RULEMAKING OVERVIEW AND PRELIMINARY MARKET AND TECHNOLOGY ASSESSMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS:

Set-top Boxes and Network Equipment

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U.S. Department of Energy
Assistant Secretary
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Appliances and Commercial Equipment Standards
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CHAPTER 1. INTRODUCTION

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LIST OF ACRONYMS

ACA	American Cable Association
APD	Auto Power Down
CA	Conditional Access
CEA	Consumer Electronics Association
CO_2	Carbon dioxide
DIF	Digital Interoperability Forum
DOCSIS	Data Over Cable Service Interface Specification
DOE	Department of Energy
DSL	Digital Subscriber Line
DTA	Digital Transport Adapter
DVR	Digital Video Recorder
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FM	Frequency Modulation
HD	High Definition
HD-DVR	High-Definition Digital Video Recorder
HEVC	High Efficiency Video Coding
HomePNA	Home Phoneline Networking Alliance
IP	Internet Protocol
IPTV	Internet Protocol Television
kWh	Kilowatt-hours
MoCA	Multimedia over Coax Alliance
MSTV	Association for Maximum Service Television
NAB	National Association of Broadcasters
NCTA	National Cable and Telecommunications Association
OTA	Over the Air
OTT	Over-the-top
RUI	Remote User Interface
SBCA	Satellite Broadcasting and Communication Association
SD	Standard Definition
SD-DVR	Standard Definition Digital Video Record
STB	Set-Top Box
TEC	Total Energy Consumption (kWh/year)
TWh	Terawatt-hours (equal to 1 billion kWh)
UEC	Unit Energy Consumption

CHAPTER 1. INTRODUCTION

1.1 SCOPE AND PURPOSE OF DOCUMENT

The United States (U.S.) Department of Energy (DOE) Appliances and Commercial Equipment Standards Program, within the Office of Energy Efficiency and Renewable Energy (EERE)'s Building Technologies Program (BT), develops and promulgates test procedures and energy conservation standards for consumer appliances and commercial equipment. As a general matter, the process for developing standards involves analysis, public notice, and consultation with interested parties.

Title III of the Energy Policy and Conservation Act (EPCA), as amended (42 U.S.C. 6291 *et seq.*), sets forth various provisions designed to improve energy efficiency. Part A of Title III of EPCA (42 U.S.C. 6291–6309) established the Energy Conservation Program for Consumer Products Other Than Automobiles," which covers consumer products and certain commercial products (referred to as "covered products")[a]. In addition to specifying a list of covered residential and commercial products, EPCA contains provisions that enable the Secretary of Energy to classify additional types of consumer products as covered products.

DOE recently published a Notice of Proposed Determination (76 FR 34914, June 15, 2011) (hereafter referred to as "proposed determination") that preliminarily determined that set-top boxes (STBs) and network equipment meet the criteria for covered products because classifying products of such type as covered products is necessary or appropriate to carry out the purposes of EPCA, and the average U.S. household energy use for STBs and network equipment is likely to exceed 100 kilowatt-hours (kWh) per year. As a result, DOE has initiated test procedure and energy conservation standards rulemaking activities for STBs and network equipment. DOE may prescribe energy conservation standards if the product meets certain additional criteria, such as "average per household energy use within the United States" in excess of 150 kWh and "aggregate household energy use" in excess of 4.2 billion kWh, for any prior 12-month period. (42 U.S.C. 6295(l)(1))

This document is a stand-alone report that provides an overview of the rulemaking process for the benefit of interested parties, and provides a preliminary market and technology assessment for STBs. The preliminary assessments are subject to revision in future phases of the rulemaking process, and do not constitute a final assessment by DOE.

[a] For editorial reasons, upon codification in the U.S. Code, Part B was re-designated Part A.

1.2 STRUCTURE OF DOCUMENT

The document is structured as follows:

- Chapter 1: Introduction.
- Chapter 2: Rulemaking and Analytical Overview. This chapter details the rulemaking process and how DOE generally seeks input from interested parties over the course of the rulemaking activity. This chapter also outlines all the stages of the analysis that DOE typically performs in support of energy conservation standards.
- Chapter 3: Preliminary Market Assessment. This chapter provides an initial overview of the current STB market, including major manufacturers, major service providers, annual shipments, installed base, average prices, and existing mandatory and voluntary regulatory programs.
- Chapter 4: Preliminary Technology Assessment. This chapter provides an initial overview of the current technology used in STBs, unit and national energy consumption, and opportunities for energy reduction. The chapter also discusses potential product evolution in the near future.
- Appendix. The appendix provides a list of definitions relevant to STBs.

CHAPTER 2. RULEMAKING AND ANALYTICAL OVERVIEW

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CHAPTER 2. RULEMAKING AND ANALYTICAL OVERVIEW

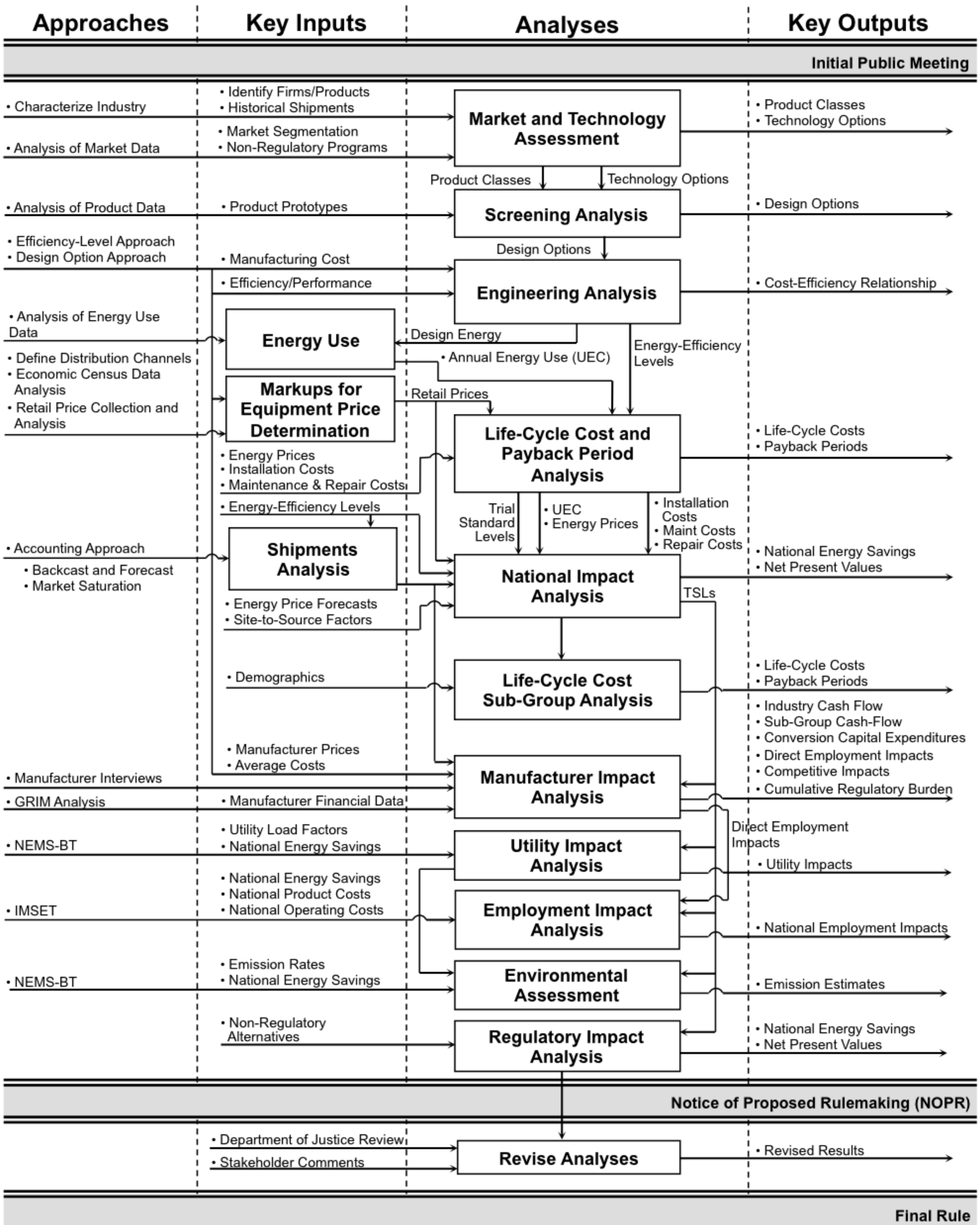
2.1 INTRODUCTION

The purpose of this chapter is to provide an overview of the rulemaking process and to describe the procedural and analytical approaches that DOE anticipates using to evaluate energy conservation standards for STBs and network equipment. This chapter is also intended to inform interested parties of the process of the standards rulemaking for STBs and network equipment and to encourage and facilitate stakeholder input during the rulemaking. It should be noted that this chapter is merely the starting point for developing standards and is not a definitive statement with respect to any issue to be determined in the rulemaking.

Section 6295(o)(2)(A) of 42 U.S.C. requires DOE to set forth energy conservation standards that are technologically feasible and economically justified and would result in significant additional energy conservation. The analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. This chapter discusses the analysis DOE intends to conduct to fulfill the statutory requirements and guidance for this standards rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost; economic impact on manufacturers and users; national benefits; impacts, if any, on utility companies; and impacts, if any, from lessening competition among manufacturers. Information regarding this rulemaking will be maintained on the DOE website at:
http://www.eere.energy.gov/buildings/appliance_standards/

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The focus of this figure is the center column, identified as "Analyses." The columns labeled "Key Inputs" and "Key Outputs" 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 stakeholders or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Lines connecting analyses show types of information that feed from one analysis to another. In general, the key outputs of each stage of the analysis become key inputs for the subsequent stages of analysis.

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process



The analyses performed and reported as part of the rulemaking process include:

- A market and technology assessment to characterize the relevant markets and existing technology options, including prototype designs.

- A screening analysis to review each technology option to decide whether it is technologically feasible; is practicable to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.

- An engineering analysis to develop cost-efficiency relationships that indicate the manufacturer's cost of achieving increased efficiency.

- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) to the cost to the consumer.

- An analysis of the annual energy use of the considered products.

- Life-cycle cost (LCC) and payback period (PBP) analyses to calculate, at the consumer level, the savings in operating costs (minus maintenance and repair costs) throughout the estimated average lifetime of the considered products, compared to any increase in purchase and installation cost likely to result from increased energy efficiency.

- A shipments analysis to forecast shipments of the considered products, which are then used to calculate the national impacts of standards on energy and net present value (NPV).

- A national impact analysis (NIA) to assess aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the national energy savings (NES) and net present value (NPV) of total consumer economic impacts.

- A manufacturer impact analysis (MIA) to assess the potential impacts of energy conservation standards on manufacturers' capital conversion expenditures, marketing costs, shipments, and research and development costs.

- An environmental assessment (EA) to analyze the potential reduction in power plant emissions of CO_2, NO_X and Hg resulting from reduced consumption of electricity associated with energy savings from the considered products.

- A monetization of emissions reduction benefits to estimate the monetary value of benefits resulting from reduced emissions of CO_2 and NO_X.

Section 2.2 provides an overview of the rulemaking process. The analyses are described in more detail in sections 2.3 to 2.17.

2.2 RULEMAKING PROCESS AND STAKEHOLDER PARTICIPATION

When DOE evaluates any new or amended energy conservation standard for "covered products" under EPCA, the statute, as amended, specifies that any standard DOE prescribes for consumer products shall be designed to "achieve the maximum improvement in energy efficiency. . . which the Secretary [of Energy] determines is technologically feasible and economically justified." (42 U.S.C. 6295(o)(2)(A)) Moreover, EPCA states that the Secretary may not establish an amended standard if such standard would not result in "significant conservation of energy," or "is not technologically feasible or economically justified." (42 U.S.C. 6295(o)(3)(B)) In determining whether a standard is economically justified, DOE considers, to the greatest extent practicable, the following seven factors:

1) The economic impact of the standard on the manufacturers and on the consumers of the products subject to such standard;
2) The savings in operating costs throughout the estimated average life of the covered products in the type (or class) compared to any increase in the price, or in the initial charges for, or maintenance expenses of the covered products which are likely to result from the imposition of the standard;
3) The total projected amount of energy (or as applicable, water) savings likely to result directly from the imposition of the standard;
4) Any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;
5) The impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;
6) The need for national energy and water conservation; and
7) Other factors the Secretary considers relevant.
   (42 U.S.C. 6295(o)(2)(B)(i) and 42 U.S.C. 6316(a))

Additional statutory requirements for prescribing new or amended standards are set forth in 42 U.S.C. 6295(o)(1)–(2)(A), (2)(B)(ii)(iii), and (3)–(5); 42 U.S.C. 6316(a).

The process for developing efficiency standards involves analysis, public notice, and consultation with interested parties. Such parties (collectively referred to as stakeholders) generally include manufacturers, consumers, energy conservation and environmental advocates, State and Federal agencies, and any other groups or individuals with an interest in energy conservation standards and test procedures. DOE considers stakeholder participation to be a very important part of the rulemaking process. Accordingly, DOE actively encourages the participation and interaction of all stakeholders during the comment period provided at each stage of the rulemaking. The broad array of stakeholders who routinely provide comments promotes a balanced discussion of critical information required to conduct the standards rulemaking.

In conducting the test procedure rulemakings and the energy (and water) conservation standards rulemakings, DOE involves stakeholders through a variety of means, including formal public notifications (*i.e.*, Federal Register notices) and public meetings. As discussed in further detail below, DOE anticipates the standards rulemaking process for STBs and network equipment to involve two major public notices, which will be published in the Federal Register:

- Notice of proposed rulemaking (NOPR). The NOPR will present: (a) a discussion of select comments received in response to any Request for Information (RFI); (b) the analysis of the impacts of standards on consumers, manufacturers, and the nation; (c) DOE's weighting of the impacts; and (d) the proposed standard levels for public comment.

- Final rule (see section 1.5). The final rule will present: (a) a discussion of comments received in response to the NOPR; (b) the revised analysis of the impacts of standards; (c) DOE's weighting of the impacts; and (d) the standard levels DOE is adopting. The final rule also establishes the compliance dates of the standards.

In addition, DOE will publish in the Federal Register a final determination of STBs and network equipment as a covered consumer product. The final determination will present: (a) a final definition of the covered products; and (b) responses to comments received from the proposed determination (76 FR 34914, June 15, 2011).

2.2.1 Notice of Proposed Rulemaking

In developing the NOPR, DOE will first review and consider all the comments it received in response to any prior RFI. DOE will conduct complete engineering, economic, and environmental impact analyses at this stage of the rulemaking. These analyses generally include a consumer LCC subgroup analysis, a complete manufacturer impact analysis, a utility impact analysis, an employment impact analysis, an environmental assessment, and a regulatory impact analysis. See below for a description of these analyses.

DOE will describe the methodology used and make the results of all the analyses available on its website for review and comments. Based on comments by stakeholders, further revisions to the analysis may be undertaken. This analytical process ends with the selection of proposed standard levels (if any) that DOE will present in the NOPR. DOE selects the proposed standard levels from the trial standard levels (TSLs) analyzed during the NOPR phase of the rulemaking. The NOPR, published in the Federal Register, will document the evaluation and selection of any proposed standards levels, along with a discussion of other TSLs considered but not selected (and the reasons for not selecting them).

The selection process for proposed efficiency standards generally runs as follows. For each product class, DOE will identify the maximum improvement in energy efficiency or maximum reduction in energy use that is technologically feasible. If DOE proposes a level that is below this maxtech level, it will sequentially explain the reasons for eliminating higher levels, beginning with the highest level considered. DOE will present the analysis results in the NOPR, with the details of the analysis provided in an accompanying Technical Support Document (TSD).

DOE considers many factors in selecting proposed standards, as described above in section 2.2. These factors and criteria are established by EPCA and take into account the many benefits, costs, and impacts of energy conservation standards. Additionally, DOE encourages stakeholders to develop joint recommendations for standard levels. DOE will carefully consider such recommendations in its decision process.

When DOE publishes the NOPR, it will provide the U.S. Department of Justice (DOJ) with a copy of the NOPR and TSD, in order to solicit feedback on the impact of the proposed standard levels on competition. DOJ will review these standard levels in light of any lessening of competition that is likely to result from the imposition of standards. (42 U.S.C. 6295(o)(2)(B)(i)(V) and (B)(ii)) DOE will consider DOJ's determination on the impacts of the proposed standard on competition in preparing the final rule. The NOPR is followed by a public comment period that includes one public meeting. DOE anticipates the comment period to be 50 days for STBs and network equipment.

2.2.2 Final Rule

After the publication of the NOPR, DOE will consider public comments it receives on the proposal (including TSLs) and accompanying analyses. On the basis of the public comments, DOE will review the engineering and economic impact analyses and proposed standards and make modifications as necessary. In addition, before it issues the final rule, DOE will consider DOJ's comments on the NOPR relating to the impacts of the proposed standard levels on competition, to determine whether changes to these standard levels are needed.

The standards rulemaking will conclude with the publication of the final rule. DOE will select the final standard levels based on the complete record of the standards rulemaking. The final rule will promulgate the final standard levels and their compliance date and explain the basis for their selection. The final rule will be accompanied by a final TSD.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including prototype designs, for STBs and network equipment.

2.3.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the products concerned. This activity assesses the industry and products, both quantitatively and qualitatively, based on publicly available information. As such, for the considered products, DOE will address the following: (1) manufacturer market share and characteristics; (2) existing regulatory and non-regulatory product efficiency improvement initiatives; and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE reviews existing literature and interview manufacturers to get an overall picture of the markets for the considered products in the United States. Industry publications and trade journals, market research firms, government agencies, and trade organizations provide the bulk of the information, including information on: (1) manufacturers and their market share; (2) shipments by capacity; and (3) market saturation. DOE uses the most reliable and accurate data available at the time of each analysis in the rulemaking. All data will be available for public review.

2.3.2 Technology Assessment

DOE typically uses information relating to existing and past technology options and prototype designs as inputs to determine what technologies manufacturers use to attain higher performance levels. In consultation with stakeholders, DOE develops a list and description of technologies for consideration for possible increases in energy efficiency of future products. Initially, these technologies encompass all those DOE believes are technologically feasible.

DOE also develops its list of technologically feasible design options through consultation with industry analysts and manufacturers of components and systems, and from trade publications and technical papers. Since many options for improving product efficiency are available in existing units, product literature and direct examination provide additional information.

2.4 SCREENING ANALYSIS

The screening analysis examines various technologies as to whether they: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. As described in section 2.3.2 above, DOE develops an initial list of efficiency-enhancement options from the technologies identified as technologically feasible in the technology assessment. Then DOE, in consultation with interested parties, reviews the list to determine if these options are practicable to manufacture, install, and service, would adversely affect product utility or availability, or would have adverse impacts on health and safety. In addition, DOE removes from the list technology options that lack energy consumption data as well as technology options whose energy consumption cannot be adequately measured by existing DOE test procedures. In the engineering analysis, DOE further considers efficiency enhancement options that it did not screen out in the screening analysis.

2.5 ENGINEERING ANALYSIS

The engineering analysis establishes the relationship between the manufacturing production cost (MPC) and the efficiency for each class of STB and network equipment. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the nation. The engineering analysis discusses the product classes DOE analyzes, the representative baseline units, the incremental efficiency levels, the methodology DOE uses to develop the manufacturing production costs, the cost-efficiency curves, the projected impact of efficiency improvements on the considered products, and the methodology DOE uses to extend the analysis to low-shipment-volume product classes.

In the engineering analysis, DOE evaluates a range of product efficiency levels and their associated manufacturing costs. The purpose of the analysis is to estimate the incremental MPCs for a product that would result from increasing efficiency levels above the level of the baseline model in each product class. The engineering analysis considers technologies not eliminated in the screening analysis, although certain technologies are not analyzed due to negligible incremental efficiency improvements or the inability of existing DOE test procedures to measure any reduction in energy use. DOE considers the remaining technologies, designated as design options, in developing the cost-efficiency curves, which are subsequently used for the LCC and PBP analyses.

DOE typically structures its engineering analysis around one of three methodologies: (1) the design-option approach, which calculates the incremental costs of adding specific design options to a baseline model; (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels without regard to the particular design options used to achieve such increases; and/or (3) the reverse-engineering or cost-assessment approach, which involves a "bottom-up" manufacturing cost assessment based on a detailed bill of materials derived from tear-downs of the product being analyzed.

Combinations of these approaches involve physically disassembling commercially available products, consulting with outside experts, reviewing publicly available cost and performance information, and modeling equipment cost. The efficiency levels that DOE considers in the engineering analysis are attainable using technologies currently available on the market or have been demonstrated in working prototypes. In addition, DOE associates some of the efficiency levels with specific technologies that manufacturers might use to provide interested parties with additional transparency of assumptions and results and the ability to perform independent analyses for verification.

2.6 MARKUPS ANALYSIS

DOE uses markups to convert the manufacturer costs estimated in the engineering analysis to consumer prices, which are then used in the LCC and PBP, and manufacturer impact analyses. To develop markups, DOE identifies how the products are distributed from the manufacturer to the customer. DOE calculates markups for baseline products (baseline markups) and for more efficient products (incremental markups). The incremental markup relates the change in the manufacturer sales price of higher-efficiency models (the incremental cost increase) to the change in the retailer or distributor sales price.

2.7 ENERGY USE ANALYSIS

The energy use analysis, which assesses the energy savings potential from higher efficiency levels, provides the basis for the energy savings values used in the LCC and subsequent analyses. The goal of the energy use analysis is to generate a range of energy use values that reflects actual product use in American homes. The analysis uses information on use of actual products in the field to estimate the energy that would be used by new products at various efficiency levels.

Measurements of field energy use often vary considerably from the rated usage as determined by the DOE test procedure. To determine the field energy use by products that would meet possible energy efficiency standards, DOE generally uses data for a wide range of households. An example of such data might include a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

New energy conservation standards affect products' operating expenses—usually decreasing them—and consumer prices for the products—usually increasing them. DOE analyzes the effect of imposing standards on consumers by evaluating changes in the LCC of owning and operating the product. To evaluate the change in LCC, DOE uses the cost-efficiency relationship derived in the engineering analysis, along with the usage derived from the energy use analysis. Inputs to the LCC calculation include the purchase price of a product, energy expenses associated with operating the product, the lifetime of the unit, and a discount rate.

Because the installed cost of a product typically increases while operating cost typically decreases in response to new standards, there is a time in the life of products having higher-than-baseline efficiency when the net operating-cost benefit (in dollars) since the time of purchase is equal to the incremental first cost of purchasing the higher-efficiency product. The length of time required for products to reach this cost-equivalence point is known as the payback period (PBP).

Recognizing that several inputs to the determination of consumer LCC and PBP are either variable or uncertain, DOE conducts the LCC and PBP analysis by modeling both the uncertainty and variability in the inputs using Monte Carlo simulation and probability distributions. DOE develops LCC and PBP spreadsheet models incorporating both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program).

As described above in section 2.7, DOE develops samples of individual households that use the considered product. DOE is able to perform the LCC and PBP calculations for each household to account for the variability in energy consumption and electricity price associated with actual users of the considered product. DOE identifies several other input values for estimating the LCC, including retail prices, discount rates, and product lifetime. DOE characterizes discount rates and product lifetime with probability distributions.

DOE develops discount rates for residential consumers from estimates of the interest rate, or finance cost, applied to purchases of residential products. Following accepted principles of financial theory, the finance cost of raising funds to purchase such products can be interpreted as: (1) the financial cost of any debt incurred to purchase products, principally interest charges on debt; or (2) the opportunity cost of any equity used to purchase products, principally interest earnings on household equity.

DOE considers installation, maintenance and repair costs for the efficiency levels considered in a rulemaking. Typically, small incremental changes in energy efficiency produce no, or only minor, changes in repair and maintenance costs over baseline efficiency products. Products having efficiencies that are significantly greater than baseline models can incur increased repair and maintenance costs, as they are more likely to incorporate technologies that are new to the industry.

2.9 SHIPMENTS ANALYSIS

Forecasts of product shipments are needed to calculate the national impacts of standards on energy use and NPV, and future manufacturer cash flows. DOE develops shipment forecasts based on an analysis of key market drivers for each considered product. In DOE's shipments model, shipments of products are driven by new housing construction, stock replacements, and other types of purchases.

The shipments models take an accounting approach, tracking market shares of each product class and the vintage of units in the existing stock. Stock accounting uses product shipments as inputs to estimate the age distribution of in-service product stocks for all years. The age distribution of in-service product stocks is a key input to calculations of both the NES and NPV, because operating costs for any year depend on the age distribution of the stock.

DOE also considers the impacts on shipments from changes in product purchase price and operating cost associated with higher energy efficiency levels.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the NES. DOE determines the NPV and NES for the efficiency levels considered for each of the product classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepares a Microsoft Excel spreadsheet model to forecast NES and the national consumer economic costs and savings resulting from new standards. The spreadsheet model uses typical values as inputs (as opposed to probability distributions). To assess the effect of input uncertainty on NES and NPV results, DOE may conduct sensitivity analyses by running scenarios on specific input variables.

Several of the inputs for determining NES and NPV depend on the forecast trends in product energy efficiency. For the base case (which presumes no standards), DOE uses the efficiency distributions developed for the LCC analysis, and assumes some rate of change over the forecast period. DOE typically uses a roll-up scenario in developing its forecasts of efficiency trends after standards take effect. Under a roll-up scenario, all products that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Product efficiencies above the standard level under consideration would remain the same as before the standard takes effect.

2.10.1 National Energy Savings

The inputs for determining the NES for each product analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) product stock; (4) national energy consumption; and (5) site-to-full-fuel-cycle conversion factors. DOE calculates the national energy consumption by multiplying the number of units, or stock, of each product (by vintage, or age) by the unit energy consumption (also by vintage). DOE calculates annual NES based on the difference in national energy consumption for the base case (without new efficiency standards) and for each higher efficiency standard. DOE estimates energy consumption and savings based on site energy, and converts the electricity consumption and savings to full-fuel cycle energy. Cumulative energy savings are the sum of the NES for each year in the forecast period.

2.10.2 Net Present Value of Consumer Benefit

The inputs for determining NPV of the total costs and benefits experienced by consumers of the considered products are: (1) total annual installed cost; (2) total annual savings in operating costs; (3) a discount factor; (4) present value of costs; and (5) present value of savings. DOE calculates net savings each year as the difference between the base case and each standards case in total savings in operating costs and total increases in installed costs. DOE calculates savings over the life of each product. NPV is the difference between the present value of operating cost savings and the present value of total installed costs. DOE typically uses a discount factor based on real discount rates of 3% and 7% to discount future costs and savings to present values.

DOE calculates increases in total installed costs as the difference in total installed cost between the base case and standards case (*i.e.*, once the standards take effect). Because the more efficient products bought in the standards case usually cost more than products bought in the base case, cost increases appear as negative values in the NPV. DOE expresses savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base efficiency case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

In addition to calculating the NPV of consumer benefit, DOE calculates a benefit that combines the NPV of the consumer savings, calculated for each efficiency level using 3% and 7% discount rates, with the present value of the potential economic benefits resulting from reduced CO_2 and NO_X emissions. See sections 2.15 and 2.16 for a discussion of the emissions analysis and monetization of emissions reduction.

2.11 CONSUMER SUBGROUP ANALYSIS

The consumer subgroup analysis evaluates economic impacts on selected groups of consumers who might be adversely affected by a change in the national energy conservation standards for the considered products. DOE evaluates impacts on particular subgroups of consumers primarily by analyzing the LCC impacts and PBP for those particular consumers using the LCC spreadsheet model.

DOE typically analyzes the following subgroups: (1) low-income households; and (2) households solely occupied by senior citizens.

2.12 MANUFACTURER IMPACT ANALYSIS

The MIA assesses the impacts of new energy conservation standards on manufacturers of the considered products. Potential impacts include financial effects, both quantitative and qualitative, that might lead to changes in the manufacturing practices for these products. DOE identifies these potential impacts through interviews with manufacturers and other interested parties.

DOE typically conducts the MIA in three phases, and further tailors the analytical framework based on interested parties' comments. In Phase I, an industry profile is created to characterize the industry, and a preliminary MIA is conducted to identify important issues that require consideration. In Phase II, an industry cash flow model and an interview questionnaire are prepared to guide subsequent discussions. In Phase III, manufacturers are interviewed, and the impacts of standards are assessed both quantitatively and qualitatively. Industry and subgroup cash flow and NPV are assessed through use of the Government Regulatory Impact Model (GRIM). Then impacts on competition, manufacturing capacity, employment, and cumulative regulatory burden are assessed based on manufacturer interview feedback and discussions.

2.13 EMPLOYMENT IMPACT ANALYSIS

New energy conservation standards can impact employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products, and at the affiliated distribution and service companies, resulting from the adoption 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 adoption of standards.

DOE typically investigates the combined direct and indirect employment impacts of standards using the Pacific Northwest National Laboratory (PNNL)'s "Impact of Sector Energy Technologies" (ImSET) model. The ImSET model, which was developed for DOE's Office of Planning, Budget, and Analysis, estimates the employment and income effects energy-saving technologies produced 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.

2.14 UTILITY IMPACT ANALYSIS

The utility impact analysis estimates the effects of energy conservation standards on installed electricity generation capacity and electricity generation. DOE typically adapts NEMS, which is a large multi-sectoral, partial-equilibrium model of the U.S. energy sector that the Energy Information Administration (EIA) has developed throughout the past decade, primarily for preparing EIA's *Annual Energy Outlook* (AEO). In previous rulemakings, a variant of NEMS (currently termed NEMS-BT, BT referring to DOE's Building Technologies Program), was developed to better address the specific impacts of an energy conservation standard. NEMS, which is available in the public domain, produces a widely recognized baseline energy forecast for the United States. The typical NEMS outputs include forecasts of electricity and natural gas sales, prices, and electric generating capacity.

DOE conducts the utility impact analysis as a scenario that departs from the latest AEO reference case. In other words, the energy savings impacts from amended energy conservation standards are modeled using NEMS-BT to generate forecasts that deviate from the AEO reference case.

2.15 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimates the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), and mercury (Hg) from potential energy conservation standards. DOE uses the NEMS-BT computer model, which is run similarly to the AEO NEMS model, except that product energy use is reduced by the amount of energy saved (by fuel type) at each TSL. The inputs of national energy savings come from the NIA spreadsheet model, while the output is the forecasted physical emissions. The net benefit of each TSL is the difference between the forecasted emissions estimated by NEMS-BT at each TSL 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. For the NOPR, DOE intends to use the version of NEMS-BT based on latest AEO release, which incorporates projected effects of all emissions regulations promulgated as of its release date. For the final rule, DOE intends to revise the emissions analysis, if necessary, using the most current version of NEMS-BT.

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap-and-trade programs, and DOE has preliminarily determined that these programs create uncertainty about the impact of potential energy conservation standards 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. are also limited under the Clean Air Interstate Rule (CAIR; 70 FR 25162 (May 12, 2005)), which created an allowance-based trading program. Although CAIR was remanded to 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, 2010, EPA issued the Transport Rule proposal, a replacement for CAIR. 75 FR 45210 (Aug. 2, 2010). On July 6, 2011 EPA issued the final Transport Rule, titled the Cross-State Air Pollution Rule. 76 FR 48208 (August 8, 2011). (See http://www.epa.gov/crossstaterule/). *AEO 2011* NEMS assumes the implementation of CAIR, although future iterations of the NEMS-BT model will incorporate any changes necessitated by issuance of the Transport Rule.

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. However, if potential energy conservation standards resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

As discussed above, the *AEO 2011* NEMS assumes the implementation of CAIR, which established a cap on NO_X emissions in 28 eastern States and the District of Columbia. With CAIR in effect, energy conservation standards are typically expected to have little or no physical effect on NO_X emissions in those States covered by CAIR, for the same reasons that they may have little effect on SO_2 emissions. However, potential energy conservation standards would be expected to reduce NO_X emissions in the 22 States not affected by CAIR. For these 22 States, DOE uses the NEMS-BT to estimate NO_X emissions reductions from potential energy conservation standards.

Similar to emissions of SO_2 and NO_X, future emissions of Hg would have been subject to emissions caps. In May 2005, EPA issued the Clean Air Mercury Rule (CAMR). 70 FR 28606 (May 18, 2005). CAMR would have permanently capped emissions of mercury for new and existing coal-fired power plants in all states by 2010. However, on February 8, 2008, the D.C. Circuit issued a decision in *New Jersey v. Environmental Protection Agency*, 517 F.3d 574 (D.C. Cir. 2008), in which it vacated CAMR. EPA has decided to develop emissions standards for power plants under Section 112 of the Clean Air Act, consistent with the DC Circuit's opinion on CAMR. See http://www.epa.gov/air/mercuryrule/pdfs/certpetition_withdrawal.pdf. Pending EPA's forthcoming revisions to the rule, DOE is excluding CAMR from its emissions assessment. In the absence of CAMR, a potential energy conservation standard would likely reduce Hg emissions and DOE uses NEMS-BT to estimate these reductions. However, DOE continues to review the impact of rules that reduce energy consumption on Hg emissions, and may revise its assessment of Hg emission reductions in the future.

2.16 MONETIZING CARBON DIOXIDE AND OTHER EMISSIONS IMPACTS

As part of the development of a potential energy conservation standard, DOE considers 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 TSLs considered. In order to make this calculation similar to the calculation of the NPV of consumer benefit, DOE considers the reduced emissions expected to result over the lifetime of products shipped in the forecast period for each TSL. This section summarizes the basis for the monetary values used for each of these emissions.

DOE relies on a set of values for the social cost of carbon (SCC) that was developed by an interagency process. A summary of the basis for these values is provided below.

2.16.1 Social Cost of Carbon

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 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.

2.16.1.1 Monetizing Carbon Dioxide Emissions

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. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Research

Council[a] 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 carbon dioxide emissions. Consistent with the directive in Executive Order 12866 quoted above, the purpose of the SCC estimates presented here is to make it possible for Federal agencies to incorporate the social benefits from reducing carbon dioxide 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 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 carbon dioxide 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. This concern is not applicable in general to energy conservation standards, and DOE does not attempt to answer that question here.

At the time of the preparation of this document, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010, expressed in 2010$, were $4.9, $22.3, $36.5, and $67.6 per metric ton avoided. 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,[b] although preference is given to consideration of the global benefits of reducing CO_2 emissions.

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, the interagency group has 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, the interagency group

[a] National Research Council. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* National Academies Press: Washington, DC (2009).

[b] It is recognized that this calculation for domestic values is 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.

will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

2.16.1.2 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 carbon dioxide emissions. In the final model year 2011 CAFE rule, the U.S. 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 (in 2007\$), increasing both values at 2.4 percent per year.[c] DOT also included a sensitivity analysis at \$80 per ton of CO_2. See *Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011*, 74 FR 14196 (March 30, 2009) (Final Rule); Final Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015 at 3-90 (Oct. 2008) (Available at: http://www.nhtsa.gov/fuel-economy). A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide 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 of CO_2 (in 2006\$) for 2011 emission reductions (with a range of \$0−\$14 for sensitivity analysis), also increasing at 2.4 percent per year. See *Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015*, 73 FR 24352 (May 2, 2008) (Proposed Rule); Draft Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015 at 3-58 (June 2008) (Available at: http://www.nhtsa.gov/fuel-economy). A regulation for packaged terminal air conditioners and packaged terminal heat pumps finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO_2 for 2007 emission reductions (in 2007\$). 73 FR 58772, 58814 (Oct. 7, 2008) In addition, EPA's 2008 Advance Notice of Proposed Rulemaking on Regulating Greenhouse Gas Emissions Under the Clean Air Act identified what it described as "very preliminary" SCC estimates subject to revision. 73 FR 44354 (July 30, 2008). EPA's global mean values were \$68 and \$40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 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 carbon dioxide 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. 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

[c] Throughout this section, references to tons of CO2 refer to metric tons.

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.

2.16.1.3 Current Approach and Key Assumptions

Since the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates. 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. 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.

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: 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.

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. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time, as depicted in Table 2.16.1.

Table 2.16.1 Social Cost of CO_2, 2010–2050 (in 2007 dollars per metric ton)

	Discount Rate			
	5% Avg	3% Avg	2.5% Avg	3% 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

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 Federal agencies participating in the interagency process to estimate the SCC.

DOE recognizes the uncertainties embedded in the estimates of the SCC used for cost-benefit analyses. As such, DOE and others in the U.S. Government intend to periodically review and reconsider those estimates 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.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE uses the most recent values identified by the interagency process, adjusted to current dollars using the GDP price deflator. For each of the four cases specified, the values used for emissions in 2010 are \$4.9, \$22.3, \$36.5, and \$67.6 per metric ton avoided (values expressed in 2010\$). To monetize the CO_2 emissions reductions expected to result from new OR amended energy conservation standards, DOE uses the values identified in Table A1 of the "Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,"[d] appropriately adjusted to current dollars. To calculate a present value of the stream of monetary values, DOE discounts 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.

[d] Table A1 presents SCC values through 2050. For DOE's calculations, it derives values after 2050 using the 3-percent per year escalation rate used by the interagency group.

2.16.2 Valuation of Other Emissions Reductions

DOE investigates the potential monetary benefit of reduced NO_X emissions from the TSLs it considers. As noted above, DOE takes into account how new OR amended energy conservation standards would reduce NO_X emissions in those 22 States not affected by the CAIR. DOE estimates 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 $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $450 to $4,623 per ton in 2010$).[e] In accordance with OMB guidance, DOE conducts 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.[f]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg emissions in its rulemakings.

2.17 REGULATORY IMPACT ANALYSIS

DOE prepares a regulatory impact analysis (RIA) under Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735, October 4, 1993, which is subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) at the Office of Management and Budget. The RIA evaluates non-regulatory alternatives to standards, in terms of their ability to achieve significant energy savings in the considered products at a reasonable cost, and compares the effectiveness of each one to the effectiveness of the adopted standards.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can result in substantial improvements to energy efficiency or reductions in energy consumption. DOE considers the likely effects of non-regulatory initiatives on product energy use, consumer utility, and LCC. DOE bases its assessment on the actual impacts of any such initiatives to date, but also considers information presented regarding the impacts that any existing initiative might have in the future.

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

CHAPTER 3. PRELIMINARY MARKET ASSESSMENT

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CHAPTER 3. PRELIMINARY MARKET ASSESSMENT

3.1 INTRODUCTION

This chapter provides a preliminary assessment of the STB market in the United States. The assessment includes categories and potential product classes, major manufacturers, major service providers, relevant trade associations, annual shipments, the installed base, market trends, and emerging or niche market segments. This chapter also discusses existing mandatory and voluntary regulatory programs.

3.2 CATEGORIZING SET-TOP BOXES

A STB can be generically defined as a device whose primary function is to receive television or video signals and deliver them to a consumer display or recording device (see Appendix for a complete list of definitions). Market analysts and service providers categorize pay-TV STBs into three base types and four feature classes, resulting in 12 unique groups of pay-TV STBs (Table 3.2.1). This form of categorization distinguishes between: (1) what type of service provider (*i.e.*, base type) a consumer is choosing from, and (2) what pay-TV STB feature class a consumer is selecting for their home. In addition, there are over-the-top options (OTT) and other STBs that do not provide conditional access (see sections 3.9 and 3.10).

Table 3.2.1 Pay-TV STB Categories

Base Types
Cable
Satellite
Internet Protocol Television (IPTV)
Feature Classes
Standard definition (SD) receiver
High definition (HD) receiver
Standard definition digital video recorder (SD-DVR)
High definition digital video recorder (HD-DVR)

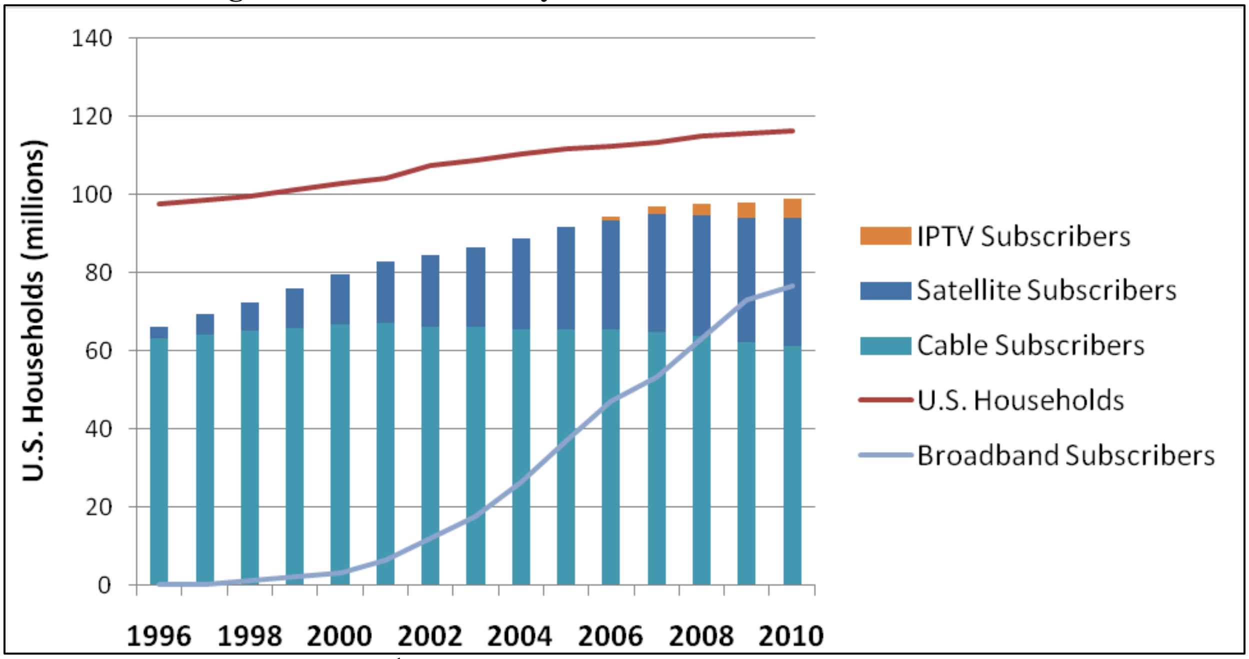
In addition, STBs without a DVR can have 1-way or 2-way communication with the service provider. 2-way communication allows for pay-per-view and video-on-demand functionality, although a DVR is necessary for such content to be stored locally. STBs with a DVR have 2-way communication. STBs with only 1-way communication currently represent a relatively small percentage of the market, and are losing market share in favor of 2-way STBs. 1-way cable STBs can be used, however, as an expensive way to connect secondary TVs with cable service in a home (as opposed to using simpler thin clients).

In general, market data for pay-TV STBs are presented in this format (and perhaps include a few additional feature classes). Existing STB energy efficiency policies, however, categorize STBs slightly differently. While the market segment (*e.g.*, Cable, Satellite, IPTV) of a STB remains a key distinction, feature class (*e.g.*, SD, HD, SD-DVR, HD-DVR) has not been used as a specific way of grouping STBs for existing standards purposes. HD and DVR capability are instead considered additional functionalities, not specific types of STBs, among many other types of additional functionalities (*e.g.*, advanced video processing, home network interface, multi-stream, multi-room, removable media player/recorder). A base functionality, determined by the market segment, combines with a set of additional functionalities (which can be used with any base type). This is the approach adopted by ENERGY STAR and with the European voluntary agreement, where the base functionality and additional functionalities determine the total energy consumption allowance for a given STB. When necessary, DOE divides covered products into product classes by the type of energy used, the capacity of the product, and any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) As part of this rulemaking proceeding, DOE will evaluate the market for STBs and potentially separate covered products into product classes based on the criteria described above.

3.3 MARKET OVERVIEW

The current STB market has developed into a complex mix of deployed devices and service offerings. Over 80 percent of U.S. homes subscribe to pay-TV provided by their cable, satellite or phone company (Figure 3.3.1), resulting in over 160 million installed pay-TV STBs in U.S. homes.[1] In recent years, however, viewership has declined as consumers moved to streaming online content only. Cable TV, in particular, lost over 2 million video subscribers in 2010, a bigger loss than the 1.5 million customers in 2009.[2] Nevertheless, pay-TV remains the biggest piece of the media consumption market. Some consumers are replacing their pay-TV service with broadband-based services using OTT options (including both hardware and software options), such as AppleTV, Netflix, and Roku. Traditional pay-TV service includes a monthly subscription fee with additional pay-per-view options (*e.g*., live events, movies), whereas OTT options include pay-per-view only (*e.g.*, AppleTV, Amazon Instant Video) or a monthly subscription for unlimited content (*e.g.*, Netflix, Hulu). Pay-TV service providers are now offering similar features on their STBs. This assessment focuses on the pay-TV STB market specifically in the following sections (3.4 to 3.8), but provides an overview of the separate market for over-the-top options in section 3.9 and stand-alone devices in section 3.10.

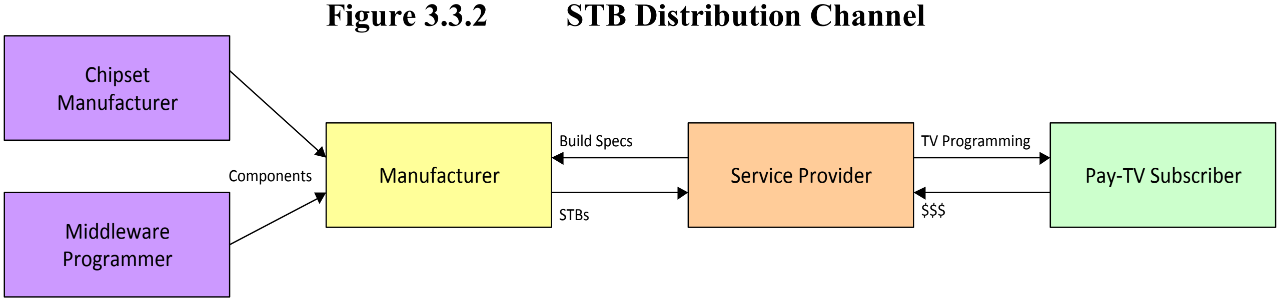
Figure 3.3.1 U.S. Pay-TV and Broadband Market Trends



Source: Hardy and Swofford (2011).[1] *Figure based on U.S. Census (www.tvb.org; OECD; and other public data).*[3] *Reprinted with permission.*

Pay-TV STB market actors fall into four main categories: (1) chip manufacturers, (2) middleware developers, (3) STB manufacturers and (4) service providers (Figure 3.3.2). This market assessment focuses on STB manufacturers and service providers as these two groups have the most influence on the energy consumption of pay-TV STBs. Hardware manufacturers design and produce STBs based on the demand and requirements of service providers. Service providers purchase a large number of STBs from these manufacturers.[4] The largest pay-TV service providers (*e.g.*, DirecTV and Comcast; see section 3.5) ultimately decide on the chipset, middleware, and features offered for a deployed STB. They then present these product offerings to smaller service providers as off-the-shelf designs to reduce development costs. After procurement, service providers control box deployment, configuration, maintenance, and refurbishment. All service providers own the STBs and supply them to the consumer as part of a service agreement.[4] As a result, any potential changes in STB design and operation require the involvement of all actors in this supply chain and distribution system, including the service providers. Figure 3.3.2 outlines the components in the STB distribution channel chain

Figure 3.3.2 STB Distribution Channel



3.4 MAJOR MANUFACTURERS

Service providers purchase their STBs through a bidding process that multiple manufacturers compete in to meet requested specifications at the lowest cost.[4] For example, a large service provider might specify a box including high definition video capability, MoCA networking capability, six tuners, and a DVR. Currently, Motorola, Cisco, Pace, and EchoStar own the majority of the STB manufacturing market in the U.S. (see Table 3.4.1). The development timeline for STB hardware is similar regardless of service provider type, typically ranging from 6 to 18 months for motherboard and system design and three to five years for silicon design. The 6 to18 month lead-time refers to the development of the motherboard and system based on available silicon technology.

Table 3.4.1 Major Pay-TV STB Manufacturers (2010)

Company	Market Share	Cable	Satellite	IPTV
Motorola	35%	x		x
Cisco	18%	x		x
Pace	18%	x	x	
EchoStar	12%		x	
Other	18%		N/A	

Note: These market shares are for U.S. STBs only.
Source: IMS Research.[5]

3.5 MAJOR SERVICE PROVIDERS

In the U.S., service providers supply the majority of STBs to the consumer. Major service providers have considerable influence over the manufacturer in terms of choice of middleware, content protection features, applications and other functionalities. The pay-TV STB market is different from the markets for most other consumer electronics devices, in that consumers have little influence on the type of STB installed in their home. Service providers use STBs to store the latest user information, electronic program guide data and security codes to ensure only paid subscribers have access to content.[4] These data are frequently updated (*e.g.*, dynamic channel allocation, dynamic security codes), which is one reason why some STBs require a relatively long time to wake-up from a deep sleep. Table 3.5.1 lists the top ten U.S. pay-TV service providers by number of subscribers. Table 3.5.2 shows STB purchases by service providers in 2010.

Table 3.5.1 Major Pay-TV Service Providers (2011)

Service Provider	Segment	Pay-TV Subscribers
Comcast	Cable	22,525,000
DirecTV	Satellite	19,433,000
Dish Network	Satellite	14,056,000
Time Warner Cable	Cable	12,235,000
Cox Communications	Cable	4,838,000
Charter Communications	Cable	4,413,000
Verizon (FiOS) Communications	Cable†	3,848,000
AT&T	IPTV	3,407,000
Cablevision Systems	Cable	3,284,000
Bright House Networks	Cable	2,139,000

† Verizon FiOS provides TV on a fiber optic backbone, using cable network technology inside the home. AT&T U-Verse uses IPTV technology to deliver content via high speed DSL.

Source: National Cable Telecommunications Association.[6]

Table 3.5.2 Estimated Purchases of STBs by Major Pay-TV Service Providers (2010, in thousands)

Service Provider	Grand Total
Comcast	16,430
DirecTV	7,413
Dish Network	5,293
AT&T	3,456
Verizon (FiOS) Communications	3,153
Time Warner Cable	2,293
Cox Communications	1,263
Charter Communications	1,048
Bright House Networks	793
Cablevision Systems	687
Other	904

Source: IMS Research.[5]

3.6 INDUSTRY TRADE GROUPS AND ASSOCIATIONS

STB manufacturers and service providers are typically associated with the following groups (descriptions are adapted from group websites):

American Cable Association (ACA). ACA's membership comprises of cable, phone, and fiber-to-the-home operators and municipalities, who deliver basic and advanced services, such as high definition television, next generation Internet access and digital phone, to more than 7 million

households and businesses, some of whom have no other means of receiving these services.
http://www.americancable.org/

Association for Maximum Service Television (MSTV). Trade organization focused on over-the-air broadcast technology and policy issues.
http://www.mstv.org/

CableLabs. Cable Television Laboratories, Inc. (CableLabs®) is a non-profit research and development consortium that is dedicated to pursuing new cable telecommunications technologies and to helping its cable operator members integrate those technical advancements into their business objectives.
http://www.cablelabs.com/

Consumer Electronics Association (CEA). CEA is a standards and trade organization for the consumer electronics industry in the United States.
http://www.ce.org/

Digital Living Network Alliance (DLNA). A collection of various companies, the DLNA has developed interoperability guidelines that outline standards for device communication and content sharing among various devices within the home.
http://www.dlna.org/

Multimedia over Coax Alliance (MoCA). MoCA is an open, international technology standard body promoting networking of multiple streams of high definition video around the home using the existing coaxial cabling. The MoCA standard uses the existing coax cabling in the home for connecting devices such as STBs, PVRs, home gateways, wireless access point and game consoles, among others.
http://www.mocalliance.org/

National Association of Broadcasters (NAB). NAB is a trade organization for radio and television broadcasters, serving its members' interests in federal government, industry and public affairs; improving the quality and profitability of broadcasting; encouraging content and technology innovation; and identifying ways stations serve their communities.
http://www.nab.org/

National Cable and Telecommunications Association (NCTA). The National Cable and Telecommunications Association, formerly the National Cable Television Association, is the principal trade association of the cable industry in the United States.
http://www.ncta.com/

RVU Alliance. The RVU Alliance is a consortium of leading content service provider, semiconductor and consumer electronics companies gathered to advance the use of Remote User Interface (RUI) technology for home networked television entertainment, ensuring interoperability among devices implementing RVU's RUI technology, and educating the market about RVU technology.
http://www.rvualliance.org/

Satellite Broadcasting and Communications Association (SBCA). The Satellite Broadcasting and Communications Association is the national trade organization representing all segments of the consumer satellite industry.
http://www.sbca.com/

3.7 ANNUAL SHIPMENTS, INSTALLED BASE, AND AVERAGE PRICES

Table 3.7.1 to Table 3.7.3 provide additional market data and forecasts for annual shipments, the installed base, and average prices of STBs. The average prices span all STB product classes (*e.g.*, SD, HD, DVR, thin client, etc.) estimated to be sold that year. Cable remains the most prominent form of pay-TV, but increased popularity of both satellite and IPTV service offerings may change the landscape over the next few years. In terms of feature classes, the HD-DVR box is gaining significant share across all three market segments.

Table 3.7.1 Estimated and Projected Shipments of Pay-TV STBs in the U.S. by Base Type and Feature Class (in thousands)

	2009	2010	*2011*	*2012*	*2013*	*2014*	*2015*
Cable	23,803	25,607	*25,007*	*26,867*	*21,474*	*19,693*	*18,874*
Satellite	12,563	13,348	*13,465*	*14,338*	*14,123*	*13,774*	*13,767*
IPTV	3,461	3,598	*3,753*	*4,527*	*4,483*	*4,767*	*5,109*
Total DVR	11,975	14,929	*16,656*	*19,934*	*18,099*	*17,734*	*16,876*
Total non-DVR	27,852	27,624	*25,569*	*25,798*	*21,981*	*20,500*	*20,874*

Source: IMS Research.[7]

Table 3.7.2 Estimated and Projected Installed Base of Pay-TV STBs in the U.S. by Base Type (in thousands)

	2009	2010	*2011*	*2012*	*2013*	*2014*	*2015*
Cable	80,228	95,206	*103,550*	*113,349*	*116,383*	*116,151*	*113,309*
Satellite	57,859	59,782	*62,147*	*62,138*	*60,353*	*57,347*	*54,125*
IPTV	5,997	8,508	*10,959*	*13,713*	*16,185*	*18,620*	*20,648*

Source: IMS Research.[7]

Table 3.7.3 Average Estimated and Projected Prices of Pay-TV STBs in the U.S. by Base Type

	2009	2010	*2011*	*2012*	*2013*	*2014*	*2015*
Cable	$61-$223	$56-$218	*$52-$214*	*$48-$210*	*$44-$195*	*$41-$189*	*$38-$183*
Satellite	$60-$190	$55-$180	*$51-$171*	*$47-$163*	*$44-$154*	*$41-$147*	*$40-$140*
IPTV	$94-$192	$132-$182	*$123-$173*	*$115-$165*	*$106-$156*	*$46-$149*	*$43-$141*

Source: IMS Research.[7]

3.8 RELEVANT CONSUMER ISSUES

3.8.1 Principal Agent Problem

Pay-TV STBs differ from other consumer electronics devices because the service provider owns the STB, not the consumer. Therefore, even though the consumer pays the electricity bill, it is the service provider that decides what STB is used and how much energy it uses.[1] This situation, where one entity pays the first cost but another pays the operating cost, is known as a principal agent problem.[8] The principal agent problem is most evident when service providers include the STB hardware as part of a rental agreement.[9] This service agreement, including leased equipment, is the most common arrangement in the U.S. pay-TV market today. The principal agent problem offers only limited incentive for service providers to deploy more costly energy efficient STBs, beyond any efficiency required for increased utility. Although STB manufacturers are capable of building more efficient STBs, they only build to the service provider specifications, which is largely cost and quality-of-service driven. This situation is potentially the most significant barrier to reducing the national energy consumption of STBs in the U.S.

3.8.2 Other Issues

Other key consumer issues include the following:

- Long Start-up Times. When a STB is powered off, it often takes two to five minutes to start (or “boot”) up and resume full functionality. This is why most STBs do not power down. This lead time is necessary for the STB to communicate with the service provider, download the latest electronic programming guide, check subscription entitlements, and enable all the appropriate conditional access.
- Limited Customization/Choice. Customers have limited choice of what type of STB their service provider deploys to their home. In addition, the middleware installed by the service provider often gives little to no options for customization (*e.g.*, view options, channel filtering, etc.). This is related to the principle agent problem.
- IPTV Limitations. Currently, IPTV technology is not widely deployed across the United States. Due to bandwidth constraints, the video feed is compressed, resulting in minor artifacting and/or inferior picture quality. It is unclear, however, if this is widely

perceived by consumers. In addition, it is very expensive to deploy fiber-to-the-home or high-speed digital subscriber lines in order to carry a pure IPTV signal to a large percentage of homes.

3.9 OVER-THE-TOP OPTIONS

Consumers are increasingly utilizing media on demand to accommodate their lifestyles. Many viewers prefer sports, news, and season finales in real time, whereas TV series and movies can be recorded and watched at a later time. Consumers are watching content on a variety of different media (*e.g.*, TV, tablet, laptop, cell phone) depending on their circumstances and location. Pay-TV service providers are working quickly to offer growing video on demand libraries, DVRs, multi-room functionality, and tablet PC streaming. Consumers can now access, however, a large amount of content outside the pay-TV spectrum. As a result, a growing number of consumers are canceling pay-TV subscriptions. Devices that access content outside the pay-TV spectrum are referred to as "over-the-top" (OTT) because they go "over-the-top" of a pay-TV subscription. Both hardware like AppleTV and software like Netflix supplement the video on demand library offered by the pay-TV provider. These devices are well-suited to watching older movies, sports highlights, and past TV episodes. The most recent content, however, is typically delayed anywhere from a day to a month, making OTTs a limited substitute for new broadcast content. OTTs are generally divided into three groups:

OTT STBs. These include the hardware and software necessary to stream video content to a display. Like a pay-TV STB, these devices generally sit in close proximity to a television. What hinders OTT STBs is their lack of content. Without a number of the latest shows and live sports or news content, these options still offer only a portion of the content that the pay-TV industry provides. Examples of OTT STBs are included in Table 3.9.1.

Table 3.9.1 Select Over-the-Top STBs

Name	Company	Description	Comments
AppleTV	Apple	Hardware with installed software that offers video library (ITunes Store)	Over 1 million units sold in 2010
Boxee Box	Boxee	Hardware with installed software (named Boxee) that offers video library and additional applications	Boxee Inc. startup company supported by various venture capital firms; collaborated with D-Link in developing Boxee Box device
Roku	Roku	Hardware with installed software that offers video library (Roku Channel Store)	Private consumer electronics firm in CA, USA
WD TV Live Hub	Western Digital	STB device with additional storage capability	Computer hard drive manufacturer

OTT Services. These are the services that can be installed on a host to make video streaming possible. They include online video libraries, video subscription services, and media player software. Note that some OTT set-top manufacturers also provide OTT service (*e.g.*, Apple, Boxee). Examples of OTT services are included in Table 3.9.2.

Table 3.9.2 Select Over-the-Top Services.

Name	Company	Description	Comments
Boxee	Boxee	Software (cross platform freeware media player)	Boxee Inc. startup company supported by various venture capital firms; collaborated with D-Link in developing Boxee Box device
Google TV	Google	Software built into CE products (*e.g.*, Sony TV, Logitech STB)	Expected to partner with more CE makers in 2011
Hulu	Hulu	Website and OTT subscription service	Hulu launched in the U.S. in 2008 and has become a popular OTT option
iTunes	Apple	Software that offers video library (and other media) across Apple's devices	First introduced by Apple in 2001 and has become the most popular music library software
Kylo	Kylo	Software (open source television-based Internet browser)	Hillcrest Labs introduced Kylo in Spring 2010
Netflix	Netflix	Content subscription service	Offers on-demand streaming and rental by mail service
SlingBox	Sling	Preinstalled place shifting software installed on traditional STBs	Acquired by EchoStar in 2007 for approximately $380 million
Vudu HDX, VuduBox	Vudu	Software built into products from various television and blu-ray player manufacturers.	Acquired by Walmart in 2010 for approximately $100 million

OTT Hosts. These include consumer electronics that offer OTT services as a secondary function. For example, the primary use of a video game console is to play video games, but some game consoles are also capable of streaming Netflix movies. OTT hosts are not the focus of this assessment. Examples of OTT hosts include the following:

- Video game consoles
- Personal computers
- Blu-ray players
- Internet-enabled TVs
- Cell Phones
- Tablets

3.10 STAND-ALONE DVRS AND DTAS

Other types of STBs not associated with service providers include stand-alone DVRs and digital transport adaptors (DTAs, also known as simple STBs in Europe). Stand-alone DVRs can be purchased through retail, whereas DTAs are primarily used in the U.S. to convert digital signals to analog signals for use with older analog televisions.

TiVo provides the only known stand-alone DVR in the U.S. Today's TiVo boxes are typically configured as cable STB by adding a CableCARD (to enable conditional access). Most TiVo customers use their TiVo DVR to replace their cable DVR. The standard TiVo costs $100 and requires a $20 monthly service fee. Instead of leasing a DVR from the cable service provider, the consumer would lease a CableCARD from the service provider and install it in the TiVo. The benefit of the TiVo is a robust user interface, electronic channel guide, OTT content, and a lower cable bill (if the cable service provider has a separate fee for a DVR rental). TiVo cannot display, however, video on demand programming from the service provider. Due to the CableCARD access, the TiVo STB is generally considered a cable STB.

TiVo can also be connected to a digital antenna and used as a DVR for free-to-air content for households that do not subscribe to pay-TV. This likely represents only a very small fraction of TiVo users, however. Furthermore, with the advent of Internet-enabled TVs and game consoles that can access the same OTT content as TiVo, there is only a marginal benefit associated with having the streaming functionality integrated into the same user interface as broadcast TV. In the coming months, TiVo will be working with DirecTV to manufacture a TiVo DVR that will be sold through DirecTV and not retail[10]; this STB would be classified as a satellite STB.

Stand-alone DVRs and DTAs represent a very small market share. Furthermore, the market share is declining as consumers opt for pay-TV service or other OTT options, and as consumers purchase newer televisions capable of digital input. As a result, these devices are not the focus of this assessment.

3.11 EXISTING REGULATORY AND VOLUNTARY PROGRAMS

3.11.1 ENERGY STAR

ENERGY STAR's Version 1.0 STB product specification went into effect on January 1, 2001. Tier 1 energy efficiency criteria took effect immediately, and more stringent Tier 2 criteria were expected to become effective on January 1, 2004. However, in June 2003, the EPA extended the Tier 1 criteria indefinitely based on input from stakeholders. On December 16, 2004, the EPA notified stakeholders of its intent to suspend the STB specification effective February 2, 2005. In March 2007, the EPA announced its intention to re-open the process to revise the ENERGY STAR program for STBs.

Version 2.0 Tier 1 came into effect on January 1, 2009. Version 2.0 qualification requirements were based on a total energy consumption (TEC) allowance for (i) base functionality and (ii) additional functionalities. The TEC approach assumes a typical duty cycle for each mode. The current specification is Version 3.0, which came into effect on September 1, 2011. Version 4.0 is scheduled to come into effect on July 1, 2013. Both Version 3.0 and 4.0 use the same TEC allowance approach, in addition to defining general criteria for external power supplies, maintenance activities, auto power down (APD) and deep sleep. EPA finalized both Version 3.0 and 4.0 on January 21, 2011. See Table 3.11.1 for ENERGY STAR requirements for STBs.

Table 3.11.1 ENERGY STAR Requirements for STBs

STB Type	Version 3.0 (kWh/yr)	Version 4.0 (kWh/yr)
Base Functionality		
Cable	60	45
Satellite	70	50
IPTV	50	25
Cable DTA	35	25
Terrestrial	22	18
Thin Client / Remote	35	20
Additional Functionality		
Advanced Video Processing	12	8
CableCARD	15	15
DVR	45	36
DOCSIS	20	15
HD	25	16
Home Network Interface	10	8
Multi-room	40	30
Multi-stream (cable / satellite)	16	8
Multi-stream (Terrestrial / IP)	8	6
Removable Media Player	8	8
Removable Media Player / Recorder	10	10

Source: EPA.[11,12]

As of October 17, 2011, there are 40 ENERGY STAR qualified STB models.[13] They include the following:

- 10 cable STBs, including HD, HD multi-room, and HD-DVR multi-room models.
- 10 satellite STBs, including SD, HD, HD multi-room, and HD-DVR multi-room models.
- 19 IPTV STBs, including HD, HD-DVR, HD multi-room, and HD-DVR multi-room models.
- 1 thin client STB. This is a HD model.

3.11.2 Federal Communications Commission

The U.S. Federal Communications Commission (FCC) has attempted to separate proprietary security from hardware in the U.S. cable industry via the mandatory CableCARD requirement. CableCARD allows any cable STB to be compatible with all service providers. The initial implementation of CableCARD did not, however, support electronic program guide, video-on-demand or pay-per-view features. As a result, although all cable STBs must have CableCARD, the majority of cable service providers also utilize additional proprietary security protocols to enable 2-way communication functionality such as video-on-demand.

The FCC's recently published National Broadband Plan details another path to achieve separable security in a second attempt to increase competition in the U.S. market. The FCC now recommends an approach where the service providers can own the home's gateway device. The device would require an internal TV tuner and conditional access capability and the ability to stream video in a standard format. This would allow third party STBs and display devices that are interoperable with all service providers (*i.e.*, cable, satellite, and IPTV) to be sold through retail channels. The new initiative, named AllVid, is currently in the notice of inquiry stage.[14] If the FCC decides that AllVid is viable and receives sufficient industry support, the notice of inquiry may become a notice of proposed rulemaking.

3.11.3 Summary of International Programs

Several policy initiatives related to STBs, both in development and currently in effect, exist at the international level (Table 3.11.2). The following subsection section focuses on the recent European voluntary industry agreement.

Table 3.11.2 Select International Policy Pertaining to STBs

Jurisdiction	Equipment Addressed	Policy Approach	Advantages	Disadvantages
Australia and New Zealand	complex STBs	Maximum Platform Allowance (MPA) power level for active standby and on mode that is dependent on the type of STB	Simple and easy to implement	No incentive for multi-room or thin clients
Canada	Complex STBs	Minimum energy performance standard (draft).Total energy consumption (TEC) approach with base type + functional adders	Simple and easy to implement; harmonized with ENERGY STAR and Europe	Covers only cable and satellite STBs. No incentive for multi-room or thin clients
China	simple and complex STBs	Endorsement label	Covers all modes of operation	Varying definitions of simple vs. complex STBs and operation modes when compared to U.S. and Europe
China	simple and complex STBs	Draft regulation (in process); Modal power (On and Standby Modes) plus functional adder	Would cover all STBs sold in China	No expected incentive for multi-room or thin clients

European Union Voluntary Agreement	complex STBs	Total energy consumption (TEC) approach with base type + functional adders	Approach supported by EU service providers; can frequently update	Does not cover 100% of STBs in Europe
Japan - Top Runner Program	DVD recorders with tuners	Total energy consumption (TEC) approach with base type + functional adders	Simple and easy to implement	HDD capacity as metric; does not address auto-power down
South Korea - e-Standby Program	simple and complex STBs	Targets standby power limits for "active" and "passive" standby modes.	Simple and easy to implement	Does not regulate On mode; little flexibility for manufacturers to pursue comprehensive energy efficiency across all modes
Switzerland	simple and complex STBs	Endorsement label	Harmonized with EU's TEC approach from Code of Conduct	Must revise functional adders as new features become available

3.11.4 European Union Voluntary Agreement on Set-Top Boxes

European industry, together with energy efficiency stakeholders, worked to develop a voluntary agreement for STBs, formally the "Industry Voluntary Agreement to improve the energy consumption of Complex Set Top Boxes," as an alternative to a mandatory requirement. The agreement was designed as a self-regulatory instrument, and came into effect July 1, 2010.[15]

The European voluntary agreement employs a total energy consumption approach to evaluating STB energy savings, similar to ENEGRY STAR. The calculation is based on the assumption that a STB will be in on mode for 9 hours and in standby for 15 hours per day. For devices that support auto-power down, an additional allowance is made, and it is assumed that auto-power down will result in the device being in on mode for only 4.5 hours per day.

The total energy allowance methodology incorporates an allowance for base functionality, plus allowances for specific, additional functionalities present across a duty cycle. Different STB types have different base allowances and additional allowances are given for DVRs, Advanced Video and High Definition processing, and additional tuners. Table 3.11.3 compares the total energy allowances for base functionality and additional functionality, for both ENERGY STAR and the EU voluntary agreement.

Table 3.11.3 U.S. ENERGY STAR and EU Voluntary Agreement Total Energy Allowances (in kWh)

Base Functionality	ENERGY STAR 2.0	EU Voluntary Agreement *(Tier 1)*	ENERGY STAR 3.0 *(effective September 1, 2011)*
Duty Cycle	**14 On, 10 Stby - or - 7 On, 7 APD, 10 Stby**	**9 On, 15 Stby - or - 4.5 On, 19.5 Stby (APD enabled)**	**14 On, 10 Stby - or - 7 On, 7 APD, 10 Stby**
Cable	70	45	60
Satellite	88	45	70

IP	45	40	50
Additional Functionality			
Additional Tuners / Multi-stream	53	20	16
Advanced Video Processing	18	20	12
DVR	60	20	45
High Definition	35	20	25
Multi-room	44	38	40
DOCSIS / Return Path for EU	20	60	20

Source: EPA and DIF.[11,15]

3.12 EXISTING TEST PROCEDURES

Released in January 2011, the most recent ENERGY STAR test procedure revision requires power measurements for several different types of activities. This version came into effect at the same time Version 3.0 program requirements did, in September 2011. The test procedure requirements include measurements for watching Live TV, recording Live TV to DVR, playing back recorded TV from DVR, recording Live TV to removable media and playing back recorded TV from removable media. Measurements are typically taken in three different reference channels: network TV, live sports, and live news. Measurements are also required for STBs that have a sleep mode, auto power down feature and deep sleep state, as well as multi-room and thin client STBs.

Other relevant test procedures include the Canadian Standards Association's (CSA) test procedure C380-08[16], the Consumer Electronics Association's (CEA) industry standards CEA-2013[17] and CEA-2022[18], and the International Electrotechnical Commission's (IEC) industry standard IEC-62087[19]. The IEC test procedure uses a simplified ENERGY STAR test procedure methodology, with less required activity measurements (no reference channels) and slightly different operating mode definitions. ENERGY STAR may potentially modify its test procedure approach in future versions to better harmonize with the IEC. While the ENERGY STAR and IEC test methods use different terminology, the CSA test procedure C380-11, currently in public review, explains how IEC terminology maps to ENERGY STAR terms such that IEC STB test measurements can be used in conjunction with the energy allowance equations documented in the ENERGY STAR program requirements to determine product qualification status.

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CHAPTER 4. PRELIMINARY TECHNOLOGY ASSESSMENT

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4.1 TECHNOLOGY OVERVIEW

Television signals in the U.S. have evolved from analog to digital signals. Recent regulatory mandates have shut off analog television signals, in order for wireless broadband providers to use that portion of the wireless spectrum. In the U.S., satellite, cable, and telecommunication service providers transmit their television signals digitally. While local channels are available to any cable-ready TV, video-on-demand, premium channels, and electronic channel guides all require some type of STB to protect the content streaming into the home.

In its simplest form, a STB is a digital transport adapter that receives television signals from a service provider and delivers them to a consumer display and/or recording device.[1] These simplest STBs may include an electronic program guide and the ability to view premium channels, but offer no video on demand or pay per view options. More advanced STBs offer multiple tuners and have two-way communication with the service provider, making it possible to request customized content, such as video-on-demand. Advanced STBs with the ability to record and timeshift content are called digital video recorders (DVRs). The newest STB form factor is a home gateway. These devices connect to multiple thin clients, which are low powered STBs that can only communicate within the home. The home gateways include up to fourteen tuners, process the video signals for all the attached thin clients, and can act as an Internet modem as well. Regardless of complexity, each STB is specific to the delivery technology, be it cable, satellite, or IPTV.

4.2 MARKET SEGMENT INFRASTRUCTURE

The types of STBs in households generally depend on the type of service provider, given that each type of service provider has a different video delivery approach (*i.e.*, infrastructure technology). Each of the three main infrastructure technologies (cable, satellite, and IPTV) use varying amounts of energy. Field study power measurements of select STBs are provided in section 4.5.

4.2.1 Cable

Cable television has historically dominated the U.S. pay-TV landscape. U.S. cable service providers operate regionally as well as nationally, and rarely compete against one another. Today's cable TV infrastructure is a hybrid between fiber optic and coaxial cable, allowing for a larger throughput of data than either satellite or IPTV's systems. The service provider sends every available channel to the STB, where the TV tuner picks the desired channel. Additional services, such as frequency modulation (FM) radio programming, high-speed Internet, and telephone are sent through the same cable, but using different frequencies.

4.2.2 Satellite

Television satellites are geosynchronous, meaning they orbit in sync with the earth and stay in the same position above the ground at all times. This makes it possible for a satellite dish to transmit data without readjusting its position. Satellite service providers broadcast, or uplink, signals to a satellite that they either own or lease for channel space. A transponder on the satellite receives the uplinked signals, converts the signal, and relays it to home satellite dishes. Each satellite occupies a particular location in orbit, and transmits signals across frequency bands assigned by the Federal Communications Commission (FCC). Satellite service providers deploy their STBs as part of a subscription package.

4.2.3 Internet Protocol Television (IPTV)

IPTV is the newest pay-TV market segment. The concept first gained market share in France in the 1990s, but it was not until 2006 that the United States had an IPTV service provider (AT&T). IPTV provides television via the Internet. Cable and satellite function by sending every channel directly to the STB in the home and allowing the user to tune in to the channel(s) they want to watch. With IPTV, the service provider sends only the requested channel(s) to a home gateway, which routes the channel(s) to the corresponding STB. This is similar to how a network router sends a requested website to the corresponding computer.[a] Similar to cable and satellite pay-TV, IPTV provides a channel guide, live broadcasting, time-shifted content (*i.e.*, content recorded via a DVR), and video on demand content. IPTV service providers deploy their STBs as part of a subscription package.

4.3 COMPONENTS

Similar to a computer, a STB has a variety of components, as shown below in Figure 4.3.1:

1) **Basic Components.** These include typical interfaces (including an IR receiver for a remote control), digital displays (*e.g.*, timer, channel display, internal power supply, and a primary tuner and demodulator. In the case of satellite STBs, the power supply also powers the low noise block-downconverter on the dish (this power consumption is not measured as part of any current efficiency policy).
2) **Conditional Access Module.** The CA module (*e.g.*, CableCARD) is placed before the demultiplexer and is used for descrambling the encrypted signal, and also provides a smart card interface for various security features.
3) **Digital Decoder (a.k.a. Demultiplexer).** A digital decoder receives the signal given by the demodulator, and then demultiplexes & decompresses the video requested by the user.
4) **CPU (Processor).** As in a regular PC, the CPU takes care of interactions between all the hardware peripherals and software modules inside a STB.

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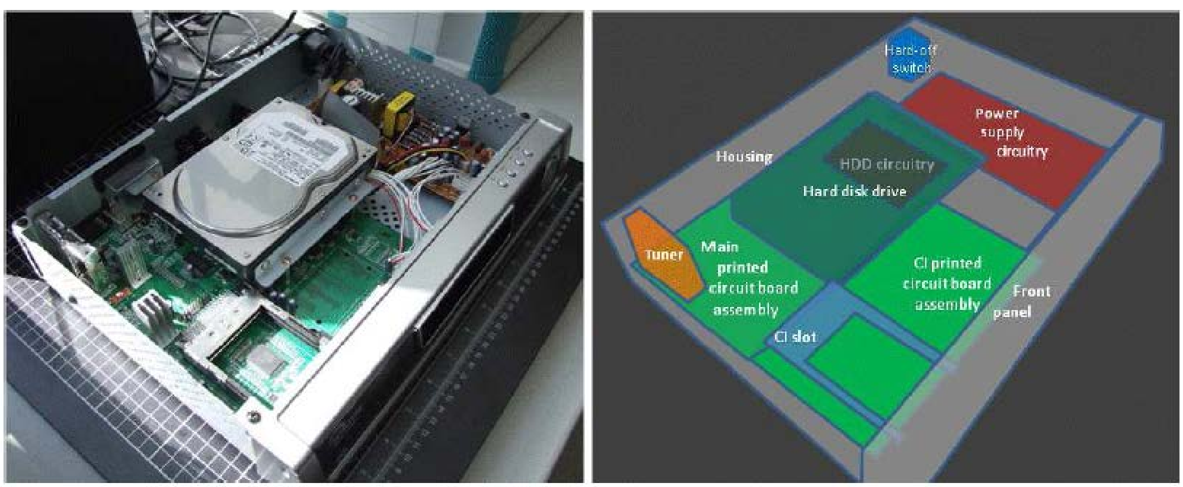
[a] While many boxes can be connected like a computer using Cat5E Ethernet wire, many AT&T installations use the HomePNA protocol over coax or phoneline.

5) **DRAM (Dynamic Random Access Memory).** DRAM is used to store volatile data for all software needs.
6) **Video DRAM.** Video DRAM is used in a STB for storing the decoded video image that is being output to the television or video recorder.
7) **NVRAM (Non-Volatile Random Access Memory).** NVRAM is needed for persistent memory needs for the STB. Generally, STB configurations are written into NVRAM to keep the settings persistent during power cycles and to provide a consistent user experience.
8) **Hard Disk Drive (HDD).** This component is for STBs with digital video recorder (DVR) functionality, used to save and store video content for later viewing. The HDD is also sometimes used by the service provider to store electronic program guide information.
9) **High Definition (HD) Functionality.** High definition is an additional functionality not normally categorized as a component itself. It requires a STB that includes additional graphics processing, along with an HD-enabled TV and subscription to HD-content.
10) **Data Modem.** This is the data tuner necessary to provide two-way data communication with the service provider, to allow for features such as video on demand and provide accurate billing for viewed programs. Two-way data communication is sometimes referred to as return path functionality.
11) **Second TV Tuner.** Allows the STB to handle two channel feeds simultaneously, enabling picture-in-picture viewing or recording one show while watching another (recording is only available for STBs with a DVR).

Figure 4.3.1 Example of STB Internal Components



Source: Mudgal, Schischke, and Iyama (2008).[2] *Reprinted with permission.*

4.4 SELECT FUNCTIONALITY AND FEATURES

This section reviews select functionality and features available in STBs. ENERGY STAR uses an approach giving a total energy consumption (in kWh) allowance to many of these functionalities/features, applied to a base allowance. Additional functionality not described below includes advanced video processing, push video, home network interface, multi-stream, and removable media player/recorder. The Appendix includes information regarding these functionalities.

4.4.1 Digital Video Recorder (DVR)

DVRs are STBs with the ability to save shows for later viewing or to pause/fast-forward live TV. The term DVR is often used two ways: one referencing the functionality (*e.g.*, a STB with DVR functionality) and the other as the type of STB (*e.g.*, HD-DVR). Because one tuner is required for each channel the user "tunes in" to, DVRs typically have multiple tuners, so the user can record a show while watching live TV.

4.4.2 High Definition (HD)

Similar to the rise of DVR functionality, the capability to output high definition (HD) content has become a very popular functionality of STBs. For a viewer to be able to watch content in HD, they need: (1) an HD-enabled STB, (2) an HD-enabled TV, and (3) access to HD-content as part of their pay-TV subscription. ENERGY STAR defines HD as the capability to transmit or display video signals with resolution greater than or equal to 720p.[1] 720p refers to a resolution of 1280 x 720.

4.4.3 Multi-room Technology

The pay-TV industry is moving toward multi-room solutions. As an example, instead of deploying three DVRs in a home, one for each TV, a user would have one DVR that acts as a server and two thin clients. The server DVR includes all the tuners and performs all the transcoding, so thin clients no longer need to communicate with the service provider, only the server DVR within the home. This enables the consumer to schedule recordings on a central DVR and view these recordings and live TV from any TV in the home. "Networked STBs that facilitate whole-home DVR functionality are becoming more common, and pay-TV service providers are looking to these solutions to provide differentiation, increased customer satisfaction, and ultimately new revenue streams".[3]

By definition, multi-room is the capability to provide independent audio/video content to multiple devices within a single-family dwelling. This definition does not include the capability to manage gateway services for multi-subscriber scenarios.[1]

4.4.4 Middleware

Middleware is software that can communicate between the service provider head-end and network equipment. The term head-end generally refers to a pay-TV service provider's local transmission facility. Middleware is similar to an operating system in a computer, although the customer does not see it. The customer sees the service provider applications software, such as a channel guide and video on demand. Several cable operators have adopted tru2way/OCAP specifications as the standard for their middleware.[b] IPTV stakeholders, on the other hand, have yet to come to a clear consensus on any standardized middleware platform. DirecTV was a founding member of the RVU Alliance, which is a middleware solution created for DVR server/thin client networks, and functions with cable or satellite.

4.4.5 Content Protection

STBs typically contain some type of encryption that ensures customers only have access to the services that they have paid for. Conditional access is a term that refers to the encryption, decryption and authorization techniques employed to protect content from unauthorized viewing.[1] Before the FCC-mandated CableCARD, each STB was proprietary to the service provider and included propriety conditional access protocols. In efforts to bring STBs to retail, the FCC mandated all service providers provide their customers with a CableCARD, which is a separable form of conditional access. Shortly thereafter, video-on-demand became very popular and could only be accessed through proprietary service provider STBs since CableCARD does not support video-on-demand. This development drove consumers to lease STBs from their service providers.

4.4.6 Content Availability

There is a growing consumer demand to access content on a variety of consumer electronic devices. "Consumers expect to have multiple options for consuming content, but content owners fear that once content is on the network, it is vulnerable to misuse and piracy".[3] The Digital Living Network Alliance (DLNA) has developed interoperability guidelines which outline standards for device communication and content sharing among various devices within the home.[4]

4.5 ENERGY CONSUMPTION

4.5.1 National Energy Use of STBs

Residential electricity consumption in the U.S. totals over 1,300 billion kilowatt-hours (kWh) annually (Table 4.5.1). Consumer electronics devices are becoming more commonplace in the U.S., and their resulting electricity consumption is growing relative to other end uses. STBs are a contributor to that energy use. Previous studies have estimated total U.S. STB energy consumption at approximately 20 billion kWh per year and 23 billion kWh per year.[5,6] Other work has estimated national STB energy consumption as high as 27 billion kWh per year, or even higher.[7,8] These estimates suggest STBs consume approximately 2 percent of total residential electricity consumption. Most experts agree that STB energy use is project to increase significantly, both domestically and internationally (Figure 4.5.1). At 27 billion kWh per year, this results in approximately 16 million metric tons of carbon dioxide (CO_2) emissions annually.[9]

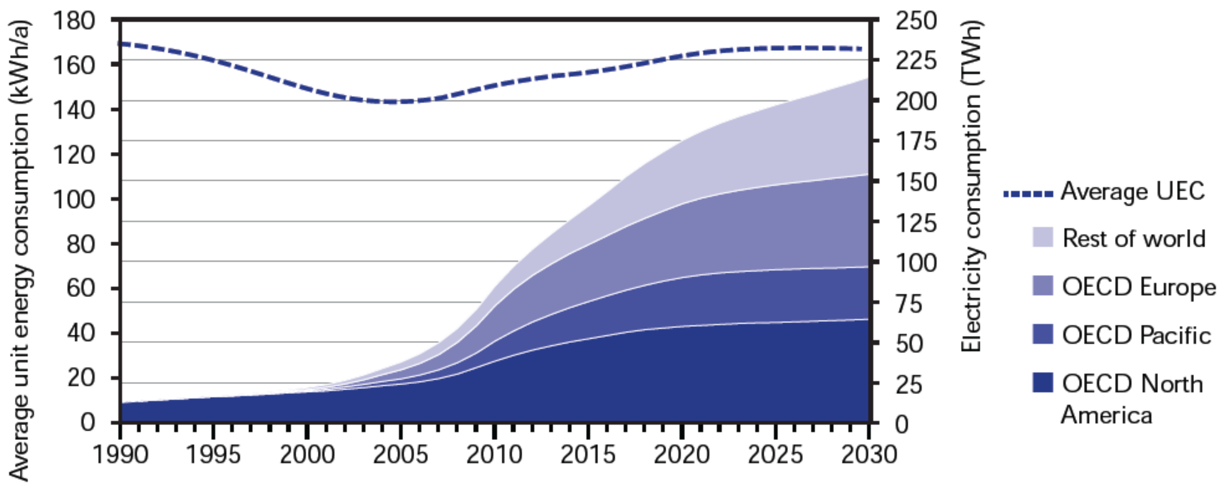
[b] See http://www.tru2way.com/ and http://www.cablelabs.com/opencable/ for more information.

Table 4.5.1 U.S. Annual Residential Electricity Consumption by End Use (2011)

End-Use	Quadrillion Btu	Billion kWh	Share of Total
Space Cooling	0.80	234	17.3%
Lighting	0.70	205	15.1%
Water Heating	0.44	129	9.5%
Space Heating [a]	0.42	123	9.1%
Refrigeration	0.36	106	7.8%
Televisions and Set-Top Boxes	0.34	100	7.3%
Clothes Dryers	0.18	53	3.9%
Computers and Related Equipment	0.18	53	3.9%
Cooking	0.11	32	2.4%
Dishwashers [b]	0.09	26	2.0%
Freezers	0.08	23	1.9%
Clothes Washers [b]	0.03	9	0.6%
Other — Miscellaneous Uses	0.89	261	19.2%
Total	4.63	1,357	100.0%

[a] Includes fans and pumps. [b] Excludes energy for water heating.
Source: EIA (2011).[10]

Figure 4.5.1 Projected Energy Use of STBs



Source: IEA (2009).[8] *Reprinted with permission.*

The majority of STBs today currently consume nearly the same power whether or not the device is being actively used to watch or record television. As a result, approximately two-thirds of the total annual energy use of STBs (an estimated 18 billion kWh/year) occurs when a consumer is neither watching nor recording a show.[7]

4.5.2 Unit Energy Consumption of STBs

Each new generation of STBs includes faster processors, more memory, larger hard drives, and many other new features into a box with limited size and limited ability to remove heat with cooling fans. The need to maintain a power limit in the face of significant feature advances has resulted in tremendous efficiency gains over the last decade. Although efficiency has improved, STB count per home is also increasing, resulting in increased total household energy consumption. Service providers have made only limited gains in reducing STB energy consumption when subscribers are neither watching nor recording video (though active energy use has indeed decreased).

A recent study measured the energy consumption of 58 pay-TV STBs deployed in the U.S. over the past two years, along with a small number of pay-TV STBs in Europe.[7] A few emerging OTT STBs like AppleTV were also measured. The key conclusions were:

- U.S. STBs continue to use almost as much power when not in use as when active. However, leading European service providers have begun to solve this problem in their newest STBs.
- Satellite HD-DVRs in this study drew slightly more power than their cable counterparts (Table 4.5.2). This trend may, however, change over time. IPTV, which is rapidly gaining market share compared to cable and satellite, enables the use of lower-power STBs. The most efficient U.S. HD-DVRs tested were IPTV boxes, drawing approximately 18 watts when active, 15 watts less than the average cable or satellite HD-DVR. European IPTV HD-DVRs demonstrated on mode power levels of less than 10 watts.
- Pay-TV STB unit energy consumption has held steady in the last few years as the increased energy consumption of advanced features has offset component-level efficiency gains.
- Consumers are increasingly getting their video content from a variety of new broadband video streaming services, including Netflix, Hulu, AppleTV, and the just-introduced GoogleTV. Consumers can access these services via Internet-enabled TVs, video game consoles, Blu-ray players, or dedicated OTT STBs. The data included two of these OTT devices. The most efficient device in the study was an OTT STB, which drew just 3 watts in on mode and under 1 watt in sleep mode.
- Many consumers currently use these streaming devices in addition to their pay-TV STB. This streaming capability is likely to be integrated into future-generation TVs. These TVs will be able to stream video from sources such as Netflix, Hulu, and locally stored content on the home's DVR. The study did not expect these low-power streaming devices to replace the central DVR in the near future.

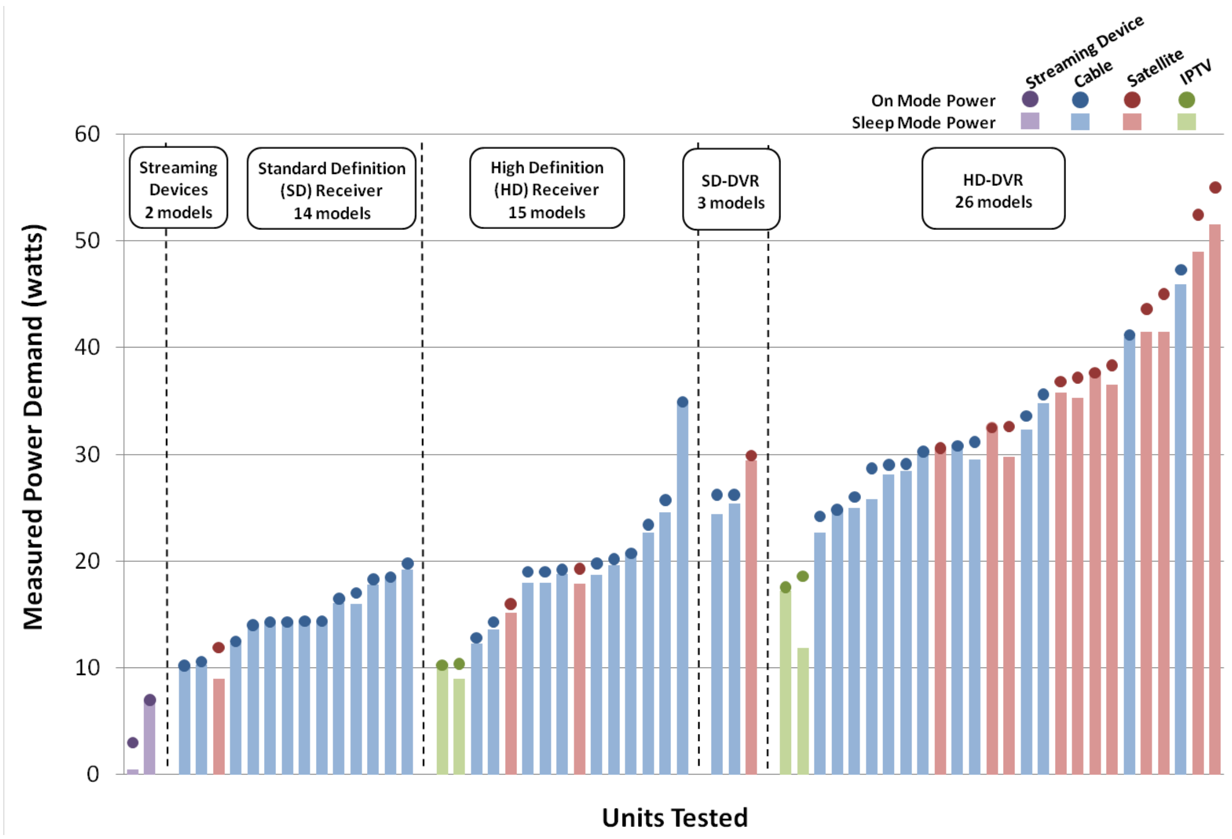
Table 4.5.2 STB Power Use by Segment and Technology Type

	Average On-Mode Power (W)	Average Sleep-Mode Power (W)	Units Measured
Cable			
SD	15	15	13
HD	21	20	11
SD-DVR	26	25	2

HD-DVR	32	31	13
Satellite			
SD	12	9	1
HD	18	17	2
SD-DVR	30	29	1
HD-DVR	40	38	11
IPTV			
SD-DVR	10	10	2
HD-DVR	18	15	2
OTT			
STB	5	4	2

Source: Hardy and Swofford (2011).[7]

Figure 4.5.2 STB Power Demand, Measured from 58 Pay-TV STBs

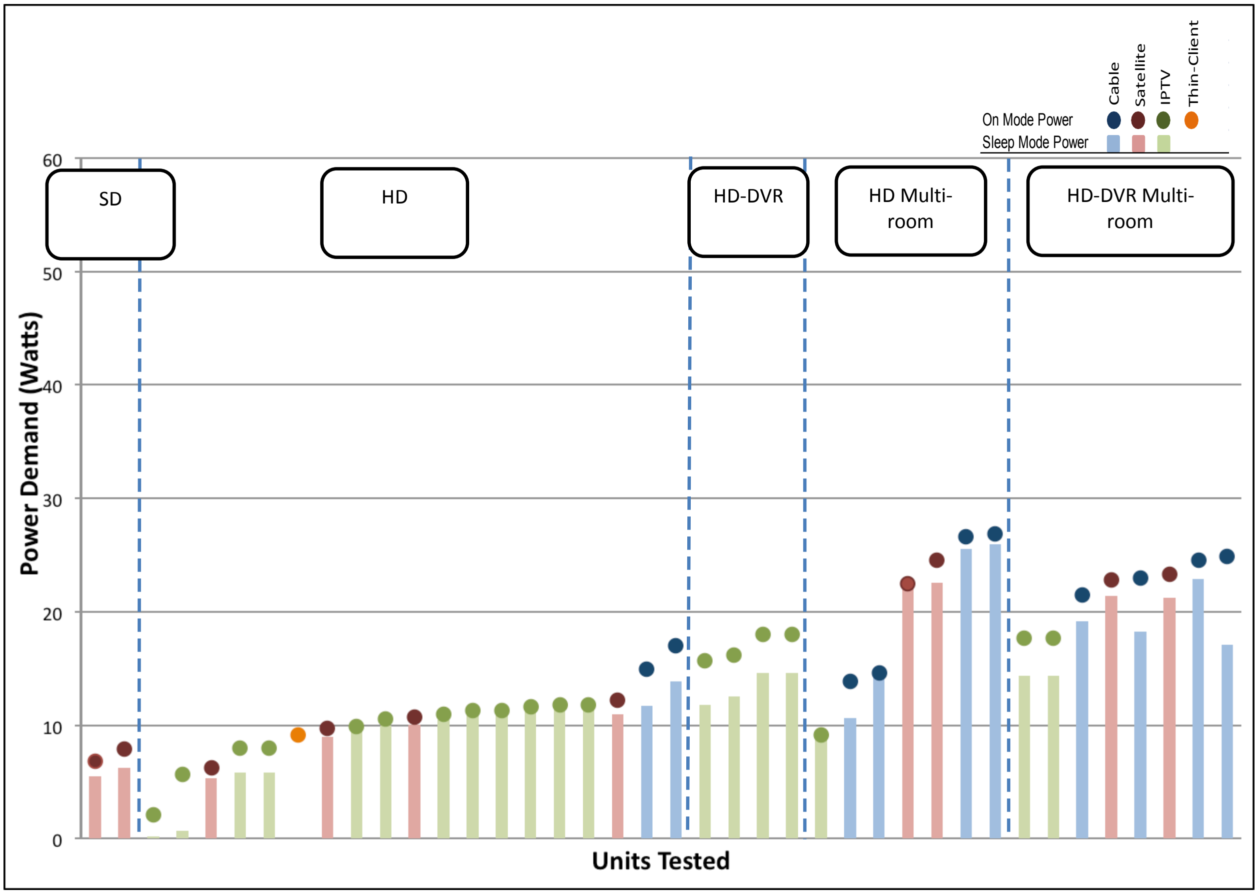


Source: Modified from analysis used in Hardy and Swofford (2011).[7] *Reprinted with permission.*

Figure 4.5.2 shows the on mode and sleep mode power levels measured for all the devices in the study. On mode measurements are represented by dots, whereas sleep mode measurements are represented by bars. The measurements are grouped by broad STB functionality, and color-coded by base type (cable, satellite, IPTV, OTT). The major trends observed include: (a) a general increase in power with increased functionality (in particular HD and DVR); (b) a general increase in power for satellite STBs; (c) low power for IPTV and OTT STBs; and (d) very little difference between on mode and sleep mode power for the majority of STBs.

It is important to note, however, that the STBs measured in the study are up to two years old, and may not fully represent current models. These measurements are, however, higher than from similar studies in 2006 and 2007.[8] Figure 4.5.3 shows a similar figure for ENERGY STAR-qualified STBs, as of Oct. 17, 2011. As these are qualified models, they exhibit the best efficiency for STBs in their class. On average, these models are consuming significantly less power than the average models in Figure 4.5.2, especially for HD-DVR models.

Figure 4.5.3 Recent ENERGY-STAR-qualified STB Power Demand



Source:EPA (2011).[11]

Table 4.5.3 lists the estimated power use of various STB components. These estimates, however, are a few years old, and may not fully represent modern functionality. Included in these power use estimates is the power required for the return path (communication with the service provider). Several current technologies can be used for the return path, including:

- Plain Old Telephone System (POTS) – uses low speed dial-up modem to communicate infrequently with the service provider. Energy consumption is negligible.

- Ethernet – keeps network presence active at all times, even in standby. Ethernet has low power consumption (~1W).
- ADSL – keeps network presence active at all times, even in standby. ADSL has higher power consumption (few watts up to 10 watts depending on type and speed). ADSL specification allows for low power states, although often they are not used by manufacturers or telecommunication companies. Current European best practice is ADSL2 (2nd generation ADSL), which uses 2.6W - 3W. VDSL2 (2nd Generation VDSL) uses 3.5 – 6W.
- DOCSIS - keeps network presence active at all times, even in standby. DOCSIS has higher power consumption than ADSL. Current installations average from 5W up to 12W depending on type and speed of connection. DOCSIS currently does not have low power modes, although in DOCSIS 3 it should be possible to reduce the number of communication channels from 4up/8down to 1/1, but no service provider has done this commercially as yet. The best practice DOCSIS 3 would use 6.2 - 7.1W.

Table 4.5.3 Estimated Power Use Breakdown for Cable and Satellite Pay-TV STBs

Functionality (F) or Component (C)	On Mode Power Use (watts)	% of Energy Consumption for HD Receiver	% of Energy Consumption for HD-DVR STB
Basic Components (C)	10	30%	24%
Data Modem (C)	10	30%	24%
High Definition (F)	8	25%	20%
Hard Disk Drive (C)	8	N/A	20%
Second TV Tuner (C)	5	15%	12%
	Total	**100%**	**100%**

Source: Mudgal, Schischke, and Iyama (2008).[2]

4.6 POTENTIAL ENERGY EFFICIENCY MEASURES

Service providers and manufacturers continue to improve on mode STB efficiency, by improving power supply efficiency and utilizing efficient components. Although the industry has made progress, the increased energy consumption of advanced features has offset component-level efficiency gains. Recent estimates suggest efficient pay-TV STBs and service provider networks could reduce the energy use of the installed base of STBs by 30 to 50 percent by 2020.[7]

Efficient networks are an important part of the solution, but there are significant barriers to improving them. If a cable user disconnects their STB from the network by powering it off, the head-end reports a service fault and an engineer can be called. Similarly, on satellite systems, software updates and subscription information may degrade over time, and the user may find they have no longer have a subscription when they turn the box on again. The cost to change the network infrastructure is potentially very large, and requires a long planning horizon. Changes to the STB are likely relatively low cost and easier to achieve than those to the existing network infrastructure.

The primary energy savings opportunities identified by recent studies[7,8,12] (Table 4.6.1) include:

- Enabling STBs to automatically power down to much lower power levels when not in use (*e.g.*, in the middle of the night, while users are at work).
- Shifting to whole-home solutions that include a main STB connected to the primary TV and either TVs specially-designed to access the video content stored on the main box or low-power thin client STBs that serve the same function.

These two opportunities are explained in detail below. Although other areas for energy efficiency improvement are worth mentioning (*e.g.*, efficient power supplies, efficient components), power management and multi-room technology offer the most comprehensive means for maximizing energy savings without hindering the consumer experience.

Table 4.6.1 Energy-Saving Strategies for STBs

Measure Number	Measure Name	Explanation	Relative Savings Opportunity	Difficulty
1	Power management	Switch off components when not actually required, including hard disk, image processing chips, and multiple tuners	High	Moderate
2	Utilize multi-room technology	Shifting to whole-home solutions that include a main box connected to the primary TV with either TVs specially-designed to access the video content stored on the main box or low-power thin client STBs that serve the same function	High	Low
3	More efficient components	Install switch-mode power supply and more efficient chips for image conversion	Moderate	Moderate
4	Reduce disk energy use	Install more efficient disk designs, switch to flash memory, or store content at a remote server	Moderate	Moderate
5	Lower clock speeds on chips	Reduce processing speed to minimum speed for type of image transmitted	Low	Low
6	Consolidate boxes	Some homes use two or more boxes to provide signals to several televisions	High	Moderate
7	Relax security requirements	Service provider currently restricts ability of box to enter low power modes to guard against hackers and to protect content	Moderate	High
8	Allow user to set functionality	Through a control panel, the user could modify settings to more precisely match his needs, possibly resulting in even greater energy savings	Low	Moderate

Note: Some measures overlap (*e.g.*, measure 2 helps to achieve measure 6 in theory). Table has been modified to include multi-room technology.

Source: IEA (2007),[12] Table 37: Energy-saving strategies for set-top boxes. p. 147. Based on presentations at the "Workshop on Energy-Efficient Set-Top Boxes and Digital Networks" at the IEA, Paris, France, 4-6 July 2007.

4.6.2 Power Management

Modern STBs draw nearly as much power when they are off or in sleep mode as they do when in use. There are "concerns about the energy use of today's STBs because the power needed by the STB when the user is watching/recording programming and the power needed by the STB when the user has physically hit the off button are virtually the same".[13] STB components, such as hard drives and tuners, could be powered down when not in use without significantly impacting the user experience.[6] This would considerably lower the power draw of STBs when they are not in use (*i.e.*, watching or recording a show). Best in class power management schemes include both light and deep sleep states.

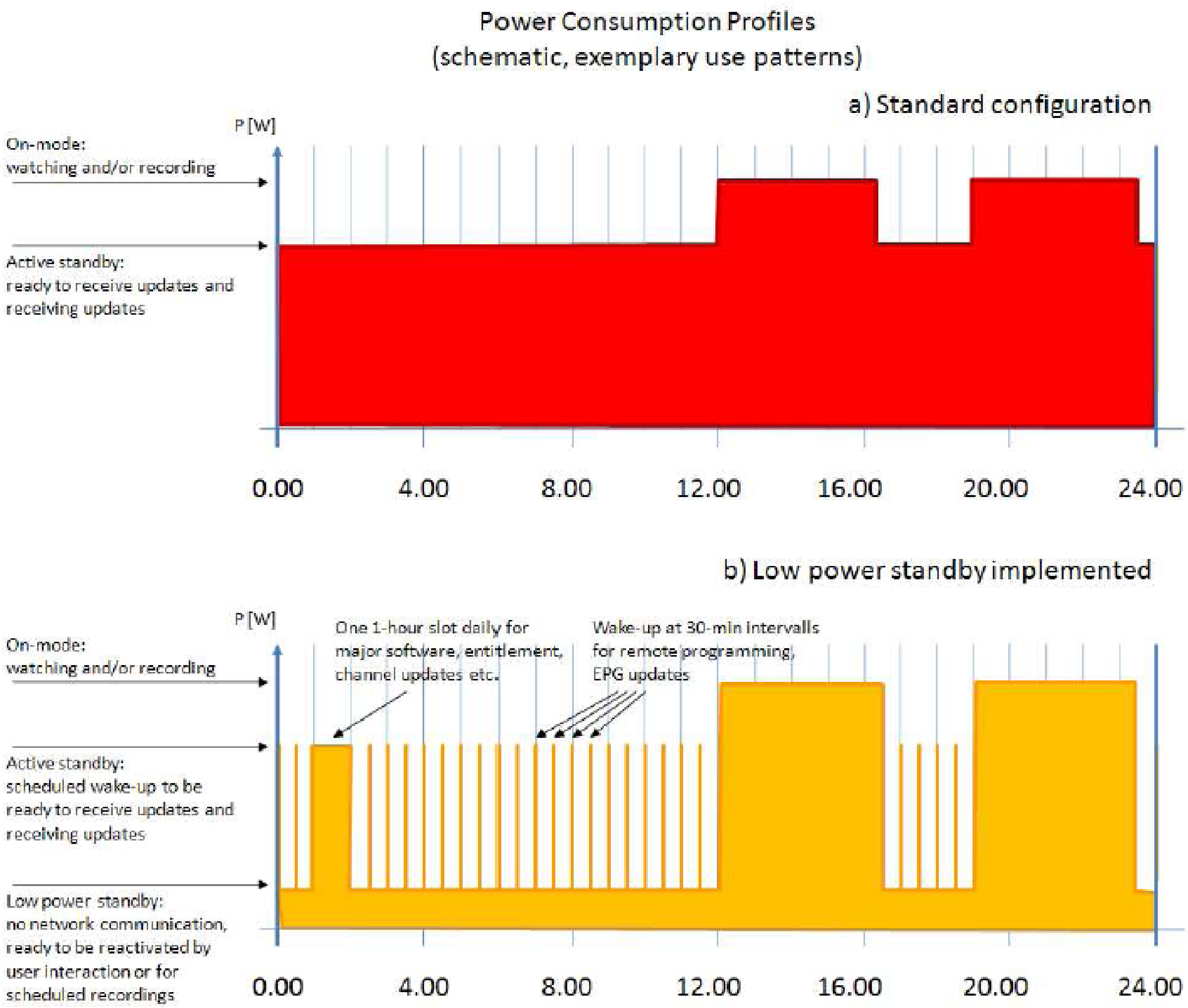
In the U.S., no pay-TV service provider has initiated a significant power management scheme to date. "Unfortunately, incorporating a sleep mode in STBs is more difficult to implement because a sleep mode solution would need to be developed and specified by service providers and agreed upon by hardware manufacturers, software developers, and communication protocol experts".[13] There exist some reasons as to why such power management schemes have yet to be enabled in the U.S. Reasons include security, long boot-up times, updates to electronic program guides, and the need for the STB to continuously stay connected to the network, among others. On the other hand, select service providers in Europe have already begun implementing power management schemes despite the above-mentioned issues.

European satellite service provider Sky Broadcasting offers an example of energy efficient STB hardware. They offer a HD-DVR that draws 23 watts in on mode and 13 watts in a light sleep state.[7] Light sleep is a state in which there is no video output, no recording functions, but network connections are maintained. The STB enters light sleep when the user presses the power button on the remote. In addition, the STB enters a 1 watt deep sleep state between 11pm and 4am (unless the consumer is actively using the device), after which it enters a light sleep state. This deep sleep feature may be disabled by the consumer, and a warning appears if the TV is on but there has been a long period of inactivity (see Figure 4.6.1). The STB requires 90 seconds to wake up from a deep sleep, and wakes up almost instantly from a light sleep. During deep sleep, the STB periodically and briefly wakes up every 30 minutes to check for updates and for new program recording requests, before returning to deep sleep. Figure 4.6.2 illustrates this sleep behavior schematically. Anecdotal reports suggest that Sky Broadcasting has received almost no negative feedback, that consumers are mostly happy with (or unaware of) the changes to the STB operating behavior and that there is a low incidence of consumers disabling the auto-power-down feature.

Figure 4.6.1 Deep Sleep Warning from Sky Broadcasting

Source: Mudgal, Schischke, and Iyama (2008).[2] Reprinted with permission.

Figure 4.6.2 Schematic Deep Sleep Power Consumption Profile



Source: Mudgal, Schischke, and Iyama (2008).[2] Reprinted with permission.

Chinese manufacturer Skyworth produces another example of an efficient STB. Their cable STBs consume only 8 W by employing low power components and an efficient power supply. The standby power is only 1 W, and the technologies needed to achieve this low standby power add only US$ 1 to the cost of each box. In addition, the wake-up time from this standby level is only 15 seconds.[8]

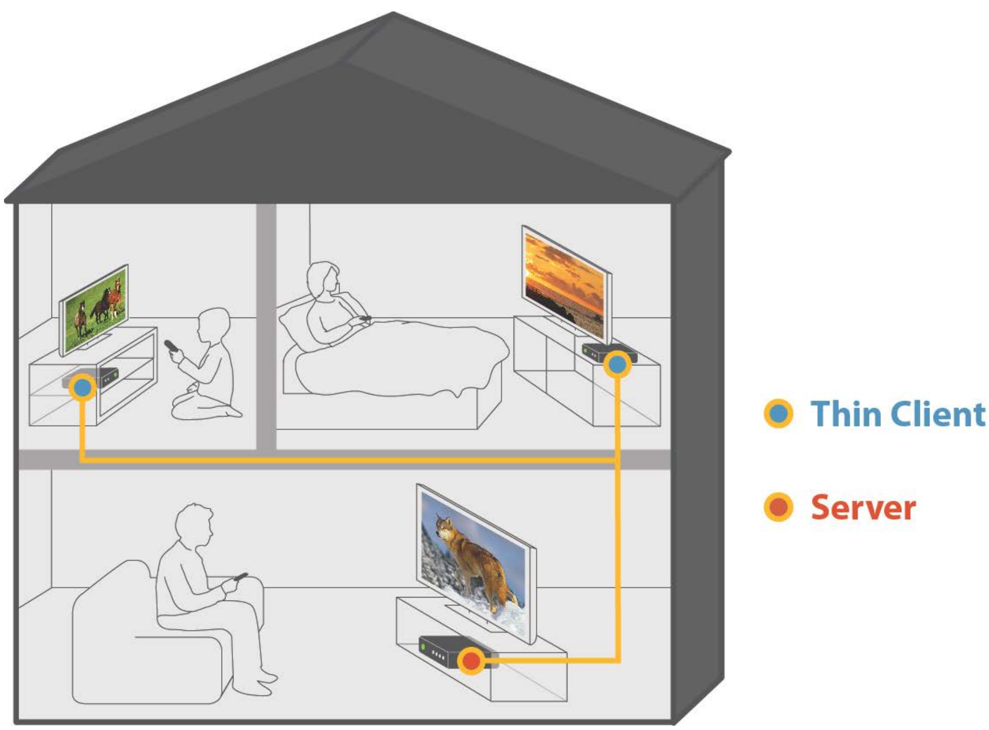
4.6.3 Multi-Room Technology

Multi-room technology enables consumers to schedule recordings once on a central DVR and to view these recordings and live TV from any TV in the home. Multi-room STBs with DVRs provide additional consumer utility since consumers can access programs saved on their main STB hard drive from any connect TV in the house, and switch rooms while watching the same show. This is a premium feature that is sought after by consumers and is rapidly gaining popularity.

Multi-room technology is new to the market, but it has the opportunity to limit national STB energy by eliminating the need for multiple fully functional and energy consumptive STBs in one home. Instead of multiple, fully-functional STBs, a home could be outfitted with a central STB with multiple tuners, and several low-power thin-client STBs with minimal functionality (Figure 4.6.3). Multi-room is only applicable to households with more than one STB.

True thin-client STBs do not require all of the components and functionality (and associated energy use) of a primary STB in the home. Implementing thin clients can significantly reduce household energy use. A central and fully functional DVR STB would communicate to the service provider and contain the conditional access and network connectivity necessary to provide pay-TV content to the home. This box would then serve other client boxes in the home connected to other TVs around the house. These client boxes would not need select functionality and components such as conditional access or DVRs, as they only need to be able to communicate to the central box to obtain content as needed. Thin clients can draw as little as 8 W.[7]

Figure 4.6.3 Example Multi-Room Configuration



Source: Hardy and Swofford (2011).[7] *Reprinted with permission.*

Some multi-room solutions currently deployed do not use true thin clients. Instead, the service provider uses fully functional STBs in the client role. Although this limits the number of DVRs in the home, it is not an optimal solution, and is potentially only saving energy at the household level for 4-5 STBs/house or more. Replacing the auxiliary boxes with true thin clients eliminates this problem.

Another strategy for reducing energy consumption involves TVs themselves serving as clients, which can obtain the content they need from the single and central DVR STB in a home. This would eliminate the need for thin client STBs altogether and would reduce household energy use by consolidating devices. TVs are already trending toward Internet capability, with growing feature sets and functionality. The reduction in household energy from eliminating the need for multiple STBs may potentially offset any power premium that these additional features in the TV would entail.

The RVU Alliance is a consortium of consumer electronics groups working to accelerate the availability of service provider content throughout the connected home.[14] RVU's goal is to use its Remote User Interface (RUI) technology for home networked television entertainment, ensuring interoperability among devices implementing RVU's RUI technology, and educating the market about RVU technology. As innovation takes place in the market, service providers are encouraged to shift to multi-room solutions that only require one main STB and much lower power thin client STBs for the other TVs in the home.

The main gateway STB, however, may use significantly more energy than a normal STB. A multi-room solution might therefore not save much energy per house if there are only 2 or perhaps 3 STBs in a house. There is rapid innovation in multi-room technology, and multi-room STB power consumption is changing quickly. There is currently insufficient data to precisely determine how many STBs per home are required before a multi-room setup would save energy,

4.7 ASSESSMENT OF FUTURE PRODUCT EVOLUTION

The pay-TV STB has evolved past its originally intended role. Initially limited to acting as a gateway for rendering pay-TV content to viewers, STBs are now technically capable of serving as a media center for the entire home. Technical innovation continues to take place at a rapid pace in both the pay-TV market and consumer electronics in general. Both have a significant impact on the STB. New opportunities already being implemented in some of today's STBs include blending broadcast and Internet content, remotely accessing content, other placeshifting features, targeted advertising, social networking applications, and additional storage.[15] This section provides a brief overview of the importance of blending content, placeshifting, and other advanced video features, and their impact on the evolution of the STB.

4.7.1 Blending Content and Device Consolidation.

The convergence of pay-TV, Internet video, and user-stored content will have a large impact on the role of the STB over the next decade. For example, currently, Google TV's software enables users to search and watch broadcast video content, browse the Internet, and organize media stored on a DVR, all while sitting in front of a TV rather than a computer. Google TV software is also currently available on two hardware devices: the Logitech Revue (a dedicated STB) and Sony's Internet TV with Google TV. The future of TV will likely be a mixture of technology and delivery methods, though service providers will remain influential stakeholders in the pay-TV arena.[16]

Additionally, STBs and network equipment are likely to become consolidated, with a single gateway device providing television and Internet access to the home. EPA already includes "home network interface" in its list of additional functionalities for the ENERGY STAR STB program.[1] Given that many users obtain Internet and television service from the same service provider, and that both services can be delivered via the same medium (*e.g.*, cable), it is very natural for STBs and modem/routers to become integrated.

4.7.2 Placeshifting

The term placeshifting refers to technology that allows the user to watch video content on multiple devices, and ultimately multiple locations. Whereas timeshifting simply refers to the use of a DVR to be able to watch content whenever you want, placeshifting makes content available to the screen in front of the user, be it a TV, laptop, tablet, or cell phone. Any screen with an Internet connection would be able to view broadcast TV, saved DVR content, or Internet videos. This type of viewing flexibility is becoming increasingly popular with consumers.

The ultimate goal of placeshifting is to make video content, paid and free, available on all types of consumer electronics devices. One challenge of making pay-TV subscriptions available across multiple devices is ensuring adequate content protection, making sure the content is only viewed by those who pay for it. Video content owners are aware of past issues related to peer-to-peer file sharing, particularly with respect to music content.

Important issues regarding the development of these cross-platform initiatives include:[3]

- How content providers, service operators and their consumer electronics partners agree on industry-wide digital rights management schemes;
- The development of authentication solutions that account for the consumer as both a subscriber to premium pay-TV services and a user of online services;
- The role of consumer electronics such as home computers and residential gateways to transcode media and apply appropriate management rules on content; and
- Consumer demand for paying a premium on cross-platform content services.

4.7.3 Advanced Video Functionality

In the next few years, STBs will begin to offer advanced video functionality, including full 1080p high definition video, high efficiency video coding (HEVC) which saves on bandwidth, 3-D signals, and ultra high definition video.

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APPENDIX: DEFINITIONS

VARIOUS GENERAL DEFINITIONS

A set-top box is an electronic device that receives a video signal and converts it for display on a television or, increasingly, on a computer monitor.[1]

A set-top box is the generic name for a device used to convert an incoming TV broadcast signal to one that can be seen on a screen, and it therefore sometimes referred to as an integrated receiver decoder.[2]

A set-top box is a cable, satellite, Internet Protocol or other device whose primary function is to receive television signals from a specific source and deliver them to a consumer display and or recording device, such as a television or DVR.[3]

A set-top box is a device that connects to a television and some external source of signal, and turns the signal into content then displayed on a screen.[4]

A set-top box is any dedicated equipment that receives, processes and stores data from digital broadcasting streams and related services, and provides output audio and video signals.[5]

BASE TYPE[3]

Cable. A set-top box whose primary function is to receive television signals from a broadband, hybrid fiber/coaxial, or community cable distribution system with conditional access (CA) and deliver them to a consumer display, thin-client/remote set-top box, and/or recording device.

Satellite. A set-top box whose primary function is to receive television signals from satellites and deliver them to a consumer display, thin-client/remote set-top box, and/or recording device.

Cable Digital Transport Adapter (DTA). A minimally-configured set-top box whose primary function is to receive television signals from a broadband, hybrid fiber/coaxial, or community cable distribution system and deliver them to a consumer display and/or recording device.

Internet Protocol (IP). A set-top box whose primary function is to receive television/video signals encapsulated in IP packets and deliver them to a consumer display, thin-client/remote set-top box, and/or recording device.

Terrestrial. A Sset-top box whose primary function is to receive television signals over the air (OTA) or via community cable distribution system without conditional access (CCA) and deliver them to a consumer display, thin-client/remote set-top boxB, and/or recording device.

Thin-client / Remote. A set-top boxB that (1) is designed to interface between a Multi-room set-top box and a TV (or other output device), (2) has no ability to directly interface with a Service Provider, and (33) relies solely on a multi-room set-top box for content. Any set-top box that meets the definition of a cable, satellite, IP, or terrestrial STTB is not a thin-client/remote set-top box.

PRODUCT FEATURES/COMPONENTS[3]

Base Functionality. The primary functionality that defines the ENERGY STAR criteria applicable to a particular set-top box. Base Functionality is one of the following: Cable, Satellite, IP, Terrestrial or Thin-Client/Remote.

Advanced Video Processing. The capability to encode, decode, and/or transcode audio/video signals in accordance with standards H.264/MPE G 4 or SMPTTE 421M.

CableCARD. The capability to decrypt premium audio/video content and services and provide other network control functions via a plug-in conditional access module that complies with the ANSI/SCTTE 28 HOST-PPOD Interface Standard.[a]

Digital Video Recorder (DVR). The capability to store video in a digital format to a rewritable disk drive or other non-volatile storage device integrated into a set-top box. This definition excludes video capture software for personal computers or server-based DVR capabilities.

Data Over Cable Service Interface Specification (DOCSIS®). The capability to distribute data and audio/video content over cable television infrastructure in accordance with the CableLabs® Data Over Cable Service Interface Specification.[b]

European Data Over Cable Service Interface Specification (EuroDOCSIS). An international suite of standards that define interface requirements for cable modems involved in high-speed data and video/audio content distribution over cable television systems.

High Definition (HD) Resolution. The capability to transmit or display video signals with resolution greater than or equal to 720p.

Home Network Interface. The capability to interface with external devices over a high bandwidth network (e.g., IEEE 802.11 (WiFi), MoCA, HPNA). For purposes of this specification, IEEE 802.3 wired Ethernet is not considered a Home Network Interface.

Multi-room. The capability to provide independent audio/video content to multiple devices within a single-family dwelling. This definition does not include the capability to manage gateway services for multi-subscriber scenarios.

Multi-stream. The capability to deliver two or more simultaneous audio/video streams to a consumer display, thin-client/remote set-top box, or recording device. The simultaneous streams may be delivered via a physically separate input or via the primary input. This definition does not include out-of-band tuners.

Removable Media Player. The capability to decode digitized audio/video signals on DVD or Blu-ray Disc optical media.

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[a] http://www.scte.org/standards/
[b] http://www.cablelabs.com/specifications/

Removable Media Player / Recorder. The capability to decode and record digitized audio/video signals on DVD or Blu-ray Disc optical media.

OPERATIONAL MODES[3]

On Mode. Where the product is connected to a mains power source, has been activated and may be providing one or more primary functions. The common terms "active", "in-use" and "normal operation" also describe this mode.

Sleep Mode. Where the product is connected to a mains power source, is not providing a primary function, and offers one or more of the following user oriented or protective functions which may persist for an indefinite time:

1) To facilitate the activation of other modes (including activation or deactivation of On mode) by remote switch (including remote control), internal sensor, timer;
2) Continuous function: information or status displays including clocks;
3) Continuous function: sensor-based functions.

Deep Sleep State. A power state within Sleep Mode characterized by reduced power consumption and increased time required to return to full On Mode functionality.

OTHER DEFINITIONS[3]

Automatic Power Down (APD). The capability of a device to switch itself from On mode to Sleep mode after a predetermined period of time (APD timing) has elapsed. APD timing begins when the following criteria have been met:

1) The device has ceased performance of all primary functions; or
2) The last user input has been received (e.g., remote control signal, volume adjustment).

Primary Function.

1) Delivery of live or recorded audio/video content to a thin-client/remote set-top box or local/remote recording device is considered a primary function;
2) Delivery of live or recorded audio/video content to a consumer display within four hours of last user interaction/input is considered a primary function;
3) Continuous device functions (e.g., clocks, status displays, indicator lamps) are NOT considered primary functions.

Service Provider. A business entity that provides audio/video content to subscribers with whom it has an ongoing contractual relationship. A Service Provider distributes ENERGY STAR qualified set-top boxes to end users under a lease or rental arrangement.

Conditional Access. The encryption, decryption, and authorization techniques employed to protect content from unauthorized viewing. CableCARD and Downloadable Conditional Access System (DCAS) are examples of conditional access technology.

Digital Television Adapter (DTA). A device that receives terrestrial (over the air) digital signals and converts them to an analog output suitable for analog TVs. DTAs do not provide digital signal output. This definition does not include converters for satellite or cable digital signals or devices that perform multiple functions (e.g., DVD players with DTA capability).

Game Console. A stand-alone device whose primary function is to process video game content. The primary inputs for game consoles are special hand-held controllers rather than the mouse and keyboard used by a conventional computer. Game consoles are equipped with audio/video outputs for use with televisions as the primary display, rather than an external monitor or integrated display. Game consoles typically do not use a conventional general-purpose operating system, but often perform a variety of multimedia functions such as: DVD/CD playback, digital picture viewing, and digital music playback.

Out-of-band Tuner. A tuner compliant with standards ANSI/SCTE 55-1 2002, ANSI/SCTE 55-2 2002, or similar, that is used to gain access to data channels outside of the primary audio/video source signal. These tuners may facilitate two-way communication to allow a set-top box to exchange data (e.g., diagnostics) with the Service Provider, and may enable access to Pay-Per-View or other rich-media interactive content.

Typical Energy Consumption (TEC). A means for evaluating energy efficiency through a calculation of expected energy consumption for a typical user over a one year period, expressed in units of kWh/year.

Unit Under Test (UUT). The device being tested.

Product Family. A group of product models that are: (1) made by the same manufacturer, (2) subject to the same ENERGY STAR qualification criteria, and (3) of a common basic design. Product models within a family differ from each other according to one or more characteristics or features that either: (1) have no impact on product performance with regard to ENERGY STAR qualification criteria, or (2) are specified herein as acceptable variations within a product family. For Set-top Boxes, acceptable variations within a product family include aesthetic housing changes that do not affect the thermal characteristics of the device (e.g., color, labeling, or other cosmetic modifications).

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