a number of fixture types as listed below.

- $175/fixture for replacing > 250W parking lot fixture, wall pack, or parking garage fixture with new LED fixture
- $100/fixture for replacing <250W outdoor pole decorative fixture with new LED fixture
- $35/fixture for replacing a downlight fixture with new LED fixture
- $20/lampfor replacing a MR-16, pin-based lamp with new LED lamp

LED parking lot, wall pack, parking garage, and outdoor pole decorative fixtures must be listed on DesignLights Consortium Qualified Products List.

www.designlights.org/documents/NEEPDLCQPL.xls .

LED downlights and MR16, pin-based lamps must carry ENERGY STAR® label. See the following links for qualified commercial products:

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LU.

More information: https://siliconvalleypower.com/index.aspx?page=1938

18A.2 COLORADO INCENTIVE PROGRAMS

Longmont Power and communication in collaboration with Boulder County, the City of Boulder, the City of Longmont, Xcel Energy and Platte River Power Authority offers the EnergySmart energy efficiency program. Rebates for replacement of lighting components with higher energy efficiency alternatives are listed below

High bay fluorescent fixtures replacing HID

Must have high efficiency electronic ballasts. Replacement fixtures with less lamps than specified will be considered.

- $103/fixture for replacing 175-250W HID with 2 to 3-lamp T5HO, 2 to 4-lamp T8
- $179/fixture for replacing 310-400W HID with 3-lamp T8VHO, 4 to 6-lamp T5HO, 6 to 8-lamp T8
- $38276/fixture for replacing 750W HID with 6-lamp T8VHO, 8-lamp T5HO, 12 to 16-lamp T8
- $496/fixture for replacing 1000W HID with 8-lamp T8VHO, 10- lamp T5HO, 18 to 20-lamp T8

CM replaces incandescent, halogen, HPS, or MV.

- $181/fixture for >250W
- $126/fixture for 151-250W
- $55/fixture for <150W or less

PMH replaces incandescent, halogen, HPS, or MH or MV systems

- $266/fixture for >749W
- $125/fixture for 320-749W

- $63/fixture for 175-319W
- $55/fixture for <175W

CMH replaces incandescent, halogen, or MH, MV, or HPS

- $181/fixture for >250W
- $126/fixture for 151-250W
- $55/fixture for <151W
- $392/20W to 25W Integrated Ceramic Metal Halide lamps

Exterior LED canopy, soffit fixtures wall packs, and pole lamp replace any HID or incandescent system that uses 3-6 times more energy

- $135/fixture for 25-60W
- $180/fixture for >60W

Parking garage lighting replace HPS or MH with fluorescent or LED

- $110/fixture for replacing 100-174W HID with LED
- $84/fixture for replacing 150W or 175W HID systems with T5HO or T8
- $52/fixture for replacing 100-149W HID systems with T5HO or T8 (requires 40% energy reduction)

For more information: http://www.energysmartyes.com/

Xcel EnergySM offers a variety of technology specific rebate incentives for retrofits, renovations and new construction. Funding is also available to assist with lighting redesign studies, with rebates of up to $400 per kW saved when the recommendations are implemented. Efficient lighting equipment not listed in the prescriptive rebates may be eliegible for a Custom Efficiency rebate. The following rebates are offered for replacement lamps:

High-bay fluorescent fixtures with high efficiency electronic ballasts

- $159/fixture for 8-lamp T8VHO, 10-lamp T5HO, or 18- to 20-lamp T8 replacing 1000W HID lamp systems
- $76/fixture for 6-lamp T8VHO, 8-lamp T5HO, or 12- to 16-lamp T8 replacing 750W HID lamp systems
- $50/fixture for 3-lamp T8VHO, 4- to 6-lamp T5HO, or 6- to 8-lamp T8 replacing 310-400W HID lamp systems

- $25/fixture for 2-lamp T5HO, 3-lamp T5HO, or 4-lamp T8 replacing 175-250W HID lamp systems

Parking garage fluorescent fixtures with high efficiency electronic ballasts

- $50/fixture for 4-foot 2-lamp and 3-lamp T5HO or T8 replacing HID systems (150W or 175W) , 10-lamp T5HO, or 18- to 20-lamp T8 replacing 1000W HID lamp systems

Industrial multi-CFL fixtures and systems

- $45/fixture rebate to replace incandescent or HID systems

HPS fixtures replacing incandescent, halogen or MV

- $30/fixture for 151-250W HPS replacing incandescent, halogen or MV
- $45/fixture for >250W HPS replacing incandescent, halogen or MV

PMH fixtures replacing incandescent, halogen, MV, HPS, or MH systems.

- $128/fixture for 750W+ PMH replacing incandescent, MV, HPS, or MH systems
- $100/fixture for 320-749W PMH replacing incandescent, MV, HPS, or MH systems
- $40/fixture for 176-319W PMH replacing incandescent, MV, HPS, or MH systems
- $45/fixture for <176W PMH replacing incandescent, MV, HPS, or MH systems

CMH fixtures replace incandescent, halogen or HID systems (MV, HPS, MH)

- $105/fixture for 251W+ CMH replacing >75W incandescents or halogens with 25W integrated CMH lamps
- $80/fixture for 151-250W CMH replacing incandescent, halogen, metal halide, MV, or HPS systems with CMH systems
- $86/fixture for <150W CMH replacing incandescent, halogen, metal halide, MV, or HPS systems with CMH systems
- $15/fixture for 25Wintegrated CMH replacing >75W incandescents or halogens with 25W integrated CMH lampsExterior LED canopy and soffit fixtures replace MH systems

HPS, PMH, CMH and LED rebate notes: These rebates are available specifically for standard retrofit projects in which the lumen output of the proposed system is similar to the existing system and the energy savings is within a reasonably expected range. Retrofits with unusually large or small energy savings and/or lumen reductions must apply through the Custom Efficiency program and obtain preapproval prior to purchase. Contact your account manager or the Business Solutions Center at 1-800-481-4700 if you have questions regarding your specific application.

Information about the EnergySmart program can be found here: http://cypress-ltd.net/eligibility/.

Information about the LightenUP program: http://www.prpa.org/energy/business/lightenup.htm.

Specifically for Xcel Energy programs: http://www.xcelenergy.com/Save_Money_&_Energy/Find_a_Rebate/Lighting_Efficiency_-_CO.

For more information: http://www.energysmartyes.com/business/rebates-financing.

Small businesses with peak demand of 400kW or less are eligible for a free lighting assessment and energy saving recommendations. See: http://www.xcelenergy.com/Save_Money_&_Energy/Find_a_Rebate/Small_Business_Lighting_-_CO.

18A.3 CONNECTICUT INCENTIVE PROGRAMS

Connecticut Light and Power (part of Northeast Utilities) sponsors an Express Service Lighting Rebate program. The following rebates are available to promote energy-efficient lighting in retrofit applications (applications due by 12/31/2013):

- $15/fixture for using new pulse start metal halide lamps with matching electronic ballast. Indoor and outdoor fixtures are eligible.
- $15/fixture for using new pulse start metal halide fixture with electronic ballast replacing metal halide fixture of >200W. Indoor and outdoor fixtures are eligible.
- $25/fixture for induction technology retrofit kit or fixture (Tier 1). One-for-one replacement of incandescent or HID lamps (MV, HPS, MH, PMH). Indoor and outdoor fixtures are eligible.
- $50/fixture for induction technology retrofit kit or fixture (Tier 2). One-for-one replacement of incandescent or HID lamps (MV, HPS, MH, PMH). Indoor and outdoor fixtures are eligible.

The Small Business Energy Advantage program provides support to small businesses (10-200kW average 12-month peak demand). Support includes energy assessments and funding for energy efficient products including lighting.

More information: http://www.cl-p.com/Business/SaveEnergy/BusinessRebates.aspx.

Groton Utilities' lighting efficiency program provides cash incentives for new fixture installation or retrofits of old lighting fixtures to energy efficient systems. Groton Utilities' lighting efficiency program also provides rebates for installation of lighting occupancy controls and daylight harvesting and dimming controls. A $20 rebate per fixture is offered for installing new PMH fixtures in new construction. A $0.14 incentive is offered for each kW-hour saved by installing energy-efficient retrofit lighting.

More information: http://grotonutilities.com/conserv.asp?l=2.

United Illuminating manages three programs promoting energy-efficiency lighting that applies to HID lighting. The Energy Conscious Blueprint Program focuses on reducing energy consumption in a building. This program offers incentives on both a lighting power density basis, as well as, a technology basis and promotes the use of fluorescent technologies with electronic ballasts, HID, induction, and LED technologies. Outdoor Lighting, Light the NightSM provides commercial customers with exterior lighting design services, and the ability to have equipment purchased, installed, and maintained for a monthly fee. United Illuminating also participates in the Express Service that Connecticut Light and Power also promotes with the following rebates:$15/fixture for using new pulse start metal halide lamps with matching electronic ballast. Indoor and outdoor fixtures are eligible.

- $15/fixture for using new pulse start metal halide fixture with electronic ballast replacing metal halide fixture of >200W. Indoor and outdoor fixtures are eligible.
- $25/fixture for induction technology retrofit kit or fixture (Tier 1). One-for-one replacement of incandescent or HID lamps (MV, HPS, MH, PMH). Indoor and outdoor fixtures are eligible.
- $50/fixture for induction technology retrofit kit or fixture (Tier 2). One-for-one replacement of incandescent or HID lamps (MV, HPS, MH, PMH). Indoor and outdoor fixtures are eligible.

The Small Business Energy Advantage program provides support to small businesses (10-200kW average 12-month peak demand). Support includes energy assessments and funding for energy efficient products including lighting.

More information: http://www.uinet.com/wps/portal/uinet/business/!ut/p/c5/vY_JcqNAEES_xR9gdbM1cETQMC1BI4SERF8UaEFGzSIziO3rjW92OGZ8cbjyWFX5MgEDk8qkza5Jk1VlkoM9YOjg-sTxTJUYJAoUSGQiBv7aFKCjgh3YQ_kQ3oY7Gfm4vo1B31iG6NXbzrMw9DAS_uKebizch9tq9LgMKXxZUJd0gqYLkR1gw-7LkgdPEyv-yAqRPLGwoW4IhY4gfpuEfb74-v--h_8YAwL6pyouIAZM_eDi69bksglIoKkCVCWw-cHG_2VR-Iss8UdZC8CyYzHrTsUMznRB1ZGiI01RkCRIMtid4061KmpYOGzj6-s-jqRyYeKzS1mWpRJBndA9Q3Pr8krSIGsl33T6ZDxxZorHS5NntbTCu2KVoDtZp75HiSaKOY6Hy5mXXqevRCzpcP7Km9t1zs8PM_drNrEzxX5e2kM6Rg97aKtwHNK8n1f-sIx4w45YWS7rF2_L5xdTR06essboD_nh5NT1w0pte3-fut2L1kVrjabv8oynN1IfTaA!/dl3/d3/L2dBISEvZ0FBIS9nQSEh/?pcid=418325804103e89ead44bf23a70da287.

18A.4 FLORIDA INCENTIVE PROGRAMS

Florida Power and Light (FP&L) manages a Business Lighting Program that works to reduce the utility's peak demand from 3 pm to 6 pm during summertime weekdays. Installation of PMH and electronic ballasts in MH fixtures and CMH in hard wired fixtures qualify for lighting incentives, as does the adoption of induction lighting. The incentive is an upfront discount for the work performed by an independent contractor.

More information: http://www.fpl.com/business/energy_saving/programs/interior/lighting.shtml

Progress Energy has energy efficiency programs for both new construction and retrofit projects that will pay between $1 and $5 per fixture (for new construction, the space must exceed Florida Building Energy Code by 10% to be eligible for incentives). CMH technology is eligible. The Business Energy Check program will provide a customized report with energy-saving recommendations and available rebates specific to an owner's facility. The outdoor lighting program offers a lease program that includes design, installation, repairs and maintenance. They claim little or no installation costs, assuming normal installation conditions. With ENERGY STAR for small business, a variety of support and information is provided to reduce energy waste and costs.

More information: https://www.progress-energy.com/florida/business/index.page and https://www.progress-energy.com/florida/business/save-energy-money/energy-efficiency-for-business.page?.

18A.5 IDAHO INCENTIVE PROGRAMS

Avista Utilities Commercial Lighting Incentive Program offers incentives for replacing exterior HID fixtures with higher energy-efficient HID, LED, or induction fixtures or replacing indoor HID fixtures with more efficiency fluorescent fixtures. Rebates for replacing high wattage exterior HID (400W and 1000W) with 400W and 200 W induction lamps have been discontinued in the 2012 program. Avista's incentives are also available for new construction on a case-by-case basis.

Specific rebates include:

Fluorescent fixture replacing HID fixture (MH, HPS, MV)-interior$100/fixture for 4-foot 8-lamp T8 fixture replacing 400W HID fixture

- $100/fixture for 4-foot 6-lamp and 8-foot T8 fixture replacing 400W HID fixture
- $105/fixture for 4-foot 4-lamp T5HO fixture replacing 400W HID fixture
- $55/fixture for 5-foot 4-lamp T8 or 2-lamp T5HO fixture replacing 250W HID fixture

CMH fixture/lamp replacing incandescent fixture/lamp

- $30/fixture for 25W CMH replacing > 100W incandescent flood

LED fixture/lamp replacing HID fixture/lamp – exterior

- $75/fixture for 10-15W LED fixture replacing 70-90W HID fixture
- $175/fixture for 20-26W LED fixture replacing 175W HID fixture$200/fixture for 50-60W LED fixture replacing 250W HID fixture
- $175/fixture for 75-85W LED fixture replacing 250W HID fixture

Induction fixture/lamp replacing HID fixture/lamp – exterior

- $100/fixture for 20-25W induction fixture replacing 100W HID fixture
- $150/fixture for 40W induction fixture replacing 175W HID fixture

Higher efficiency HID fixture/lamp replacing low efficiency HID fixture/lamp – exterior

- $200/fixture for 250W "Digital HID" fixture replacing 100W HID fixture
- $500/fixture for 400-575W "Digital HID" fixture replacing 1000W HID fixture

Avista also offers site-specific (custom) incentives for some energy efficiency projects that are not covered by other prescriptive programs. Incentives apply to measures with energy savings lasting 10 years or longer that meet or exceed the higher of the current energy code or industry practice that are applicable to the project.

More information: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/incentive_6.aspx.

Idaho Power offers a series of incentives related to energy efficient lighting for retrofits, new constructions and for large customers and/or complex energy saving projects. Retrofit incentives only apply to interior lighting upgrades (street, area, and parking lot lighting is excluded). Eligible technologies include replacing high bay fixtures with more energy efficient fluorescent technology and energy efficiency gains using CMH or PMH. Specific incentives for retrofits include:

Fluorescent fixture replaces higher wattage high-bay fixture

- $180/fixture for 10 or 12 lamp 4-foot T8 and electronic ballast or 8 or 10 lamp 4-foot T5HO and electronic ballast replacing 751-1100W fixture of any type
- $110/fixture for 6 or 8 lamp 4-foot T8 and electronic ballast or 4 or 6 lamp 4-foot T5HO and electronic ballast replacing >400W fixture of any type
- $75/fixture for 6 lamp 4-foot T8 and electronic ballast or 2,3, or 4 lamp 4-foot T5HO and electronic ballast replacing 200-399W fixture of any type
- $75/fixture for 4 lamp 4-foot T8 and electronic ballast replacing >200W fixture of any type

CMH or PMH fixture replaces higher wattage fixture

- $105/fixture for > 361W CMH or PMH replacing > 600W fixture of any type
- $55/fixture for 251-360W CMH or PMH replacing > 450W fixture of any type
- $30/fixture for 150-250W CMH or PMH replacing > 295W fixture of any type

New construction incentives for interior light load reductions include $0.05/square foot for 10-19.9% below code allowed wattage and $0.15/square foot for >20% and higher below code allowed wattage. Exterior lighting systems designed and installed at least 15% better than code minimum qualify for an incentive of $200 per kW below code.

Incentives for large and midsized commercial and industrial entities are also offered for customers located in Idaho with a Basic Load Capacity (BLC) of at least 500 kW. Other large customers who have entered into IPUC-approved special contracts with Idaho Power Company pursuant to Schedule 19 may also qualify. For qualifying audits, Idaho Power provides an incentive of up to 50% of the audit cost, but not to exceed $10,000. Each customer site is limited to one detailed audit each year. Financial incentive is based upon the least of two calculations: 1) $0.12 per kWh saved per year or 2) 70% of project cost. Projects must be completed within one year of signing an agreement with Idaho Power.

More information: http://www.idahopower.com/EnergyEfficiency/Business/Programs/.

18A.6 INDIANA INCENTIVE PROGRAMS

Duke Energy's Smart Saver incentive program and the Energizing Indiana incentive program offer rebates for replacing various HID fixtures with more energy-efficient fluorescent fixtures, PMH replacing HID, CMH replacing incandescent or halogens, and LED or induction replacing HID. Incentives include:

T5HO high-bay fluorescent fixture replaces HID fixture

- $60/fixture for T5HO high-bay 6-lamp fluorescent fixture replacing a 400-999W HID fixture
- $50/fixture for T5HO high-bay 4-lamp fluorescent fixture replacing a 400-999W HID fixture
- $40/fixture for T5HO high-bay 3-lamp fluorescent fixture replacing a 250-399W HID fixture
- $30/fixture for T5HO high-bay 2-lamp fluorescent fixture replacing a 150-249W HID fixture

CMH fixture replaces halogen fixture

- $30/fixture for 150W CMH fixture replacing total of 360W halogens

- $30/fixture for 100W CMH fixture replacing total of 270W halogens
- $30/fixture for 70W CMH fixture replacing total of 225W halogens
- $30/fixture for 50W CMH fixture replacing total of 195W halogens

CMH fixture replaces incandescent or halogen fixture

- $30/fixture for 39W CMH fixture replacing >150W incandescent or halogen
- $30/fixture for 20W CMH fixture replacing >100W incandescent or halogen

CMH fixture replaces incandescent flood lamp

- $10/lamp for <25W CMH with integral ballast replacing >70W incandescent flood light

LED or induction fixture replacing HID – exterior

- $400/fixture for LED or induction fixture replacing >400W HID
- $250/fixture for LED or induction fixture replacing 251-400W HID
- $150/fixture for LED or induction fixture replacing 176-250W HID
- $100/fixture for LED or induction fixture replacing <175W HID

LED or induction fixture replacing HID – garage

- $200/fixture for LED or induction fixture replacing >400W HID
- $120/fixture for LED or induction fixture replacing 251-400W HID
- $65/fixture for LED or induction fixture replacing 176-250W HID
- $45/fixture for LED or induction fixture replacing <175W HID

PMH replaces HID fixture

- $30/fixture for 320W PMH replacing 400W HID

Common fixtures that may qualify under Smart Saver Custom program for retrofits only (rebate amount TBD):

- T5 HO HB 8L replacing 750-999W HID
- T8 HB 4ft 3L replacing 150-249W HID
- T8 HB 4ft 4L replacing 250-399W HID

- T8 HB 4ft 6L replacing 400-999W HID
- T8 HB 4ft 8L replacing 400-999W HID
- 42W 8 lamp HB CFL replacing 400W HID

More information: http://www.duke-energy.com/indiana-business/energy-management/lighting-incentive.asp.

18A.7 IOWA INCENTIVE PROGRAMS

Ames Electric Department manages the Smart Energy Commercial Lighting Program and offers only a handful of rebates for select technologies and power ranges. The incentives are available for replacing existing or for new equipment:

- $15 per fixture is available for MH fixtures with lamps rated under 250W
- $25 per fixture is available for PMH fixtures with lamps in the range of 250W-360W
- $20 per fixture is available for HPS fixtures with lamps under 250W
- $25 per fixture is available for HPS fixtures with lamps in the range of 250W-400W

Commercial custom rebates may also be available that offer $500 for every kW saved.

More information: http://www.cityofames.org/index.aspx?page=999.

MidAmerican Energy Company's EnergyAdvantage lighting equipment program offers rebates for some fixture technologies, but also for specific HID lamps. $ 25 per fixture is available for 320W or less and $50 per fixture for greater than 320W PMH fixtures. MidAmerican also provides a rebate of $3 per lamp for 330-360W MH lamps replacing 400W lamps. The incentives are available for replacing existing fixtures or for new equipment.

More information: http://midamericanenergy.com/ee/ia_bus_rebates_lighting.aspx.

18A.8 KENTUCKY INCENTIVE PROGRAMS

Duke Energy offers several rebates for replacing lighting fixtures with more energy efficient equipment.

T8 high-bay fluorescent fixture replaces HID fixture

- $40/fixture for T8 high-bay 4-foot 8-lamp Fluorescent Fixture replacing a 400-999W HID fixture
- $50/fixture for T8 high-bay 4-foot 6-lamp Fluorescent Fixture replacing a 400-999W HID fixture

- $40/fixture for T8 high-bay 4-foot 4-lamp Fluorescent Fixture replacing a 250-399W HID fixture

- $30/fixture for T8 high-bay 4-foot 3-lamp Fluorescent Fixture replacing a 150-249W HID fixture

T5HO high-bay fluorescent fixture replaces HID fixture

- $75/fixture for T5HO high-bay 8-lamp fluorescent fixture replacing a 750-999W HID fixture

- $40/fixture for T5HO high-bay 6-lamp fluorescent fixture replacing a 400-999W HID fixture

- $50/fixture for T5HO high-bay 4-lamp fluorescent fixture replacing a 400-999W HID fixture

- $40/fixture for T5HO high-bay 3-lamp fluorescent fixture replacing a 250-399W HID fixture

- $30/fixture for T5HO high-bay 2-lamp fluorescent fixture replacing a 150-249W HID fixture

PMH replaces HID fixture

- $25/fixture for 320W PMH replacing 400W HID

More information: http://www.duke-energy.com/kentucky-business/energy-management/lighting-incentive.asp.

18A.9 MAINE INCENTIVE PROGRAMS

Efficiency Maine, a program of the Maine Public Utilities Commission, does not offer a rebate for HID fixtures. However, the program offers between $10 and $65 for a high intensity fluorescent fixture replacing an HID fixture. Other retrofits with newer more efficient fluorescent or LED technology are eligible for rebates as long as there is a net energy savings (e.g., fluorescent high bay, LED outdoor area fixture, LED wallpack, LED parking garage fixture, etc. are all eligible for rebates when replacing HID or any other less efficient lighting technology). No HID incentives are given for new construction, only for fluorescent and LED technology. Custom lighting incentives are available based on power density requirements (i.e., installed watts per square foot must be at least 20% less than the lighting power density required by the Maine Energy Code for the space of building type).

More information: http://www.efficiencymaine.com/at-work/business-programs/incentive-applications.

18A.10MASSACHUSETTS INCENTIVE PROGRAMS

National Grid offers incentives for new equipment as well as replacing existing equipment. The Energy Initiative for existing facilities offers rebates for both fixtures and lamp/ballast systems. National Grid offers $70 for installing a PMH fixture that saves at least 50W. They offer $85 per fixture for completely replacing an existing >200W MH fixture with a new PMH fixture. Again, the program does not list any specific wattage requirements for the existing or new fixture, but a savings of at least 64W is required. $75 per fixture is available for replacing a specialty MH fixture with a MH fixture that saves at least 55W. Integral MH PAR lamps that offer energy savings of at least 27W over existing MH PAR lamps are eligible for a $20 rebate. No incentives specifically for HID fixtures are listed in National Grid's new construction program. However, the program offers $20 to $40 per fixture for HIF. The applications recommended for these fixtures are some of the typical locations for HID fixtures such as high bays.

More information: https://www.nationalgridus.com/masselectric/business/energyeff/energyeff.asp.

Nstar manages a Construction Solution and Business Solutions program that aims to promote energy-efficient lighting in renovations and new construction projects. For business customers, the retrofit program provides $70 for installing a PMH fixture that saves at least 50W. They offer $85 per fixture for completely replacing an existing >200W MH fixture with a new PMH fixture. Again, the program does not list any specific wattage requirements for the existing or new fixture, but a savings of at least 64W is required. $75 per fixture is available for replacing a specialty MH fixture with a MH fixture that saves at least 55W. Integral MH PAR lamps that offer energy savings of at least 27W over existing MH PAR lamps are eligible for a $20 rebate. No incentives specifically for HID fixtures are listed in the new construction program. However, the program offers $20 to $40 per fixture for HIF.

More information: .

Reading Municipal Lighting Department offers incentives to replace existing interior 400W HID fixtures with new T5 or T8 high output fixtures. The program offers $100 per fixture and no other requirements are listed. For more information:

http://www.rmld.com/Pages/rmldma_commercial/EEP.

Western Massachusetts Electric (WMECo) offers rebates to commercial customers for lighting. $25 incentive is offered for replacing MH, MV or HPS fixtures with PMH fixtures, as long as there is 50W or more in energy savings. Rebates of $150 are offered for replacing 250W MH with 54T5HO fluorescent fixtures (2/3 lamp) (117/176W) and for replacing 400W MH with 54T5HO (4 lamp) (234W) fluorescent fixtures New construction incentives are available for reducing lighting power density from the baseline established by applicable code. Wattage reductions >15% (Tier 1) are eligible for up to $0.40 per watt saved, while wattage reduction of 25% (Tier 2) are eligible for up to $1 per watt saved. There are no restrictions on fixture types for Tier 1, whereas Tier 2 requires a majority of the fixtures to be T5 or T5HO, LED, CMH or other innovative lighting technologies.

More information: http://www.wmeco.com/business/saveenergy/EnergyEfficiencyPrograms/Lighting.aspx.

18A.11MINNESOTA INCENTIVE PROGRAMS

Alexandria Light and Power – Commercial Energy Efficiency Rebate Program sponsors the Bright Energy Solutions® program. The following retrofit incentives are offered for indoor lighting systems that operate during daytime hours for a minimum of 1,800 hours per year: All installations must be completed by 12/31/2013.

T8 high-bay fluorescent fixtures with electronic ballasts replacing HID (MH, MV, HPS) or incandescent

- $130/fixture for one 16-lamp or two 8-lamp replacing 1000W or larger
- $140/fixture for one 12-lamp replacing 1000W or larger
- $150/fixture for one 10-lamp replacing 1000W or larger
- $100/fixture for one 8-lamp replacing 750W or larger
- $70/fixture for one 8-lamp replacing 400-749W
- $120/fixture for one 6-lamp replacing 750W or larger
- $85/fixture for one 6-lamp replacing 400-749W or larger
- $70/fixture for one 4-lamp replacing 250W or larger
- $45/fixture for one 3-lamp replacing 150W or larger

T5HO high-bay fluorescent fixtures with electronic ballasts replacing HID (MH, MV, HPS) or incandescent

- $150/fixture for one 12-lamp or two 6-lamp replacing 1000W or larger
- $175/fixture for one 10-lamp or two 5-lamp replacing 1000W or larger
- $200/fixture for one 8-lamp replacing 1000W or larger
- $110/fixture for one 8-lamp replacing 750W or larger
- $125/fixture for one 6-lamp replacing 750W or larger
- $70/fixture for one 6-lamp replacing 400--749W
- $90/fixture for one 4-lamp replacing 400W or larger
- $70/fixture for one 3-lamp replacing 250-749W

- $75/fixture for one 2-lamp replacing 250W or larger
- $60/fixture for one 2-lamp replacing 150W or larger

CMH and PMH replacing incandescent or HID

- $75/fixture for <20W CMH replacing 100W or larger incandescent
- $75/fixture for <39W CMH replacing 150W or larger incandescent$75/fixture for <150W CMH replacing 500W or larger incandescent
- $20/fixture for 320W PMH replacing 400W or larger HID or incandescent
- $30/fixture for 750W PMH replacing 1000W or larger HID or incandescent

There are 23 Utilities that participate in this program. No incentives for HID lighting are offered for new construction.

More information:
http://www.brightenergysolutions.org/municipalities/?category=business&state=mn.
Anoka Municipal Utility has a Commercial Lighting Rebate program that includes both retrofit and new construction applications. The program runs between 1/1/2013 and 3/31/2014.

The following rebates are available for retrofits:

T5 and T8 high-bay fluorescent fixtures with electronic ballasts replacing HID (MH, MV, and HPS)

- $175/fixture for one 8-lamp T8HO, 10-lamp T5HO, or 18 to 20-lamp T8 replacing 1000W HID
- $175/fixture for one 6-lamp T8HO, 8-lamp T5HO, or 12 to 16-lamp T8 replacing 750W HID
- $125/fixture for one 3-lamp T8HO, 4 to 6-lamp T5HO, or 6 to 8-lamp T8 replacing 310-400W HID
- $85/fixture for one 2-lamp T5HO, 3-lamp T5HO, or 4-lamp T8 replacing 175-250W HID

MH and HPS replacing incandescent, MV, or halogen with HPS

- $55/fixture for 251W+
- $35/fixture for 151-250W
- $25/fixture for 150W or less

PMH replacing incandescent, MV, HPS, or MH

- $100 /fixture for 750W+
- $75/fixture for 320-749W
- $50/fixture for 176-319W
- $30/fixture for 175W or less

CMH replacing incandescent, halogen or HID

- $55/fixture for 250W+
- $35/fixture for 151-250W
- $25/fixture for 150W or less

LED wall pack fixtures – exterior and parking garage installations replacing HID

- $75/fixture for <150W LED system that uses 3-6 times less energy than an existing HID

LED – exterior canopy and soffit fixtures replacing HID

- $150/fixture for 25-150W LED system that uses 3-6 times less energy than an existing HID

More information: http://anokaelectric.govoffice3.com/index.asp?Type=B_BASIC&SEC={B1A779DE-6099-444C-AEB5-540A215F5EAE}.

Austin Utilities offers incentives to its commercial and industrial customers to install energy-efficient equipment in their facilities. Retrofit systems must show a net reduction in kW usage from that of the existing lighting system to be eligible for rebates. The rebates must be submitted by 12/31/2013.

The rebate incentives for retrofits offered on HID lamps are as follows:

MH and PMH fixture retrofits

- $17/fixture for installing a MH fixture of 32W, 50W, 70W and 100W
- $25/fixture for installing a magnetic ballast PMH of 150W and 175W
- $26/fixture for installing an electronic ballast PMH of 150W
- $40/fixture for installing a magnetic ballast PMH of 200W and 250W

- $55/fixture for installing a magnetic ballast PMH fixture of 320W, 350W and 400W
- $61/fixture for installing an electronic ballast PMH fixture of 320W
- $55/fixture for installing a magnetic ballast PMH fixture of 400W
- $110/fixture for installing a magnetic ballast PMH fixture of 400 W with two lamps
- $85/fixture for installing a magnetic ballast PMH fixture of 575W
- $65/fixture for installing a magnetic ballast PMH fixture of 750W
- $65, $130 and $195/fixture for installing a magnetic ballast PMH of 875W with 1, 2 and 3 lamps respectively
- $10/lamp for installing a MH lamp of 360W with ferro-electric capacitor

CMH fixture retrofits

- $20/lamp for installing a 25W integrated CMH
- $20/lamp for installing a 205W CMH
- $20/lamp for installing a 330W CMH
- $40/lamp for installing a 830W CMH
- $50/fixture for installing a 150W or less CMH
- $45/fixture for installing a 151W-250W CMH
- $60/fixture for installing 251W or more CMH

HPS fixture retrofits

- $17/fixture for installing an HPS fixture of 35W, 50W, 70W, 100W and 150W
- $28/fixture for installing an HPS fixture of 200W and 250W
- $45/fixture for installing an HPS fixture of 310W, 400W, 600W and 750W

T8 and Super T8 fluorescent lamps and fixtures with electronic ballasts replacing MH

- $78/fixture for a 8-lamp 192W F32T8-RLO/Reflector lamp and fixture replacing a 400W MH
- $24/fixture for a 1-lamp 37W F32T8-HBF/Reflector lamp and fixture replacing a 100W MH

- $30/fixture for a 2-lamp 73W F32T8-HBF /Reflector lamp and fixture replacing a 150W MH
- $36/fixture for a 3-lamp 93W F32T8-HBF /Reflector lamp and fixture replacing a 175W MH
- $42/fixture for a 4-lamp 146W F32T8-HBF /Reflector lamp and fixture replacing a 250W MH
- $78/fixture for a 6-lamp 186W F32T8-HBF /Reflector lamp and fixture replacing a 400W MH
- $56/fixture for a 4-lamp 146W F32 Super T8 with >15 ft. ceiling height installation replacing a 250W MH
- $61/fixture for a 4-lmap 146W F32 Super T8/Reflector with >15 ft. ceiling height installation replacing a 250W MH
- $105/fixture for a 6-lamp 186W F32 Super T8/Reflector with >15 ft. ceiling height installation replacing a 400W MH
- $125/fixture for a 8-lamp 292W F32 Super T8/Reflector with >15 ft. ceiling height installation replacing a 600W MH

T5 fluorescent fixtures with electronic ballasts replacing MH, HID, or HPS

- $90/fixture for a 4-lamp 48W T5HO/Reflector replacing a 400W HID
- $45, $40, $60, or $85/fixture rebate for a 1, 2, 3, or 4- lamp 54W T5HO replacing a 150W, 175W, 250W, or 400W MH, respectively
- $45, $85, $135, $165 or $85/fixture rebate for a 3, 4, 8, 10, or 12-lamp 54W T5HO/Reflector replacing a 150W, 175W, 250W, or 400W MH, respectively
- $115/fixture for a 6-lamp 351W T5HO/Reflector replacing a 600W HPS

Compact fluorescent lamp replacing MH

- $25/lamp for 180W CFL replacing a 400W MH

Compact fluorescent lamp-hardwired fixtures (not screw-based) replacing MH

- $30/unit for 9-lamp industrial 318W multi-CFL replacing a 400W MH

Induction lamps and fixtures replacing HID

- $17.50/unit for 15-22W induction lamp replacing a 70W HID
- $22/unit for 23-39W induction lamp replacing a 100W HID

- $41/unit for 40-149W induction lamp replacing a 175W HID
- $60/unit for 150-199W induction lamp replacing a 250W HID
- $100/unit for 200-299W induction lamp replacing a 400W HID
- $100/unit for 300-400W induction lamp replacing a 1000W HID

LED lamps and fixtures replacing less efficient lighting technology

- $20/lamp for ENERGY STAR rated LED light bulbs >10W
- $30/fixture for ENERGY STAR rated LED fixtures
- $0.24 per W saved for non-ENERGY STAR LED lamps and fixtures

HID rebate incentives offered for new construction include:

MH and PMH fixtures – new construction

- $7.50/fixture for installing new MH fixture of 32W, 50W, 70W and 100W
- $6/fixture for installing new magnetic ballast PMH of 150W and 175W
- $6.50/fixture for installing new electronic ballast PMH of 150W
- $8/fixture for installing new magnetic ballast PMH of 200Wand 250W
- $12/fixture for installing new magnetic ballast PMH fixture of 320W, 350W and 400W
- $15/fixture for installing new electronic ballast PMH fixture of 320W
- $12/fixture for installing new magnetic ballast PMH fixture of 400W
- $24/fixture for installing new magnetic ballast PMH fixture of 400 W with two lamps
- $20/fixture for installing new magnetic ballast PMH fixture of 575W
- $15/fixture for installing new magnetic ballast PMH fixture of 750W
- $15, $30 and $45/fixture for installing new magnetic ballast PMH of 875W with 1, 2 and 3 lamps respectively
- $5/lamp for installing new MH lamp of 360W with ferro electric capacitor

CMH fixtures – new construction

- $8/lamp for installing new 25W Integrated CMH

- $8/lamp for installing new 205W CMH
- $8/lamp for installing new 330W CMH
- $16/lamp for installing a 830W CMH
- $20/fixture for installing new 150W or less CMH
- $10/fixture for installing new 151W-250W CMH
- $15/fixture for installing 251W or more CMH

HPS fixtures – new construction

- $7.50/fixture for installing new HPS fixture of 35W, 50W, 70W, 100W and 150W
- $15/fixture for installing new HPS fixture of 200W, 250W, 310W, 400W, 600W and 750W

More information: http://www.austinutilities.com/pages/business_conserve.asp.

The city of North St. Paul offers retrofit and new construction lighting rebates. HPS, PMH and CMH are eligible for incentives. Incentives are also offered to replace some HID technologies with higher efficiency lighting. Systems must result in a net load reduction in kW usage from that of the existing lighting system and lighting equipment must be operated during weekday on-peak demand hours (6 a.m. – 9 p.m.). With the exception of the exterior LED canopy and soffit fixtures rebate and parking garage lighting rebates, rebates apply only to interior lighting retrofit programs only. Qualifying customers must apply for rebates by 11/20/2013. For retrofits, the incentives are as follows:

High bay fluorescent fixtures with electronic ballasts replacing HID

- $85, $110, $135, and $160 for replacing 175-250W, 310-400W, 750W, and 1,000W HID systems with T5HO (2-3 lamp), T5HO (4-6 lamp), T5HO (8-lamp), and T5HO (10-lamp) high-bay fluorescent fixtures with electronic ballasts, respectively
- $85, $110, $135, and $160 for replacing 175-250W, 310-400W, 750W, and 1,000W HID systems with T8 (4 lamp), T8 (6-8 lamp) or T8VHO (3-lamp), T8 (12-16-lamp) or T8VHO (6-lamp), and T8 (18-20-lamp) or T8VHO (8-lamp) high-bay fluorescent fixtures with electronic ballasts, respectively

HPS replacing incandescent, halogen, or MV

- $30 and $50 for replacing incandescent, halogen, or MV with 151-250W or 251W and higher HPS, respectively

CMH replacing incandescent, halogen, HPS, MH, or MV

- $50, $75, and $100 for replacing incandescent, halogen, HPS, MH or MV with 150W or less, 151-250W, or 251W and higher CMH fixtures, respectively.
- $20 for replacing 75-150W incandescent or halogen lamps with 20-25W integrated CMH lamps.

PMH replacing incandescent, halogen, HPS, MH, or MV

- $30, $50, $75, and $100 for replacing incandescent, halogen, MV, HPS, or MH with 175W or less, 176-318W, 320W-749W, and 750W and higher PMH fixtures, respectively.

Exterior LED canopy and soffit fixtures replacing HID

- $150 per fixture for replacing MH systems with exterior LED canopy and soffit fixtures with 25-150W

Fluorescent parking garage lighting replacing HID

- $75 per fixture for T8, 2- and 3-lamp, 4ft and T5HO, 2- and 3-lamp replacing 175W or 150W HID.

For new construction, the incentives are as follows for CMH and PMH fixtures:

- $25, $35, $20, and $15 for 150W or less, 151-250W, >250W CMH fixtures and 20-25W integrated CMH lamps
- $8, $10, $15, and $25 for 175W or less, 176-319W, 320-749W, and 750W and higher PMH fixtures

More information: http://www.northstpaul.net/index.asp?Type=B_DIR&SEC={DD1A3517-B8B4-4747-9B15-B484608C6B94}&DE={5A122A25-0B4F-47FA-B32D-31489BD9D3FE}.

Connexus® Energy, along with the Dakota Electric Association (East Central Energy, Elk River Municipal Utilities, Minnesota Valley Electric cooperative, Shakopee Public Utilities, Stearns Electric Association) offers rebates for both retrofit applications and new construction. Connexus recommends replacing HID with T5HO, T8, or T8VHO fixtures, replacing incandescent or MV with MH or HPS fixtures, replacing incandescent, MV, HPS, or MH with PMH fixtures, and replacing incandescent, halogen, MV, HPS, or PMH with CMH fixtures. In all cases, replacement lamp wattage must be lower.

Fluorescent lamps replacing HID

- $36, $65, $80, and $100 to replace 250W, 310-400W, 750W, and 1000W HID systems with (2-lamp T5HO, 3-lamp T5HO, or 4-lamp T8), (3-lamp T8VHO, 4-6-

lamp T5HO, or 6-8-lamp T8), (6-lamp T8VHO, 8-lamp T5HO, or 12-16-lamp T8), and (8-lamp T8VHO, 10-lamp T5HO, or 18-20-lamp T8) respectively.

Replacement of less efficient lighting with more efficient, lower wattage HPS

- $20, $30, and $45 to replace <150W, 151-250W, and >250W systems with HPS.

Installation of new PMH replacing older less efficient technology

- fixtures ≤175W are eligible for $28 per fixture,
- fixtures in the range of 176W to 319W are eligible for $45 per fixture,
- fixtures between 320W to 749W have a $50 per fixture rebate, and
- fixtures over 750W have a rebate of $70 per fixture

CMH technology is also included in the retrofit program

- $25 per fixture <50W
- $35 per fixture 51-150W
- $50 per fixture that draws power in the range of 151W to 250W
- $75 per fixture that draws more than 251W

Connexus's new construction program is similar. MH or HPS fixtures rated at less than 151W are eligible for a $6.60 per fixture rebate.

PMH fixtures have the following incentives

- $6.50 per fixture ≤175W
- $8.80 per fixture in the range of 176W to 319W
- $13.20 per fixture in the 320W to 749W range
- $19.80 per fixture rated over 749W

CMH technology rebates are as follows

- $22 per fixture ≤150W
- $11 per fixture that draws power in the range of 151W to 250W
- $16.50 per fixture that draws more than 250W

Dakota Electric and Minnesota Valley Electric also offer $110 per fixture for replacement of >250W HID with 25-150W exterior LED soffit or canopy.

More information:

- http://www.connexusenergy.com/rebatescomm.aspx
- https://www.dakotaelectric.com/business/programs/rebates_grants_and_loans/lighting_rebates
- https://www.eastcentralenergy.com/rebatesbusiness.aspx
- http://www.elkriverutilities.com/cipeleccomm.php
- http://www.mvec.net/business/grants_rebates.asp
- http://www.shakopeeutilities.com/commrebates.htm
- http://www.stearnselectric.org/grantsbus.htm

Otter Tail Power Company focuses on demand reduction with incentives based on a kW savings. Through the Minnesota Conservation Improvement Program (CIP, rebates of 40¢ per watt saved are offered when low efficiency lighting technology is replaced with higher efficiency technology.

- HPS, high efficiency MH, and induction replacing incandescent and low-efficiency fluorescent
- High-efficiency fluorescent, HPS, PMH, and induction replacing MV
- High-efficiency fluorescent, PMH, and induction replacing standard MH

For new construction, rebates include:

- $225 per kW for installed T8 and T5 fluorescent and CMH
- $50 per kW for installed induction and low wattage T8 (<28W)

More information: https://www.otpco.com/SaveEnergyMoney/SD%20-EEP/Pages/lightingEEP_SD.aspx

18A.12MISSOURI INCENTIVE PROGRAMS

Empire District Electric Company offers rebates to certain commercial and industrial customers for the installation of energy efficiency equipment. They provide a rebate of $50/fixture for installing a PMH. The lamp wattage must be either 320 or 360W as a replacement for 400W MH or HPS. They also offer a $50 rebate on replacing HID with T5 or T5HO lamps with electronic ballast.

$1 per watt per square foot rebates may be available based on lighting power density if overall lighting power is reduced 25% below the requirements of local energy code.

More information: http://empire.programprocessing.com/content/Home.

Kansas City Power and Light (KCP&L) offers $50 per fixture rebates for replacing HID with high efficiency fluorescent fixtures in high bay and other applications, including parking lots. $50 per fixture rebates are also available for 320W and 360W PMH replacing 400W MH and HPS fixtures.

More information: http://www.kcplsave.com/business/default.html.

18A.13MONTANA INCENTIVE PROGRAMS

Flathead Electric Cooperative offers a variety of incentives for installing new and replacing existing equipment in their Commercial Lighting Rebate Program.

For new construction projects:

- $40 per CMH fixture ranging in wattage from 20W to 100W
- $50 per CMH fixture ranging in wattage from 101 to 400W

For retrofit applications an overall wattage reduction of 25% must be achieved to qualify

CMH replacing incandescent, MV, T12, MH, HPS or LPS

- $80 per CMH fixture in wattage range of 99W or less that replaces an incandescent, MV, T12, MH, HPS or LPS
- $150 per CMH fixture for wattages 100W or more that replaces an incandescent, MV, T12,, MH, HPS or LPS
- $30 per 20-30W self-ballasted CMH display light replacing incandescent, MV, MH, or HPS

High output T5 or T8 fluorescent replacing incandescent, MV, MH, HPS, and HID

- $120, $140, $160, and $180 for replacing MV, HPS, probe-start MH, incandescent, and HID with 40-129W (1-2 lamp T5 or equivalent T8), >130W (3 lamp T5 or T8 equivalent), >190W (4 lamp T5 or equivalent T8), and >250 W (5-12 lamp T5 or equivalent T8), respectively. Note: 250W fluorescent must replace > 450W HID.

High performance T8 or normal output T5 fluorescent replacing T12, incandescent, MV, MH, and HPS

- $25, $30, $50, $55, $65, and $30 for replacing T12, MV, HPS, probe-start MH, incandescent, and with upgrade to 1 HP lamp with HP electronic ballast, upgrade to 1 HP lamp with HP electronic ballast and either a low-ballast factor or low-wattage lamp (<28W), upgrade to 2-4 HP lamps with electronic ballast, upgrade to 2-4 lamps with electronic ballast and low ballast factor or low-wattage lamp, upgrade to HP lamps with electronic ballast eith de-lampling from a T12 baseline, and upgrade to T8 lamps with electronic ballast with de-lamping from a T8 baseline.

Standard T8 or T5 fluorescent lamp and ballast replacing incandescent, MV, MH, and HPS

- $10 and $20 for replacing MV, HPS, probe-start MH, and incandescent with upgrade to 1 lamp with standard electronic ballast and upgrade to 2-4 lamps with standard electronic ballast.

Hardwired compact fluorescent replacing incandescent, MV, MH, and HPS/LPS

- $40 and $80 for replacing MV, HPS/LPS, probe-start MH, and incandescent with <49 watts with electronic ballast and >50W or more with electronic ballast.

Induction replacing incandescent, MV, T12 HO/VHO, MH, HPS and LPS

- $80, $150, and $400 for replacement of incandescent, MV, T12HO/VHO, MH or HPS/LPS with <99W, 100-399W, and >400W induction fixture, respectively

PMH replacing incandescent, MV, T12 HO/VHO, MH, HPS and LPS

- $80, $150, and $400 for replacement of incandescent, MV, T12HO/VHO, MH or HPS/LPS with <200W (<150W and below for HPS), >200W (PMH only), and >400W (replacing >1000W HID), respectively

Various rebates are available for LED replacing MV, MH, and HPS, including recessed fixtures, outdoor fixtures (wall packs, parking lot, bollards), and canopy light fixtures.

More information: http://www.flatheadelectric.com/energy/Rebates.html.

18A.14NEW HAMPSHIRE INCENTIVE PROGRAMS

National Grid offers incentives for new equipment as well as replacing existing equipment. For new construction, $35 per fixture is offered for track, recessed, or surface mounted 20-100 W MH specialty lighting with electronic ballasts,

For existing facilities, $50 is offered for new PMH lamps with electronic ballast installed per the manufacturer's specifications and applicable codes. $70 is offered for an entirely new PMH fixture and electronic ballast. $50 per fixture is offered for 20-100W MH specialty lighting fixtures with electronic ballasts in track, recessed or surface mount positions. Incentives of $10-$20 are offered for replacement of lower efficiency directional lighting with integral LED directional lighting.

More information:
https://www.nationalgridus.com/granitestate/business/energyeff/5_light_a.asp

The New Hampshire Electric Cooperative incentive program for energy efficient lighting offers $35 when MH fixtures for retail or display lighting are used in new construction. Fixtures must be from 20W to 100W and may be track, recessed, or surface mounted and used for high quality display type lighting.

For existing large businesses, The New Hampshire Electric Cooperative offers $50 for new PMH lamps with electronic ballast installed per the manufacturer's specifications and applicable codes. $70 is offered for an entirely new PMH fixture and electronic ballast. More information: http://www.nhec.com/business_energysolutions_largebusiness.php

More information: http://www.nhec.com/business_energysolutions_newbusiness.php

18A.15NEW JERSEY INCENTIVE PROGRAMS

New Jersey Clean Energy is a statewide program that promotes energy efficiency and renewable energy. The specific program with HID rebates is the New Jersey SmartStart Buildings® and offers the following incentives:

Induction replacing HID

- $50 per induction lamp, power coupler, and generator that can retrofit an existing ≥100W HID fixture. Replacement unit must use 30% less wattage than existing HID system.
- $70 per induction lighting fixture ≥100W replacing an HID fixture. Replacement unit must use 30% less wattage than existing HID system.
- $25 per PMH fixture rated at 150W or more for new construction

For new construction, $1 per watt per square foot is offered for indoor and outdoor (attached to building only) if the energy efficiency threshold achieved is ≥5% more efficient than New Jersey code (ASHRAE 90.1-2007). The maximum incentive is $30 per qualified fixture.

More information:

http://www.njcleanenergy.com/commercial-industrial/programs/nj-smartstart-buildings/contacts-resources/program-guide/pdf/pdf

http://www.njcleanenergy.com/commercial-industrial/programs/nj-smartstart-buildings/application-forms/regular-forms/regular-forms

18A.16NEW YORK INCENTIVE PROGRAMS

The Long Island Power Authority manages a Commercial Construction Program and Commercial Efficiency Program to promote energy-efficient lighting for retrofit and in new construction projects.

For retrofits, available rebates include:

- $35 for integrated ballast CMH PAR lamp replacing incandescent or halogen PAR lamps of greater wattage
- $75 for ≤100W CMH with remote ballast replacing incandescent or halogen track system of greater wattage
- $15 for 205W CMH lamp replacing 250W MH lamp or 330W CMH lamp replacing 400W MH lamp
- $125 for high intensity fluorescent fixture replacing esiting HID, T12 or incandescent fixture
- $75 for CFL interior parking garage retrofit kit replacing HID or fluorescent fixtures operating during daylight hours
- $200 for LED interior parking garage fixture replacing HID or fluorescent fixtures operating during daytime hours

For new construction, available rebates include:

- $20 per integrated ballast CMH PAR lamp
- $45 [er CMH fixture for high ceiling retail and industrial
- $45 per ≤100W CMH with remote ballast for down light, directional, accent or track lighting
- $75 per HID fixture controlled via hi-low occupancy sensor or daylight controls

More information: http://www.lipower.org/commercial/efficiency/commercial.html.

18A.17OHIO INCENTIVE PROGRAMS

Dayton Power and Light offers the following incentives for retrofitting less efficient lighting under their Rapid Rebates® program: Equipment must be purchased and installed after 1/11/2013.

Replacing HID systems with the following LED or induction lighting systems

- $50 and $100 per fixture for LED or induction replacing ≤175W with annual operating hours <8760 and ≥8760 hours, respectively
- $75 and $150 per fixture for LED or induction replacing 176-250W with annual operating hours <8760 and ≥8760 hours, respectively
- $120 and $200 per fixture for LED or induction replacing 251-400W with annual operating hours <8760 and ≥8760 hours, respectively

Replacing HID systems with the following T5HO or four foot T8 lamps

- $30 per T5HO high-bay 2-lamp fixture replacing HID fixture
- $40 per T5HO high-bay 3-lamp fixture replacing HID fixture
- $50 per T5HO high-bay 4-lamp fixture replacing HID fixture
- $60 per T5HO high-bay 6-lamp fixture replacing HID fixture
- $70 per T5HO high-bay 8-lamp fixture replacing HID fixture
- $80 per T5HO high-bay 10-lamp fixture replacing HID fixture
- $25 per T8 high-bay 2-lamp fixture replacing HID fixture$30 per T8 high-bay 3-lamp fixture replacing HID fixture
- $40 per T8 high-bay 4-lamp fixture replacing HID fixture
- $50 per T8 high-bay 6-lamp fixture replacing HID fixture
- $55 per T8 high-bay 8-lamp fixture replacing HID fixture
- $65 per T8 high-bay 10-lamp fixture replacing HID fixture

Whole building baseline improvement incentive rewards are offered to customers who design their buildings to be more efficient than a baseline building constructed to ANSI/ASHRAE/IESNA Standard 90.1-2007. To receive an incentive, a project must achieve an annual electric energy (kWh) and demand (kW) saving of 5% or better than the baseline.

More information: http://www.dpandl.com/save-money/business-government/rapid-rebates/lighting-rebates/

http://www.dpandl.com/save-money/business-government/new-construction-rebates/whole-building-new-construction/

Duke Energy offers the following rebates for retrofits if the fixture operates a minimum of 1800 hours per year:

Replacing HID systems with T8 four foot lamps with electronic ballasts

- $30 per T8 high-bay 3-lamp fixture replacing 150-249W HID fixtures
- $40 per T8 high-bay 4-lamp fixture replacing 250-399W HID fixtures
- $50 per T8 high-bay 6-lamp fixture replacing 400-999W HID fixtures
- $60 per T8 high-bay 8-lamp fixture replacing 400-999W HID fixtures

Replacing HID systems with T5 lamps with electronic ballasts

- $30 per T5HO high-bay 2-lamp fixture replacing 150-249W HID fixtures
- $40 per T5HO high-bay 3-lamp fixture replacing 250-399W HID fixtures
- $50 per T5HO high-bay 4-lamp fixture replacing 400-999W HID fixtures
- $60 per T5HO high-bay 6-lamp fixture replacing 400-999W HID fixtures
- $75 per T5HO high-bay 8-lamp fixture replacing 750-999W HID fixtures

Rebates of $50 per fixture are also offered for replacing a 400W HID with a 42W 8-lamp compact fluorescent and $25 per fixture for replacing a 400W HID with a 320W PMH.

More information: http://www.duke-energy.com/indiana-business/energy-management/energy-efficiency-incentives.asp.

18A.18OREGON INCENTIVE PROGRAMS

Columbia River Public Utility District sponsors a Business Lighting Retrofit and new construction rebate program. To be eligible, retrofit projects must achieve a 25% or greater kWh savings and new construction must achieve a 20% or greater kWh savings. Rebates are offered for more energy efficient lighting technology to replace T12, incandescent, MH, HPS, LPS, and MV lamps. Rebates for lighting retrofits to replace these fixtures include:

CMH

- $80 per new CMH fixture <99W
- $150 per new CMH fixture >100W
- $30 per new CMH 20-30W screw-in display light

Induction

- $80 per new screw-in induction fixture
- $80 per new <99W induction fixture
- $150 per new 100-399W induction fixture
- $400 per new >400W induction fixture

LED

- $120 per new screw-in LED barn light or area light
- $30 per new LED recessed cans, track heads, dock lights, or wall packs

- $15 per new LED for backlit outdoor or indoor signage or perimeter outdoor lighting

Hardwired compact fluorescent

- $40 per new <49W hardwired compact fluorescent with electronic ballast
- $80 per new >50W hardwired compact fluorescent with electronic ballast

PMH

- $80 per new <200W pulse-start or electronic MH
- $150 per new 200-399W pulse-start or electronic MH (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89)

Replacing a >1000W HID with a new >400W pulse-start or electronic MH is eligible for a $400 rebate (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89).

$120, $140, $160 and $180 rebates are available for replacing incandescent, MV, HPS or MH with new T5HO or T8 HP fixtures of 40-129W, 130-189W, 190-249W, and >250W, respectively.

$35 and $60 are offered for new occupancy sensors, timers, photocells, and control panels for 50-200W systems and >200W systems, respectively.

Replacing >400W HID with LED canopy lights is eligible for a $230 rebate, after BPA approval under the Demonstration Technologies offerings.

For new construction, a $40 and $50 incentive are offered for 20-100W and 101-400W CMH fixtures, respectively.

A $30 per fixture incentive is offered for using LED recessed downlight, docklight, or wall packs under the Demonstration Technologies offerings for new construction.

More information: http://www.crpud.net/business.

Eligible equipment is listed in the downloadable lighting calculator at the bottom of the page: http://www.crpud.net/business/lighting-retrofit-program-for-commercial-customers

Emerald People’s Utility District previously sponsored a Lighting Retrofit Rebate Program. This program has changed to the Commercial Energy Program. EPUD will perform lighting audits of existing buildings and make recommendations for improvements. EPUD will estimate the possible rebates and perform economic analysis. If the project moves forward, EPUD can help with construction management assistance. EPUD’s website describes the program and explains past projects including fluorescent lighting retrofits in offices, schools, barns, retail stores, and industrial facilities.. Rebates are available for retrofitting old fluorescent fixtures, utilizing new CMH, LED and induction technology, and utilizing occupancy sensors and timers.

Rebates for lighting retrofits to replace these fixtures include:

CMH

- $80 per new CMH fixture <99W
- $150 per new CMH fixture >100W
- $30 per new CMH 20-30W screw-in display light

Induction

- $80 per new screw-in induction fixture
- $80 per new <99W induction fixture
- $150 per new 100-399W induction fixture
- $400 per new >400W induction fixture

LED

- $120 per new screw-in LED barn light or area light
- $30 per new LED recessed cans, track heads, dock lights, or wall packs
- $15 per new LED for backlit outdoor or indoor signage or perimeter outdoor lighting

Hardwired compact fluorescent

- $40 per new <49W hardwired compact fluorescent with electronic ballast
- $80 per new >50W hardwired compact fluorescent with electronic ballast

PMH

- $80 per new <200W pulse-start or electronic MH
- $150 per new 200-399W pulse-start or electronic MH (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89)

Replacing a >1000W HID with a new >400W pulse-start or electronic MH is eligible for a $400 rebate (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89).

$120, $140, $160 and $180 rebates are available for replacing incandescent, MV, HPS or MH with new T5HO or T8 HP fixtures of 40-129W, 130-189W, 190-249W, and >250W, respectively.

$35 and $60 are offered for new occupancy sensors, timers, photocells, and control panels for 50-200W systems and >200W systems, respectively.

Replacing >400W HID with LED canopy lights is eligible for a $230 rebate, after BPA approval under the Demonstration Technologies offerings.

For new construction, a $40 and $50 incentive are offered for 20-100W and 101-400W CMH fixtures, respectively.

A $30 per fixture incentive is offered for using LED recessed downlight, docklight, or wall packs under the Demonstration Technologies offerings for new construction.

More information: http://www.epud.org/myBusiness/comEnergyProg.aspx.

Energy Trust of Oregon aims to promote energy-efficient lighting upgrades by offering cash incentives. Rebates are available for LED lighting replacing HID or incandescent sources if a >25% energy savings is realized.

- $30 for recessed downlighting if the fixture is ENERGY STAR qualified

Custom lighting and new construction rebates may also be available.

More information: http://energytrust.org/commercial/equipment-upgrades-remodels/.

Idaho Power offers a series of incentives related to efficient lighting. MH lighting is specifically identified. These incentives only apply to lighting upgrades for interior lighting (street, area, and parking lot lighting is excluded). Eligible MH fixtures include PMH or CMH that are replacing higher wattage sources. Lighting retrofits must achieve 25kWh energy savings per unit to be considered for an incentive. The incentives are the following:

- $30for PMH or CMH fixtures between 150W to 250W when replacing a fixture drawing >295W.
- $55.00 for PMH or CMH fixtures between 251W to 360W when replacing a fixture drawing >450W.
- $105.00 for PMH or CMH fixtures of >361W when replacing a fixture drawing >600W.
- $75, $75, $110, $180 for T5/T8 high bay fixtures replacing less efficient fixtures (e.g., HID) of >200W, 200-399W, >400, or 751-1100W
- $0.50 per lamp for 4-foot T8 and T5HO lamps replacing T12 or HID

More information: http://www.idahopower.com/EnergyEfficiency/Business/Programs/EasyUpgrades/LightingControls.cfm.

Midstate Electric sponsors a Business Lighting Retrofit and new construction rebate program. To be eligible, retrofit projects must achieve a 25% or greater kWh savings and new construction must achieve a 20% or greater kWh savings. Rebates are offered for more energy efficient lighting technology to replace T12HO/VHO, incandescent, MH, HPS, LPS, and MV lamps.

Rebates for lighting retrofits to replace these fixtures include:

CMH

- $80 per new CMH fixture <99W
- $150 per new CMH fixture >100W
- $30 per new CMH 20-30W screw-in display light

Induction

- $80 per new screw-in induction fixture
- $80 per new <99W induction fixture
- $150 per new 100-399W induction fixture
- $400 per new >400W induction fixture

LED

- $120 per new screw-in LED barn light or area light
- $30 per new LED recessed cans, track heads, dock lights, or wall packs
- $15 per new LED for backlit outdoor or indoor signage or perimeter outdoor lighting

Hardwired compact fluorescent

- $40 per new <49W hardwired compact fluorescent with electronic ballast
- $80 per new >50W hardwired compact fluorescent with electronic ballast

PMH

- $80 per new <200W pulse-start or electronic MH

- $150 per new 200-399W pulse-start or electronic MH (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89)

Replacing a >1000W HID with a new >400W pulse-start or electronic MH is eligible for a $400 rebate (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89).

$120, $140, $160 and $180 rebates are available for replacing incandescent, MV, HPS or MH with new T5HO or T8 HP fixtures of 40-129W, 130-189W, 190-249W, and >250W, respectively.

$35 and $60 are offered for new occupancy sensors, timers, photocells, and control panels for 50-200W systems and >200W systems, respectively.

Replacing >400W HID with LED canopy lights is eligible for a $230 rebate, after BPA approval under the Demonstration Technologies offerings.

For new construction, a $40 and $50 incentive are offered for 20-100W and 101-400W CMH fixtures, respectively.

A $30 per fixture incentive is offered for using LED recessed downlight, docklight, or wall packs under the Demonstration Technologies offerings for new construction.

In addition to providing information about the rebates, Midstate's website lists local business that have reduced their operating expenses by using Midstate's lighting rebates.

More information:

http://www.midstateelectric.coop/Product-and-Services/Commercial--Industrial/Energy-Efficiency-Rebates/.

Lighting rebates are listed in the .xls Lighting Calculator file here: http://www.test.bpa.gov/energy/n/projects/lighting.

18A.19TEXAS INCENTIVE PROGRAMS

Austin Energy Commercial Energy Management Services offers rebates and incentives to promote energy efficient lighting. The program offers $300/kW of reduced energy usage for replacement of HID lighting with T8 or T5 fluorescent fixtures or induction fixtures for high-bay applications. The systems must operate at least 10 hours per day and during the 2pm-8pm period weekdays. $6 per lamp for CMH (screw-in) is offered to replace incandescent.

New construction rebates are also available for energy efficient lighting that exceed the International Energy Conservation Code (IECC 2009) efficiency levels, including City of Austin amendments. Small Business rebates are available for small to midsize and not-for-profit organizations. Every commercial rebate offered by Austin Energy is available to small businesses, but include an additional 30% bonus rebate and can cover of to 70 percent of the installed cost.

More information: http://www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/Commercial/Commercial%20Energy/lighting.htm

18A.20VERMONT INCENTIVE PROGRAMS

Efficiency Vermont, a statewide non-profit organization funded out of an efficiency charge applied to the electricity bill, offers various rebates and incentives for installing energy efficient lighting. Rebates are offered for any energy efficient lighting equipment that replaces less efficient equipment. 2-lamp HPT8 or T5 fluorescent fixtures are eligible for a $30 rebate. Hardwired CFL fixtures ≥20W are eligible for a maximum $20 rebate. Various interior LED product rebates are available for replacing recessed and surface mount fixtures, track lighting, display case, and high and low bay fixtures. Rebates for $20-$250 are available for installing exterior LED fixtures including parking garage, canopy, wall-mount area lighting, bollards and outdoor flood fixtures. Many MH lamps are eligible for rebates through the SMARTLIGHT program, which pays rebate amount directly to lighting distributors to enable customers to obtain high efficiency lighting at costs comparable to conventional products.

Custom incentive programs also exist for new construction that uses energy efficient lighting exceeding code. Incentives for exterior lighting are almost exclusively focused on LED technology.

More information: http://www.efficiencyvermont.com/for_my_business/ways-to-save-and-rebates/commercial_lighting/Rebates.aspx

18A.21WASHINGTON INCENTIVE PROGRAMS

Avista Utilities Commercial Lighting Incentives offers incentives for HID interior and exterior fixtures. Incentives are applicable for equipment installed after 1/1/2013.The following rebates are offered for replacing HID (MH, HPS, MV) with more energy efficient PMH, fluorescent, LED or induction lighting:

T5HO or T8 fluorescent fixture replacing HID fixture – interior

- $55 for 4-lamp T8 or 2-lamp T5HO (5-foot) replacing 250W HID fixture, or $90 with occupancy sensor.
- $110 for 4-lamp T5HO (4-foot) replacing 400W HID fixture, or $150 with occupancy sensor.
- $100 for 6-lamp or 8-lamp T8 (4-foot) replacing 400W HID fixture

CMH fixture replacing incandescent flood – interior

- $20 for 25W CMH replacing > 100W incandescent flood

LED, PMH, or induction fixture replacing HID fixture – exterior

- $75 for 10-20 W LED replacing 70-110W HID fixture
- $100 for 20-25W induction replacing 100W HID fixture
- $175 for 20-30W LED Wall Pack replacing 175W HID fixture
- $150 for 40W induction replacing 175W HID fixture
- $200 for 50-60W LED replacing 250W HID fixture
- $175 for 75-85W LED replacing 250W HID fixture
- $150 for 250W PMH replacing 400W HID fixture
- $400 for 400-575W PMH replacing 1000W HID fixture

Custom site-specific incentives are also available.

More information: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/incentive_6.aspx.

Benton Public Utility District sponsors a Lighting Energy Efficiency Program (LEEP). Rebates typically mirror those offered by the Bonneville Power Association, but are subject to revision. Offer valid through 9/30/2013 or until funding expires. Incentives are offered for more energy efficient lighting technology to replace T12HO/VHO, incandescent, MH, HPS, LPS, and MV lamps as follows:

CMH

- $80 per new CMH fixture <99W
- $150 per new CMH fixture >100W
- $30 per new CMH 20-30W screw-in display light

Induction

- $80 per new screw-in induction fixture
- $80 per new <99W induction fixture
- $150 per new 100-399W induction fixture
- $400 per new >400W induction fixture

LED

- $120 per new screw-in LED barn light or area light
- $30 per new LED recessed cans, track heads, dock lights, or wall packs
- $15 per new LED for backlit outdoor or indoor signage or perimeter outdoor lighting

Hardwired compact fluorescent

- $40 per new <49W hardwired compact fluorescent with electronic ballast
- $80 per new >50W hardwired compact fluorescent with electronic ballast

PMH

- $80 per new <200W pulse-start or electronic MH
- $150 per new 200-399W pulse-start or electronic MH (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89)

Replacing a >1000W HID with a new >400W pulse-start or electronic MH is eligible for a $400 rebate (must have lamp life > 15,000 hours, lumen maintenance >70%, CRI >65, initial system lumens/watt >89).

$120, $140, $160 and $180 rebates are available for replacing incandescent, MV, HPS or MH with new T5HO or T8 HP fixtures of 40-129W, 130-189W, 190-249W, and >250W, respectively.

$35 and $60 are offered for new occupancy sensors, timers, photocells, and control panels for 50-200W systems and >200W systems, respectively.

Replacing >400W HID with LED canopy lights is eligible for a $230 rebate, after BPA approval under the Demonstration Technologies offerings.

For new construction, a $40 and $50 incentive are offered for 20-100W and 101-400W CMH fixtures, respectively.

A $30 per fixture incentive is offered for using LED recessed downlight, docklight, or wall packs under the Demonstration Technologies offerings for new construction.

Incentives are also available for custom projects that improve efficiency, including industrial lighting that is interactive with HVAC systems.

Eligible equipment is listed in the downloadable lighting calculator under the “program info” tab: http://www.bpa.gov/Energy/N/projects/Lighting/

More information: http://www.bentonpud.org/conservation/commercial_rebate_programs/

Richland Energy Services sponsors the Energy Efficiency Commercial Lighting Program. Lighting rebates cannot exceed 70% of the total project cost and the project must show at least a 30% wattage reduction.

Fluorescent replaces T12 fluorescent, T8 de-lamp, incandescent or MV fixtures - new or retrofit

- $20 per high performance T8 or T5 lamp and ballast (1 lamp)
- $40 per high performance T8 or T5 lamp and ballast (2-4 lamps)
- $10 per standard T8 or T5 lamp and ballast (1 lamp)
- $20 per standard T8 or T5 lamp and ballast (2-4 lamp)

Fluorescent, CFL, CMH or induction replaces incandescent, T12HO/VHO, HPS, LPS or MV fixtures -new or retrofit

- $40 per hardwired compact fluorescent <49W (new fixture or retrofit kit)
- $80 per hardwired compact fluorescent >50W (new fixture or retrofit kit)
- $80 per <99W CMH (new fixture)
- $150 per >100W CMH (new fixture)
- $3 per 1-24W screw-in CFL or cold cathode (lamp only)
- $6 per 25-45W screw-in CFL or cold cathode (lamp only)
- $12 per >45W screw-in CFL or cold cathode (lamp only)
- $80 for <99W induction (new fixture)
- $150 for >100W induction (new fixture)

T5, T8, PMH, or electronic MH replaces T12HO/VHO, HPS, LPS MV, probe-start MH or incandescent fixtures - new fixture

- $120 per 40-129W (1-2 lamp T5) or equivalent T8
- $140 per 130-189W (3 lamp T5) or equivalent T8
- $160 per 190-249W (4 lamp T5) or equivalent T8
- $180 per >250W (5-12 lamp T5) or equivalent T8
- $150 per 200-399W PMH or electronic MH
- $200 per >400W PMH or electronic MH

Incentives are also offered for installing occupancy sensors, timers, photocells and control panels:

- $35 for 50-200 watts controlled
- $60 for 200 watts controlled

More information: http://www.ci.richland.wa.us/index.aspx?NID=183.

Puget Sound Energy's Custom Retrofit Grant Programs and Incentives typically pay for about 50% of a project's cost, and may fund up to 70% of the installed cost. The program covers efficiency retrofits and upgrades on existing facilities, new construction, and expansion of existing facilities.

A $25 rebate is offered for each 22-28W CMH PAR lamp installed in place of existing incandescent PAR/BR lamps.

For small business rebates are offered to replace higher wattage incandescent and HID fixtures:

- $75-$100 for higher efficiency MH and HPS
- $95-$190 for converting to T8 or T5 fluorescent warehouse lighting
- $110-$130 for converting to CFL higher-wattage wall packs
- $40-80, depending on controlled wattage, for installing lighting controls

PSE's Enhanced Lighting Program offers a bonus over PSE's standard incentive level for customers who implement comprehensive retrofits involving all lighting associated with a building. Incentives of $0.30 per kWh/yr saved; up to a maximum of 70% of the eligible project costs are available.

More information: http://pse.com/savingsandenergycenter/ForBusinesses/Pages/Rebates-and-Incentives.aspx

Seattle City Light manages a program called Energy Smart Services Financial Incentives that provides financial incentives to small, medium and large businesses for replacing inefficient lighting with approved energy-efficient lighting equipment. This program offers incentives for specific technologies, but pays per kWh saved. HID and induction lighting are specifically allowed for the incentive programs and both are eligible for 23 cents per kWh saved for medium and large commercial customers. CMH screw-in incentive of $0.07/kWh saved is also offered. In addition a 10% technology bonus is available demonstrating new or innovative technologies. Small commercial incentives include an $85 rebate for a MH or HPS fixture that replaces a less efficient fixture and realizes at least a 90W reduction. Financial incentives are also offered for installing HID fixtures that go beyond energy code requirements in new construction.

More information: http://www.seattle.gov/light/conserve/business/cv5_fi.htm.

18A.22 WISCONSIN INCENTIVE PROGRAMS

Eau Claire Energy Cooperative offers $15 per PMH CMH and HPS fixture. Only retrofit applications are applicable. Other incentives are offered through the Focus on Energy program and include:

CMH (total CMH wattage must be lower than existing total incandescent wattage to qualify)

- $25 for installing 20-70W CMH fixtures (new construction), or as a replacement for incandescent fixtures.
- $15 for <25W CMH retrofit that replaces a 70-100W incandescent flood or spot lamp.

PMH (must be permanently-wired ballast and lamp retrofit or complete new fixture – screw in retrofit lamps do not qualify)

- $25 per fixture to replace a 400W HID with 320W PMH (retrofit only)
- $50 to install a 320W electronic ballast and PMH or CMH lamp instead of or replacing 400W HID fixtures/components (retrofit and new construction)
- $50 to install a 750W PMH instead of or replacing 1000W HID fixtures/components (retrofit and new construction)
- $15 per controlled HID fixture using a occupancy based high/low control

The following incentives are offered for replacing HID fixtures with T8 or T5HO linear fluorescent high-bay fixtures or using fluorescent fixtures in new construction:

- $25 per <155 total fixture watts (4-lamp T8, 2-lamp T5HO, 3-lamp T5HO, or other T8 or T5HO <155W) replacing 250-399W HID
- $25 per <365 total fixture watts (6-lamp T5HO, 8-lamp T8, or other T8 or T5HO <365W) replacing 400-999W HID
- $50 per <250 total fixture watts (6-lamp T8, 4-lamp T5HO, or other T8 or T5HO <250W) replacing 400-999W HID
- $50 per <800 total fixture watts (two 6-lamp T5HO or other T8 or T5HO between 500W and 800W) replacing 1000W HID
- $100 per <500 total fixture watts (6-lamp T5HO, 8-lamp T5HO, 8-lamp T8, 10-lamp T8, two 6-lamp T8, two 4-lamp T5HO, or other T8 or T5HO <500W) replacing 1000W HID

LED exterior fixtures are eligible for rebates if a>40% wattage reduction from existing HID fixtures is achieved for all HID fixture types.

- $40/fixture for LED pole mounted fixture and canopy fixture

- $25/fixture for LED wall-pack and parking garage fixture

For agribusiness facilities, the following incentives are offered:

- $25 per fixture to install 320W PMH gasketed fixtures/components designated as "suitable for wet locations" instead of, or as a replacement for, 400W HID fixtures of the same classification

- $40 per fixture to install 300W induction fixtures/components instead of, or as a replacement for, 400W HID fixtures

- $25 and $50 per fixture to install high ceiling fluorescent fixtures instead of, or as a replacement for, 250-399W and 400-999W HID fixtures, respectively

LED exterior fixtures are eligible for rebates if a>40% wattage reduction from existing HID fixtures is achieved for all HID fixture types.

- $40/fixture for LED pole mounted fixture and canopy fixture

- $25/fixture for LED wall-pack fixture

Other energy efficiency lighting may be considered under the custom rebates program.

More information: http://www.ecec.com/content/main.php?button=Incentives

http://www.focusonenergy.com/Incentives/Business/Lighting.aspx

http://www.focusonenergy.com/about/participating-utilities

Riverland Energy Cooperative offers $15 per fixture for CMH, PMH and HPS replacements. Only retrofit applications are applicable. Custom rebates may also be available for use of other energy efficient lighting.

More information: http://www.riverlandenergy.com/content/rebates