Appendix G – GPRA07 Building Technologies (BT) Program Documentation

Introduction

The mission of the Building Technologies Program is to develop technologies, techniques, and tools for making residential and commercial buildings more energy efficient, productive, and affordable. **Table G-1** outlines the activities characterized for the GPRA07 Building Technologies Program. Characterizations and inputs for these activities were provided to the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) as inputs to EERE's integrated modeling effort. Between the time that the original activity list was developed for the integrated modeling process and the time that the final budget request was submitted, a small number of activities were added into, subtracted from, or moved within the request; however, these changes were not reflected within the modeling process. The specific impact of these changes on the integrated benefits estimates is not known, but would be expected to be minimal.

Table G-1. Building Technologies Subprograms, Projects, and Activities

Subprogram	Project	Activity
Residential Buildings Integration	Research & Development: Building America	Research & Development: Building America
	Residential Building Energy Codes	Residential Building Energy Codes
Commercial Buildings Integration	Research & Development	Research & Development
	Commercial Building Energy Codes	Commercial Building Energy Codes
Emerging Technologies	Lighting R&D	Lighting R&D: Solid-State Lighting
		Lighting R&D: Controls *
	Space Conditioning & Refrigeration R&D	Refrigeration R&D: Hy-Pak MA *
		Refrigeration R&D: Thermotunneling Based Cooling
		Refrigeration R&D: Integrated Heat Pump
	Appliances & Emerging Technologies R&D	Appliances & Emerging Tech R&D: Solid-State Lighting Market Acceptance **
	Building Envelope R&D	Window Technologies: Electrochromic Windows
		Window Technologies: Superwindows
		Window Technologies: Low-E Market Acceptance
		Thermal Technologies: Advanced Wall Systems
		Thermal Technologies: Next Generation Attic Systems
		Thermal Technologies: Next Generation Envelope Materials
	Analysis Tools and Design Strategies	Analysis Tools and Design Strategies
Equipment Standards and Analysis	Equipment Standards and Analysis #	Standards: Electric Motors, 1-200 HP
		Standards: HID Lamps
		Standards: Distribution Transformers
Technology Validation and Market Introduction	Rebuild America	Rebuild America
	Energy Star	Energy Star: Clothes Washers
		Energy Star: Refrigerators

		Energy Star: Room Air Conditioners
		Energy Star: Dishwashers
		Energy Star: CFLs
		Energy Star: Windows
		Energy Star: Home Performance

* activities that were not funded in the final FY07 budget request
** activity that was moved to Lighting R&D
# excludes other Standards activities that were added following the passage of the Energy Policy Act of 2005

Often such analysis requires the development and use of enabling or simplifying assumptions. In many cases, no citable sources exist for substantiating assumptions. Therefore, assumptions are developed through an iterative process with project managers, project contractors, and GPRA analysts. Often, we base these assumptions on project knowledge and experience, as there are varying degrees of corroborative studies available on which project information can be substantiated, depending on the maturity of the project. Enabling assumptions are sometimes relatively crude and should be revisited annually as new and better data are developed.

1.0 Residential Buildings Integration

The long-term goal of Residential Buildings Integration is to develop cost-effective technologies and building practices that will enable the design and construction of net Zero Energy Buildings (ZEB) – houses that produce as much energy as they use on an annual basis – by 2020.

1.1 Residential Building Energy Codes

Project Description. The Residential Building Energy Codes project improves the minimum or baseline energy efficiency of new federal and model residential building codes. The project promulgates upgraded standards for Federal residential buildings. The project works with the International Code Council to upgrade the energy-efficiency requirements of its model energy codes. State, and local jurisdictions then adopt and implement these upgraded model energy codes. The long-term goal is to improve the minimum energy efficiency by 20% to 25% in new low-rise residential building construction.

1.1.1 Significant Changes from FY06

No significant changes were made to this program for the FY07 effort. In previous years, all of the building codes activities have been modeled together, independent of funding source, with code development funded activities funded under BT and codes training and deployment activities funded as part of the Weatherization and Intergovernmental Activities Program (WIP). The impact of the individual codes activities (residential, commercial, and training and assistance) has been allocated to the individually funded activities based on the presumed impacts of greater compliance of existing codes as well as future code development and adoption. The FY 2006 activity within WIP to provide incentive funding and technical assistance to aid in the adoption, compliance, and enforcement of codes was discontinued in FY 2007, although the State Energy Program Grants program within WIP is expected to continue to fund similar activities, as they have done historically. The expected impact on the BT-funded portion of the codes activities is not anticipated to be significant.

1.1.2 Target Market

Market Description. The market includes new and renovated residential low-rise buildings, three stories or less in height, requiring code permits.

Size of Market. In recent years approximately 1.6 million single-family residential building permits have been issued[2]. Although not all jurisdictions currently have energy efficiency building codes in place, the Pacific Northwest National Laboratory (PNNL) estimates that about 80 percent all new residential construction comes under building energy code requirements. Also, consumers spend several billion dollars a year on remodeling and renovating projects in private residences, about half of which are estimated to be covered by an energy code. One market not covered by codes is manufactured homes, which fall under Housing and Urban Development (HUD) jurisdiction and regulations.

Baseline Technology Improvements. Initial compliance with new codes was assumed to be lower in the base case, i.e., without the Building Energy Codes project, than with the project. For FY07, the percentage of potential savings, in the first year of implementation of the single future code, was assumed to be approximately 35% for heating and cooling measures without the project.

Baseline Market Acceptance. Under the baseline scenario, 23 states were assumed to have adopted the International Energy Conservation Code (IECC 2000 or IECC 2003) standard by the end of 2005. The GPRA estimates were partly based on states' accelerated schedule of adoption of the IECC 2000 and IECC 2003 codes. Through the efforts of the Building Energy Codes project, 31 states were assumed to have adopted the 2000 or 2003 standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of three years nationwide.

1.1.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT assumed a five-year payback period on investment to develop incremental investment costs (i.e., an annual energy cost savings of $1 implies an initial investment of $5).

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing savings estimates.

- Improved environment and more comfortable buildings.
- Lower home maintenance and repair activities
- Reduced pollution due to the reduced burning of fossil fuels and electricity generation, which improves air quality and mitigates the negative impacts of global warming.

1.1.4 Methodology and Calculations

Inputs to Base Case. With respect to codes, it is indeterminate as to whether, and to what extent potential future code improvements are incorporated into the National Energy Modeling System (NEMS) base case. The NEMS-GPRA07 base case includes some improvements to the building shell efficiency; however, the basis for these improvements (e.g., general building practice improvements, changes in codes requirements, improvements in materials) is not specified by the Energy Information Administration (EIA). Codes that have been issued (but that have not gone into effect) may be included in the NEMS-GPRA07 base case, but would not be included in the GPRA forecast of savings for the code development activity, because it no longer would be funded. The GPRA estimates include only an estimate of savings due to potential future codes.

Technical Characteristics. The FY 2007 GPRA estimates are based on the future development of more stringent building codes. The energy-savings methodology was applied at a state level to better link changes in the national codes (e.g., IECC 2006) with variations in climate by states (and differences among states) in their adoption and enforcement of codes.

The IECC's ongoing activities are expected to lead to more stringent residential standards in the future. The Department of Energy (DOE) is assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the IECC standard projected to become available in the latter part of the current decade. BT estimated that the results of these upgrades were to reduce heating and cooling loads in new residential structures by 10%. Without these activities, BT assumed that an equivalent national (IECC) standard would not be developed within the time frame of the analysis.

Expected Market Uptake. The project's activities were assumed to improve future building codes. The analysis assumed that when states first adopt the new standard (assumed to become available in the 2006-2007 time frame), the potential energy savings from moving to the new standard would be 84% at the time of adoption, increasing to 90% with the effect of the project after the first 10 years. [a]

1.1.5 Sources

(1) "Building Technologies Program: 2006 Multi-Year Program Plan." U.S. Department of Energy Buildings Technology Program, March 2005.

(2) U.S. Bureau of Census. New Privately Owned Housing Units Authorized: Annual 2004 Data. Accessed online on January 2006 at http://www.census.gov/const/www/C40/table2.html#annual.

[a] The 84% assumption is based upon two other assumptions: 1) 60% of new homes fully comply with the new code, and 2) for the other 40% of new homes, 60% of the potential energy savings is achieved.

1.2 Research and Development: Building America

Project Description[1,2]. The project's long-term goal is to develop integrated cost-effective whole-building strategies to enable residential buildings to use up to 70 percent less total energy than current code-compliant buildings by 2020 and provide up to 30 percent in additional energy savings through the use of integrated onsite power systems.[b] BT also will develop techniques to integrate new home energy efficiency and onsite power technology into existing homes to improve the energy efficiency of existing homes by up to 30 percent. In addition, user-friendly residential control packages are expected to be designed that interconnect and drive all components and reduce summer peak energy consumption by 100 percent when needed and annual energy consumption by 10-20 percent, by 2025.

1.2.1 Significant Changes from FY06

Existing buildings were added to the target market for the input characterization for FY07.

1.2.2 Target Market

Market Description [1]: The target market primarily includes all new residential homes. The new home energy conservation approaches will also be tested and demonstrated in existing homes beginning FY 2007. The impacts on existing homes from this program are modeled to begin in 2010.

Size of Market[4]: Each year about 1.6 million new single-family housing unit building permits are issued.

Market Introduction: Initial penetration of zero-net energy designs began in the southwest in 2003 and the design approach is anticipated to expand into the northern climate zones beginning in 2008[5]. The renewable technologies supported by this project currently exist; however, penetration into the general market is expected to continue to be extremely low without DOE funding because the technology is currently unaffordable for production home builders. BT assumed that Building America activities would not occur without DOE funding; therefore, no acceleration of market acceptance was modeled.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

1.2.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price - Incremental Cost for each level of energy savings in new homes[2]:

- 40% whole house savings costs $1,850/household (HH)
- 60% whole house savings costs $5,300/HH

[b] Whole house energy savings are measured relative to the BA Research Benchmark Definition (Building America, Building America Research Benchmark Definition, Version 3.1, November 11, 2003, National Renewable Energy Laboratory) which consists of the 2000 IECC requirements plus lighting, appliances and plug load energy levels (www.buildingamerica.gov)

- 70% whole house savings costs $15,000/HH
- By 2020, incremental costs are assumed to fall by 50%.
- One hundred percent savings (including renewable resources) costs $31,000/HH declining to $9,100 by 2020.

In developing the cost of solar technologies as part of the 70% incremental cost, BT assumed that the solar program meets it stated goal. BT assumed that Building America is credited for savings beyond 20% of the baseline (see the Methodology and Calculations section below). Incremental costs for existing buildings have not yet been determined.

Key Consumer Preference/Values – Nonenergy Benefits. The following nonenergy characteristics were not considered in developing savings estimates:

- Improved comfort, durability, and occupant health from better indoor air quality
- Reduced on-site generated waste
- Reduced maintenance.

1.2.4 Methodology and Calculations

New Residential Technical Characteristics and Market Uptake

For any one year, the Building America project's energy savings are calculated by multiplying the number of homes built with Building America techniques that year multiplied by the percent savings per home. Added to this are the energy savings, accrued in that year, for Building America homes built in previous years, beginning in 2007.

BT developed incremental costs for whole-building energy savings using Navigant Consulting's Residential Optimization Model (ROM, Version 5.7)[(2)]. Cost increments were developed for three levels of percentage savings from the baseline: -40%, -60%, and -70%. BT assumed that half of the costs and corresponding savings for the first level (equivalent to 20% savings from the baseline) would occur as a result of other related programs in BT, namely appliance standards, building codes, and Energy Star homes. Thus, the net savings percentages with Building America are translated to 20%, 40%, and 50% of the baseline unit. The ROM model simulations and savings percentage assumptions formed the inputs for NEMS-GPRA07.

The ROM simulations were conducted for four cities: Minneapolis, Boston, Atlanta, and Phoenix (see **Table G-2**). Each city represents a proxy for a climate region in the U.S. Population weights to develop a national average were assigned in rough fashion (see **Table G-3**). Because the NEMS shell module only treats heating and cooling, the energy savings from the inputs shown in **Table G-2** will underestimate the potential savings from BT's Residential R&D program. NEMS does produce the number of new homes that are deemed to use one of the five shell packages available in the model. Assuming the same cost and performance of the technologies not modeled specifically in the shell module, the total savings are assumed to be roughly three times that shown in the model.[c] These additional savings beyond heating and cooling would occur in lighting, water heating, and other appliances in homes built to Building America criteria. The challenge for the integrated modeling effort is to

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[c] The factor of "three" is based on PNNL's assumption that space conditioning energy use in new homes would be about one-third of the total end-use energy affected by these technologies.

try to incorporate these additional savings which are due to the program, with a link to the number of homes using advanced shell packages four and five (as shown in **Table G-4**).

Shell package #4 is assumed to represent a "baseline" scenario for high-efficiency homes, based upon current costs. Building America activities are designed to seek innovative methods to reduce those costs in the future. The impact of this aspect of the program is shown in Shell package #5. Starting in 2010, the overall cost of the package is assumed to be 20% lower than the baseline ($223 versus $278), and then falling an additional 10% relative to the baseline every five years.

Table G-2. ROM Simulation Results for Representative Cities

		Minneapolis		Boston		Atlanta		Phoenix	
Cost Impact									
All Technologies	Building America	Total Cost	Delta Cost	Total Cost	Delta Cost	Total Cost	Delta Cost	Total Cost	Delta Cost
Base		$46,499		$25,164		$22,884		$28,384	
20%									
40%	20%	$48,297	$899	$27,373	$1,105	$24,818	$967	$29,646	$631
60%	40%	$51,543	$5,044	$30,793	$5,629	$28,376	$5,492	$32,671	$4,287
70%	50%	$62,467	$15,968	$39,880	$14,716	$39,784	$16,900	$40,112	$11,728
Energy Use		MMBtu/HH		MMBtu/HH		MMBtu/HH		MMBtu/HH	
Base		214.9		191.7		164.2		176.0	
20%		172.0		153.4		131.3		140.8	
40%		129.0		115.0		98.5		105.6	
60%		107.5		95.9		82.1		88.0	
70%		64.5		57.5		49.3		52.8	

Table G-3. Population Weights and Incremental Costs for Representative Cities

		Incremental Costs, Building America		
City	Weight	20%	40%	50%
Minneapolis	0.2	$899	$5,044	$15,968
Boston	0.3	$1,105	$5,629	$14,716
Atlanta	0.3	$967	$5,492	$16,900
Phoenix	0.2	$631	$4,287	$11,728
Average *		$927	$5,203	$15,024
HVAC share **	0.3	$278	$1,561	$4,507

*Costs for percentage reduction in whole-building energy use
**Costs for percentage reduction in heating and cooling consumption

Table G-4. Suggested Adjustments to NEMS Shell Factors

Heating Shell Efficiency Adjustments (multiplicative factors)						
Package	2003	2005	2010	2015	2020	2025
4*	1.00	0.80	0.80	0.60	0.50	0.50
5*	1.00	1.00	0.80	0.60	0.50	0.50
Cooling Shell Efficiency Adjustments (multiplicative factors)						
Package	2003	2005	2010	2015	2020	2025
4	1.00	0.80	0.80	0.60	0.50	0.50
5	1.00	1.00	0.80	0.60	0.50	0.50
Shell Cost Adjustment Factors (Amount Subtracted)						
Package	2003	2005	2010	2015	2020	2025
4	0	-$278	-$278	-$1,561	-$4,507	-$4,507
5			-$223	-$1,093	-$2,704	-$2,254

* Packages 4 and 5 represent Building America

** Costs are incremental, above the baseline

The fundamental premise that leads to wide adoption of the technology is that existing technologies and DOE projects will eventually reduce energy use by about 70% and reduce summer peak loads to zero. This, in turn, will result in significantly less solar electric and solar thermal technology needed to supply the home's load. The combination of lower building loads and onsite power will shave summer peak loads and thereby alleviate some of the need to expand the grid to accommodate system summer peaks.

Existing Residential Technical Characteristics and Market Uptake

The performance goal for existing residential is to reduce whole-house energy use by 20% by 2010. The expected market uptake is based on U.S. Census renovated space estimates and project management input.[8] Estimated market penetration rates for whole house design for existing homes are found in **Table G-5**.

Table G-5. Whole House Energy Efficient Design - Existing Residential Homes Market Penetration

Year	Percent of Existing Stock
2007	0.0000
2008	0.0000
2009	0.0000
2010	0.0092
2011	0.0203
2012	0.0336
2013	0.0487
2014	0.0653
2015	0.0829
2016	0.1006
2017	0.1178
2018	0.1337
2019	0.1479
2020	0.1600

1.2.5 Sources

(1) "Building Technologies Program: 2006 Multi-Year Program Plan." Draft. U.S. DOE, March 2005.

(2) Final Draft: Zero Energy Homes' Opportunities for Energy Savings: Defining the Technology Pathways Through Optimization Analysis, U.S. Department of Energy Building Technologies Program, October 2003.

(3) U.S. Department of Energy, Building America Research Benchmark Definition. Version 3.1, November 11, 2003. Accessed online March 2004, at http://www.eere.energy.gov/buildings/building_america/benchmark_def.html.

(4) U.S. Bureau of Census. New Privately Owned Housing Units Authorized: Annual 2004 Data. Accessed online on January 2006 at http://www.census.gov/const/www/C40/table2.html#annual.

(5) Information obtained in discussions with the project manager, Lew Pratsch, August/September 2003.

(6) New Houses Sold, by Region, by Sales Price: Annual Data. U.S. Census Bureau, Manufacturing and Construction Division. www.census.gov/const/regsoldbypricea.pdf, accessed August 8, 2003.

(7) Buildings Energy Databook (July 26, 2003), Table 5.1.1., "2001 Five Largest Residential Homebuilders."

(8) U.S. Census Bureau 2000. *1997 Economic Census Construction Geographic Area Series."* U.S. Department of Commerce, March 2000. Washington D.C.

2.0 Commercial Buildings Integration

The long-term goal of the Commercial Buildings Integration subprogram is to develop cost-effective technologies and building practices that will enable the design and construction of net Zero Energy Buildings – commercial buildings that produce as much energy as they use on an annual basis – by 2025.

2.1 Commercial Building Energy Codes

Project Description. The Commercial Building Energy Codes project improves the minimum energy efficiency of new commercial and multifamily high-rise buildings and additions and alterations to existing buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for federal commercial and high-rise residential building types. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. These upgraded national energy standards are then adopted by federal, state, and local jurisdictions as part of their building codes. The project's long-term goal is to improve minimum energy efficiency by 30% to 35% in new commercial building construction. Energy use will be reduced by states and local jurisdictions widely adopting the national standards as building energy codes.

2.1.1 Significant Changes from FY06

No significant changes were made to this program for the FY07 effort. In previous years, all of the building codes activities have been modeled together, independent of funding source, with code development funded activities funded under BT and codes training and deployment activities funded as part of the Weatherization and Intergovernmental Activities Program (WIP). The impact of the individual codes activities (residential, commercial, and training and assistance) has been allocated to the individually funded activities based on the presumed impacts of greater compliance of existing codes as well as future code development and adoption. The FY 2006 activity within WIP to provide incentive funding and technical assistance to aid in the adoption, compliance, and enforcement of codes was discontinued in FY 2007, although the State Energy Program Grants program within WIP is expected to continue to fund similar activities, as they have done historically. The expected impact on the BT-funded portion of the codes activities is not anticipated to be significant.

2.1.2 Target Market

Market Description. The market includes new commercial and multifamily high-rise (above three stories) buildings and all additions/renovations to commercial buildings requiring permits.

Size of Market. The commercial market size is about 2 billion square feet of new commercial floor space each year. The Federal sector represents nearly 2.3% overall of new commercial building construction.

Baseline Technology Improvements. Initial compliance with new codes was assumed to be lower in the base case, i.e., without the Building Energy Codes project. For FY07, the percentage of potential savings, in the first year of the single future code, was estimated to be approximately 20% for envelope measures and 30% for lighting measures without the project.

Baseline Market Acceptance. The FY 2007 GPRA estimates are based on the future development of more stringent building energy codes.

2.1.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT developed incremental investment costs by assuming a five-year payback period on investment (i.e., an annual energy cost savings of $1 implies an initial investment of $5).

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing savings estimates.

- Improved environment and more comfortable buildings.
- Lower building maintenance and repair activities
- Reduced pollution due to the reduced burning of fossil fuels and electricity generation, which improves air quality and mitigates the negative impacts of global warming.

2.1.4 Methodology and Calculations

Inputs to Base Case. With respect to building codes, it is indeterminate the extent to which potential future code improvements are incorporated into the NEMS-GPRA07 base case. The NEMS-GPRA07 base case does include some improvements to the building shell efficiency; however, the basis for these improvements (e.g., general building practice improvements, changes in code requirements, and improvements in materials) is not specified by EIA. The impact of accelerated adoption and improved compliance by states of recently issued national building standards (e.g., ASHRAE 90.1-1999) is included in the GPRA forecast of savings. Therefore, BT did not provide inputs to change the base case assumptions for program markets.

Technical Characteristics. Energy savings from this project result from some basic improvements to the overall energy efficiency of commercial buildings in their space-heating, space-cooling, and lighting loads. This project funds research analysis of cost-effective levels of energy codes for new commercial and multifamily high-rise buildings.

Improvements to building codes are primarily supported by research efforts to review existing codes and specific targeted areas of building energy use, as well as the adoption of code modifications that promote cost-effective reductions in these energy-use areas. The adoption process for the research work has typically taken place in three areas:

- Upgrading ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings"(1)
- Upgrading the Federal commercial and multifamily high-rise building energy code, 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings"(2)
- Upgrading the International Energy Conservation Code (IECC).(3)

The FY 2007 GPRA estimates are based on the future development of more stringent building energy codes. The energy-savings methodology was applied at a state level to better link changes in the codes with variations in climates by states and differences among states in their adoption and enforcement of building codes. The discussion below uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology, but appropriate state averages were used in the analysis.

The ongoing activities of the ASHRAE 90.1 committee were assumed to lead to more stringent commercial-building standards in the future. DOE was assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the ASHRAE standard, estimated to become available in the latter part of the current decade. The GPRA analysis assumed that the overall result of these upgrades is to reduce electricity consumption by 10% and natural gas consumption by 10% in new commercial buildings.

Expected Market Uptake. As part of work for an unpublished analysis of the historical impacts of Building Energy Codes in August 2003, the baseline assumptions regarding the acceleration effect of the overall program were modified (e.g., program training and assistance) activities leading to states adopting (the most recent national ASHRAE or IECC) codes more rapidly than they would have otherwise). In general, *without* the training and assistance elements of the building codes project, the states were classified into groups that: 1) immediately (one or two years) adopted the 90.1-1989 ASHRAE code, 2) would have adopted within five years or 3) would have adopted within 10 years..[d] These time periods were then reduced by one year for each successive major code cycle after the 1989 code. (For example, a five-year lag for 90.1-1989 is assumed to fall to four years for the 90.1-1999 code, three years for the ASHRAE 90.1-2004 code, and two years for the next major update of the code). The overall impact of this change was to decrease the average lag between the publication of a new standard and when it is adopted – without the project. For the scenario involving a new commercial code (circa 2009), states are assumed to adopt that code over a period extending from 2011 to 2022, with a mean adoption year of 2015.

2.1.5 Sources

(1) ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers and Illuminating Engineering Society.
(2) 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings," *Code of Federal Regulations*, as amended.
(3) International Energy Conservation Code. 2003. International Code Council, Falls Church, Virginia.
(4) ASHRAE/IES Standard 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

[d] The historical record for states adopting the 90.1-1989 standard was 1) two states adopted within the first two years of publication, and 2) 24 states had adopted by 1998. Three states are not considered in the analysis as they had had active code development programs in their own states: California, Oregon, and Florida.

(5) ASHRAE/IES Standard 90.1-2001, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(6) U.S. Department of Energy. March 2002. "Commercial Buildings Determinations, Explanation of the Analysis and Spreadsheet (90_1savingsanalysis.xls)." http://www.energycodes.gov/implement/determinations_com.stm

2.2 Research and Development

Project Description.(1) In order to reach net zero conventional energy buildings (ZEB) by 2025, DOE will employ integrated whole-building strategies to enable commercial buildings to be designed and constructed to use 70% less energy. By 2010, the BT goal is to integrate design approaches, highly efficient component technologies and controls, improved construction and maintenance practices, and operating procedures that will make new and existing commercial buildings durable, healthy and safe for occupants, and will reduce energy use for new buildings by 50% and by 30% for existing buildings, relative to conventional practice. [e]

2.2.1 Significant Changes from FY06

For FY07, BT changed the out-year performance and cost inputs for new buildings, which were held constant through the analysis period for the FY06 effort. Additionally, BT estimates that Commercial Technology R&D would accelerate the adoption of relevant energy-savings products, technologies and designs by 5 years. This estimate is a revision from a 10 year period (assumed in FY06).

2.2.2 Target Market

Market Description(1): Although this project does not explicitly exclude any particular building type, the types of commercial buildings that will most likely be impacted by the technologies developed by this project primarily include small commercial buildings with relatively high energy use intensities such as assembly, education, food service, food sales, lodging, mercantile and service, and office buildings.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

Baseline Market Acceptance. In 1998, PNNL conducted a study examining the historical market penetration for 10 energy-efficient products related to the buildings sector. The results of this study are documented in the PNNL report, *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)(6). The study suggested several generic penetration curves based on the type of equipment of interest. BT used the curve related to design products to model this project.

[e] Energy savings are measured relative to the 2001 International Energy Conservation Code (IECC).

2.2.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price.
Total Building Cost of Conventional Technology(4): Average of $101/ft^2 for the targeted new commercial and multifamily; $0 for existing buildings.
Total Building Cost of BT Technology(5): $103/ft^2 for new commercial and multifamily, increasing to $107/ft^2 in 2020[f]; $4/ ft^2 for existing buildings.
Incremental Cost(5): 2% above base for new buildings, increasing to 6% above base in 2020; $4/ft^2 for existing buildings.

Key Consumer Preference/Values – Nonenergy Benefits. The following nonenergy characteristics were not considered in developing energy output estimates:

- Reduced operation and maintenance expenses
- Improved indoor environmental quality
- Increased property asset value
- Higher tenant satisfaction and retention rates
- Increased technology sales.

2.2.4 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics (2,3). In concert with the Analysis, Tools, and Design Strategies project, the performance goals are to reduce heating and cooling loads by 50% in new small commercial construction as compared with ASHRAE 90.1-2004, increasing to 70% savings by 2020. The goal is also to save 30% in existing buildings.[g]

Expected Market Uptake. The market penetration goal(3) is to accelerate the penetration of high-performance building designs, such that 55% of new commercial and multifamily construction (**Figure G-1**) and 20% of existing construction incorporates the products supported by this project by 2025 (**Figure G-2**). Penetration curves were developed based on market diffusion curves developed by PNNL(6). BT assumed that this project accelerates the adoption of relevant energy-savings products, technologies and designs by 5 years.

[f] Cost estimates corresponding with 70% energy savings are based on escalation estimates associated with similar energy savings in residential sector. Cost escalation estimates are based on Navigant Consulting's Residential Optimization Model (Version 5.7)
[g] The percentage of the load reduction attributed between Commercial R&D and Analysis Tools and Design Strategies is in proportion with their respective budget requests.

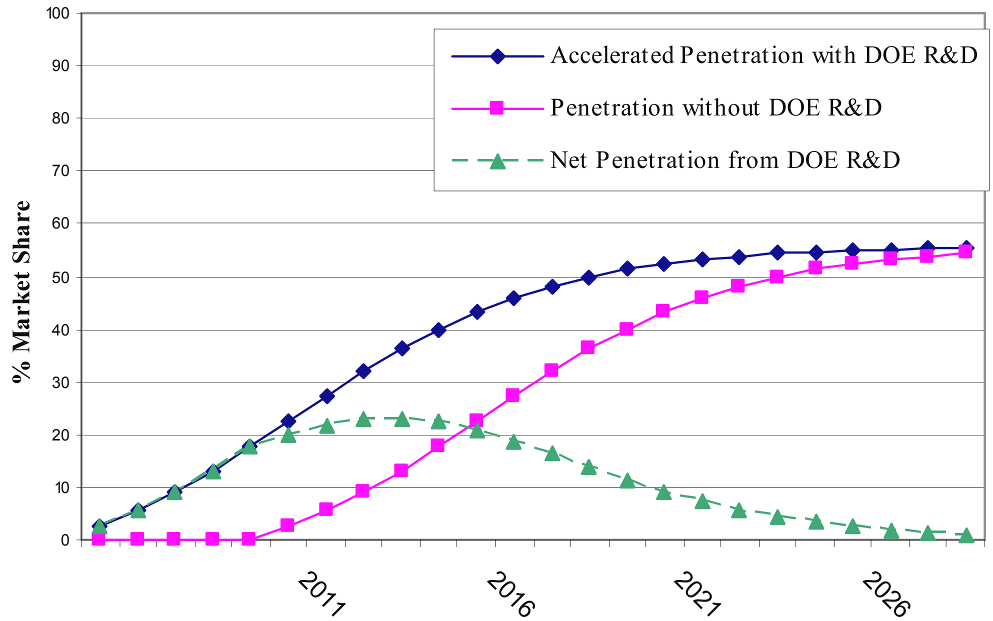

Figure G-1. Market-Penetration Curve for Commercial R&D Project Targeting New Buildings

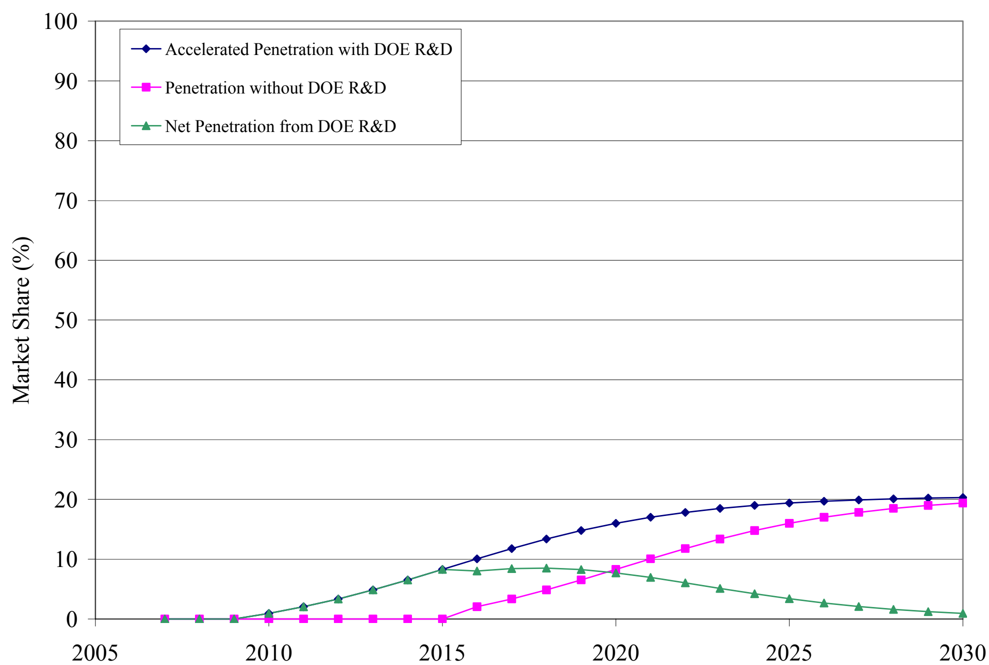

Figure G-2. Market-Penetration Curve for Commercial R&D Project Targeting Existing Buildings

2.2.5 Sources

(1) "Building Technology Program: Research, Development and Demonstration Plan, Planned Program Activities for 2004-2010." Final Draft. U.S. DOE, January 9, 2004.

(2) Torcellini, Paul, et. al. Lessons Learned from Field Evaluation of Six High-Performance Buildings, NREL/CP-550-36290, National Renewable Energy Laboratory, June 2004.

(3) E-mail correspondence with project manager, Dru Crawley, June 2003.

(4) RS Means Company, Inc. 2002. "RS MEANS Square Foot Costs." 23rd Edition, Kingston, MA.

(5) Kats, Greg (Capital E), et. al. "The Costs and Financial Benefits of Green Buildings," A Report to California's Sustainable Building Task Force. October 2003.

(6) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

3.0 Equipment Standards and Analysis

The Equipment Standards and Analysis subprogram seeks to develop minimum energy efficiency standards that are technologically feasible and economically justified.

3.1 Electric Motors, 1-200 HP

Project Description(1). The Energy Policy Act of 1992 (EPAct) requires that general purpose, polyphase, single speed, squirrel-cage induction motors rated from 1-200 horsepower (HP) manufactured for sale in the U.S. from October 1997 onward meet minimum efficiency standards. The EPAct standard was adapted from earlier standards promulgated by the National Electrical Manufacturer's Association (NEMA). NEMA maintains a more stringent voluntary standard known as NEMA Premium™. DOE is proposing to change the minimum requirements for motor efficiency to be comparable to the NEMA Premium™. The efficiency standard targets motors designed for use under usual service conditions without restriction to a particular application or type of application. Motors covered by the Energy Policy Act (EPAct) account for 50-70 percent of all integral[h] horsepower motors sold.

3.1.1 Significant Changes from FY06

This characterization represents a new activity for FY07.

3.1.2 Target Market

Market Description(1). Industrial motor systems are the largest single electrical end use in the U.S. economy. According to the United States Industrial Electric Motor Systems Market Opportunity Assessment, electric motors used in industrial processes consumed 679 billion kWh (approximately 7.5 quads of primary energy) in 1994. Commercial sector motors are much more numerous than industrial motors, and tend to be smaller. In 1995, there were 123 million commercial sector motors in total. About 36 million commercial motors fall in the EPAct size range.

Size of Market. There is an installed base of 12.3 million industrial sector units and 4.1 million commercial sector units, 1-200HP, that are subject to EPAct. There are about 1.5 million industrial motors shipped annually, and an additional 0.54 million commercial units.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

3.1.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. No price information was available or used to model this program.

[h] Motors below 1 horsepower (HP) are known as fractional horsepower motors; those 1 HP and above are known as integral.

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Reduced CO_2 and SO_X emissions
- Increased life of equipment operating at cooler temperatures
- Reduced first costs that transform new technologies into commodities.

3.1.4 Methodology and Calculations

Technical Characteristics.
Energy performance assumptions are based on DOE's FY2005 Technical Support Document, Appendix A, and include the following:

- Base Case: Average electric motor energy consumption: 25.61 thousand kWh/yr
- Performance: Standard results in 2% average reduction in energy
- Equipment lifetime: 15 years
- Start Date: Effective date of standard is 2010.

Expected Market Uptake. BT assumed that the entire stock of existing motors is replaced with motors meeting the standard by 2025 (the standard goes into effect in 2010, so within 15 years, the estimated lifetime, all motors have been replaced). Subsequent increases in savings are only from increases in new sales (as opposed to replacement sales).

Based on forecasted shipment data[(1)], **Tables G-6 and G-7** contain the energy savings calculations.

Table G-6. Annual Industrial Energy Savings

Year	In-Year Energy Savings from Sales (million kWh/yr Site)	Total Annual Energy Savings – Installed Base (million kWh/yr Site)	Annual Energy Savings – Installed Base (TBtu/yr Site)
2007	0.0		
2008	0.0		
2009	0.0	-	-
2010	652.3	652.3	2.2
2011	665.3	1,317.6	4.5
2012	678.6	1,996.2	6.8
2013	692.2	2,688.3	9.2
2014	706.0	3,394.4	11.6
2015	720.1	4,114.5	14.0
2016	734.5	4,849.0	16.5
2017	749.2	5,598.3	19.1
2018	764.2	6,362.5	21.7
2019	779.5	7,142.0	24.4
2020	795.1	7,937.1	27.1
2021	811.0	8,748.1	29.8
2022	827.2	9,575.3	32.7
2023	843.8	10,419.1	35.5
2024	860.6	11,279.7	38.5
2025	225.6	11,505.3	39.3
2026	230.1	11,735.4	40.0
2027	234.7	11,970.1	40.8
2028	239.4	12,209.5	41.7
2029	244.2	12,453.7	42.5
2030	249.1	12,702.8	43.3

Table G-7. Annual Commercial Energy Savings

Year	In-Year Energy Savings from Sales (million kWh/yr Site)	Total Annual Energy Savings – Installed Base (million kWh/yr Site)	Annual Energy Savings – Installed Base (TBtu/yr Site)
2007	0.0		
2008	0.0		
2009	0.0	-	-
2010	176.7	176.7	0.6
2011	180.2	356.8	1.2
2012	183.8	540.6	1.8
2013	187.5	728.1	2.5
2014	191.2	919.3	3.1
2015	195.0	1,114.3	3.8
2016	198.9	1,313.3	4.5
2017	202.9	1,516.2	5.2
2018	207.0	1,723.2	5.9
2019	211.1	1,934.3	6.6
2020	215.3	2,149.6	7.3
2021	219.6	2,369.3	8.1
2022	224.0	2,593.3	8.8
2023	228.5	2,821.8	9.6
2024	233.1	3,054.9	10.4
2025	61.1	3,116.0	10.6
2026	62.3	3,178.3	10.8
2027	63.6	3,241.9	11.1
2028	64.8	3,306.7	11.3
2029	66.1	3,372.9	11.5
2030	67.5	3,440.3	11.7

3.1.5 Sources

(1) U.S. Department of Energy 2005. Appendix A: FY2005 Technical Support Document. Accessed online on January 2006 at http://www.eere.energy.gov/buildings/appliance_standards/pdfs/fy05_priority_setting_app_a.pdf

3.2 HID Lamps

Project Description. [1] High Intensity Discharge (HID) Lamps are electric lamps that produce light in a small arc tube under high internal pressure. Typical applications for these lamps are street and roadway lighting, area lighting such as parking lots and stadiums, industrial and commercial building interior lighting, commercial, industrial and residential security lighting, and landscape lighting. There are three HID lamp types: mercury vapor, metal halide, and high pressure sodium and the least efficient of these is mercury vapor. The Energy Policy and Conservation Act (EPCA, 42 U.S.C.6317(a)(1)) requires the Department of Energy (the Department) to undertake a determination to see if energy conservation standards for HID lamps would be technologically feasible and economically justified, and would result in significant energy savings.

3.2.1 Significant Changes from FY06

This characterization represents a new activity for FY07.

3.2.2 Target Market

Market Description: According the draft Technical Support Document published in December 2004,[(2)] mercury vapor lamps account for about one-sixth of the approximately 140 TWh used by all high intensity sources. Thus mercury vapor lamps use about 75 TBtu of delivered electricity per year.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

Market Introduction. BT assumed that the effective date of the standard would be 2010.

3.2.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Costs as defined by the NEMS commercial model (file Ktech.txt)

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Reduced CO_2 and SO_X emissions
- Increased life of equipment operating at cooler temperatures

3.2.4 Methodology and Calculations

From documents on the BT web site[(1)] related to the setting of efficiency standard for HID lamps, the basic impact will likely be the elimination of mercury vapor lamps via a federal efficiency standard. As stated in the documentation of expected impacts in the Technical Support Document, "… the focus is on a possible standard that could be met by lamps with efficacies above those typical of today's MV lamps." Subsequent events have confirmed that choice for modeling the standard. The EPAct 2005 requires that mercury vapor lamp ballasts shall not be manufactured or imported after January 1, 2008.

Technical Characteristics.
The commercial model in NEMS contains several lighting segments that include mercury vapor, metal halide (MH), and high pressure sodium (HPS). The market segments considered by the NEMS model are low-bay applications (< 25 feet high) and high-bay applications (> 25 feet high) for high-intensity discharge lamps. **Table G-8** shows the efficacies used in the NEMS input files for these common lamp technologies and the typical wattages for those lamps. For purposes of modeling the HID standard in the GPRA integrated model, mercury vapor lamps were no longer one of lighting technology choices in these two market segments in the expected year of the standard.

Table G-8. Efficacies for Common HID Lamp Types in NEMS (Lumens/Watt, lpw)[i]

Application	Mercury Vapor	Metal Halide	High Pressure Sodium
Low-bay	34 lpw (175 watts)	46 lpw (pulse) (100 watts)	59 lpw (70 watts)
High-bay	37 lpw (400 watts)	61 lpw (pulse) (250 watts)	83 lpw (200 watts)

Performance Parameters. 40 lumens per watt for mercury vapor; 70 lumens per watt for metal halide; and 90 lumens per watt for high pressure sodium.

3.2.5 Sources

(1) BT Appliances and Commercial Equipment Standards web site, accessible at: http://www.eere.energy.gov/buildings/appliance_standards/commercial/high_intensity_lamps.html.
(2) High-Intensity Discharge Lamps Analysis of Potential Energy Savings, December 2004, accessible at: http://www.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/hid_energy_savings_report.pdf.

3.3 Distribution Transformers

Project Description. Distribution transformers convert high-voltage electricity from distribution centers to lower-voltage electricity for use at the household level. During this conversion process, a small fraction of heat is lost. The Energy Policy and Conservation Act (EPCA) of 1975 established an energy conservation program for major household appliances. The National Energy Conservation Policy Act of 1978 amended EPCA to add Part C of Title III, which established an energy conservation program for certain industrial equipment. The Energy Policy Act of 1992 amended EPCA to add certain commercial equipment, including distribution transformers.

The department is currently conducting two rulemakings for Distribution Transformers: an energy conservation standard and a test procedure.

3.3.1 Significant Changes from FY06

For the FY07 effort, the effective date of the standard was changed from 2008 to 2010 based on the current rule-making schedule.

3.3.2 Target Market

Market Description[(3)]. Over one million new distribution transformers are purchased annually. Utility distribution transformers account for an estimated 61 billion kWh of the annual energy

[i] Source is the ktech.wk1 spreadsheet containing cost and performance characteristics for the NEMS commercial module used for the 2006 AEO reference projection.

lost in the generation and delivery of electricity. Additional transformer losses in non-utility applications are estimated to be 79 billion kWh.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

3.3.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT assumed a 10-year payback period on investment to develop incremental investment costs (i.e., an annual energy cost savings of $1 implies an initial investment of $10).

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Reduced CO_2 and SO_X emissions

3.3.4 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics

Performance Target. Savings estimates for a distribution transformer standard were based on the DOE Draft ANOPR Analysis for Distribution Transformers Rulemaking (January 6, 2004).(1) The analysis assumed the following:

- Average savings of 140 watts per unit
- A transformer sales forecast (see **Table G-9**).
- 0% sales complying with the new level without the standard (this was taken into account in calculating the 140 watts average savings)
- 8,760 annual operating hours per unit
- 30-year life of equipment.

BT assumed that the distribution transformer standard would not go into effect until 2010, based on the BT 2006 Multi-Year Program Plan indicating that the final rule would be issued September 2007, with the standard going into effect three years later.(2) The savings estimate of 140 watts per unit installed was multiplied by the estimated hours of operation and then by the forecasted number of units installed.

Expected Market Uptake

Table G-9. Distribution Transformer Market Penetration (# of units)

Year	Transformer Sales Forecast
2010	1,582,000
2011	1,614,000
2012	1,646,000
2013	1,673,000
2014	1,701,000
2015	1,729,000
2016	1,756,000
2017	1,782,000
2018	1,810,000
2019	1,840,000
2020	1,870,000
2021	1,898,000
2022	1,929,000
2023	1,960,000
2024	1,994,000
2025	2,025,000
2026	2,058,000
2027	2,090,000
2028	2,124,000
2029	2,158,000
2030	2,192,000

3.3.5 Sources

(1) DOE Draft ANOPR Analysis for Distribution Transformers Rulemaking, January 6, 2004.
(2) "Building Technologies Program: 2006 Multi-Year Program Plan." Draft. U.S. DOE, March 29, 2005.
(3) Barnes, P.R., S. Das, B.W. McConnell, J.W. Van Dyke, 1997. *Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers*. ORNL-6925, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

4.0 Emerging Technologies

The Emerging Technologies subprogram seeks to develop cost effective technologies (e.g., lighting, windows, and space heating and cooling) for residential and commercial buildings that can reduce the total energy use in buildings by 60% to 70%. The improvement in component and system energy efficiency, when coupled with research to integrate onsite renewable energy supply systems into the commercial building, can result in marketable net zero energy designs.

4.1 Analysis Tools and Design Strategies

Project Description.[1] The Analysis Tools and Design Strategies project researches the interrelationship of energy systems and building energy performance, develops various building analysis tools to more accurately model energy use in new and existing buildings, and provides recommendations and strategies to cost effectively lower energy use and improve building performance. The project focuses on whole-building software tools for evaluating energy efficiency and renewable energy. The project also focuses on non-software solutions such as improved standards, guidelines, and performance measurements, all of which bring about excellence in designing new buildings. The project's long-term goal is to improve energy designs for all building types through a number of widely used analytical tools and guidance documents.

4.1.1 Significant Changes from FY06

BT estimates that Analysis Tools and Design Strategies would accelerate the adoption of relevant energy-savings products, technologies and designs by 5 years. This estimate is a revision from a 10 year period (assumed in FY06).

4.1.2 Target Market

Market Description: Although this project does not explicitly exclude any particular building type, the types of commercial buildings that most likely will be impacted by the technologies developed by this project include those with relatively higher energy use intensities such as assembly, education, health care, lodging, and office buildings.

Market Introduction[1,3]: BT assumed that this project accelerates the introduction and market penetration of the advanced building energy tools and design strategies by 5 years. Historically, there have been a number of building energy tools that have been developed privately; however, most of these tools use algorithms, code, and modules developed by DOE. BT estimated that a proportion of these activities (50%) would not occur without DOE funding. These assumptions are necessary in the absence of citable sources documenting DOE’s influence on building energy tool adoption and algorithm attribution.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

Baseline Market Acceptance. In 1998, Pacific Northwest National Laboratory (PNNL) conducted a study examining the historical market penetration for 10 energy-efficient products related to the buildings sector. The results of this study are documented by PNNL[(5)]. The study suggested several generic penetration curves based on the type of equipment of interest. BT used the curve related to design products to model this project.

4.1.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price[(3,4)]. Although the tools supported by this project are distributed free of charge, users must invest a certain amount of time to learn the tools. Without a user-friendly interface, approximately one person-month is required to be come proficient with the tools. Analysis Tools and Design Strategies is currently developing energy-simulation tools without a user-friendly interface. This allows the private sector to contribute its knowledge of user needs and market competition to design their own user-friendly interface.

Key Consumer Preference/Values – Nonenergy Benefits. The following nonenergy characteristics were not considered in developing energy output estimates:

- Improved indoor environmental quality, such as thermal comfort and ventilation adequacy
- Improved indoor air quality
- Fire safety
- Overall environmental sustainability (i.e., Green Buildings).

4.1.4 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics[(2)]. In concert with Commercial Buildings R&D project, the performance goals are to reduce heating and cooling loads by 50% in new small commercial construction and by 30% in existing buildings.[j]

Expected Market Uptake[(3)]. The market penetration goal is to accelerate the penetration of high-performance building design, such that 55% of new commercial and multifamily construction and 20% of existing construction incorporates the products supported by this project by 2025. BT assumes that this project accelerates the adoption of relevant energy-savings products, technologies and designs by 5 years.

[j] The percentage of the load reduction attributed between Commercial R&D and Analysis Tools and Design Strategies is in proportion with their respective budget requests.

4.1.5 Sources

(1) "Building Technology Program: Research, Development and Demonstration Plan, Planned Program Activities for 2004-2010." Final Draft. U.S. DOE, January 9, 2004.
(2) Torcellini, Paul, et. al. *Lessons Learned from Field Evaluation of Six High-Performance Buildings,* NREL/CP-550-36290, National Renewable Energy Laboratory, June 2004.
(3) E-mail correspondence with project manager, Dru Crawley, June 2003 and June 2004.
(4) Kats, Greg (Capital E), et. al. "The Costs and Financial Benefits of Green Buildings," A Report to California's Sustainable Building Task Force. October 2003.
(5) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

4.2 Appliances and Emerging Technologies R&D: Solid State Lighting Market Acceptance

Project Description(1)**:** The purpose of this program is to accelerate the market acceptance of solid-state lighting technologies. This will be accomplished through a variety of methods potentially including:

- Competitive technology procurements
- Late-stage technology refinement in conjunction with influential product users
- Field performance evaluation and verification for the benefit of large-scale buyers
- Product performance testing
- Product design competitions in cooperation with major market actors
- Voluntary product guidelines and conventions

4.2.1 Significant Changes from FY06

The activities modeled for Appliances and Emerging Technologies R&D changed for FY07. The only activity modeled for FY07 is Solid State Lighting Acceptance, which is a new activity.

4.2.2 Target Market

Market Description: The market is the entire market for solid-state lighting.

Size of Market: Lighting consumes 26% (3.9 QBtu) of the primary energy used in commercial buildings, which had building stock of about 69 billion ft^2 in 2000.[k]

4.2.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Given that this is a market acceptance program there will be no direct cost borne by the consumers.

[k] According to a report completed for DOE by Navigant Consulting ("U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate," September 2002), the amount of energy used for lighting is greater than EIA has traditionally estimated. The report estimates that commercial lighting requires 4.2 QBtu and residential lighting requires 2.2 QBtu.

Key Consumer Preferences/Values[1]: This program recognizes that market acceptance is determined by the buyers' perspective and needs. Price, reliability, and performance are key consumer values for lighting.

4.2.4 Methodology and Calculations

As advanced appliance, equipment, and envelope technologies emerge, the AET program plays a key role in expanding and accelerating the market acceptance of technologies that are not only on the critical pathway to ZEB in the future but also relevant to the broader new and retrofit residential and commercial building sectors in the near term.[1]

Market Introduction: It is projected that this program will accelerate the market penetration of the technology by 2 years.

Expected Market Uptake: **Figure G-3** (with largely hypothetical numbers) illustrates the market uptake concept. In the graph it is assumed that the Emerging Technologies R&D Program accelerates the penetration of SSL technologies by 2 years. Hence the benefit of the emerging technology program is captured by the yellow line (the difference between the purple line and the blue line).

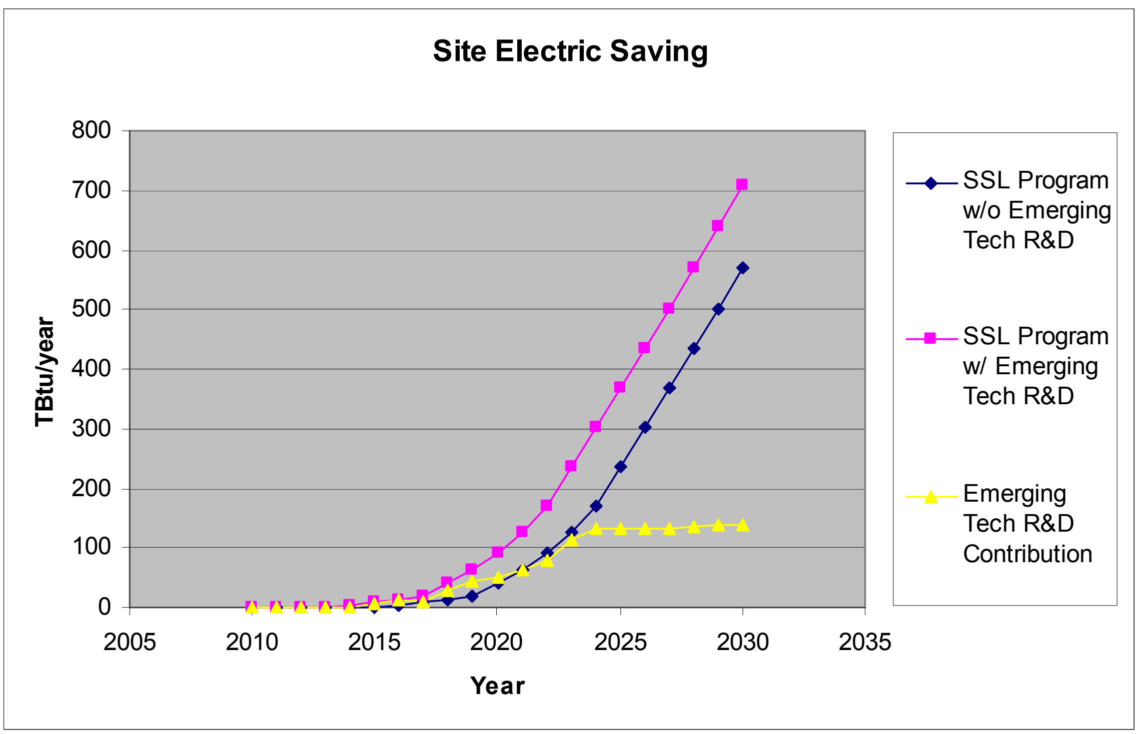

Figure G-3. Solid State Lighting Market Uptake Concept

4.2.5 Sources

1) "Building Technologies Program: 2006 Multi-Year Program Plan." Draft. U.S. DOE, March 29, 2005.

4.3 Envelope Research and Development: Windows

Project Description[1]**.** Windows typically contribute about 30 percent of overall building heating and cooling loads with an annual impact of about 3.7 quads, with an additional potential savings of 1 quad from daylight use. The BT approach is to first convert windows from their current role as significant thermal losses to the point where they are energy neutral, and then move to a higher level of performance, where they contribute to a net energy surplus in a ZEB, thus offsetting other energy costs.

About 60 percent of window sales are to the residential sector and 40 percent to commercial, so that this program targets both sectors. Sales are evenly distributed between new construction and existing buildings, so both markets are included in the R&D program. Because the energy needs of residential users differ from commercial, and new construction and renovation/retrofit are different, and because all performance is strongly influenced by climate and orientation, the development of a single "silver bullet R&D solution" that solves all problems is not possible. Furthermore, window impacts on building energy use are linked to other building systems. Therefore the technical approach of the Windows activity is built around three themes:

1. The need for a broad portfolio of cost-effective advanced technologies to address the disparate heating, cooling and daylighting needs of these different conditions;
2. Recognition that these advanced glazing and façade technologies will perform best when they are optimized as part of fully integrated building systems to address competing performance needs as a function of time, climate, building type and orientation; and
3. The need for decision-support infrastructure to rate and label products, and tools to select and optimize window selection and design solutions. For existing energy efficient products, rating and labeling an entire suite of products with a strong focus on commercial building applications will remove barriers for product specification and promotion by industry and non-profit organizations.

4.3.1 Significant Changes from FY06

No significant changes were made to this program for the FY07 effort.

4.3.2 General Target Market

Market Description: The market includes new and existing commercial and residential buildings in all climate zones.

Size of Market: 500 million square feet of windows for commercial buildings and approximately 55 million manufactured units sold each year for residential and light commercial.

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

4.3.3 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Reduced utility and building peak loads
- Reduced HVAC Requirements and first costs
- Improved indoor comfort and aesthetics.

4.3.4 Electrochromic Windows

Project Description.(1) Windows are capable of providing solar heat when it is needed, rejecting solar gain to reduce cooling loads, and offsetting most of a building's lighting needs during daylight hours. To fully accomplish these functions, windows and skylights must continuously and dynamically control their transmittance of sunlight and daylight. In commercial buildings the dynamic tradeoffs between cooling load reductions and daylight utilization are particularly complex. Glazings whose solar optical properties can be varied rapidly over a wide dynamic range are needed to address these performance needs. Research activities include development of durable chromogenic coatings, emphasizing electrochromic technology for the first generation of products and the exploration of other switchable coating mechanisms with lower cost, faster switching and wider dynamic range over time. Work includes fundamental coating technology, characterization, durability testing, prototype testing, and controls integration and optimization including field-testing.

4.3.4.1 Target Market

Market Introduction: 2010; This project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.

4.3.4.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental Installed Cost over competing technology (Low-e Double-Pane Windows)

- 2010: $54.42/ ft^2
- 2011: $44.42/ ft^2
- 2012: $34.42/ ft^2
- 2013: $24.42/ ft^2
- 2014: $19.42/ ft^2
- 2015: $14.42/ ft^2
- 2016: $9.42/ ft^2
- 2017: $7.42/ ft^2
- 2018: $5.42/ ft^2
- 2019: $3.42/ ft^2
- 2020: $1.42/ ft^2

4.3.4.3 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO). Note that the base technology to which this technology is being compared is that of low-e double pane windows.

Technology Characteristics
Performance Parameters: Performance parameters for Electrochromic Windows are presented in **Table G-10**.

Table G-10. Performance Parameters for Electrochromic Windows

End Use	Shading Coefficient	U-Value
Heating	0.6	0.25 Btu/ft2·°F
Cooling	0.1	0.25 Btu/ft2·°F

Performance Target: Performance characteristics vary by building type and climate zone. The estimated savings per building were determined by simulating residential and commercial buildings in all climate zones (see **Table G-11**). Commercial lighting savings are estimated to be 5% in all regions.

Table G-11. Performance Targets for Electrochromic Windows

Region	Sector	End Use	New Building Savings	Existing Building Savings	Units
Northern	Commercial	Heating	1.83	1.61	MMBtu/ksf
		Cooling	4.62	4.58	MMBtu/ksf
North Central	Commercial	Heating	1.88	1.66	MMBtu/ksf
		Cooling	5.80	5.52	MMBtu/ksf
South Central	Residential	Heating	3.91	4.38	MMBtu/HH
		Cooling	11.16	11.30	MMBtu/HH
	Commercial	Heating	0.94	0.88	MMBtu/ksf
		Cooling	5.75	5.51	MMBtu/ksf
Southern	Residential	Heating	3.00	3.61	MMBtu/HH
		Cooling	7.51	7.76	MMBtu/HH
	Commercial	Heating	0.56	0.53	MMBtu/ksf
		Cooling	3.05	2.92	MMBtu/ksf
Weighted National Average (Southern and South Central for Residential)	Residential	Heating	3.65	4.16	MMBtu/HH
		Cooling	10.13	10.28	MMBtu/HH
	Commercial	Heating	1.43	1.28	MMBtu/ksf
		Cooling	4.96	4.81	MMBtu/ksf

Note: MMBtu is millions of Btus; Ksf is thousand square foot; HH is household

Window Lifetime: 20 years.

Expected Market Uptake. The goal is to obtain 50% of window sales by 2020 in the commercial sector, and 20% of window sales by 2020 in the residential sector. Penetration curves were developed and documented based on market diffusion curves developed by

PNNL[2]. The "Accelerated" penetration curve represents the percent of electrochromic window sales with the DOE project; the "Net" penetration curve represents the percent of sales attributable to DOE, as BT assumed that the DOE project would accelerate market acceptance by 10 years. See penetration curves in **Figures G-4 through G-7**.

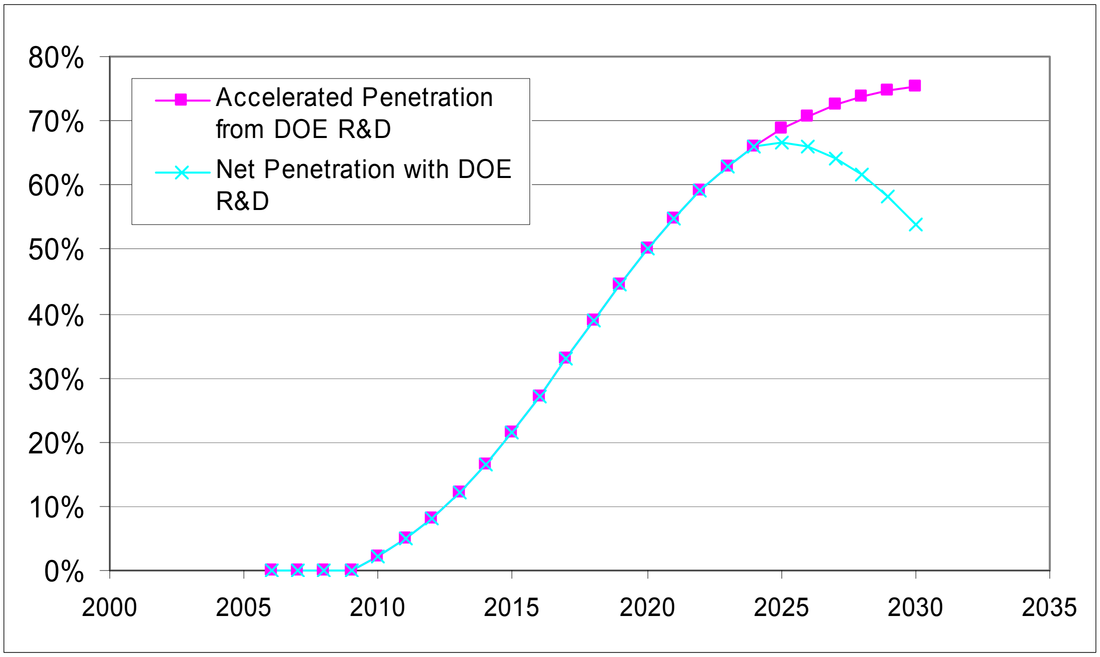

Figure G-4. Electrochromic Windows – New Commercial Buildings Percent of Sales

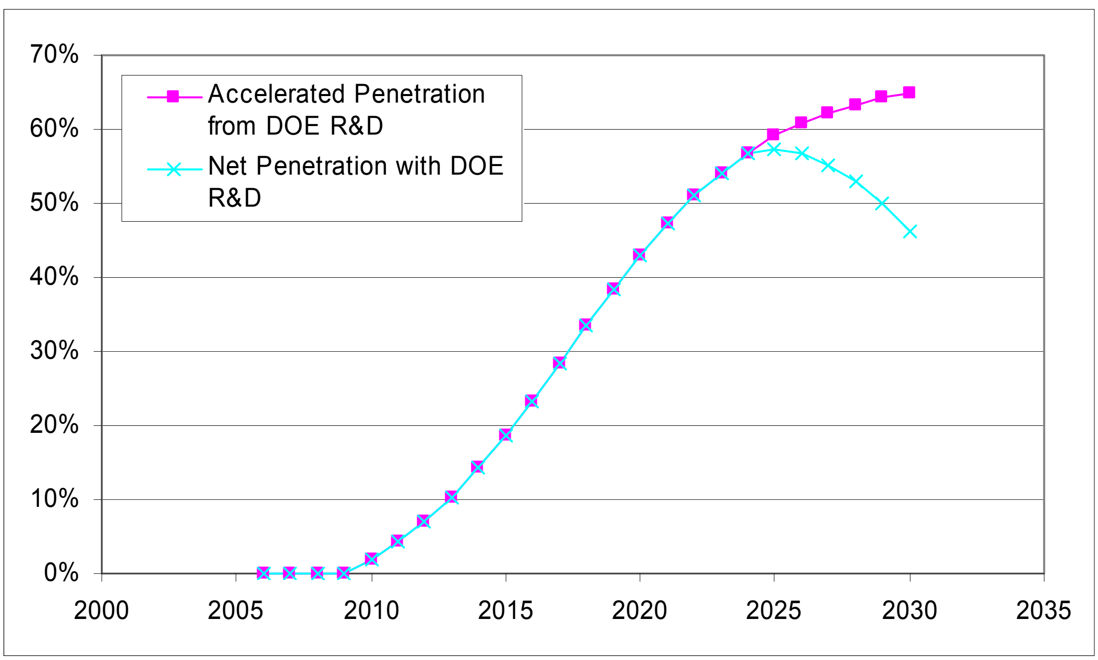

Figure G-5. Electrochromic Windows – Existing Commercial Buildings Percent of Sales

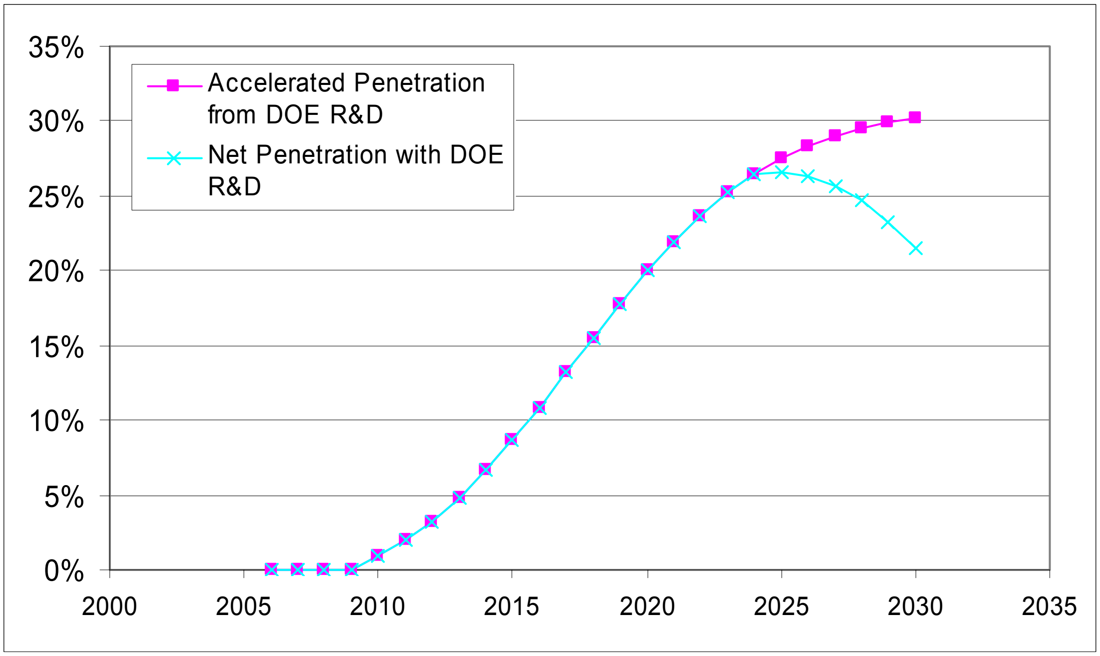

Figure G-6. Electrochromic Windows – New Residential Buildings Percent of Sales

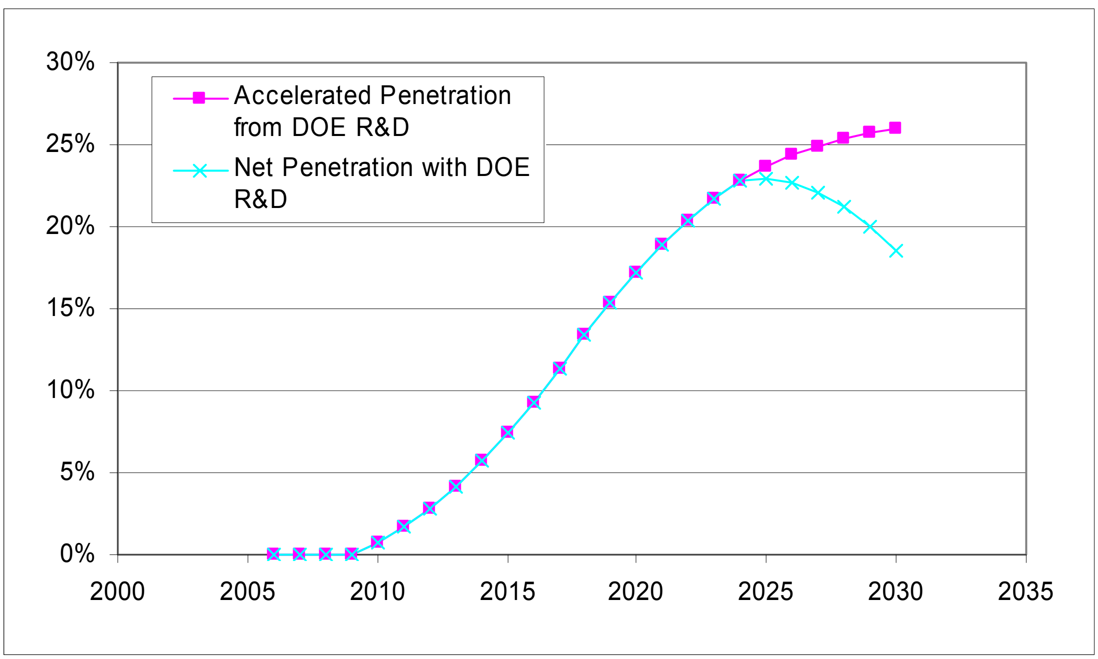

Figure G-7. Electrochromic Windows – Existing Residential Buildings Percent of Sales

4.3.5 Superwindows

Project Description. [(1)] With heating loads being the largest end-use impact, improving winter performance has the potential for large energy savings. Low-E gas-filled windows introduced in the 1980s have now captured more than 40% of the residential market. But, heat loss rates for whole windows must be reduced by at least a factor of 2 to approach levels needed for zero-energy buildings. Highly leveraged competitive R&D will be conducted towards achieving these impacts. Research activities will include basic and exploratory research on advanced optical coatings, gas filled and evacuated cavities, microporous transparent insulating materials, improved edge and frame materials; and applied research to support rating, design tools, and implementation of efficient window technologies.

4.3.5.1 Target Market

Market Introduction: 2007; BT assumed that this project would accelerate the introduction of this technology into the marketplace by 10 years.

4.3.5.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental Installed Cost Over competing technology (Low-e Double-Pane Windows)

- 2007: $6.00/ft^2
- 2020: $4.00/ft^2
- 2030: $3.00/ft^2

4.3.5.3 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO). Note that the base technology to which this technology is being compared is that of low-e double pane windows.

Technical Characteristics

Performance Parameters: Superwindows have maximum U-value[l] and solar heat gain coefficient (SHGC)[m] for four climate zones. These climate zones do not directly correspond to the traditional climate zones used in CBECS or RECS; they also do not correspond to the census divisions used in NEMS. These new climate zones are based on the eight climate zones that were developed as part of the IECC 2003 code change cycle or Residential IECC Code Change (RICC). In general, the Superwindow zones map from the RICC zones **(Table G-12)**.

Table G-12. Mapping of RICC Zones to Superwindow Zones

RICC Zone	Superwindow Zone
1	Southern
2	Southern
3	South/Central
4	North/Central
5	Northern
6	Northern
7	Northern
8	Northern

To construct the four Superwindow zones there was a fair amount of smoothing required due to geo-political boundaries, existing codes, and commercial regions. For example, a strict

[l] U-Value is defined as the rate of heat loss, in Btu per hour, through a square foot of surface.
[m] SHGC is the fraction of solar radiation admitted through a window.

adherence of the eight RICC zones to four Superwindow zones shown above would have portions of California in all four Superwindow zones and would result in discontinuities in the zones across the country. The final result is that California is wholly within the South/Central zone and all four Superwindow zones are continuous across the country. Performance parameters are listed in **Table G-13**.

Table G-13. Performance Parameter Maximums for Superwindows

Region	End Use	Shading Coefficient	U-Value
Northern	Heating	0.6087	0.10 Btu/ft2·°F
	Cooling	0.2609	0.10 Btu/ft2·°F
North Central	Heating	0.6807	0.10 Btu/ft2·°F
	Cooling	0.2609	0.10 Btu/ft2·°F
South Central	Heating	0.1304	0.20 Btu/ft2·°F
	Cooling	0.1304	0.20 Btu/ft2·°F
Southern	Heating	0.1304	0.20 Btu/ft2·°F
	Cooling	0.1304	0.20 Btu/ft2·°F

Performance Target: Performance characteristics vary by climate zone. The estimated savings per building were determined by simulating residential buildings in all climate zones (see **Table G-14**).

Table G-14. Performance Targets for Superwindows

Region	Sector	End Use	New Building Savings	Existing Building Savings	Units
Northern	Residential	Heating	10.80	11.15	MMBtu/HH
		Cooling	4.29	4.31	MMBtu/HH
North Central	Residential	Heating	8.83	9.18	MMBtu/HH
		Cooling	5.05	5.15	MMBtu/HH
South Central	Residential	Heating	-0.08	0.02	MMBtu/HH
		Cooling	10.10	10.32	MMBtu/HH
Southern	Residential	Heating	1.64	1.90	MMBtu/HH
		Cooling	6.32	6.66	MMBtu/HH
Weighted National Average	Residential	Heating	6.24	6.51	MMBtu/HH
		Cooling	6.34	6.44	MMBtu/HH

Lifetime: 30 years

Expected Market Uptake. The goal is to obtain 65% of window sales in new residential buildings and 33% in existing residential buildings by 2020. Penetration curves were developed based on market diffusion curves developed by PNNL and documented in the 2004 PNNL report, *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (Elliott, et. al). The "Accelerated" penetration curve represents the percent of superwindow sales with the DOE project; the "Net" penetration curve represents the percent of superwindow sales attributable to DOE, as BT assumed that the DOE project would accelerate market acceptance by 10 years. See penetration curves in **Figures G-8 and G-9**.

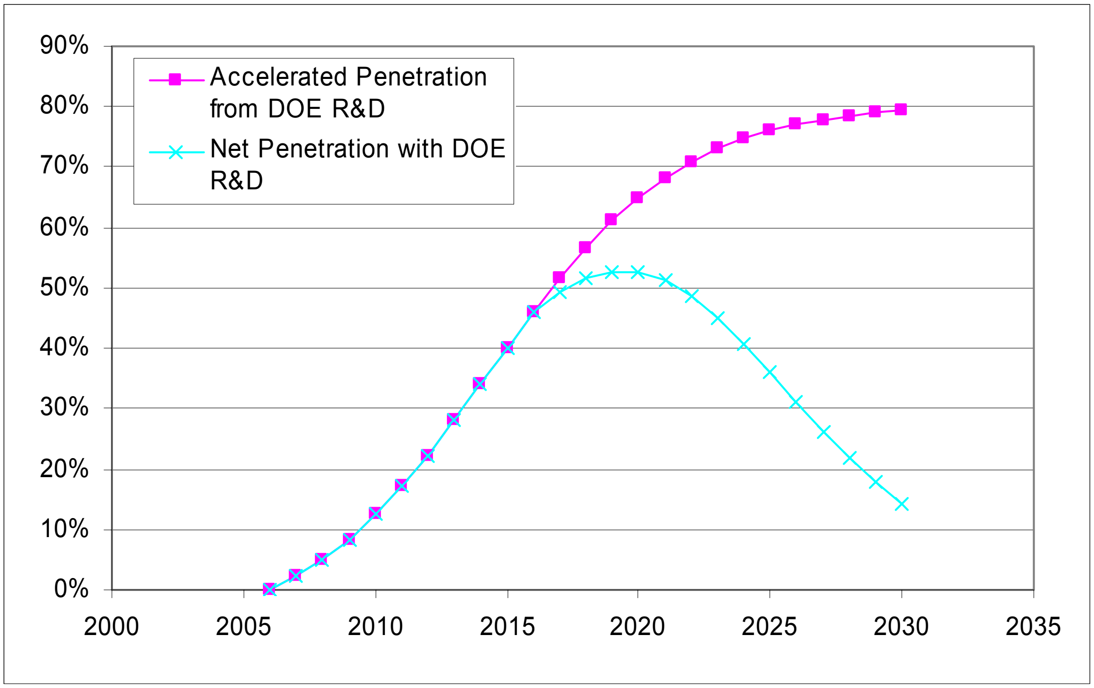

Figure G-8. Superwindows – New Residential Buildings Percent of Sales

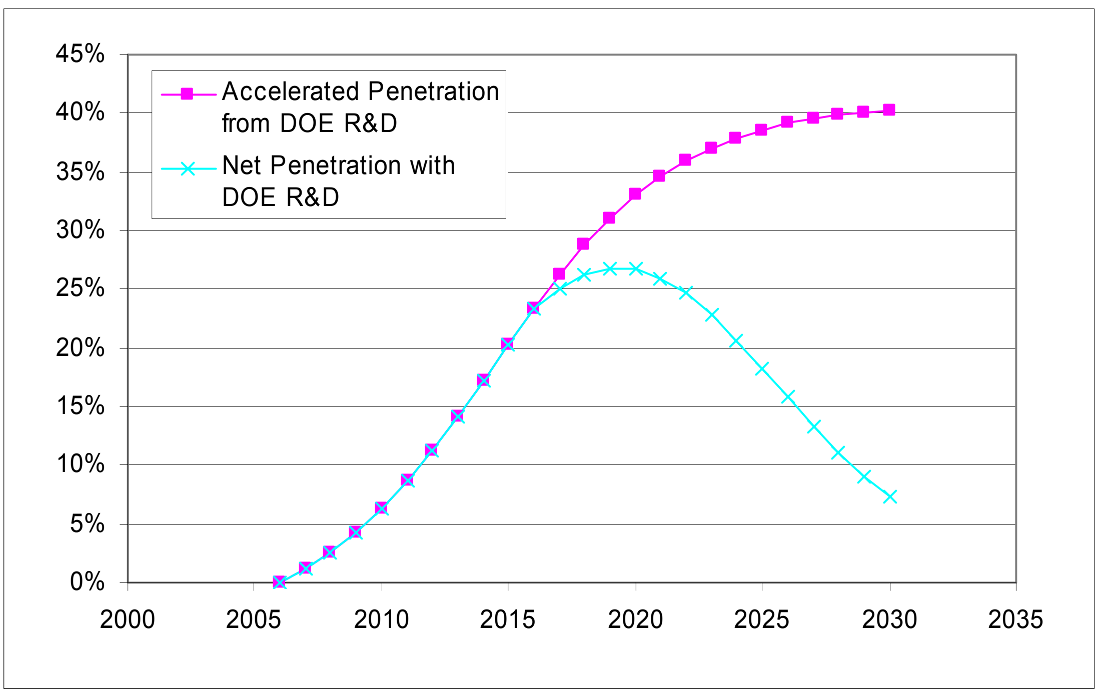

Figure G-9. Superwindows – Existing Residential Buildings Percent of Sales

4.3.6 Low-Emissivity Glass Acceptance

Project Description. [(1)] Low-e windows have at least one surface coated with a thin, nearly invisible, metal oxide or semiconductor film that reduces the heat transfer through windows. The conventional windows that they replace have no coating. Currently low-e windows represent less than 20% of the commercial market and are not the default product for builders in the residential market, constituting about 40% of that market. Additional research that supports industry and nonprofit energy efficiency programs from FY07 through FY09 can significantly increase the penetration of these energy-efficient products. The purpose of the program is to increase the penetration of low-e glass from 40% in the residential market and 10% in the commercial market to 100% in both markets by 2020. Two programs, Low-e Market Acceptance and Energy Star Windows, form the joint means to achieving the low-e penetration goal; hence, the savings will be split equally. The performance of the low-e glass is as described for the Electrochromic and Super Windows baseline.

4.3.6.1 Target Market

Market Introduction: The technology is commercially available. BT assumed that this project would accelerate the penetration in the marketplace by 10 years.

4.3.6.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental Installed Cost over Conventional Double-Pane Windows

- 2005: $1.00/ft^2
- 2015: $0.50/ft^2

4.3.6.3 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics

Performance Parameters: Low-e Windows have maximum U-value and SHGC for four different climate zones. These climate zones do not directly correspond to the traditional climate zones used in CBECS or RECS; they also do not correspond to the census divisions used in NEMS. These new climate zones are based on the eight climate zones that were developed as part of the IECC 2003 code change cycle or Residential IECC Code Change (RICC). In general the Low-e zones map from the RICC zones as follows in **Table G-15**.

Table G-15. Mapping of RICC Zones to Low-e Zones

RICC Zone	Low-e Zone
1	Southern
2	Southern
3	South/Central
4	North/Central
5	Northern
6	Northern
7	Northern
8	Northern

To construct the four Low-e zones, there was a fair amount of smoothing required due to geo-political boundaries, existing codes, and commercial regions. For example, a strict adherence of the eight RICC zones to four Low-e zones shown above would have portions of California in all four Low-e zones and would result in discontinuities in the zones across the country. The final result is that California is wholly within the South/Central zone and all four Low-e zones are continuous across the country. Performance parameters are listed in **Table G-16**.

Table G-16. Performance Parameter Maximums for Low-e Windows

Region	Shading Coefficient	U-Value
Northern	0.60	0.35 Btu/ft2·°F
North Central	0.55	0.40 Btu/ft2·°F
South Central	0.40	0.40 Btu/ft2·°F
Southern	0.40	0.65 Btu/ft2·°F

Performance Target: Performance characteristics vary by building type and climate zone. The estimated savings per building were determined by simulating residential and commercial buildings in all climate zones (see **Table G-17**).

Table G-17. Performance Targets for Low-e Windows

Region	Sector	End Use	New Building Savings	Existing Building Savings	Units
Northern	Residential	Heating	8.17	8.30	MMBtu/HH
		Cooling	0.06	0.19	MMBtu/HH
	Commercial	Heating	6.24	5.73	MMBtu/ksf
		Cooling	-0.45	-0.58	MMBtu/ksf
North Central	Residential	Heating	2.88	2.94	MMBtu/HH
		Cooling	1.72	1.79	MMBtu/HH
	Commercial	Heating	2.98	2.77	MMBtu/ksf
		Cooling	0.74	0.68	MMBtu/ksf
South Central	Residential	Heating	0.09	0.00	MMBtu/HH
		Cooling	10.50	10.39	MMBtu/HH
	Commercial	Heating	0.75	0.66	MMBtu/ksf
		Cooling	5.91	5.62	MMBtu/ksf
Southern	Residential	Heating	-1.48	-1.77	MMBtu/HH
		Cooling	9.18	8.77	MMBtu/HH
	Commercial	Heating	-0.14	-0.14	MMBtu/ksf
		Cooling	5.21	4.98	MMBtu/ksf
Weighted National Average	Residential	Heating	3.82	3.82	MMBtu/HH
		Cooling	4.43	4.42	MMBtu/HH
	Commercial	Heating	3.36	3.08	MMBtu/ksf
		Cooling	2.25	2.07	MMBtu/ksf

Expected Market Uptake. The purpose of the program is to increase the penetration of low-e glass from 40% in the residential market and 10% in the commercial market to 100% in the residential market by 2020 and in the commercial market by 2025. Both programs, Low-e Market Acceptance and Energy Star Windows, form the joint means to achieving the low-e penetration goal – the savings are to be split equally. Penetration curves were developed based on market diffusion curves developed and documented by PNNL[2]. The "Accelerated" penetration curve represents the percent of superwindow sales with the DOE project; the "Net" penetration curve represents the percent of sales attributable to DOE, as BT assumed that the DOE project would accelerate market acceptance by 10 years. The penetration rates are shown in **Figures G-10 and G-11**. For Low-e Market Acceptance/ Energy Star Windows, BT assumed that these projects would accelerate the acceptance of this technology in the marketplace by 10 years.

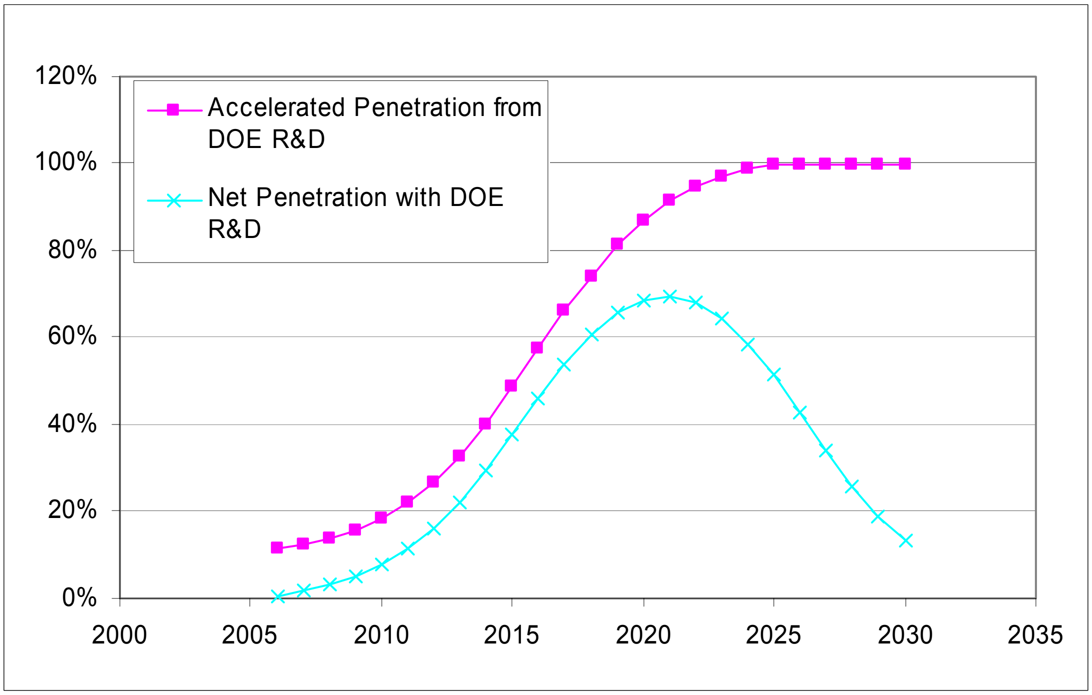

Figure G-10. FY07 Low-e Windows – Commercial Buildings Percent of Sales

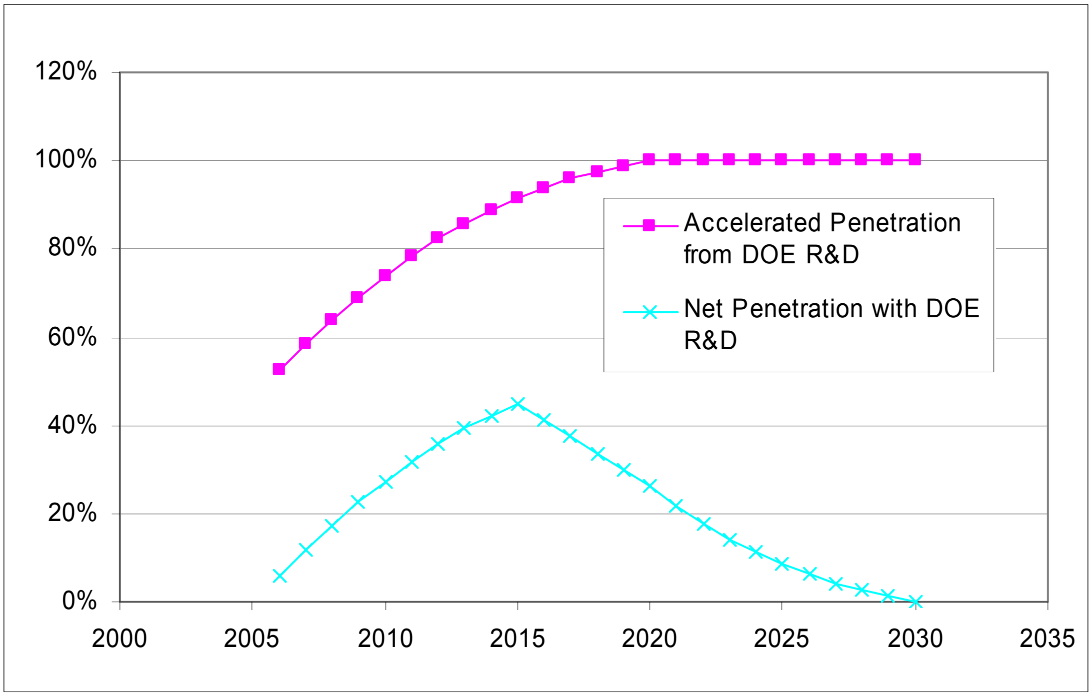

Figure G-11. FY07 Low-e Windows – Residential Buildings Percent of Sales

4.3.7 Sources

(1) "Building Technology Program: Research, Development and Demonstration Plan, Planned Program Activities for 2004-2010." Final Draft. U.S. DOE, January 9, 2004.

(2) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

4.4 Envelope Research and Development: Thermal

The Building Technology Program's long range goal of developing Zero Energy Buildings (ZEB) by 2025 will require more cost effective, durable and efficient building envelopes. Reducing envelope heat transfer will significantly facilitate attainment of a practical ZEB since a significant amount of space heating and cooling energy is lost through inefficient envelopes.[(1)]

To make ZEB affordable, efforts to reduce the energy required for the building are a necessary complement to efforts to reduce the cost of renewable, on-site power. Forty-three percent of the primary energy used in a residence is spent on space heating and cooling. [(2)]

4.4.1 Significant Changes from FY06

The thermal activities are new for FY07.

4.4.2 Advanced Wall Systems

Project Description[(1)]**:** Develop new types of regionally optimized wall systems that are inexpensive and are insensitive to moisture ingress. Additionally, invent and evaluate new techniques for window/wall interface. The goal for the advanced wall systems project is to make these systems constructed by 2010 twice as efficient as Building America's regional benchmarks with no additional envelope failure risk.

4.4.2.1 Target Market

Market Description: The market is new single family residential home.

Size of Market: In 2003, 1,386,300 new single-family homes were built.

4.4.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. At market introduction: 30% above conventional insulation and window material costs or about $1980/single family house[n]. At maturity (10 years): equal to conventional.

Key Consumer Preferences/Values[(1)]**:** A market resistance to increased wall thickness has jeopardized opportunities to improve the energy efficiency of this envelope component in many regions. Therefore, advanced materials and systems are needed that deliver significant improvements in energy performance without increasing wall thickness.

4.4.2.3 Methodology and Calculations

Technology Characteristics
Market Introduction: 2010

Performance Parameters: Performance and design parameters for baseline and Advanced Wall Systems are presented below.
Baseline: Wall has R-value of 10 Btu/hr·ft^2·F° (U-value = 0.1 hr·ft^2·F°/Btu) and includes fenestration.

- Windows
    - 15% of wall area
    - Double pane wood or vinyl
    - U-value = 0.36 Btu/hr·ft^2·F°
    - Shading coefficient = 0.48
- Opaque Wall
    - 85% of wall area
    - Wood siding on wood frame
    - U-value = 0.054118 Btu/hr·ft^2·F°

[n] Based on a new 2,349 ft^2 house (NAHB—2004 single family home) with roughly 470 ft^2 of window area (20% of floor area and 15% of wall area) and 1,666 ft^2 of insulated ceiling area (RECSS 2001—average number of stories is 1.41)

Advanced: Wall has R-value of 20 Btu/hr·ft^2·F° (U-value = 0.05 hr·ft^2·F°/Btu) and includes fenestration.

- Windows
  - 15% of wall area
  - Advance window
  - U-value = 0.18 Btu/hr·ft2·F°
  - Shading coefficient = 0.48
- Opaque Wall
  - 85% of wall area
  - Wood siding on wood frame
  - U-value = 0.027059 Btu/hr·ft^2·F°

Performance Target: Tables G-18 and G-19 present the changes in heating and cooling loads by regions for Advanced Wall Systems. These data are presented in both absolute and percentage terms.

Table G-18. Heating and cooling load decrease per household per year (MMBtu/year)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
MBtu/year	Heat	13.1	13.1	15.0	15.6	5.8	7.5	5.2	9.4	5.2	9.2
MBtu/year	Cool	-1.2	-1.2	-1.1	-1.0	-0.9	-0.7	-0.3	0.8	-2.3	-0.7

Table G-19. Heating and cooling load decrease per household per year (% decrease)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
% Decrease	Heat	30.4%	30.4%	28.2%	27.6%	38.2%	37.1%	43.7%	33.9%	45.8%	32.3%
% Decrease	Cool	-10.5%	-10.5%	-12.0%	-9.8%	-2.9%	-2.5%	-0.7%	2.7%	-14.8%	-2.8%

Lifetime: Same as baseline or longer.

4.4.3 Next Generation Attic Systems

Project Description[(1)]**:** Develop and regionally optimize the next generation of attic systems (e.g., insulation, ventilation strategy, component location, ducts). Also investigate new attic structural systems that will allow for automated construction and develop reliable consensus-based rating methods to assess energy efficiency options for roofing systems. The goal for the next generation attic systems project is to make these systems constructed by 2013 twice as efficient as Building America's regional benchmarks with no additional envelope failure risk.

4.4.3.1 Target Market

Market Description: The market is new single family residential homes.

Size of Market: In 2003, 1,386,300 new single-family homes were built.

4.4.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. At market introduction: 30% above conventional insulation material costs or about $165/single family house.[o] At maturity (10 years): equal to conventional.

Key Consumer Preferences/Values: Consumers largely ignore attics and are mostly concerned about envelope failure.

4.4.3.3 Methodology and Calculations

Market Introduction: 2013

Performance Parameters: Performance and design parameters for baseline and Next Generation Attic Systems are presented below.

Baseline: Roof has R-value of 30 Btu/hr·ft^2·F° (U-value = 0.0333 hr·ft^2·F°/Btu).
- Shingle or shake roof with attic
- Unconditioned

Next Generation: Roof has R-value of 45 Btu/hr·ft^2·F° (U-value = 0.0222 hr·ft^2·F°/Btu).
- Shingle or shake roof with attic
- Conditioned

Performance Target: Tables G-20 and G-21 present changes in heating and cooling loads by regions for Next Generation Attic Systems. These data are presented in both absolute and percentage terms.

Table G-20. Heating and cooling load decrease per household per year (MMBtu/year)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
MBtu/year	Heat	3.0	3.0	3.5	3.7	1.2	1.5	1.0	2.1	1.1	2.1
MBtu/year	Cool	0.3	0.3	0.2	0.2	0.8	0.8	1.1	1.2	0.6	0.7

Table G-21. Heating and cooling load decrease per household per year (% decrease)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
% Decrease	Heat	7.1%	7.1%	6.7%	6.5%	8.0%	7.6%	8.2%	7.6%	10.0%	7.3%
% Decrease	Cool	2.4%	2.4%	1.7%	2.4%	2.4%	2.7%	2.9%	4.1%	3.6%	2.9%

Lifetime: Same as baseline or longer.

[o] Based on a new 2,349 ft^2 house (NAHB—2004 single family home) with roughly 1,666 ft^2 of insulated ceiling area (RECSS 2001—average number of stories is 1.41)

4.4.4 Next Generation Envelope Materials

Project Description[(1)]: Develop a portfolio of new insulation and membrane materials, including the exterior finishes, having residential and commercial application. The major components of strategy are:

- Develop next generation of low density thermal insulation materials.
- Develop reflective exterior wall finishes.
- Develop smart membrane materials with climatically tuned properties.
- Develop thermochromic roofing surfaces using microstructures down to the nanoscale.

4.4.4.1 Target Market

Market Description: The market is new single family residential home.

Size of Market: In 2003, 1,386,300 new single-family homes were built.

4.4.4.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. At market introduction: 30% above conventional insulation material costs or about \$535/single family house.[p] At maturity (10 years): equal to conventional.

Key Consumer Preferences/Values[(1)]: Roofing products and wall finishes for cooling dominated climates need to be aesthetically pleasing to the consumer but reflect large percentages of solar radiation.

4.4.4.3 Methodology and Calculations

Market Introduction: 2015

Performance Parameters: Performance and design parameters for baseline and Next Generation Envelope Materials are presented below.

Baseline: Wall has R-value of 10 Btu/hr·ft^2·F° (U-value = 0.1 hr·ft^2·F°/Btu) and includes fenestration. Roof has R-value of 30 Btu/hr·ft^2·F° (U-value = 0.0333 hr·ft^2·F°/Btu).

- Windows
  - 15% of wall area
  - Double pane wood or vinyl
  - U-value = 0.36 Btu/hr·ft^2·F°
  - Shading coefficient = 0.48
- Opaque Wall
  - 85% of wall area
  - Wood siding on wood frame
  - U-value = 0.055118 Btu/hr·ft^2·F°

[p] Based on a new 2,349 ft^2 house (NAHB—2004 single family home) with roughly 470 ft^2 of window area (20% of floor area and 15% of wall area), 2,662 ft^2 of opaque wall area, and 1666 ft^2 of insulated ceiling area (RECSS 2001—average number of stories is 1.41)

- Roof
  - Shingle or shake roof with attic
  - Unconditioned
  - Insulation R-value is 29.2

Next Generation: Wall has R-value of 11.1 Btu/hr·ft^2·F° (U-value = 0.090031 hr·ft^2·F°/Btu) and includes fenestration. Roof has R-value of 43.8 Btu/hr·ft^2·F° (U-value = 0.022834 hr·ft^2·F°/Btu).

- Windows (unchanged)
  - 15% o f wall area
  - Double pane wood or vinyl
  - U-value = 0.36 Btu/hr·ft^2·F°
  - Shading coefficient = 0.48
- Opaque Wall
  - 85% of wall area
  - Wood siding on wood frame
  - U-value = 0.042389 Btu/hr·ft^2·F°
- Roof
  - Shingle or shake roof with attic
  - Unconditioned

Performance Target: Tables G-22 and G-23 present changes in heating and cooling loads by regions for Next Generation Envelope Materials. These data are presented in both absolute and percentage terms.

Table G-22. Heating and cooling load decrease per household per year (MMBtu/year)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
MBtu/year	Heat	5.5	5.5	6.4	6.7	2.3	2.9	1.9	3.9	2.2	3.8
MBtu/year	Cool	0.2	0.2	0.1	0.2	0.9	0.9	1.4	1.8	0.5	0.9

Table G-23. Heating and cooling load decrease per household per year (% decrease)

		New England	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*National*
% Decrease	Heat	12.7%	12.7%	12.0%	11.7%	15.2%	14.5%	16.3%	13.8%	19.0%	13.3%
% Decrease	Cool	2.1%	2.1%	1.0%	2.1%	2.9%	3.2%	3.7%	5.9%	3.4%	3.5%

Lifetime: Same as baseline or longer.

4.4.5 Sources

1) "Building Technology Program: Research, Development and Demonstration Plan, Planned Program Activities for 2004-2010." Final Draft. U.S. DOE, January 9, 2004.
2) D&R International, Ltd., The 2005 Building Energy Databook," Silver Spring MD, August 2005

4.5 Lighting Research and Development

4.5.1 Significant Changes from FY06

No significant changes were made to this program for the FY07 effort.

4.5.2 Solid-State Lighting

Project Description. The Solid-State Lighting activity develops and accelerates the introduction of solid-state lighting and seeks to achieve the following for lighting:

- Significantly greater efficacy than conventional sources, such as T8 fluorescents
- Easy integration into building systems of the future
- Ability to provide the appropriate color and intensity for any application
- Ability to last 20,000 to 100,000 hours
- Ability to readily supplement natural sunlight.

4.5.2.1 Target Market

Market Description: The market includes all commercial buildings, with some technologies being introduced into residential buildings.

Size of Market[(1)]: Lighting consumes 26% (3.9 QBtu) of the primary energy used in commercial buildings, which had building stock of about 69 billion ft^2 in 2000.[q]

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

4.5.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Helps maintain U.S. semiconductor leadership
- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate-change goals
- Improves U.S. productivity from better lighting in work environments
- Coordinates with and receives technical advice from an industry consortium of for-profits companies representing the traditional lighting and semiconductor industries.

4.5.2.3 Methodology and Calculations

Technical Characteristics. Key assumptions concerning the likely dates of introduction and the expected efficacies were influenced by two sources: 1) "The Case for a National Research

[q] According to a report completed for DOE by Navigant Consulting ("U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate," September 2002), the amount of energy used for lighting is greater than EIA has traditionally estimated. The report estimates that commercial lighting requires 4.2 QBtu and residential lighting requires 2.2 QBtu.

Program on Semiconductor Lighting,"[2] a white paper prepared by Hewlett-Packard and Sandia National Laboratories and presented in late 1999 at an industry forum; and 2) a more extended study[3] conducted by Navigant Consulting for BT in late 2003; the study presented price and performance improvement curves for solid-state lighting that were developed in close consultation with industry experts.
NEMS characterizes each lighting technology by source efficacy level (lumens/watt), capital cost ($/1000 lumens or $/kLumen), and annual maintenance cost of lamps. For new technologies, the capital costs can be reduced along a logistic-shaped curve. The NEMS model divides the commercial lighting market into five major groups: 1) incandescent CFL (point source), 2) 4-foot fluorescent, 3) 8-foot fluorescent, 4) high-intensity discharge (HID) low bay and 5) HID high bay. Solid-state lighting was assumed to compete in all market groupings with different color rendition index lamps.

Given the cost and efficacy assumptions, the NEMS model chooses among these technologies for each building type in each census division. For each group, the market is assumed to be further segmented, with each segment characterized by a different discount rate in its decision-making criteria. Within each segment, a lighting technology is selected based on minimum annualized cost.

Solid-state lighting was also assumed to be available in the residential lighting market, where it competes with conventional incandescent and compact fluorescent options.

Table G-24 summarizes the cost and performance inputs for the solid state lighting technologies used in NEMS-GPRA07 for FY 2007.

Table G-24. Solid-State Lighting Cost and Efficiency Assumptions – FY 2007 GPRA

	Efficacy				Price (2004$/klm)			
	Low CRI	Med CRI	High CRI	V.High CRI	Low CRI	Med CRI	High CRI	V.High CRI
2005	55	39	24	8	$ 70.85	$ 132.15	$ 182.88	$ 288.17
2006	60	44	28	11	$ 62.22	$ 123.45	$ 172.51	$ 269.09
2007	65	49	32	14	$ 50.87	$ 110.25	$ 156.40	$ 240.15
2008	70	54	37	17	$ 40.17	$ 95.23	$ 137.43	$ 207.21
2009	75	59	41	20	$ 30.79	$ 79.33	$ 116.59	$ 172.35
2010	79	65	45	23	$ 23.07	$ 63.75	$ 95.37	$ 138.20
2011	85	71	49	25	$ 17.05	$ 49.60	$ 75.37	$ 107.17
2012	90	77	54	28	$ 12.56	$ 37.60	$ 57.82	$ 80.85
2013	96	84	60	31	$ 9.31	$ 28.00	$ 43.39	$ 59.81
2014	102	90	65	37	$ 7.01	$ 20.69	$ 32.15	$ 43.78
2015	107	96	72	42	$ 5.41	$ 15.31	$ 23.74	$ 32.00
2016	113	102	78	47	$ 4.31	$ 11.47	$ 17.66	$ 23.58
2017	118	108	84	53	$ 3.56	$ 8.78	$ 13.36	$ 17.68
2018	123	114	91	58	$ 3.05	$ 6.93	$ 10.37	$ 13.61
2019	129	118	97	65	$ 2.70	$ 5.65	$ 8.31	$ 10.82
2020	133	123	103	72	$ 2.47	$ 4.79	$ 6.91	$ 8.92
2021	137	128	109	80	$ 2.32	$ 4.20	$ 5.96	$ 7.64
2022	141	133	114	87	$ 2.21	$ 3.81	$ 5.32	$ 6.77
2023	144	136	119	94	$ 2.14	$ 3.54	$ 4.89	$ 6.19
2024	147	140	124	101	$ 2.10	$ 3.36	$ 4.59	$ 5.80
2025	150	143	129	107	$ 2.06	$ 3.24	$ 4.40	$ 5.54
2026	152	146	132	113	$ 2.04	$ 3.16	$ 4.27	$ 5.36
2027	155	149	135	120	$ 2.03	$ 3.11	$ 4.18	$ 5.24
2028	158	151	139	123	$ 2.02	$ 3.07	$ 4.12	$ 5.16
2029	159	152	142	127	$ 2.01	$ 3.05	$ 4.08	$ 5.11
2030	160	153	145	131	$ 2.01	$ 3.03	$ 4.05	$ 5.07

4.5.2.4 Sources

(1) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C..

(2) Haitz, R., and F. Kish (Hewlitt-Packard Co) and J. Tsao and J. Nelson (Sandia National Laboratories). 1997. "Case for a National Research Program on Semiconductor Lighting," White paper presented at the 1999 Optoelectronics Industry Development Association forum in Washington D.C., October 6, 1999.

(3) Navigant Consulting, 2003. *Energy Savings Potential of Solid-State Lighting in General Illumination Applications*. Prepared for DOE's Office of Building Technologies by Navigant Consulting, Washington D.C.

4.5.3 Lighting Controls

4.5.3.1 Target Market

Market Description: The market includes all commercial buildings, with some technologies being introduced into residential buildings.

Size of Market: Lighting consumes 26% (3.9 quadrillion Btu) of the primary energy used in commercial buildings, which had a building stock of about 69 billion ft^2 in 2000[1].

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

4.5.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT assumed a 4-year payback period on investment to develop incremental investment costs (i.e., an annual energy cost savings of $1 implies an initial investment of $4).

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered in developing energy output estimates:

- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate-change goals
- Improves U.S. productivity from better lighting in work environments

4.5.3.3 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics. Various field studies[2] have shown a very large energy savings potential for lighting controls, primarily using occupancy and daylighting controls. These studies have shown that aggressively implementing controls can save 20% to 40% of lighting energy use. BT supports the development of more advanced systems—through both research and field testing—that will further reduce energy used for lighting in commercial buildings. BT support of research to evaluate the interrelationship between human vision and efficient light use will also contribute to future energy savings.

For FY 2007, the impact of the BT activities in lighting controls and efficient lighting practices was assumed to yield an incremental 5% reduction in lighting energy use compared with current practice. (By *incremental*, the BT activities are assumed to lead to further savings over and above the control technologies that the private sector offers now and are likely to offer.)

Expected Market Uptake. BT assumed that up to 60% of new commercial buildings could incorporate these technologies and that 20% of the existing stock could be retrofitted with these systems by 2020. A time profile of penetration rates was based on the historical pattern of market penetration observed for electronic ballasts. An S-shaped penetration curve was fit to historical market shares for electronic ballasts and then applied to project future adoption of advanced lighting distribution systems and controls. This curve indicated that nearly 50% of the ultimate market penetration was achieved after nine years.

4.5.3.4 Sources

(1) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C.
(2) See http://eande.lbl.gov/btp/450gg/publications.html and www.cmpco.com/services/pubs/lightingfacts/controls.html
(3) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

4.6 Space Conditioning and Refrigeration R&D

The Building Technology Program's long range goal of developing Zero Energy Buildings (ZEB) by 2025 will require more efficient and less expensive HVAC equipment if ZEBs are going to be widespread and affordable. Equipment integration (waste heat from one appliance is beneficially used by another) and new approaches to providing space conditioning are integral to this goal.

4.6.1 Significant Changes from FY06

For FY07, new activities for Space Conditioning R&D were characterized for the GPRA estimates.

4.6.2 Hy-Pak MA

To make ZEB affordable, efforts to reduce the energy required for the building are a necessary complement to efforts to reduce the cost of renewable, on-site power.[1] Eleven percent of the primary energy used in commercial buildings is spent on space cooling. [2]

Project Description: Develop a cost-effective, hydronic rooftop HVAC unit that reduces energy consumption 50% and delivers 0 to 100% ventilation air

4.6.2.1 Target Market

Market Description: The market is commercial buildings. Because of the evaporative nature of the device the market is limited to dry west coast climates only.

Size of Market: The applicability varies by census region. This technology takes advantage of evaporative cooling and therfore is applicable only in dry and marine climates. **Table G-25** contains the portion of the census region to which this technology could be applied:

Table G-25. Percentage of census region to which Hy-Pak MA technology is applicable

New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	National
0%	0%	0%	0%	0%	0%	8.87%	100%	97.31%	23.02%

Market Introduction: 2008

4.6.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.

- Cost at market introduction: 2 times cost of conventional technology (Simple payback: 2-3 years).
- Cost at maturity (10 years): 1.5 times cost of conventional technology (Simple payback: 1-1.5 years)

Key Consumer Preferences/Values: Because this technology uses evaporative cooling in the condenser and indirect evaporative cooling of the ventilation air it is not likely to be accepted by consumers in areas of high relative humidity.

4.6.2.3 Methodology and Calculations

Performance Parameters: Performance parameters for baseline and rooftop AC and HyPak-MA are presented below.

- Baseline: Conventional rooftop air conditioning—11.2 EER
- HyPak-MA: 16.8 EER

Lifetime: Same as baseline.

Expected Market Uptake: Anticipated market share in 2018 is 20% of rooftop AC market in applicable regions.

4.6.3 Thermotunneling Based Cooling

To make ZEB affordable, efforts to reduce the energy required for the building are a necessary complement to efforts to reduce the cost of renewable, on-site power.(1) Eleven percent of the primary energy used in buildings is spent on space cooling.(2) In addition, refrigeration uses seven percent of the primary energy used in buildings.(2) Savings associated with refrigeration are not considered here.

Project Description: Develop high efficiency, compact, quiet, environmentally friendly, reliable cooling without the use of moving parts or refrigerants. Cooling using themortunneling technology involves the transport of hot electrons across a gap between two low work function electrodes[r], from the object to be cooled (the cathode) to the heat rejection electrode (the anode).

4.6.3.1 Target Market

Market Description: The market is all residential and commercial cooling.

Size of Market: All commercial and residential air conditioning equipment in new and existing residential and commercial buildings.

Market Introduction: 2010

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[r] A work function is the energy needed to extract an electron from a material; a low work function ≡ <1.0eV (where eV is electron-volt).

4.6.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.

- Cost at market introduction: 75% of the cost of conventional technology
- Cost at maturity (10 years): 25% of the cost of conventional technology

Key Consumer Preferences/Values: Quieter, more reliable air conditioning equipment should have a market advantage.

4.6.3.3 Methodology and Calculations

Performance Parameters: Performance and design parameters for baseline and Thermotunneling Based Cooling are presented below.

- Baseline: COP ~ 40-45% of Carnot efficiency
- Thermotunneling Based Cooling: 65% of Carnot efficiency; including ancillary equipment the net results is a 35% increase in cooling efficiency.

Lifetime: Same as baseline or longer.
Expected Market Uptake: Anticipate market share of 70% at maturity

4.6.4 Integrated Heat Pump

To make ZEB affordable, efforts to reduce the energy required for the building are a necessary complement to efforts to reduce the cost of renewable, on-site power. Thirty-one percent of the primary energy used in a residence is spent on space heating, cooling, and water heating.(2)

Project Description: Develop an integrated, multifunction heat pump that provides space heating, cooling, water heating and dedicated dehumidification.(3)

4.6.4.1 Target Market

Market Description: The market is new single family residential homes.

Size of Market: In 2003, 1,386,300 new single-family homes were built.

Market Introduction: 2010

4.6.4.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.

- Cost at market introduction: 2.5 times cost of conventional heat pump without water heating capability ($2700 versus $1100 for a 1.5 ton unit)
- Cost in 5 years: 1.7 times cost of conventional heat pump without water heating capability ($1900 versus $1100 for a 1.5 ton unit)

Key Consumer Preferences/Values: Dedicated dehumidification should enhance sales in high humidity markets.

4.6.4.3 Methodology and Calculations

Performance Parameters: Annual operating cost savings of $400/year over conventional unit due to higher efficiency and dual production (simultaneous cooling and hot water production)

Lifetime: Same as baseline.

Expected Market Uptake: Anticipate market share is 8% in 5 years and 30% ultimately.

4.6.5 Sources

1) "Building Technology Program: Research, Development and Demonstration Plan, Planned Program Activities for 2004-2010." Final Draft. U.S. DOE, January 9, 2004.
2) D&R International, Ltd., The 2005 Building Energy Databook," Silver Spring MD, August 2005
3) Building Technologies Program Fiscal Year 2006 Annual Operating Plan: Project Proposal for Residential ZEB-Enabling Equipment. CEBT002

5.0 Technology Validation and Market Introduction

This effort seeks to accomplish effective delivery of the full menu of efficiency and renewable resources aligned with community and customer focus. The activities focus on the end-user needs, rather than individual EERE programs, and provide easier access to EERE's array of technologies and resources to ensure they are part of the economic solutions for communities across the country.

5.1 Rebuild America

Project Description. Rebuild America accelerates energy-efficient improvements in existing buildings through community-level partnerships and focuses on K-12 schools, colleges, and universities, State and local governments, public and multi-family housing, and commercial buildings. Rebuild America connects people, resources, proven ideas, and innovative practices to solve problems. The project provides one-stop shopping for information and assistance on how to plan, finance, implement, and manage retrofit projects to improve buildings energy efficiency and helps communities find other resources on renewable energy applications, efficient new building designs, energy education, and other innovative energy conservation measures.

5.1.1 Significant Changes from FY06

This project was previously included in the program structure under Weatherization and Intergovernmental Programs. For FY07, the project was moved under BT. For modeling purposes, the characterization of the project did not change.

5.1.2 Target Market

Market Description. The general target market includes new and existing multifamily housing; public/assisted single-family residential units; and commercial buildings, particularly new and existing assembly, health-care, lodging, office, and education buildings.

Size of Market.(4) The primary market is the commercial-building sector, which includes nearly 68 billion square feet of building space; however, the five commercial building types that this project targets make up a total of nearly 32 billion square feet. The public assistance(5) and multifamily housing that this project also targets make up an additional 27 billion square feet.

Baseline Technology Improvements. For this analysis, BT did not suggest any changes in technology improvements apart from the EIA baseline.

5.1.3 Key Factors in Shaping Market Adoption of EERE Technologies

Price.
Cost of Conventional Technology:(4) Average of $\$101/\text{ ft}^2$ for new commercial and multifamily; $0 for existing buildings.

Cost of BT Technology:[7] \$103.00/ ft^2 for new commercial and multifamily; \$3/ ft^2 (2007 to 2009), increasing to \$4/ ft^2 (2010 to 2030) for existing buildings.
Incremental Cost: 2% above base for new buildings; \$3/ft^2 (2007 to 2009), \$4/ ft^2 (2010 to 2030) for existing buildings.

Key Consumer Preference/Values -- Nonenergy Benefits.[5] The following nonenergy characteristics were not considered.

- Revitalized neighborhoods and business districts
- Improving school facilities
- Better low-income housing
- Positive economic impact from keeping dollars locally and increasing property values.

5.1.4 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets.

Technical Characteristics. The project displaces current design/building practices with the target of reducing heating, cooling, water heating, and lighting energy use in retrofitted and new buildings by 18%/ft^2 in 2007 [1] and 25%/ft^2 by 2010 [3].

Expected Market Uptake. BT assumed that this activity would not occur in the absence of DOE funding, therefore, no acceleration of market acceptance was modeled. The penetration rates shown in **Table G-26** are based on project goals of committing 2.24 billion square feet by 2010.

Table G-26. Penetration Goals for Rebuild America [2,6]

	Penetration Rate %			
Building Type*	**2007**	**2010**	**2020**	**2030**
Targeted Commercial Buildings & Multi-Family Existing	0.7	1.9	2.3	2.3
Targeted Commercial Buildings & Multi-Family New	0.7	1.9	0.0	0.0
Single-Family Existing	0.0	0.02	0.04	0.04
Single-Family New	0.2	0.24	0.0	0.0

* Unless otherwise specified, the building vintage is both new (Post 2007) and existing (2007 and prior construction).

5.1.5 Sources

(1) *Weatherization and Intergovernmental Activities Funding Profile by Subprogram.* FY 2006 Corporate Review Budget, U.S.DOE, May 2004.
(2) *DRAFT Weatherization and Intergovernmental Program Multi-*Year Program Plan, U.S.DOE, September 30, 2003.
(3) *Rebuild America 2002,* Rebuild Annual Report, 2002, U.S.DOE, Washington D.C.
(4) Commercial building and multifamily square footage numbers come from Energy Information Administration. 2001. Annual Energy Outlook 2002. DOE/EIA-0383 (2002). U.S. Department of Energy, Washington, D.C.
(5) *FY 2002 Budget Request – Data Bucket Report for Rebuild America Program* (includes Energy Smart Schools and Competitively Selected Community Program) (internal WIP document).
(6) Rebuild America Key Metric Totals from Oct 2003; Dec 2003; Mar 2004; April 2004; May 2004, Spreadsheet used to document key metrics. (internal WIP document).
(7) RS Means Company, Inc. 2002. *"RS MEANS Square Foot Costs,"* 23rd Edition. Kingston, MA.

5.2 Energy Star Program

Project Description. Energy Star was introduced by the Environmental Protection Agency in 1992 as a voluntary labeling program designed to identify and promote energy efficient products, with the goal of reducing carbon dioxide emissions. Through its partnership with more than 7,000 private and public sector organizations, Energy Star delivers the technical information and tools that organizations and consumers need to choose energy-efficient solutions and best management practices.

5.2.1 Significant Changes from FY06

This project was previously included in the program structure under Weatherization and Intergovernmental Programs. For FY07, the project was moved under BT. The characterization of the project did not change.

5.2.2 General Target Market

Market Description. The market is determined by the project equipment. For FY 2007, the following residential equipment is characterized:

- Clothes washers
- Refrigerators
- Room air conditioners
- Dishwashers
- Compact Fluorescent Lamps (CFLs)
- Windows
- Home Performance

Baseline Technology Improvements. There are no technology improvements assumed apart from what appears in the Energy Information Administration (EIA) baseline.

5.2.3 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preferences/Values and Manufacturing Factors. The following nonenergy characteristics were not considered.

- Increased comfort for residential homeowners
- Decreased time spent changing incandescent lamps
- Water and water-bill savings from higher efficiency dishwashers and clothes washers
- Increased amenities with clothes washers, also decreased time required for dryer cycle
- Higher profits for manufacturers.

5.2.4 General Methodology

Market transformation projects, such as Energy Star, attempt to accelerate market penetration of existing high-efficiency technologies. The information provided by these programs is designed to influence the consumer's awareness of future energy cost savings as compared to the initial cost of the technology. From a modeling standpoint, these efforts are assumed to be represented by a reduction in the consumer's implicit discount rate or hurdle rate. The implicit discount rate for a technology is assumed to capture the perceived risk in the purchase of new products. For Energy Star technologies, most of the costs are incurred at the time the technology is purchased, while most of the energy-saving benefits occur in the future. If the implicit discount rate for a given technology is particularly high, the value a consumer places on these future energy-saving benefits will be low relative to the weight the consumer places on present costs – reflecting the consumer's uncertainty about future benefits. Therefore, to facilitate project modeling, one goal of the Energy Star project is to reduce implicit discount rates by providing additional information about the potential benefits to the consumer.

Within NEMS-PNNL[s], the two modeling parameters determining the implicit discount rate are labeled Beta1 and Beta2[(1)]. Beta1 is used as multiplicative factor with the initial cost of the appliance, and Beta2 is used to multiply the annual energy cost. The sum of the two products (i.e., Beta1 * initial cost + Beta2 * operating cost) is used in the logit specification to yield market shares for each technology. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for a specific technology. In the residential NEMS-PNNL module, the Beta1 and Beta2 coefficients vary among technologies, as do the resulting discount rates. For example, the implied discount rate for refrigerators is 16%, while the discount rate is estimated to be more than 80% for electric water heaters. Because the Beta parameters must be modified through an iterative process to achieve the discount rate goal for each technology, and because the Energy Star program goals have not changed significantly since the FY 2004 effort when the original NEMS-PNNL modifications were made, BT has not repeated this iterative process using the latest version of NEMS. References to AEO 2001 reflect the original NEMS model inputs on which the Energy Star program inputs are based.

[s] Any modification or alteration to the official NEMS model must be called out as such; for PNNL's effort, the modified version used is referred to as NEMS-PNNL

The modifications to the NEMS input file (RTEKTY)—required to estimate energy savings in NEMS-PNNL for each technology in an Energy Star project—are described in the following sections. The assumed reduction in the discount rate (from Energy Star support) is modeled by reducing the Beta1 parameter. The baseline assumptions made by the EIA, the changes in the Beta1 coefficients, and the resulting changes in the market shares for the most energy-efficient products are documented by technology.

General Expected Market Uptake. BT modeled clothes washers, refrigerators, electric water heaters, gas water heaters, room air conditioners, and dishwashers using input from EIA's *Annual Energy Outlook 2001,*[2] based on a project goal of Energy Star appliances achieving 20% of the market share by 2010.

5.2.5 Clothes Washers

5.2.5.1 Target Market

Market Description. This project targets new clothes-washer sales.

5.2.5.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. Modeling the energy savings of clothes washers is complex, because energy can be saved by reducing the consumption of the motor, hot water use, or dryer energy use. The most efficient new technology is the horizontal-axis design, which achieves the bulk of its energy savings by reducing hot water use.

The residential NEMS input file (RTEKTY) includes a column of factors that relate to hot water. The (unitless) factors can be used to adjust the hot water load associated with clothes washers and dishwashers. .

Expected Market Uptake. With the support of the Energy Star project, the Beta1 parameter, which impacts the resulting market share of each clothes-washer technology, was modified from -0.03811 to -0.0101, based on this product's project goals.

5.2.6 Refrigerators

5.2.6.1 Target Market

Market Description. This project targets new refrigerator sales.

5.2.6.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. EIA uses four separate models to represent the range of energy efficiencies in the refrigerator market. The first three models are conventional top-mount freezer models with a total capacity of 18 cubic feet. The fourth is a through-the-door model (for water and ice) and does not compete with the first three models. .

Expected Market Uptake. The *Annual Energy Outlook 2001*[(2)] baseline parameters that determined the market share for high-efficiency refrigerators are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0229}{-0.1207} \approx implicit\ discount\ rate = 19\%$$

With the support of the Energy Star project, the parameters impacting market share were assumed by BT to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0040}{-0.1207} \approx implicit\ discount\ rate^{E-Star} = 3\%$$

This was modified so that the implied discount rate was 6%. The resulting market share for the most efficient unit (400 kWh per year for the AEO2005) was roughly 17% greater than in the Baseline.

5.2.7 Room Air Conditioners

5.2.7.1 Target Market

Market Description. This project targets sales of new room air conditioners.

5.2.7.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. For 2005, EIA assumed that efficiencies of room air conditioners will range from a low of 2.83 COP (seasonal energy efficiency ratio) to a high of 3.52 COP.

Expected Market Uptake. The baseline parameters that determined the market share for high-efficiency room air conditioners are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0170}{-0.0120} \approx implicit\ discount\ rate > 100\%$$

With the support of the Energy Star project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0070}{-0.0120} \approx implicit\ discount\ rate^{E-Star} = 58\%$$

The lower hurdle rate was phased in over a 5 year period.

5.2.8 Dishwashers

5.2.8.1 Target Market

Market Description. This project targets sales of new dishwashers.

5.2.8.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. The NEMS baseline includes three levels of efficiency for dishwashers

Expected Market Uptake. The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency dishwashers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.02738}{-0.02413} \approx \textit{implicit discount rate} > 100\%$$

With the support of the Energy Star project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.01338}{-0.02413} \approx \textit{implicit discount rate}^{E-Star} = 55\%$$

5.2.9 Energy Star CFLs

5.2.9.1 Target Market

Market Description. The target market for this technology is residential non-can and non-R-Lamp Edison socket lights, which would not otherwise switch to Compact Fluorescent Lamps (CFLs).

5.2.9.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT assumed that the cost of the conventional incandescent technology is $0.75, and that there is no incremental cost associated with a comparable Energy Star CFL.

Baseline market acceptance. In 1998, PNNL conducted a study examining the historical market penetration for 10 energy-efficient products related to the buildings sector. The results of this study are documented in the PNNL report, *Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP* (2003, PNNL-14231). The resulting data were used to develop a set of generic diffusion curves. These curves were used to generate market penetration estimates for projects that do not have a forecast of annual sales targets. For the Energy Star CFL activity, the lighting diffusion curve was used.

5.2.9.3 Methodology and Calculations

Technical Characteristics. Energy Star-qualified CFLs are assumed to be 66 percent more efficient than incandescent lamps (25 W compared to 75 W)

Expected Market Uptake. Future market share growth for CFLs was extrapolated from historical sales data (see **Table G-27**). On average the CFLs are assumed to be used 4 hours per day and have a lifetime of 8000 hours.

Table G-27. Estimated CFL Sales Share and Incremental Savings

	CFL Sales Share	Incremental Savings (Billion kWh)
2005	2.3%	0.0
2010	3.5%	3.2
2015	4.5%	9.9
2020	5.5%	18.3
2025	7.0%	27.5

Due to their longer lifetimes and use in high use sockets, CFL's provide roughly 20 percent of general residential lighting demand by 2025.

5.2.10 Windows

5.2.10.1 Target Market

Market Introduction. The technology is commercially available. BT assumed that this project would accelerate the penetration in the marketplace by 10 years.

5.2.10.2 Methodology and Calculations

Performance Parameters: Energy Star Windows have maximum U-value and SHGC for four different climate zones. These climate zones do not directly correspond to the traditional climate zones used in CBECS or RECS; they also do not correspond to the census divisions used in NEMS. These new climate zones are based on the eight climate zones that were developed as part of the IECC 2003 code change cycle or Residential IECC Code Change (RICC). In general the Energy Star zones map from the RICC zones as follows in **Table G-28**.

Table G-28. Mapping of RICC Zones to Energy Star Zones

RICC Zone	Energy Star Zone
1	Southern
2	Southern
3	South/Central
4	North/Central
5	Northern
6	Northern
7	Northern
8	Northern

To construct the four Energy Star zones there was a fair amount of smoothing required due to geo-political boundaries, existing codes, and commercial regions. For example, a strict adherence of the eight RICC zones to four Energy Star zones shown above would have portions of California in all four Energy Star zones and would result in discontinuities in the zones across the country. The final result is that California is wholly within the South/Central zone and all four Energy Star zones are continuous across the country. Performance parameters are listed in **Table G-29**.

Table G-29. Performance Parameter Maximums for Low-e Windows

Region	Shading Coefficient	U-Value
Northern	0.60	0.35 Btu/ft2·°F
North Central	0.55	0.40 Btu/ft2·°F
South Central	0.40	0.40 Btu/ft2·°F
Southern	0.40	0.65 Btu/ft2·°F

Performance Target: Performance characteristics vary by building type and climate zone. The estimated savings per building were determined by simulating residential and commercial buildings in all climate zones (see **Table G-30**).

Table G-30. Performance Targets for Low-e Windows

Region	Sector	End Use	New Building Savings	Existing Building Savings	Units
Northern	Residential	Heating	8.17	8.30	MMBtu/HH
		Cooling	0.06	0.19	MMBtu/HH
	Commercial	Heating	6.24	5.73	MMBtu/ksf
		Cooling	-0.45	-0.58	MMBtu/ksf
North Central	Residential	Heating	2.88	2.94	MMBtu/HH
		Cooling	1.72	1.79	MMBtu/HH
	Commercial	Heating	2.98	2.77	MMBtu/ksf
		Cooling	0.74	0.68	MMBtu/ksf
South Central	Residential	Heating	0.09	0.00	MMBtu/HH
		Cooling	10.50	10.39	MMBtu/HH
	Commercial	Heating	0.75	0.66	MMBtu/ksf
		Cooling	5.91	5.62	MMBtu/ksf
Southern	Residential	Heating	-1.48	-1.77	MMBtu/HH
		Cooling	9.18	8.77	MMBtu/HH
	Commercial	Heating	-0.14	-0.14	MMBtu/ksf
		Cooling	5.21	4.98	MMBtu/ksf
Weighted National Average	Residential	Heating	3.82	3.82	MMBtu/HH
		Cooling	4.43	4.42	MMBtu/HH
	Commercial	Heating	3.36	3.08	MMBtu/ksf
		Cooling	2.25	2.07	MMBtu/ksf

Installed Cost:—Incremental Cost Over Conventional Double-Pane Windows

- 2005: $1.00/ft^2
- 2015: $0.50/ft^2

Expected Market Uptake. The purpose of the program is to increase the penetration of low-e glass from 40% in the residential market and 10% in the commercial market to 100% in the residential market by 2020 and in the commercial market by 2025. Both programs, Low-e Market Acceptance and Energy Star Windows, form the joint means to achieving the low-e penetration goal – the savings are to be split equally. Penetration curves were developed based on market diffusion curves developed and documented by PNNL[10]. The "Accelerated" penetration curve represents the percent of superwindow sales with the DOE project; the "Net" penetration curve represents the percent of sales attributable to DOE, as BT assumed that the

DOE project would accelerate market acceptance by 10 years. The penetration rates are shown in **Figures G-13 and G-14**. For Low-e Market Acceptance/ Energy Star Windows, BT assumed that these projects would accelerate the acceptance of this technology in the marketplace by 10 years.

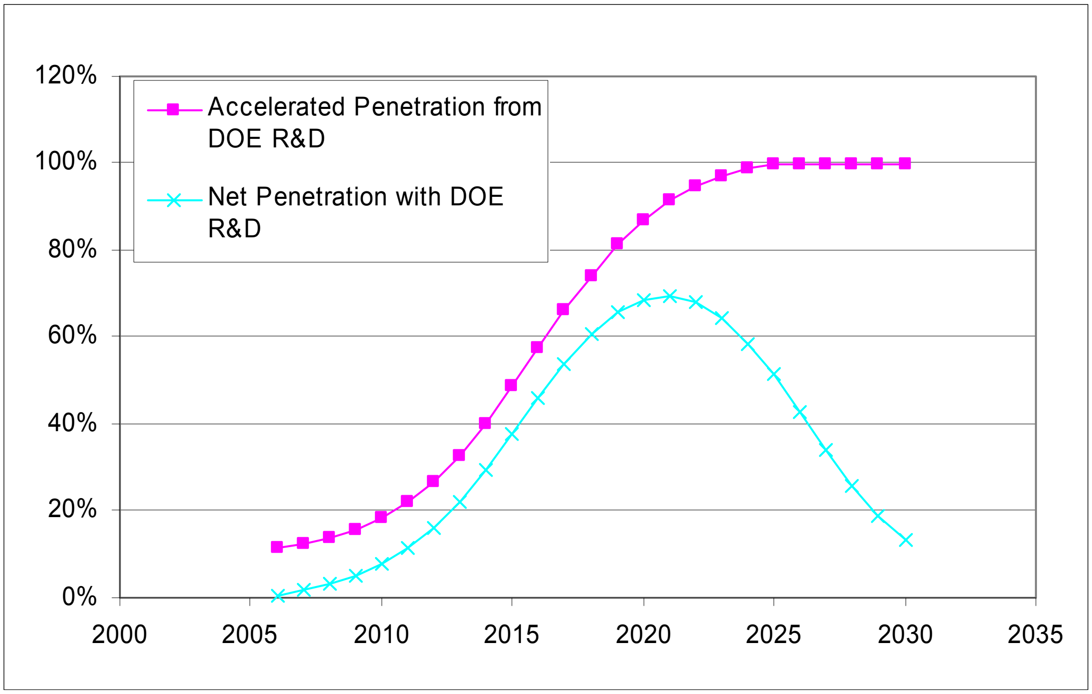

Figure G-13. FY07 Energy Star Windows – Commercial Buildings Percent of Sales

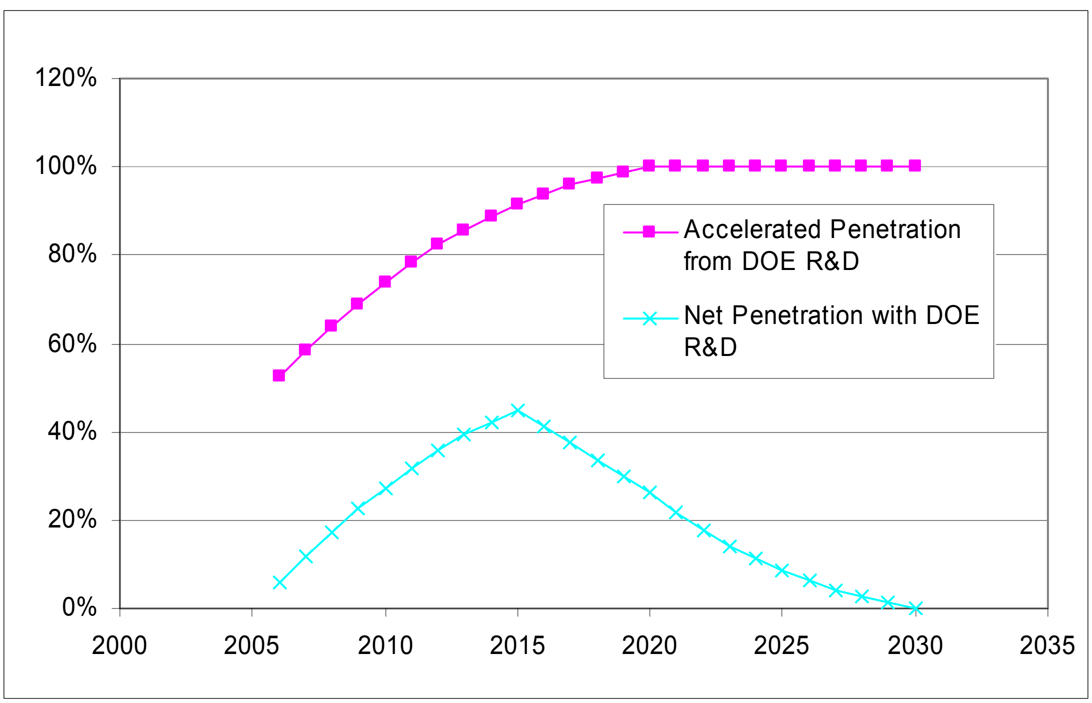

Figure G-14. FY07 Energy Star Windows – Residential Buildings Percent of Sales

5.2.11 Energy Star Home Performance

5.2.11.1 Target Market

Home Performance with Energy Star is a joint effort with the Environmental Protection Agency to develop and support pilot projects that promote whole-house retrofits for existing homes in order to save energy. Home Performance's three main components include whole-house inspections, marketing efforts, and quality assurance.

5.2.11.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. BT assumed that the cost of Home Performance pilot projects (the average price per household) would be $5,000—in FY05, Pilot Project homeowners were spending between $4,000 and $6,000 in retrofits through the Pilot Project program.[9]

5.2.11.3 Methodology and Calculations

Inputs to Base Case. BT did not provide inputs to change the base case assumptions for the program markets. BT's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO).

Technical Characteristics. BT assumed that Home Performance with Energy Star activities would primarily impact the space conditioning load of existing buildings, as most of the retrofit measures involve the building shell (e.g., insulation, windows); however, water heating and lighting loads are also reduced. Because these retrofits are occurring due to the programmatic builder certification, marketing efforts and financing options, BT assumed the activity would reap all benefits associated with the retrofits, roughly a 20% load reduction.

Expected Market Uptake. The penetration rates for Home Performance with Energy Star was developed using a diffusion model based on Fisher and Pry (1971)[11]. The equation for determining market diffusion over time is:

$$N(t) = \frac{\kappa}{1 + \exp(-\frac{\ln(81)}{\Delta t}(t - t_m))}$$

Where K = Maximum market share potential

t_m = year in which 50% of potential is reached

Δt = time to grow from 10% to 90% of potential (years)

For Home Performance with Energy Star, k=0.0002%, t_m=17, and Δt=20. These values were developed through trial and error to achieve the expected annual household impact in 2007 and in "out" years, based on discussions with the program manager. **Table G-31** displays the resulting estimated number of homes impacted based on the penetration curve developed.

Table G-31. FY 2007 Market Penetration for Energy Star Home Performance

Year	Annual No. Homes
2007	700
2008	859
2009	1,052
2010	1,284
2011	1,562
2012	1,891
2013	2,279
2014	2,729
2015	3,245
2016	3,828
2017	4,474
2018	5,177
2019	5,927
2020	6,709
2021	7,503
2022	8,291
2023	9,053
2024	9,771
2025	10,434
2026	11,031
2027	11,557
2028	12,010
2029	12,395
2030	12,714

BT assumed that the portion of the Energy Star Home Performance activity funded by DOE would not occur without DOE funding, because it allocates money for builder training and certification, program marketing support, and program-specific financing options; therefore, no acceleration of market acceptance was modeled.

5.2.12 Sources

(1) *Model Documentation Report: Residential Sector Demand Module of the National Energy Modeling System*. 2003. Energy Information Administration, Washington, D.C. DOE/EIA-M067(2003) http://tonto.eia.doe.gov/FTPROOT/modeldoc/m067(2003).pdf

(2) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

(3) "Clothes Washer Technical Support Document" source: www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html.

(4) Arthur D. Little, Inc. (ADL). 1998. "EIA Technology Forecast Updates – Residential and Commercial Building Technologies, Reference Case."

(5) Vineyard, E.A. and J.R. Sand. 1998. "Fridge of the Future: Designing a One Kilowatt-Hour/Day Domestic Refrigerator Freezer." In *1998 ACEEE Summer Study Proceedings*.

(6) National Appliance Energy Conservation Act of 1987, Public Law 100-12.

(7) http://www.energystar.gov/products/cfls/EnergyStarCFLSpecification_Final_8.9.01.pdf p.5.

(8) http://eetd.lbl.gov/btp/papers/43782.pdf *Creating Markets For New Products To Replace Incandescent Lamps: The International Experience.* Presented at the 1998 ACEEE Summer Study on Energy Efficiency in Buildings, August 23-28, 1998, Pacific Grove, CA, and published in the Proceedings. Figure 2.

(9) Based on results documented in article, "Energy Star Tackles Existing Homes," Energy Design Update, Volume 23, No. 8, August 2003 as well as discussions with Kyle Andrews, Project Manager, June 2004 and Lana Nirk, Project Manager, May, 2004.

(10) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

(11) Fisher, J.C., and R.H. Pry, (1971) "A Simple Substitution Model of Technological Change." Technological Forecasting and Social Change, 3, 75-88.