Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2006 Budget Request

Bringing you a
prosperous future where
energy is clean, abundant,
reliable, and affordable

Prepared by the

National Renewable Energy Laboratory

May 2005

NREL/TP-620-37931

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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Technical Report
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EXECUTIVE SUMMARY

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its 11 research, development, demonstration, and deployment (RDD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. EERE designs its RDD&D activities to improve the Nation's readiness for addressing current and future energy needs.

This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2006 Budget Request. EERE has adopted a benefits framework developed by the National Research Council (NRC)[1] to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development supported by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security. The specific measures or metrics of these benefits estimated for FY 2006 are identified in **Table ES.1**. These metrics are not a complete representation of the benefits or market roles of efficiency and renewable technologies, but provide an indication of the range of benefits provided. EERE is continuing to take steps to more fully represent the NRC framework.[2]

Table ES.1. EERE FY 2006 Benefits Metrics

Primary Outcome	
Energy displaced	• Reductions in nonrenewable energy consumption (quadrillion Btu/yr)
Resulting Benefits	
Economic	• Reductions in consumer energy expenditures (NEMS-GPRA06 - billion 2002 dollars/yr) • Reductions in energy-system costs (MARKAL-GPRA06 - in billion 2002 dollars/yr)
Environmental	• Reductions in carbon dioxide emissions (mmtc equivalent/yr)
Security	• Reductions in oil consumption (mbpd) • Reductions in natural gas consumption (quadrillion Btu/yr) • Avoided additions to central conventional power[3] (cumulative gigawatts)

- **Table ES.2** shows the estimated energy displaced and resulting benefits to the Nation of realizing the EERE program goals associated with the FY 2006 budget request. These impacts are the benefits expected in the reported year—that is, the benefits are annual, not cumulative (with the exception of avoided additions to conventional central power).

[1] *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001). The NRC is the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), providing services to the government, the public, and the scientific and engineering communities.

[2] In FY 2005, EERE made two key improvements: (1) adding an electricity security metric and (2) extending the analysis through the year 2050. EERE will be implementing additional portions of the framework in the future.

[3] Central conventional power includes centrally located fossil, nuclear, combined cycle, combustion turbine/diesel, and pumped storage. It does not include distributed power and renewable power (central or distributed).

Table ES.2. Summary of Annual EERE Integrated Portfolio Benefits for FY 2006 Budget Request[4,5]

EERE Midterm Benefits (NEMS-GPRA06)	2010	2015	2020	2025
Energy Displaced				
• Primary nonrenewable energy savings (quadrillion Btu/yr)	1.1	3.4	7.8	12.3
Economic				
• Energy-expenditure savings (billion 2002 dollars/yr)*	12	37	87	123
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	22	67	160	262
Security				
• Oil savings (mbpd)	0.1	0.6	1.3	2.3
• Natural gas savings (quadrillion Btu/yr)	0.5	1.1	1.9	1.8
• Avoided additions to central conventional power (cumulative gigawatts)[6]	5	49	96	137

EERE Long-Term Benefits (MARKAL-GPRA06)	2020	2030	2040	2050
Energy Displaced				
• Primary nonrenewable energy savings (quadrillion Btu/yr)	8.0	17.7	28.2	33.6
Economic				
• Energy-system cost savings (billion 2002 dollars/yr)*	43	102	188	282
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	152	364	568	699
Security				
• Oil savings (mbpd)	1.3	4.6	9.0	11.0
• Natural gas savings (quadrillion Btu/yr)	3.1	2.8	3.6	2.4

* Midterm energy-expenditure savings only include reductions in consumer energy bills, while long-term energy-system cost savings also include the incremental cost of the advanced energy technology purchased by the consumer.

Under a business-as-usual energy future, realization of these goals and the associated projected market outcomes would:

- Reduce the expected increase in U.S. energy demand by 39% in 2025 and 76% in 2050, resulting in a reduction in nonrenewable energy consumption starting in 2030. (**Figure ES.1**)
- Reduce the expected increase in U.S. consumer energy expenditures by 43% in 2025. (**Figure ES.2**)
- Reduce the expected increase in U.S. energy system costs by 6% in 2050. (**Figure ES.3**)
- Reduce the expected increase in annual U.S. carbon emissions by 45% in 2025 and 71% in 2050. (**Figure ES.4**)
- Reduce the expected increase in U.S. oil consumption (most of which is expected to originate from outside the United States) by 34% in 2025 and 98% in 2050, resulting in declining oil consumption after 2025. (**Figure ES.5**)

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[4] Estimates reflect the benefits associated with program activities from FY 2006 to the benefit year, or to program completion (whichever is nearer), and are based on program goals developed in alignment with assumptions in the president's budget. Midterm program benefits were estimated using the NEMS-GPRA06 model, based on the Energy Information Administration's (EIA) National Energy Modeling System (NEMS) and using the EIA's *Annual Energy Outlook 2004* (*AEO2004*) Reference Case. Long-term benefits were estimated using the MARKAL-GPRA06 model developed by Brookhaven National Laboratory. Results can differ among models due to structural differences. The models used in this analysis estimate economic benefits in different ways, with MARKAL reflecting the cost of additional investments required to achieve reductions in energy bills.

[5] For some metrics, the benefits estimated by MARKAL-GPRA06 do not align well with those reported by NEMS-GPRA06. Every attempt is made in the integrated modeling to use consistent baselines, input data and assumptions in both models to produce consistent results. However, NEMS and MARKAL are in some respects fundamentally different models (see Boxes 4.1 and 5.1). Discrepancies in the estimated benefits often exist simply because of these model differences.

[6] Small final changes in these estimates were not reflected in the FY 2006 Budget Request.

- Reduce the expected increase in U.S. natural gas consumption, much of which is expected to originate outside the United States, by 21% in 2025 and 18% in 2050. (**Figure ES.6**)
- Reduce the need for additions to central conventional power by 16% in 25. (**Figure ES.7**)

EERE develops these benefits projections annually to help meet the requirements of the Government Performance and Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program. This analysis helps meet GPRA requirements by identifying the potential outcomes and benefits of realizing EERE program goals (outputs). The benefits estimates do not reflect the risk of realizing these goals, which is being addressed separately.[7]

The reported benefits reflect only the net annual improvement from 2005 to 2050 of program activities included in EERE's FY 2006 Budget Request (including subsequent-year funding) and do not include the benefits from past work. The benefits estimates assume continued funding for program activities consistent with multiyear program plans.[8] By basing estimated benefits on budget levels, the analysis addresses the performance-budget integration goal of the PMA. This analysis also provides the benefits called for in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) as part of the PMA.

EERE uses two energy-economy models—NEMS-GPRA06 and MARKAL-GPRA06—to estimate the impacts of EERE programs on energy markets. The NEMS-GPRA06 model is a modified version of the National Energy Modeling System (NEMS), the midterm energy model used by the Department of Energy's Energy Information Administration (EIA). The MARKAL-GPRA06 model is a modified version of the MARKet ALlocation (MARKAL) model developed by Brookhaven National Laboratory and used by numerous countries worldwide. EERE uses NEMS-GPRA06 to estimate the midterm benefits of its programs and MARKAL-GPRA06 to estimate the long-term benefits of its programs. Descriptions of these models are provided in **Chapters 4 and 5**.

EERE uses a three-step process to estimate benefits across its portfolio:

(1) Establishment of the Baseline Case and guidance
(2) Determination of program and market inputs
(3) Assessment of program and portfolio benefits.

In **Step 1**, a Baseline Case and standard methodological approach (guidance) are developed to improve the consistency of estimates across EERE programs. The Baseline Case provides a representation of business-as-usual future energy markets without the effect of EERE programs. It also provides a consistent set of assumptions about future energy prices, conversion factors, economic growth, and other external factors, against which to analyze the impacts of EERE programs. To develop the Baseline Case through 2025, EIA's *Annual Energy Outlook 2004* (*AEO2004*) Reference Case forecast is modified to remove any identifiable effects of EERE

[7] A standard approach to risk assessment is being developed for EERE's multiyear program plans.
[8] Funding levels may increase, decrease, or remain constant, depending on the program. See Appendices B through M for information on individual multiyear program plans.

programs already included in the forecast. This is done for both the NEMS-GPRA06 model and the MARKAL-GPRA06 model.[9]

For the period after 2025, other credible sources are used to compile a set of economic and technical assumptions for MARKAL-GPRA06.[10] A summary of the Baseline Case results is included in **Appendix A**. EERE also specifies common methodological approaches (guidance) used in developing benefits estimates. This guidance identifies common definitions, the basis for assessing benefits, data requirements, etc. An overview is provided in **Chapter 2**.

In **Step 2**, analysts from throughout EERE characterize the results of the EERE programs in a format suitable for analysis within the NEMS and MARKAL integrated-modeling frameworks. For technology R&D programs, this usually requires expressing program outputs in terms of the cost and performance of a new (or improved) technology, which will compete against an existing, but improving, technology in the baseline. For deployment programs (*e.g.*, information dissemination, or codes and standards), analysts develop approaches to characterizing outputs on a case-by-case-basis using alternative modeling techniques such as altering discount rates or fixing market penetration (in the case of minimum efficiency standards). In many cases, the NEMS and MARKAL frameworks are not suitable for directly analyzing programmatic activities; as a result, "off-line" analyses are conducted. The market analyses and off-line estimates used in the integrated modeling framework are documented in **Appendices B through M.**

In **Step 3**, the program- and market-specific information from **Step 2** is incorporated into NEMS-GPRA06 and MARKAL-GPRA06. Modeling all the activities within a program together accounts for market feedbacks and interactions that can change the ultimate level of energy savings associated with realizing each program's goals. EERE adjusts off-line estimates to account for areas of overlapping program impacts. This downward revision is based on how much of the overlap or integration was captured by the off-line analysis. The benefits analysis team, based on its expert judgment, determines the amount of revision. The resulting benefits estimates of individual program analyses are listed by program, along with FY 2006 program budgets, in **Table ES.3**.

Analysts also run NEMS-GPRA06 and MARKAL-GPRA06 with all programs simultaneously represented, in order to derive estimates of the benefits of the overall EERE portfolio. This portfolio analysis accounts for interactions among EERE's programs, and tends to report reduced benefits compared to the sum of the individual programs. The fully integrated results are listed in **Table ES.2** and displayed in the graphs in this **Executive Summary**. Specific details on the representation of program outputs in NEMS-GPRA06 and the underlying program analysis and documentation are provided in **Chapter 4**. Representation of the program outputs in MARKAL-GPRA06 is provided in **Chapter 5**.

EERE is continuing to pursue a number of improvements to its benefits analysis. Important changes planned for analysis of the benefits of the FY 2007 budget request include:

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[9] Slight differences in the NEMS-GPRA06 and MARKAL-GPRA06 baselines may occur from the differences inherent in the two models.

[10] For instance, the primary economic drivers of Gross Domestic Product (GDP) and population are based on the real GDP growth rate from the Congressional Budget Office's Long-Term Budget Outlook and population growth rates from the Social Security Administration's *2002 Annual Report* to the board of trustees.

- Developing alternative scenarios that reflect potential options facing the Nation in the future (*e.g.*, higher fossil fuel prices, a carbon-constrained world).
- Potential incorporation of new metrics for security and knowledge benefits.
- Greater streamlining and consistency in the development of program-level benefits estimates.

In addition, EERE is developing methods for linking estimates of benefits from both past and future program efforts into the overarching NRC benefits framework noted above. Finally, EERE is developing a more systematic way of representing program and technology risk. Although not part of this benefits analysis *per se*, information on risk is recognized as an important component in the application of benefits information to portfolio management.

Table ES.3. U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE): FY 2006 Funding Summary and Selected 2025 and 2050 Benefits by Program[11]

Program	FY 2006 Request (thousands $)	Nonrenewable Energy Displaced (quads/yr)		Energy Expenditure Savings (billions 2002$/yr)		Energy System Cost Savings (billions 2002$/yr)		Carbon Dioxide Emissions Reductions (million mtce/yr)		Oil-Use Reductions (mbpd)	
		2025	2050	2025	2050	2025	2050	2025	2050	2025	2050
Biomass	72,164	0.1	1.1	0.0	N/A	N/A	0.6	3	19	0.0	0.4
Building Technologies	57,966	1.2	4.2	11.5	N/A	N/A	62.4	28	92	0.0	0.1
Distributed Energy Resources	56,629	0.3	0.3	1.6	N/A	N/A	1.4	11	4	0.0	0.0
Federal Energy Management	19,166	0.1	0.1	0.5	N/A	N/A	3.6	1	-0	0.0	0.0
Geothermal Technologies	23,299	0.3	2.4	0.0	N/A	N/A	5.2	8	59	0.0	0.0
Hydrogen, Fuel Cells, and Infrastructure Technologies	182,694	0.2	4.3	2.4	N/A	N/A	26.4	5	60	0.2	2.7
Industrial Technologies	56,489	2.2	0.5	12.9	N/A	N/A	3.2	44	8	0.2	-0.0
Solar Energy Technologies	83,953	0.3	1.7	1.8	N/A	N/A	2.3	8	36	0.0	0.0
Vehicle Technologies[12]	165,943	4.0	18.9	60.9	N/A	N/A	177.4	76	365	1.8	8.8
Weatherization and Intergovernmental	310,067	1.2	1.1	9.6	N/A	N/A	17.1	27	23	0.1	0.1
Wind and Hydropower	44,749	3.3	3.7	4.5	N/A	N/A	3.6	81	87	0.1	0.0
Facilities and Infrastructure	16,315	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Program Direction and Management Support	110,980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sum of programs **	**1,200,414**	**13.1**	**38.3**	**105.7**	**N/A**	**N/A**	**300.4**	**292**	**753**	**2.3**	**12.**

** The sum of program benefits differs from the EERE portfolio values in Table ES.2, because interactions among programs are not accounted for in the individual estimates. Sums may not total due to rounding.

[11] Budget request from *FY 2006 Budget-in-Brief*, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy05_budget_in_brief.pdf.
[12] The Vehicle Technologies Program is run by the Office of FreedomCAR and Vehicle Technologies.

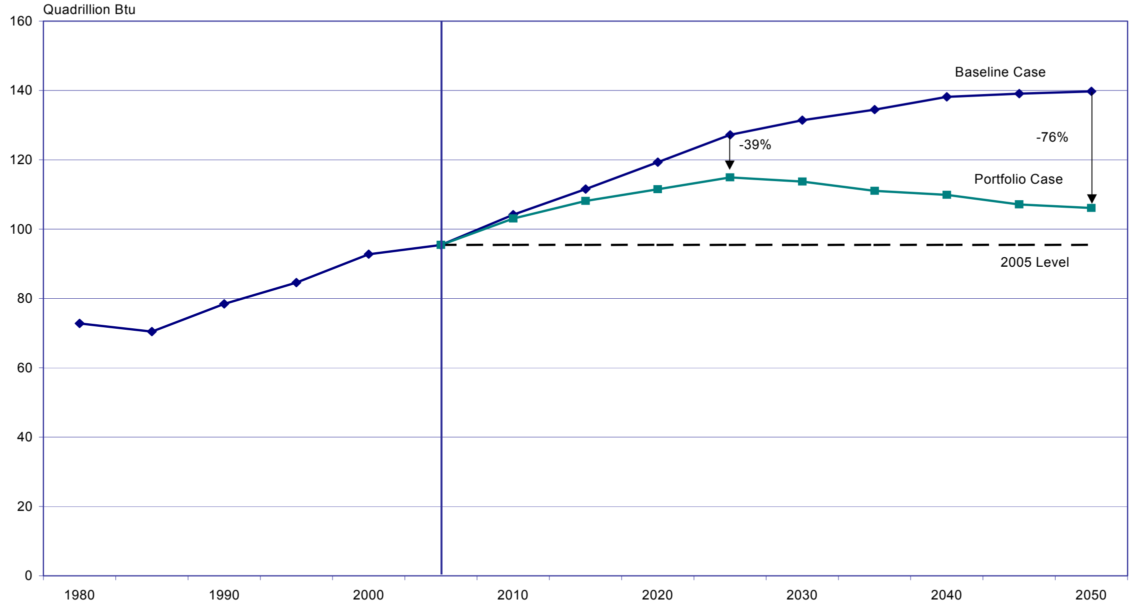

Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA06; 2030-2050: MARKAL-GPRA06.

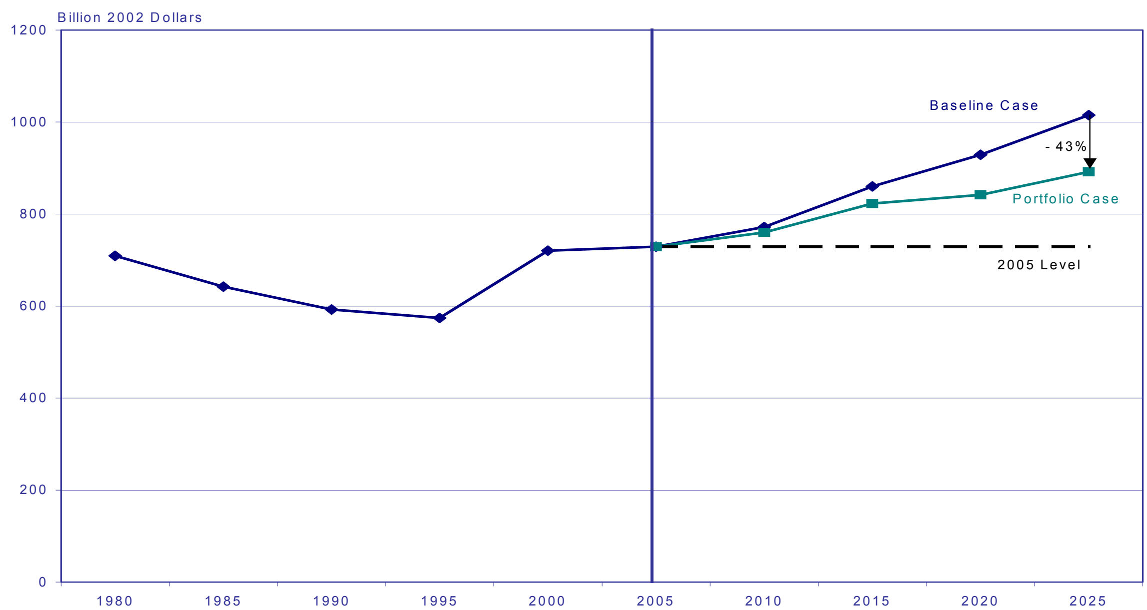

Figure ES.2. U.S. Total Energy Expenditures, 1980-2000, and Projections to 2025: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 3.4 and Table D1, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA06; 2030-2050: MARKAL-GPRA06.

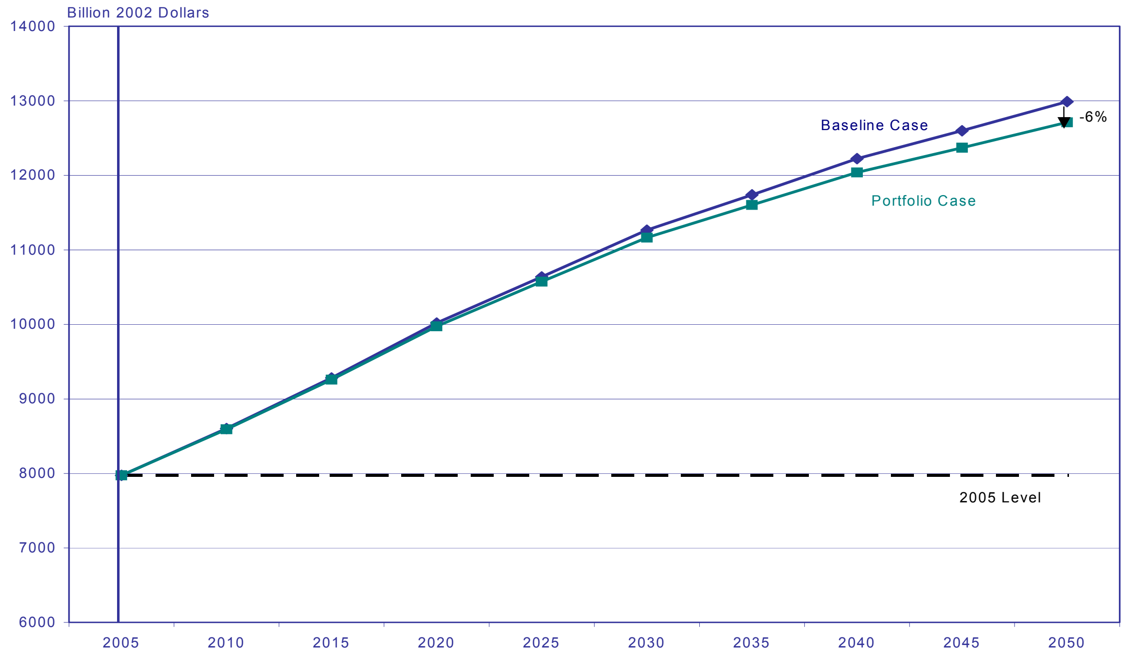

Figure ES.3. U.S. Total Energy-System Cost Projections to 2050: Portfolio Case

Note: The percentage change in the chart shown for 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2050 versus 2005. Data Source: MARKAL-GPRA06.

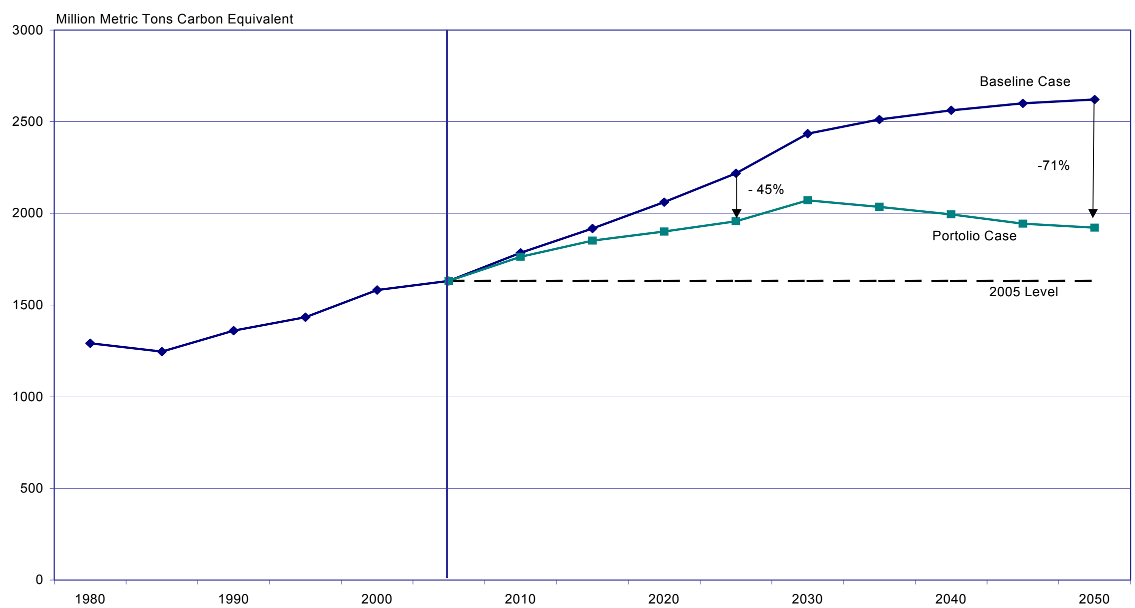

Figure ES.4. U.S. Carbon Emissions, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

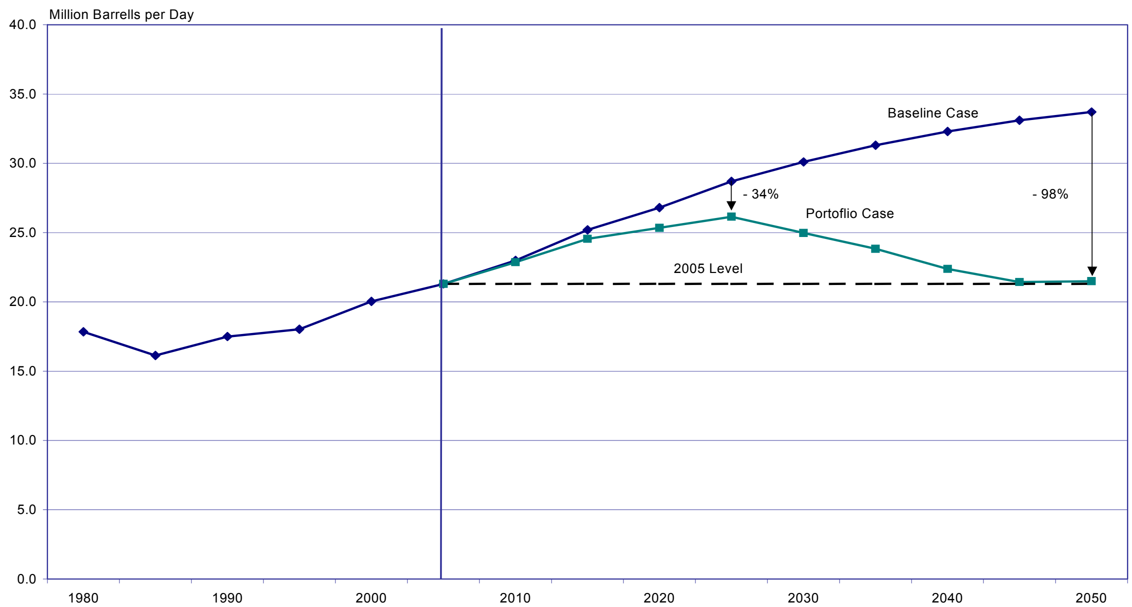

Figure ES.5. U.S. Oil Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

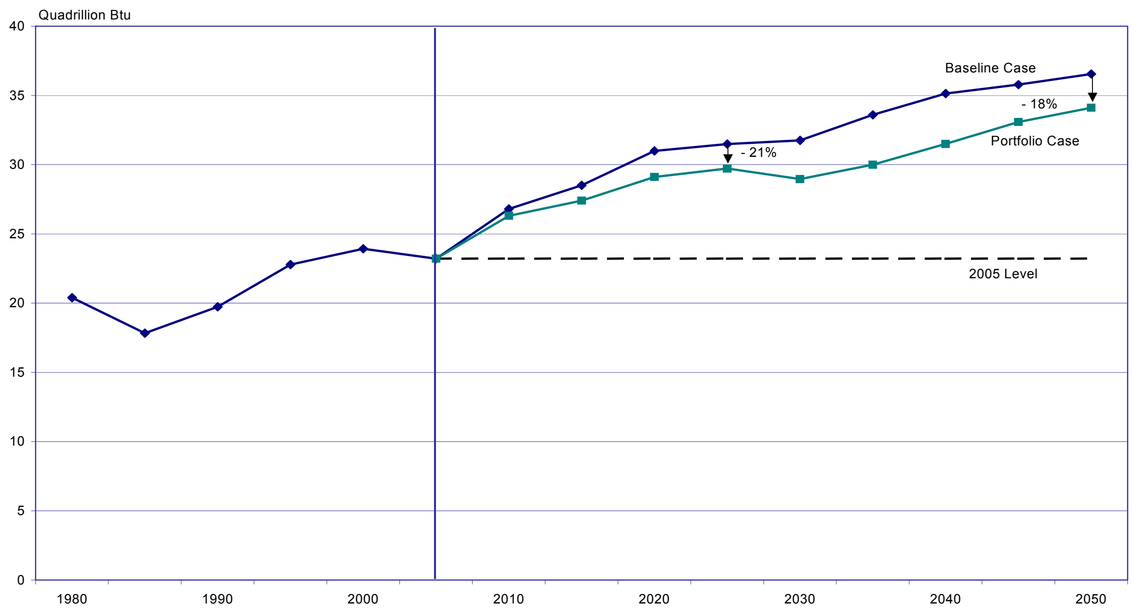

Figure ES.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

Data Sources: 1980-2000, EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

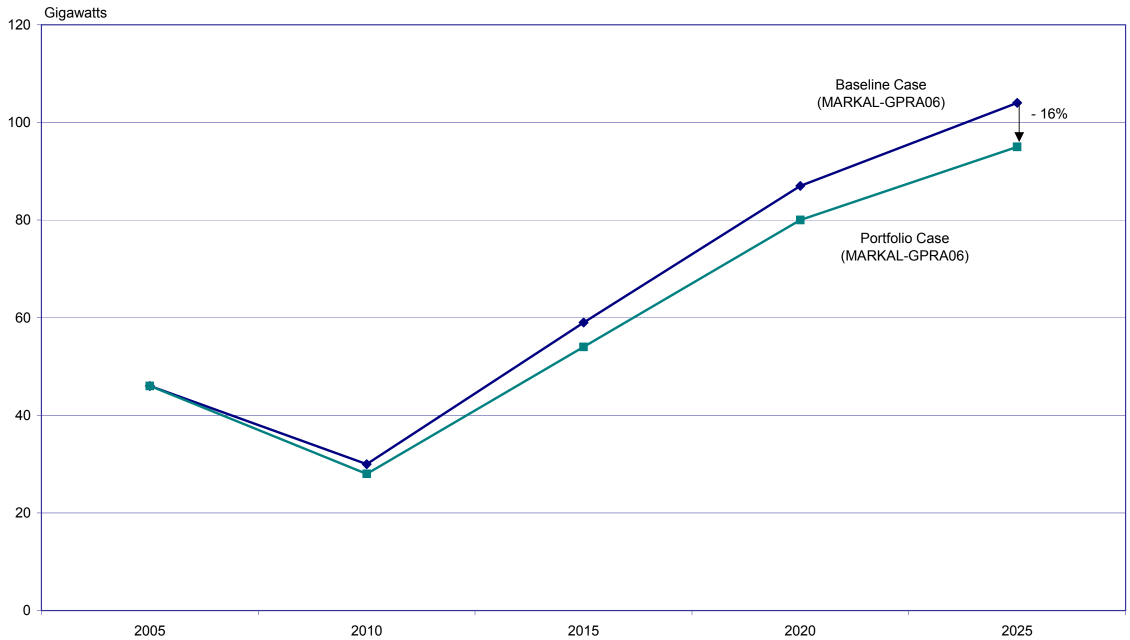

Figure ES.7. U.S. Central Conventional Electricity-Capacity Addition Projections to 2025: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2025 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 versus 2005. Data Source, MARKAL-GPRA06.

CHAPTER 1

INTRODUCTION

The Office of Energy Efficiency and Renewable Energy (EERE) develops—and encourages consumers and business to adopt—technologies that improve energy efficiency and increase the use of renewable energy. This report describes analysis undertaken by EERE to better understand the extent to which the technologies and market improvements funded by its fiscal year (FY) 2006 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

This benefits analysis helps EERE meet the provisions of the Government Performance Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program.[2] This EERE benefits analysis supports these GPRA requirements by developing an assessment of the benefits that may accrue to the Nation if the performance goals (outputs) of EERE's programs are realized. The estimates of consumer energy-expenditure savings, energy-system cost savings,[3] carbon emission savings, and reduced reliance on fossil fuels that are reported here result from the increased use of energy-efficient technologies and increased production of renewable energy resources—which are supported by the technology advances and market adoption activities pursued by EERE programs.

Shortly after GPRA was enacted, EERE initiated a corporate approach to benefits analysis that examined the energy, economic, and environmental impacts of program efforts. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions. An annual external review of the methodologies and assumptions employed was initiated in 1997 and continued through 2002 when EERE was reorganized. Although the benefits analysis has changed since it was initiated 11 years ago, the amount of energy saved or displaced continues to be the key measure of the EERE program impact.

This benefits analysis also supports the President's Management Agenda. The analysis summarized in this report is based on the modeling of program performance goals or outputs. EERE's programs develop these goals based on the following key assumptions:[4]

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[1] See http://www.eere.energy.gov/office_eere/budget.html.

[2] See the Government Performance Results Act (GPRA) of 1993 at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html and http://www.whitehouse.gov/omb/circulars/a11/02toc.html

[3] NEMS-GPRA06 estimates consumer-expenditure savings, which are the gross savings from avoiding purchased energy. They do not include all incremental investment required to achieve these savings. MARKAL-GPRA06 estimates energy-system costs savings, which includes both the savings from avoiding purchased energy and the incremental investment required for the advanced energy technology.

[4] Achieving program goals is generally not dependent on a single technical pathway, but instead encompasses a number of alternative approaches, of which some may fall short without jeopardizing realization of the final goal. The pursuit of multiple pathways can increase the likelihood of achieving program goals, thereby reducing the risk of the program. Risk is being addressed in a separate EERE effort to develop a standard approach to risk assessment.

- Programs will be funded at levels consistent with DOE's FY 2006 Budget Request.
- Funding levels will remain constant in inflation-adjusted dollars or increase to accommodate key initiatives in particular cases, as indicated.

By basing estimated benefits on budget levels, the analysis addresses the performance-budget integration goal of the PMA. This analysis also provides the benefits sought in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) for the PMA.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model[5] as the foundation for managing its portfolio of efficiency and renewable investments, and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, a logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities. The logic model employed by EERE (**Figure 1.1**) provides an integrated approach that explicitly links requested budget levels to performance goals and estimated benefits—and helps ensure that estimated benefits reflect the funding levels requested. The elements of the logic model, which are specified in GPRA, are included in the annual budget request.

Multiyear Program Plans (MYPPs), developed by each of EERE's 11 programs, address the *inputs* required, the *activities* that will be undertaken with their requested budget, the performance *milestones* they expect to achieve as they pursue these activities, and the resulting products or *outputs* of this effort.[6] Inputs may include cost-shared or leveraged funds, as well as EERE program dollars—and may also include advances by others on which the program builds. Performance milestones capture intermediate points of discernable progress toward outputs and are used by program managers, DOE, OMB, and others to track program progress toward their outputs. Outputs, often referred to as "program goals" or "program performance goals,"[7] are the resulting products or achievements of an overall area of activity. EERE's R&D programs typically specify their outputs in terms of technology advances (*e.g.*, reduced costs, improved efficiency), while deployment programs develop outputs related to their immediate market impacts (*e.g.*, number of homes weatherized). Outputs evolve over time as the program pursues increasing levels of technology performance or market penetration.[8]

This benefits analysis links these program outputs to their market impacts or outcomes. EERE's programs have discernable effects on energy markets, both by reducing the level of energy

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[5] The logic model is a fundamental program planning and evaluation tool. For more information on logic models, see: Wholey, J. S. (1987). *Evaluability assessment: developing program theory. Using Program Theory in Evaluation*. L. Bickman. San Francisco, Calif., Jossey-Bass. 33. Jordan, G. B. and J. Mortensen (1997). "Measuring the performance of research and technology programs: a balanced scorecard approach." *Journal of Technology Transfer* 22(2). McLaughlin, J. A. and G. B. Jordan (1999). "Logic models: a tool for telling your program's performance story." *Evaluation and Program Planning* 22(1): 65-72.

[6] Appendices B through M provide more information on each program's multiyear program plan and the inputs, activities, milestones, and outputs contained therein.

[7] Some programs derive their outputs through technology-cost simulation models to develop the specific requirements to meet overall program cost and performance goals. Specific details of the representation of the program outputs in NEMS-GPRA06, MARKAL-GPRA-06, and the underlying program analysis and documentation are found in Chapters 4 and 5 of this report and Appendices B through M.

[8] The level of risk for the programs is assessed qualitatively as part of the Office of Management and Budget (OMB) R&D Investment Criteria. EERE is developing a standard approach to assessing technology and program risk.

demand (through efficiency improvements) and by changing the mix of our energy supplies (through increased renewable and distributed energy production). EERE incorporates these two effects in its primary *outcome*—the displacement of conventional energy demand.

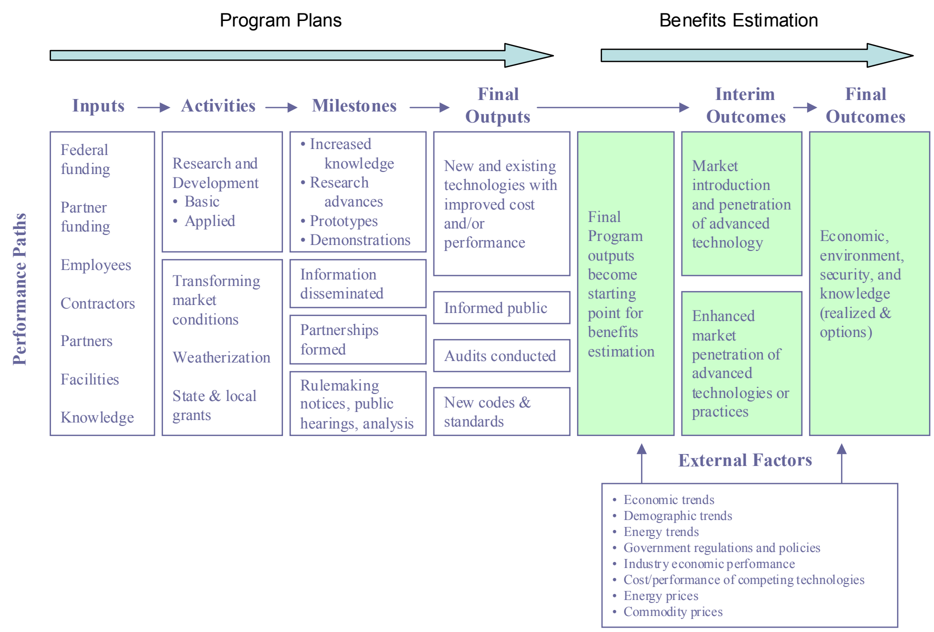

Figure 1.1. Generalized EERE Logic Model

These changes in energy use provide the basis for the economic, environmental, and security benefits estimated here. The extent to which a new technology or a deployment effort changes energy markets will depend on a variety of external factors. The future demand for energy, its price, the development of competing technologies, and other market features (such as consumer preferences) all will contribute to the marketability and total sales of a new technology.

Benefits Framework

The EERE Benefits Framework addresses the last three columns of the logic model: the link between program outputs with resulting outcomes and benefits. The benefits analysis is based on the specific program goals or outputs specified by EERE programs in their program plans and the EERE budget request, as well as estimated future energy market conditions (external factors). EERE estimates its primary outcome—displaced conventional energy consumption—by comparing future energy consumption with and without the contributions of its program outputs. The market impacts of each of the 11 programs are assessed separately and then combined to assess the benefits of EERE's overall portfolio.[9]

[9] EERE's benefits analysis, which measures final outcomes due to EERE programs and a host of other external factors as shown in Figure 1.1, is distinct from impacts analysis, which determines the portion of outcomes having a causal relationship with EERE's actions.

EERE—along with the offices of Fossil Energy (FE); Nuclear Energy, Science, and Technology (NE); and Electricity and Energy Assurance (OE)—is in the process of adopting a framework initially developed by the National Research Council (NRC) to assess the benefits associated with past EERE research efforts.[10] EERE's annual estimates of prospective benefits have been incorporated into an integrated framework addressing the benefits of both existing and future program activities. The framework is represented in a matrix, in which the rows distinguish among four types of benefits, and the columns represent different elements of time and uncertainty.

This report addresses the three shaded cells of the matrix, reflecting benefits under a business-as-usual energy future (**Figure 1.2**). EERE, FE, NE, and OE currently are developing methods for assessing the value to the country of developing technologies that prepare the Nation for unexpected energy needs. These results will be in the "option" column in future reports.[11] Similarly, EERE is in the process of extending the NRC analysis of realized benefits to include its full portfolio.

	Realized Benefits and Costs	Expected Prospective Benefits and Costs	Options Benefits and Costs
Economic Benefits and Costs		✓	
Environmental Benefits and Costs		✓	
Security Benefits and Costs		✓	
Knowledge Benefits and Costs			

Figure 1.2. FY 2006 Benefits Metrics Reported

Completing the cells of this matrix in ways that provide comparable results across programs (and DOE offices) poses a number of analytical challenges, especially in light of the varied portfolio that EERE maintains:

- **Standard baseline(s) and methodological approaches.** EERE uses the Energy Information Administration's (EIA) *Annual Energy Outlook 2004* (*AEO2004*) Reference Case as a consistent starting point for analysis of all of its programs.[12] A standard set of methodological approaches (guidance) is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE program goals. This guidance is applicable to all of EERE's program activities and markets.

[10] See *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001) for the original framework. DOE's offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Science cosponsored DOE's "Estimating the Benefits of Government-Sponsored Energy R&D" conference in March 2002 to explore ways of extending this framework to include the prospective benefits of program activities. As a result of the conference, the matrix was revised by placing knowledge as a benefit and explicitly showing expected prospective benefits and costs in addition to realized benefits and costs. The conference report is available at www.esd.ornl.gov/benefits_conference.

[11] For its retrospective study, the NRC defined an option as a technology that is fully developed—but for which existing market or policy conditions are not favorable for commercialization. Because current technology choices are known, noncommercial (but developed technologies) are options, by default.

[12] See *The Annual Energy Outlook 2004 with Projections to 2025*, January 2004, DOE/EIA-0383 (2004), available at http://www.eia.doe.gov/oiaf/archive/aeo04/index.html.

- **Varied markets.** Program activities target all end-use markets (buildings, industry, transportation, and government) and energy-supply markets (use of renewable energy as new sources of liquid and gaseous fuels, and electricity). Because these markets vary enormously in structure, regulation, and consumer preferences, a fairly detailed, market-specific analysis often is needed to gain sufficient understanding of the size and potential receptivity of each market to EERE's activities. EERE strives to incorporate these unique market features that are likely to have a significant impact on the resulting benefits.

- **Varied time frames.** The analytical time frame extends from a few years to the decades that are required for the development of new energy sources, infrastructure, market penetration, and product life cycle. This expansive time frame requires a baseline and analytical tools that can address energy markets in the short, mid-, and long term. This report addresses midterm (5–20 years) and long-term (20–50 years) time frames.

- **Numerous market feedbacks.** EERE technology and deployment efforts can have large enough effects on their respective energy markets that they generate supply or price feedbacks. EERE's technologies also can interact with each other across their respective energy markets. For example, efficiency improvements in end-use markets can be large enough to forestall the development of new electricity-generating plants, reducing the potential growth of wind and other renewable electricity sources. Past EERE experience indicates that failure to reflect market responses tends to overestimate benefit levels. EERE utilizes integrated energy-economic models to produce final benefit estimates that consider these feedbacks and interactions at the program and portfolio levels.

Benefits Analysis Team

This report summarizes program benefits analysis undertaken by experts in energy technology programs, energy markets, and energy-economic modeling. The primary team members and their areas of responsibility are listed below.

Report Managers

- EERE
  - Integrated: Brian Unruh
  - Biomass: Tien Nguyen
  - Buildings: Brian Card
  - Distributed Energy Resources (DER): Michael York
  - Federal Energy Management: David Boomsma
  - Geothermal: Cathy Short
  - Hydrogen, Fuel Cells, and Infrastructure Technologies: Jeff Dowd
  - Industry: Peggy Podolak
  - Solar: Tom Kimbis
  - Vehicle Technologies: Phil Patterson
  - Weatherization and Intergovernmental: Michael Gonzalez
  - Wind: Linda Silverman

- Contractors
    - Project Manager: Doug Norland (NREL)
    - Guidance: Doug Norland (NREL)
    - Appendices: Thomas Jenkin (NREL)
    - Editorial: Michelle Kubik (NREL)

Benefits Analysis Team

- Energy-Economic Integration–NEMS: Frances Wood, John Holte, Laura Train, Will Georgi (OnLocation Inc.)
- Energy-Economic Integration–MARKAL: Chip Friley, John Lee (BNL)
- Biomass: Lynn McLarty (TMS), David Andress (DAA), Valerie Reed (OBP)
- Buildings: Sean McDonald, Dave Anderson, David Belzer, Donna Hostick, Katie Cort, Jim Dirks, Doug Elliott (PNNL)
- DE: Chris Marnay, Kristina LaCommare (LBNL)
- Federal Energy Management: Daryl Brown, Andrew Nicholls (PNNL)
- Hydrogen and Fuel Cells: Jeff Dowd (EERE), Margaret Singh (ANL)
- Geothermal: Dan Entingh (PERI)
- Green Power: Jim McVeigh (PERI)
- Industry: Jim Reed (Independent Consultant)
- Solar: Robert Margolis (NREL), Jim McVeigh (PERI)
- Vehicle Technologies: Phil Patterson (EERE), Jim Moore (TA Engineering), Margaret Singh (ANL)
- Weatherization and Intergovernmental Programs (WIP): Sean McDonald, David Anderson, Nancy Moore (PNNL); Laura Vimmerstedt (NREL)
- Wind: Tom Schweizer, Joe Cohen, Jim McVeigh (PERI)

In all cases, these lead analysts drew from the studies and expertise of many others. Much of this supporting work can be found in the references provided here and in the appendices.

Report Organization

This report is organized into four additional chapters. **Chapter 2** describes the process and methodology employed by EERE to estimate program and portfolio economic, environmental, and security benefits from its RD&D programs. **Chapter 3** presents the overall results of the savings estimates from the individual programs and from a total EERE portfolio perspective. **Chapter 4** describes, in detail, the estimated midterm benefits of each program area using NEMS-GPRA06. **Chapter 5** describes, in detail, the estimated long-term benefits of each program area using MARKAL-GPRA06.

Thirteen appendices are included. **Appendix A** provides the Baseline Cases. **Appendices B through M** provide program-analysis team inputs for EERE's programs.

CHAPTER 2

EERE BENEFITS-ANALYSIS PROCESS

The Office of Energy Efficiency and Renewable Energy's (EERE) benefits-analysis process involves three major steps (**Figure 2.1**). In **Step 1,** EERE's Office of Planning, Budget, and Analysis (PBA) develops a standard baseline and methodological approach (guidance) to help ensure consistency in estimates across programs. In **Step 2,** EERE's programs develop specific technology and market information, which is necessary to understanding the potential roles of each program in its target markets. In **Step 3**, PBA uses this program and market information to assess the impacts of each EERE program (as well as the overall EERE portfolio) on energy markets in the United States using integrated energy-economic models.

STEP 1 – Baseline Case and Guidance

- Create a Baseline Case without EERE RDD&D.
- Make any necessary updates to EERE's guidelines on estimating benefits.

↓

STEP 2 – Program and Market Inputs

- Review the baseline projections of the timing and rate of adoption of EERE technologies.
- Assess the potential roles of each program's performance goals in these future energy markets.
- Develop inputs to Step 3.

↓

STEP 3 – Program and Portfolio Benefits Estimates

- Develop estimates of individual program benefits (the Program Cases).
- Develop estimates of the combined benefits of all programs (the Portfolio Case).

Figure 2.1. EERE Program and Portfolio Benefits-Analysis Process

Step 1: Baseline Case and Guidance

Baseline Case

The first step in the benefits analysis process is to establish an appropriate Baseline Case. The EERE Baseline Case is a projection intended to represent the future U.S. energy system without the effect of EERE programs. This Baseline Case assures that program benefits are estimated based on the same initial forecasts for economic growth, energy prices, and levels of energy demand. It also ensures that these initial assumptions are consistent with each other; e.g., that the level of electricity demand expected under the economic growth assumptions could be met at the electricity price assumed. It provides a basis for assessing how well renewable and efficiency technologies might be able to compete against future, rather than current, conventional energy technologies (e.g., more efficient central power generation). Finally, it helps assure that improvements in efficiency and renewable energy, which may occur absent EERE's RDD&D efforts, are not counted as part of the benefits of the EERE programs.

The most recent *Annual Energy Outlook* Reference Case is used as the starting point for developing the base case. The Energy Information Administration (EIA) *Annual Energy Outlook* (*AEO*) Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy (e.g., to reflect the availability of new appliances), technology improvements that might improve the efficiency of energy use, and changes in energy resource production costs, including renewable energy. Current energy market policies, such as state Renewable Portfolio Standards, which facilitate the development and adoption of these technologies, are included in the Baseline Case. This approach ensures that EERE's benefits estimates do not include expected impacts of such policies. Neither the EIA Reference Case nor the EERE Baseline Case includes any changes in future energy policies.

In establishing its Baseline Case, EERE makes a number of modifications to the *AEO2004* Reference Case (see **Table 2.1**). Modifications are made to the same model—the National Energy Modeling System (NEMS)[1]—used by EIA in developing the *AEO2004*. To distinguish it from EIA's version, the model is referred to as NEMS-GPRA06. The *AEO2004* Reference Case is also the starting point for the long-term (to 2050) benefits modeling using MARKAL-GPRA06. The Baseline Cases for both NEMS-GPRA06 and MARKAL-GPRA06 are aligned as closely as possible, but the two models are different in their internal design.[2]

Removal of EERE programs. First, several adjustments are made to remove EERE programs from the EIA Reference Case. For example, EIA's estimate of rooftop photovoltaic installations resulting from the Million Solar Roofs Initiative were removed for the EERE Baseline. The *AEO2004* assumption of roughly constant hydroelectric capacity over time was modified to

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[1] An updated version of NEMS from April 2005 was used that produces similar reference case projections as the *Annual Energy Outlook 2004* with Projections to 2025, January 2004, DOE/EIA-0383 (2004). See http://www.eia.doe.gov/oiaf/archive/aeo04/pdf/0383(2004).pdf.

[2] See Box 4.1 in Chapter 4 for an overview of NEMS and Box 5.1 in Chapter 5 for an overview of MARKAL. General information on energy-economy modeling is contained in *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs FY2005Budget Request* (May 2004), http://www.eere.energy.gov/office_eere/gpra_estimates_fy04.html.

reflect the expectation that without more environmentally benign turbine designs some reduction in hydro capacity would occur as a result of relicensing requirements. The maximum growth rates for cellulosic ethanol production were reduced by a factor of 5 because growth of this new industry is expected to be very slow without EERE program involvement.

Table 2.1. Summary of Baseline Changes from the AEO2004

	AEO2004	GPRA06 Baseline Case
Removal of EERE Programs		
Million Solar Roofs	0.4 GW installed 2005 to 2025	Removed
Photovoltaic system costs	Significant improvement	Slower rate of improvement
Hydroelectric capacity	Roughly constant hydro capacity and generation	2.2 GW reduction for 2010 to 2025
Cellulosic ethanol production	0.6 billion gallons annually by 2025	0.12 billion gallons annually by 2025
DG technology improvement	Significant improvement	Slower rate of improvement
Commercial absorption cooling efficiency	Constant over time	Increase 20 percent by 2020
Wind	30 to 44 percent capacity factors depending on wind class and year	34 to 50 percent capacity factors depending on wind class and year
Geothermal	Significant improvement	Half the rate of improvement
Energy Market Updates		
PV system size	2 kW residential, 25 kW commercial	4 kW residential, 100 kW commercial
PV maximum market share	30 percent for both residential and commercial	60 percent for residential and 55 percent for commercial
CHP commercial building maximum share	30 percent	50 percent
Commercial absorption cooling	Included in only 5 building types	Included in all 11 building types
California PV subsidy	Not included	Included for residential systems
Solar water heat	Maximum 20 percent replacement market	New and up to 50 percent replacement market
Cellulosic conversion efficiency	90 to 103 gallons of ethanol per dry ton of biomass	82 to 101 gallons of ethanol per dry ton of biomass
Structural Changes		
Wind module	One capital cost and resource multiplier for all wind classes	Capital costs and resource multipliers by wind classes
	No offshore wind technology	Offshore wind
Commercial shell efficiency	Index	Technology representation
Commercial DG algorithms		Market share and stock accounting modified

The *AEO2004* forecast includes technology improvements in all areas of energy demand and supply, and identifying what portion is due to EERE programs is extremely difficult. For GPRA2006, selected technology changes were made where the *AEO2004* appeared to already incorporate the EERE program goals. Technology assumptions that were modified for the Baseline include cost and efficiency improvements in distributed combined heat and power (CHP) technologies that were assumed to be delayed without an ongoing distributed energy (DE) program. In addition, the two composite distributed generation technologies in the electricity generation sector were modified to reflect baseline values for gas turbines, microturbines, and gas engines. The *AEO2004* includes a significant improvement in geothermal generation technology over time, similar to the program goals. To reflect what might occur without continued R&D funding, analysts reduced the cost reduction by half for the GPRA Baseline.

There are a few EERE technologies that are either not represented in the *AEO2004* Reference Case or their improvement is less than anticipated by the program in the absence of EERE programs. These technology assumptions were also modified for the GPRA06 Baseline. In commercial lighting, an advanced electrodeless fluorescent technology was replaced with a baseline projection of solid-state lighting characteristics. The efficiency of absorption cooling in commercial buildings was assumed to increase slightly, rather than remain constant over time. Offshore wind technology characteristics were added, and the onshore wind characteristics were modified. The onshore capital costs were increased slightly. More important, the capacity factors for each wind class were assumed to be higher than in the *AEO2004*, although lower than the program goals.

Energy Market Updates. A few other modifications were made to reflect EERE program assumptions or updated information about energy markets. These changes affect both the Baseline and the Benefits Cases. The size of typical PV systems was increased to 4 kW in residential and 100 kW in commercial buildings to reflect recent PV installation experience and trends. The maximum market for PV systems was increased from 30 percent to 55 percent in the commercial sector and to 60 percent for residential PVs. Similarly, the maximum market share for gas-fired distributed generation technologies was increased from 30 percent to 50 percent in the commercial sector. California PV credits were incorporated in the Pacific region. Solar water heat was added to the slate of technologies for new homes, and the share of the replacement market in which it can compete was increased from 20 percent to 50 percent. The conversion efficiency of cellulosic ethanol was reduced, because EIA's assumption appeared too optimistic.

Structural Changes. In a few cases, analysts made structural changes to improve the model's representation of markets important to EERE technologies. The wind module was modified, so that each of the three wind classes is treated more discretely with separate capital costs and resource multipliers.[3] Offshore wind was added as another technology option with resources available in the coastal regions and the regions around the Great Lakes. The shell indices in the commercial module were replaced with a technology choice algorithm necessary for later representation of EERE shell technologies. In addition, alterations to the distributed generation algorithm in the building modules were made to reflect market adoption data gathered by the DE program,[4] to account for buildings that have already installed a DG technology in prior years, and to allow greater than an annual 0.5 percent adoption in existing buildings. Absorption cooling was allowed to compete in all commercial building types, rather than only a subset, as in the *AEO2004*.

[3] In the *AEO2004* version of NEMS, these multipliers are applied to the entire wind resource in each region; whereas, in NEMS-GPRA05, they are applied separately by wind class. This latter treatment tends to be more restrictive, because cost increases due to resource depletion occur more quickly for the best wind class.

[4] *Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project*. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.

Resulting Energy Demand and Energy Intensity. The adjustments for the GPRA06 Baseline Case result in an insignificant difference in energy consumption relative to the *AEO2004* Reference Case projections. The resulting Baseline Case projects a 33 percent increase in conventional energy demand from 2005 to 2025.[5] Energy efficiency and renewable energy improvements projected to occur without EERE's program activities, however, contribute toward a 27 percent reduction in conventional energy intensity (energy used per dollar of GDP produced) over the same period (**Figure 2.2**).[6]

EERE benefits estimates do not include any of these efficiency or renewable Baseline Case improvements. Rather, the R&D improvements represented in the Baseline Case provide the "next best technologies" against which additional EERE improvements are compared. More detail from EERE Baseline Case projections is in **Appendix A**.

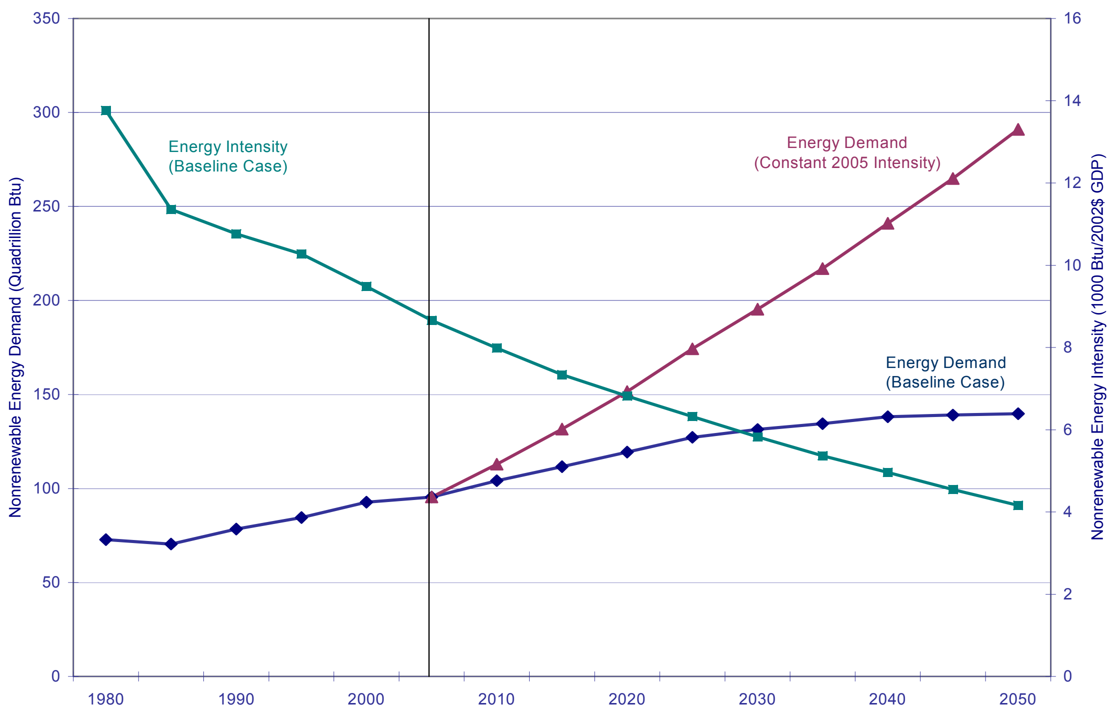

Figure 2.2. U.S. Nonrenewable Energy Demand and Energy Intensity, 1980-2000, and Baseline Projections to 2050

Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 7, 2004), Tables 1.3, D1 Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

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[5] Very similar to the AEO2004.

[6] Energy intensity changes result from a mix of structural changes in the economy (e.g., growing service sector) and efficiency improvements. Two recent EERE-sponsored studies provide additional background on understanding the sources of changes to our energy intensity: Ortiz and Sollinger, *Shaping Our Future by Reducing Energy Intensity in the U.S. Economy; Volume 1: Proceedings of the Conference* (2003, Rand Corporation) and Bernstein, Fonkych, Loeb, and Loughran, "State-Level Changes in Energy Intensity and their National Implications" (2003, Rand Corporation).

In the Baseline projections, oil prices are projected to fall from 2004 and then gradually rise through 2025, as shown in **Figure 2.3**. Natural gas prices are projected to fall more gradually through 2010 and then increase through 2025. Coal prices, on the other hand, are projected to be relatively constant in real terms with a very slight decline. Electricity prices are projected to experience a slight decrease through 2010.

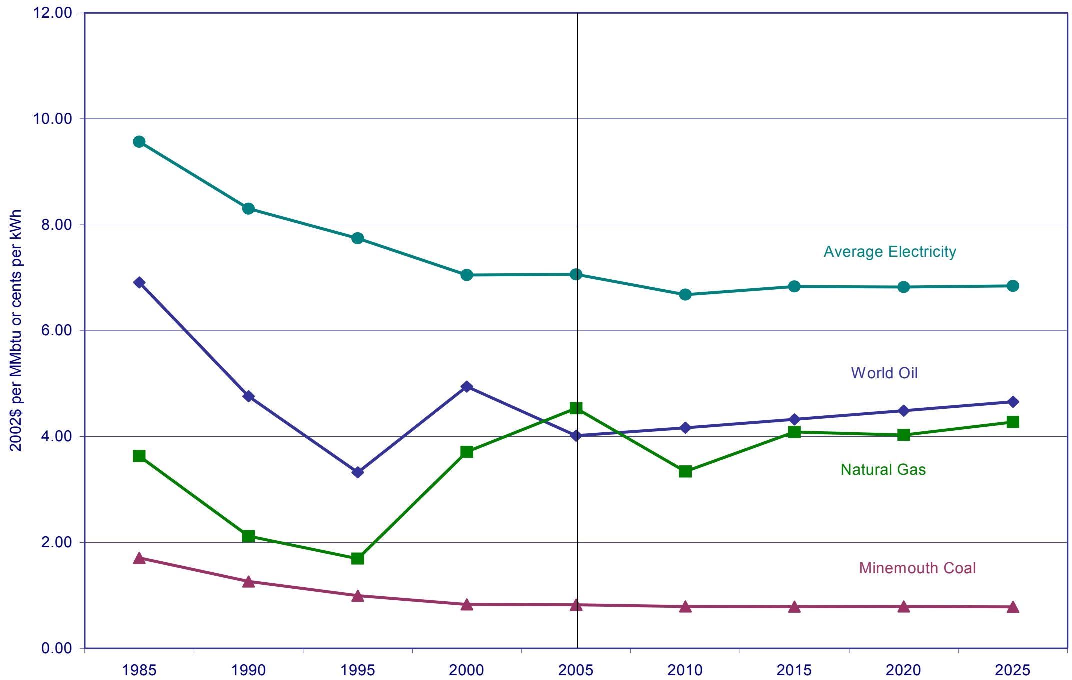

Figure 2.3. Projected Energy Prices

Guidance

In order to improve the consistency of estimates across EERE's portfolio, EERE utilizes common methodological approaches, definitions, and conversion factors. Prior to the reorganization in 2002, EERE communicated these common elements in the form of an annual "GPRA Data Call"[7] to the five EERE sectors, which undertook separate analyses based on these common guidelines. With the reorganization, the benefits-analysis team utilizes this process directly, including:

Definitions. Common definitions for benefits metrics and related terms are provided.

Converting nominal dollars to real dollars. The results of EERE's benefits analysis are reported in constant ("real") dollars as opposed to current/future year ("nominal") dollars to compensate for the effects of inflation over time. In cases where the program or other sources provide future expenditures or costs in nominal dollars, these are converted to constant dollars based on a forecasted GDP deflator.

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[7] The guidance used for FY 2006 benefits estimates followed the guidance for FY 2005 (see http://www.eere.energy.gov/office_eere/ba/gpra_estimates_fy04.html). EERE will continue to maintain standard assumptions and methodologies for estimating program benefits.

Next best technology. The benefits of EERE technologies are assessed compared to the best technologies expected to be available to the market at the time the EERE technologies are developed—not compared to the technologies available or installed today. The Baseline Case provides the future "next best technologies," against which EERE technologies will compete. In markets where the models do not have explicit technology representation, the "next best technology" is reflected in the Baseline Case rates of technology and market improvements. In most cases, EERE R&D efforts accelerate the development and introduction of these technologies, while its deployment efforts principally accelerate the market penetration of technologies once they have reached the market.[8] In specific cases, the RD&D efforts also may be directed toward changing the attributes of technologies in the market (*e.g.*, less polluting) or of developing technologies that are not reflected in the Baseline Case within the timeline of analysis. (See **Box 2.1—Impact of EERE Programs**).

Market characteristics and penetration rates. It takes time for new products to reach their full market potential, and these market-penetration rates vary considerably by technology and market. The Baseline Case includes assumptions about technology-adoption rates for many markets, primarily through the use of consumer "hurdle rates" or other representations of the trade-off between upfront investment costs and annual operating costs (including energy expenses) over time, as well as other attributes in selected cases. Where technologies are not explicitly represented, adoption rates are embedded in efficiency trends. Efficiency trends may implicitly include capital stock turnover, as well as technology efficiencies and rate of uptake of different technologies. Other market characteristics (such as regional markets, regulatory constraints, or typical start-up time for new product lines) can influence adoption rates and also may be specifically represented in the Baseline Case. For R&D activities, the market characteristics and factors affecting adoption rates remain the same for the Program Case and the Baseline Case, unless the new technology would fundamentally change the way the target markets operate (*e.g.*, accelerate stock turnover or increase consumer acceptance of new technologies). For deployment activities, the program output goals provide a basis for assessing the expected acceleration of market-penetration rates (or other changes in market characteristics), due to the program activities in the Program Case.

Technology performance and cost. For R&D programs, the benefits analysis is based on the performance and cost of the technologies being developed or deployed. For each technology (or class of technologies), key technology characteristics include:

- Expected year of technology availability
- Capital costs
- Operations and maintenance (O&M) costs
- Technology product lifetime
- Technology performance and/or energy displaced/unit by fuel type
- Other technology features that might affect market acceptance.

[8] This is a starting assumption. There may be cases in which EERE's efforts principally change the characteristics of the technologies being marketed (*e.g.*, less polluting) rather than, or in addition to, accelerating market introduction and penetration. At times, EERE may be developing technologies that are not expected to be developed by the private sector (*i.e.*, they do not show up in the Baseline Case at all). Finally, some research efforts include built-in deployment components that may result in a combined accelerated introduction and accelerated penetration effect. These variations on the basic approach described above are addressed in the program-level appendices to this report.

Box 2.1—Impact of EERE Programs

For EERE R&D efforts, the initial assumption is that the impact of the program is to accelerate the commercial introduction of a technology (see **Figure 2.4a**). In some cases, that may be the only effect. In other cases, the EERE R&D effort may develop a technology with features that can affect the ultimate size of the market, or that otherwise would not have been developed by the private sector.* For EERE deployment efforts, the initial assumption is that the impact of the program is to accelerate the rate of adoption of a technology already developed and introduced to the market (see **Figure 2.4b**). In some cases, the EERE deployment effort also may impact the total size of the market, in addition to the rate of adoption. In such cases, the program affects the maximum market share the technology achieves.

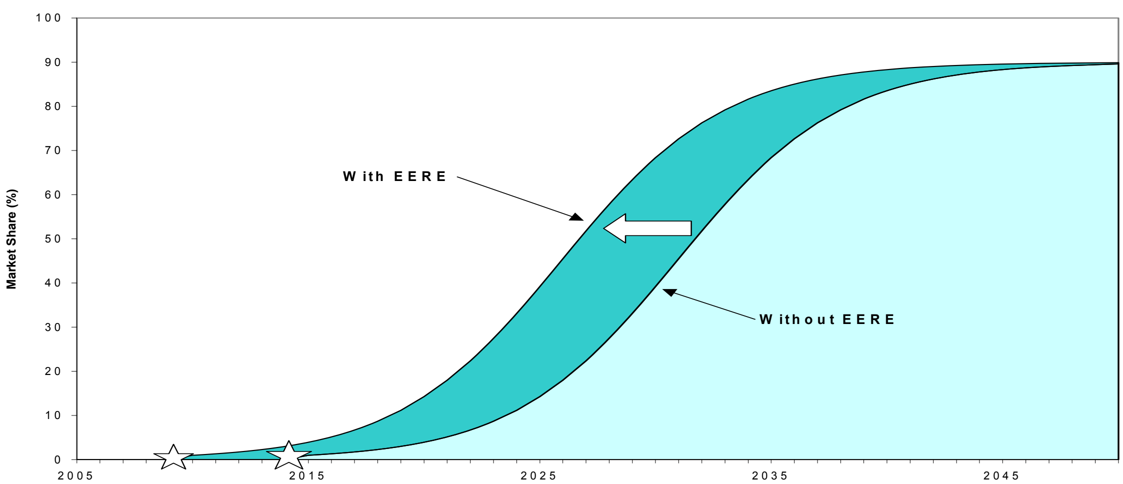

Figure 2.4a. Potential Impacts of EERE R&D Programs on Technology Introduction

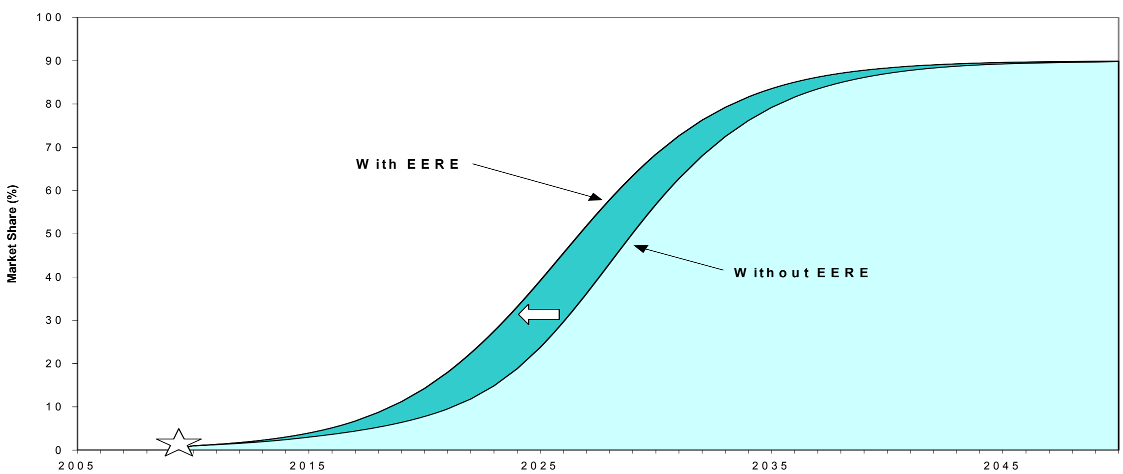

Figure 2.4b. Potential Impacts of EERE Deployment Programs on Market Penetration

*Assuming the technology, or technological characteristic, would have been developed by the private sector anyway. In some cases, technologies are so far from potential commercialization—or so risky—that private-sector firms do not invest in them. In others, the private sector lacks the market incentive to develop technology features, such as improved load-balancing for home appliances (which could improve the reliability of the electricity grid), because the markets do not provide the price signals that would generate profits from these public benefits.

Two sets of technology characteristics are of interest: Baseline Case and Program Case. The EERE Baseline Case already includes expected private-sector advances in efficiency and renewable technologies. In many cases, the specific technology characteristics are included directly in the NEMS-GPRA06 and MARKAL-GPRA06; while, in other cases, they are represented through overall rates of technology improvement—and the characteristics for specific technologies must be inferred from these rates.

For R&D efforts, the Program Case technology characteristics and costs generally reflect the program output goals. For deployment efforts, the technology characteristics remain the same in the Baseline and Program Cases.

Calculating direct energy and primary energy displaced. NEMS-GPRA06 and MARKAL-GPRA06 provide projections of direct (site) energy savings from end-use programs and the corresponding primary energy reductions. Reduced electricity demand leads to reduced generation and fuel consumption by electric power producers. The amount of fuel consumed (and saved) changes as the marginal efficiency of power production increases with the increased efficiency of conventional, central power production. When the principal market analysis is performed off-line, the resultant energy savings (expressed in direct energy terms) are used as an input to the NEMS-GPRA06 and MARKAL-GPRA06 models. The two models then compute primary energy savings based on the direct energy savings.

Calculating carbon equivalent emissions reductions. NEMS-GPRA06 and MARKAL-GPRA06 compute carbon emission reductions based on the amount of coal, oil, and natural gas consumed in the Baseline, Program, and Portfolio Cases, as well as the carbon coefficients of each energy source. Carbon emissions are computed using NEMS-GPRA06 and MARKAL-GPRA06. The carbon emissions associated with the displacement of fossil-generated electricity by efficiency or renewable technologies will vary over time and reflect the increasing efficiency of new fossil generators and the dynamic shift in fuel sources.

EERE's ability to apply these methodological approaches varies considerably by program, depending on the availability and cost of market data, the ability to assess public and private-sector technology contributions, and the capability to reflect specific market conditions in energy models available to EERE.

Step 2: Program and Market Inputs

In **Step 2**, program goals and salient target market characteristics are developed as inputs to modeling the benefits estimation in **Step 3**. The effort required under **Step 2** varies considerably, depending on the form in which programs specify their output or performance goals and how NEMS-GPRA06 and MARKAL-GPRA06 utilize this information. It ranges from the compilation of technology goals to detailed market analyses that produce technology penetration rates—and, in some cases, delivered energy savings.

NEMS-GPRA06 and MARKAL-GPRA06 contain detailed technology representations of electricity markets, most residential and commercial end uses, and vehicle choice—but use trends to represent industrial efficiency improvements and existing residential shell retrofits. For programs that address these markets, this step simply requires (1) confirming the adequacy of the target market representation in the Baseline Case and (2) providing the program goals in a format consistent with the model. Any updated market characteristic information is used to adjust NEMS-GPRA06 and MARKAL-GPRA06 for both the Baseline Case and the Program Case to avoid ascribing external factors as benefits. Analysts use the program goal information to adjust the commercialization date, technology characteristics, or market penetration rate for the Program Case. The comparison of market technology introduction and market penetration rates, with and without the program goal—and the calculation of the energy displaced—occur within NEMS-GPRA06 and MARKAL-GPRA06.

For much of EERE's portfolio, additional "off-line" analyses are needed to translate information about program technology and market characteristics into usable modeling inputs. This off-line **Step 2** analysis can range from spreadsheet calculations to the use of market-specific models to assess technology or market features that cannot be adequately represented in a broad energy-economic model, or to translate program goals into the variables used in the modeling. In general, analysts perform the most detailed off-line analyses for the Industrial Technologies Program, Weatherization and Intergovernmental Program (WIP), Federal Energy Management Program (FEMP), and portions of the Building Technologies Program. Analysts tailor these off-line analytical approaches to the characteristics of the program and target market being analyzed; but, in any case, they are conducted within the overall guidance provided through the GPRA benefits estimation process.

The market applications for EERE technologies are often very specific, and resulting energy savings for a given technology can vary significantly from one application to another. For example, the impact of upgrading building codes can vary significantly (due to differences in climate and in existing building-code standards) and therefore require analysis at the State level. The Building, Industrial, and WIP programs are most likely to require tailored analytical approaches that address these submarkets.

Where NEMS-GPRA06 and MARKAL-GPRA06 do not include technology-by-technology information (*e.g.*, cost, date of availability), or specific market-penetration rates, it is often necessary to translate program goals into the more general rates of technology improvement used by the models. This is true for the Industrial Technologies Program and some elements of the Building Technologies Program, where numerous specific technology advances or market deployment efforts will accelerate overall efficiency improvements in buildings or factories specified in the Baseline Case.

Off-line analysis also can be required for targeted submarkets that are simply not included in NEMS-GPRA06 or MARKAL-GPRA06—or for which the resulting technology use is not fully market-driven. Examples include the Federal sector (addressed by FEMP) and the Low-Income Weatherization Assistance Program, in which the Federal Government directly purchases home efficiency improvements.

Finally, supporting "off-line" analysis can be required where market functions are not well represented in a full energy-economic model. For example, consumer willingness to pay a premium for electricity produced by environmentally friendly technologies is not represented within the electricity market in NEMS-GPRA06 and MARKAL-GPRA06; and, therefore, another model specifically designed to analyze this market provides the input assumptions on this market segment. Also, programs designed to help overcome institutional barriers to efficiency adoption are often difficult to represent in market-based models.

Because estimating the benefits of achieving program performance goals requires the ability to realistically assess the extent to which future energy markets might adopt the technology and market improvements developed by EERE programs, analysts explore the following features in these off-line analyses:

Target Markets. New technologies will not necessarily be well suited to all applications served by existing markets. Technologies may occupy niche markets, especially in early years. In some cases, initial markets are geographically limited as well. Where integrated models do not represent these submarkets explicitly, it may be necessary to develop off-line estimates of the applicable market share for the technology being developed, at least in the early years.

Stock Turnover. Modeling stock turnover is crucial to estimating benefits for both new technologies and deployment programs. Analyses of the market adoption of new technologies must consider the rate at which the specific type of energy-using or -producing capital equipment is replaced, in addition to the growth rate of the overall market. Even when a technology is suitable and cost-effective for a percentage of a market, it may take a decade or more for the capital stock in that portion of the market to retire and be replaced. Particularly attractive new technologies might accelerate that turnover. EERE includes this potential for early retirement only when market evidence suggests that the technology improvement is significant enough to overcome typical hurdle rates to new investment. Although stock turnover fluctuates with business cycles, EERE does not incorporate business cycles into its Baseline or Program cases. As a result, nearer-term estimates of benefits, in particular, do not take into account year-to-year fluctuations in energy use attributable to business cycles.

Next Best Technology. Where technology representation is implicit (in a technology improvement index, for instance), the Baseline Case improvement must be translated into improvement rates for a specific set of technologies. Analysts use this set of baseline technologies to assess the specific markets in which the EERE technology might be competitive in different time frames.

Market Penetration. Over time, new technologies typically make their way into markets—and, therefore, affect energy use—gaining their share of new sales as consumers learn about the availability of the product. Manufacturing capacity then grows, and product prices fall with economies of scale and learning.[9] While price helps determine whether a product is

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[9] See Adam B. Jaffe, Richard G. Newell, and Robert N. Stavins, "Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence," Climate Issue Brief No. 19, *Resources for the Future*, Washington, D.C. (December 1999).

cost-effective, on average, energy prices vary by type of customer and region, so that new products may be cost-effective for some customers (a niche market) before they are generally cost-effective. Price, or cost-effectiveness, is often not the only aspect of the new technology or deployment program that shapes its rate of market uptake. Many non-price or cost factors affect consumer behavior.

As an example, the off-line analysis for the Industrial Technologies Program uses a spreadsheet model that provides several possible market-penetration curves. The analyst chooses a curve, based on specific information from possible R&D partners, comparison of the new technology to similar technologies, or his or her expert judgment. The benefits guidance for industrial benefits estimation includes historic penetration curves for 11 technologies and offers the analyst five choices of penetration curve shapes. The five choices are accompanied by detailed data on technology equipment, financial, industry, regulatory, and impact characteristics to aid in making the choice. In addition to choosing the shape or the penetration curve, the analyst chooses the year—after all pilot testing and demonstration phases—the new technology is expected to enter the market.

Through the use of specialized spreadsheets or other models,[10] program analysts produce estimates of market penetration and direct energy savings associated with these market sales. However, these “off-line” estimates of direct energy savings are not benefits estimates, because they do not account for market interactions. Analysts integrate these off-line estimates within the NEMS-GPRA06 and MARKAL-GPRA06 models as the final part (**Step 3**) of the process.

Step 3: Program and Portfolio Benefits Estimates

The final step for estimating the impacts of EERE’s FY 2006 Budget Request is to analyze all EERE’s programs in a consistent economic framework and to account for the interactive effects among the various programs. Estimates of individual EERE program energy savings cannot be simply summed to create a value for all of EERE, because there are feedback and interactive effects resulting from (1) changes in energy prices resulting from lower energy consumption and (2) the interaction among programs affecting the mix of generation sources and those affecting the demand for electricity.

The process begins by analysts modeling each EERE program individually within NEMS-GPRA06 and MARKAL-GPRA06 to the extent possible. In each NEMS-GPRA06 and MARKAL-GPRA06 Program Case, only the modeling assumptions related to the outputs of the program being analyzed are changed. The modeling assumptions related to the other EERE programs remain as they were in the EERE Baseline Case. Analysts model each program separately to derive estimated energy savings without the interaction of the other programs. They then compare the results from the NEMS-GPRA06 and MARKAL-GPRA06 Program Cases to the Baseline Case to measure the individual benefits of the EERE program being analyzed.

[10] In one case (the Building Technologies Program), a portion of NEMS (the buildings module) was used for off-line analysis.

For programs modeled using NEMS-GPRA06 and MARKAL-GPRA06 directly, analysts compute the Program Case by changing the assumptions representing the program outputs; *i.e.*, the goals or performance targets of the program, such as reducing low wind-speed turbine costs and improving their performance. The R&D programs are represented in NEMS-GPRA06 and MARKAL-GPRA06 through changes in technology characteristics that represent the program goals, to the extent possible. Activities designed to stimulate additional market penetration of existing technologies generally were modeled through changes in consumer hurdle rates or other appropriate market-penetration parameters, with the goal of representing the market share targeted by the program.

In cases where program goals cannot be easily modeled using NEMS-GPRA06 and MARKAL-GPRA06, analysts estimate benefits using a variety of off-line tools, as described in **Step 2**. These supporting analyses typically provide either estimates of market penetration and per-unit energy savings, or total site energy savings, which are then used as inputs to NEMS-GPRA06 and MARKAL-GPRA06. In cases where the off-line analyses produce a direct estimate of site energy savings, analysts adjust this information by an "integration factor" and incorporate it in NEMS-GPRA06 and MARKAL-GPRA06 in order to calculate primary energy savings. The amount of the integration factor is based on how much program overlap or "integration" was captured by the off-line tools. The revision is based on the expert judgment of the benefits analysis team. See **Chapters 4 and 5** for discussion of program-by-program benefit estimates, including such reductions.

Once each of the programs (or group of programs) is represented individually within NEMS-GPRA06 and MARKAL-GPRA06, the benefits of EERE's portfolio are estimated by combining all of the program goals into one EERE Portfolio Case.

Detailed projections from the EERE Baseline and Portfolio Benefits Case are in **Appendix A**.

CHAPTER 3

FY 2006 BENEFITS ESTIMATES

The Office of Energy Efficiency and Renewable Energy (EERE) estimates expected benefits for its overall portfolio and for each of its 11 programs. Benefits for the FY 2006 budget request are estimated for the midterm (2010-2025) and long term (2030-2050). Two separate models suited to these periods are employed—NEMS-GPRA06 for the midterm and MARKAL-GPRA06 for the long term.

Benefits estimates are intended to reflect the value of program activities from 2006 forward. They do not include the impacts of past program success, nor technology development or deployment efforts outside EERE's programs. This distinction is difficult to implement in practice, because many research and deployment activities provide continuous improvements that build on past success; and because EERE programs are leveraged with private-sector and other government efforts (*e.g.*, in addition to the Baseline Case, private-sector improvements).

Outcomes and Benefits Metrics

The energy efficiency improvements and additional renewable energy production facilitated by EERE's programs reduce the consumption of traditional energy resources. Reducing energy consumption affords the Nation a number of economic, environmental, and energy security benefits.[1] The extent of these benefits depends on numerous factors including which energy sources are reduced, the costs of the new technologies, and the emissions performance of the energy technologies used. Different EERE portfolios would produce a different mix of benefits, even if the overall level of primary energy savings were the same.

The public benefits resulting from these reductions in the use of traditional energy resources take many forms. Environmental improvements, for instance, can include reductions in local, regional, or global air emissions; reduced water pollution; noise abatement, etc. These public benefits are typically difficult to measure directly, and some aspects are not quantifiable. EERE has developed a set of *indicators* intended to provide a sense of the magnitude and range of the benefits its programs provide the Nation. EERE estimates benefits for the following defined metrics:

<u>Primary Outcome:</u>

> **Energy Displaced - the difference in nonrenewable energy consumption with and without the technologies and market improvements developed by EERE programs.**

[1] This is a categorization of EERE's benefits estimates, based on the framework developed by a National Research Council (NRC) committee. The framework is described in more detail in the Introduction.

Analysts measure energy savings on a primary basis, accounting for the energy consumed in producing, transforming, and transporting energy to the final consumer. Energy savings from underlying private-sector improvements in technologies are not counted. Energy displaced is reported in quadrillion Btus per year (quads/yr).

Primary Benefits:

Economic Benefits: Economic benefits are the potential for EERE technologies to make energy more affordable by reducing expenditures on energy and energy services, increase economic productivity and GDP through more efficient production processes, reduce the impact of energy price volatility on the U.S. economy by providing more efficient technologies and providing alternative energy sources, and improve the balance of trade by exporting energy technologies. Of these, EERE currently estimates two aspects of affordability—energy-expenditure savings and total system cost savings:[2]

Energy-expenditure savings – The difference in total consumer energy bills with and without the availability of technologies and market improvements developed by EERE technologies. This is an estimate of energy bill savings[3] and does not include all incremental costs to end users of acquiring the new technology. The EIA NEMS model does not currently have the capability to provide net costs in all sectors of the economy. Energy-expenditure savings are reported in billions of 2002 dollars per year.

Total system cost savings – The difference in total systems costs with and without the availability of technologies and market improvements developed by EERE technologies. Total system cost represents the economic cost to society to produce, import, convert, and consume energy. It is calculated as the sum of domestic resource-extraction costs, imported fuel costs, and the annualized capital and operating and maintenance costs of energy technologies (including end-use demand devices). Total system cost savings is a net estimate of system costs generated by MARKAL-GPRA06, which unlike the energy expenditure savings estimates generated by NEMS-GPRA06, includes the incremental costs of end-use technologies. Total system cost savings are reported in billions of 2002 dollars per year.

Environmental Benefits: Environmental benefits that can result from use of EERE technologies include, among many others, lower carbon, SOx, NOx, and other air emissions. Of these, EERE currently estimates only the impacts of its programs on carbon emissions:

Carbon savings (*i.e.*, emission reductions) – The difference in the level of U.S. energy-related carbon emissions with and without the availability of EERE technologies and associated market improvements. Carbon emission reductions result from the reductions in fossil fuel consumption when these new supply (renewables) and

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[2] Energy-expenditure savings are calculated through 2025 using the NEMS-GPRA06. Total system cost savings are calculated through 2050 using MARKAL-GPRA06.

[3] Energy efficiency improvements and increased use of nonfuel renewable energy (*e.g.*, renewable-generated electricity) reduce energy bills in two ways. Consumers who make energy efficiency or renewable energy investments benefit directly through reduced purchases of energy (quantity component). In addition, the lower demand for energy reduces the price of energy for all consumers (price component).

demand (energy-efficient) technologies are used in the market. As with the energy-savings metric, emission reductions count the effect of upstream energy savings in producing, transforming, and transporting energy to the end user. Carbon savings are reported in million metric tons of carbon (mmtc) equivalent per year.

Security Benefits: Security benefits include improvements in the reliability of fuel and electricity deliveries, reduced likelihood of supply disruptions, and reduced impacts from potential energy disruptions. EERE contributes to these security gains by reducing U.S. reliance on imported fuels, increasing the diversity of domestic energy supplies, increasing the flexibility and diversity of the Nation's energy infrastructure, reducing peak demand pressure on that infrastructure, and providing backup energy sources in the event of outages. Of these aspects of energy security, EERE has developed indicators related to concerns about fuel supplies and the reliability and diversity of electricity supplies:[4]

Oil savings – The difference in total U.S. oil consumption with and without EERE technologies and market improvements. Oil savings are reported in million barrels per day (mbpd).

Natural gas savings – The difference in total U.S. natural gas consumption with and without EERE technologies and market improvements. Natural gas savings are reported in quadrillion Btu per year (quads/yr).

Avoided additions to central conventional power – The difference in central conventional power additions with and without EERE technologies and market improvements. Avoided central conventional power additions result from electricity capacity displaced by efficiency improvements; additional distributed generation capacity (fossil or renewable); and central renewable power-generating capacity.[5] Avoided capacity additions are reported in cumulative gigawatts (GW).

In interpreting these metrics, it is important to remember that while the benefits of efficiency and renewable technologies are multifaceted, they are not always distinct or additive. Improvements in balance-of-trade or economic productivity, for instance, are contributory to improved GDP and not additional to improved GDP. Nonetheless, identifying the various types of economic or other contributions can help relate EERE's portfolio to various economic or other policy concerns.

Each of these metrics is ideally measured as a net benefit (*e.g.*, energy bill savings minus the cost to the consumer of investing in the efficient or renewable technology, or including positive and negative environmental impacts). Analysts calculate carbon emission reductions, as well as oil and natural gas savings, on a net basis, including cases in which EERE programs tend to increase rather than decrease use or emissions. While consumer-expenditure estimates calculated by

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[4] The inclusion of reliability improvements within the security category was part of the NRC suggestions on how to structure the types of EERE benefits.

[5] These measures are not additive and are not the same as a measure of peak-load reduction for conventional electricity or of improved reliability. Renewable capacity additions are not equivalent to capacity additions avoided because of differences in capacity factors and coincidence of renewable generation at system peak (*i.e.*, peak electricity-generation output of wind, for example, may not coincide with the peak demand of the utility system to which it supplies power).

NEMS-GPRA06 do not reflect the costs to consumers of purchasing more efficient or cleaner technologies, MARKAL-GPRA06 is able to provide estimates of net economic costs.

Portfolio Benefits

Table 3.1 shows the estimated economic, environmental, and security benefits of EERE's overall portfolio of investments in improved energy-efficient technologies, renewable energy technologies, and assistance to consumers in adopting these technologies. Data by five-year increments (2010 to 2025) are shown for NEMS-GPRA06 and by 10-year intervals (2020 to 2050) for MARKAL-GPRA06.[6]

Table 3.1. Annual EERE Portfolio Benefits for FY 2006 Budget Request for Selected Years[7,8]

EERE Midterm Benefits (NEMS-GPRA06)	2010	2015	2020	2025
Energy Displaced				
• Primary nonrenewable energy savings (quadrillion Btu/yr)	1.1	3.4	7.8	12.3
Economic				
• Energy-expenditure savings (billion 2002 dollars/yr)*	12	37	87	123
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	22	67	160	262
Security				
• Oil savings (mbpd)	0.1	0.6	1.3	2.3
• Natural gas savings (quadrillion Btu/yr)	0.5	1.1	1.9	1.8
• Avoided additions to central conventional power (cumulative gigawatts)	5	49	96	137

EERE Long-Term Benefits (MARKAL-GPRA06)	2020	2030	2040	2050
Energy Displaced				
• Primary nonrenewable energy savings (quadrillion Btu/yr)	8.0	17.7	28.2	33.6
Economic				
• Energy-system cost savings (billion 2002 dollars/yr)*	43	102	188	282
Environment				
• Carbon dioxide emission reductions (mmtc equivalent/yr)	152	364	568	699
Security				
• Oil savings (mbpd)	1.3	4.6	9.0	11.0
• Natural gas savings (quadrillion Btu/yr)	3.1	2.8	3.6	2.4

* Midterm energy-expenditure savings only include reductions in consumer energy bills, while long-term energy-system cost savings also include the incremental cost of the advanced energy technology purchased by the consumer.

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[6] NEMS-GPRA06 runs using one-year intervals, while Markal-GPRA06 runs using five-year intervals.

[7] Estimates reflect the annual benefits in each year associated with program activities from FY 2006 to the benefit year, or to program completion (whichever is nearer), and are based on program goals developed in alignment with assumptions in the President's Budget. Midterm program benefits were estimated using the GPRA06-NEMS model, based on the Energy Information Administration's (EIA) National Energy Modeling System (NEMS) and using the EIA's *Annual Energy Outlook 2004* (*AEO2004*) reference case. Long-term benefits were estimated using the GPRA06-MARKAL model developed by Brookhaven National Laboratory. Results can differ among models due to structural differences. The models used in this analysis estimate economic benefits in different ways, with MARKAL reflecting the cost of additional investments required to achieve reductions in energy bills.

[8] For some metrics, the benefits estimated by MARKAL-GPRA06 do not align well with those reported by NEMS-GPRA06. Every attempt is made in the integrated modeling to use consistent baselines, input data and assumptions in both models to produce consistent results. However, NEMS and MARKAL are in some respects fundamentally different models (see Boxes 4.1 and 5.1). Discrepancies in the estimated benefits often occur simply because of these model differences.

Energy Displaced: EERE's portfolio significantly dampens the expected growth in nonrenewable energy consumption. Absent the results of EERE's programs,[9] energy use is expected to grow by nearly 32 quads from 2005 to 2025, to about 127 quadrillion Btus of energy and by 44 quads from 2005 to 2050. If the goals of EERE's investment portfolio are achieved and the corresponding market outcomes realized, it will reduce nonrenewable energy consumption by more than 12 quadrillion Btu by 2025, or about 39 percent of the expected incremental growth in energy demand over this time period; and by 34 quadrillion Btus by 2050, or about 76 percent of the expected incremental growth in energy demand over this time period (see **Figure 3.1**). This results in a reduction of nonrenewable energy consumption starting in 2030 despite a growing economy.

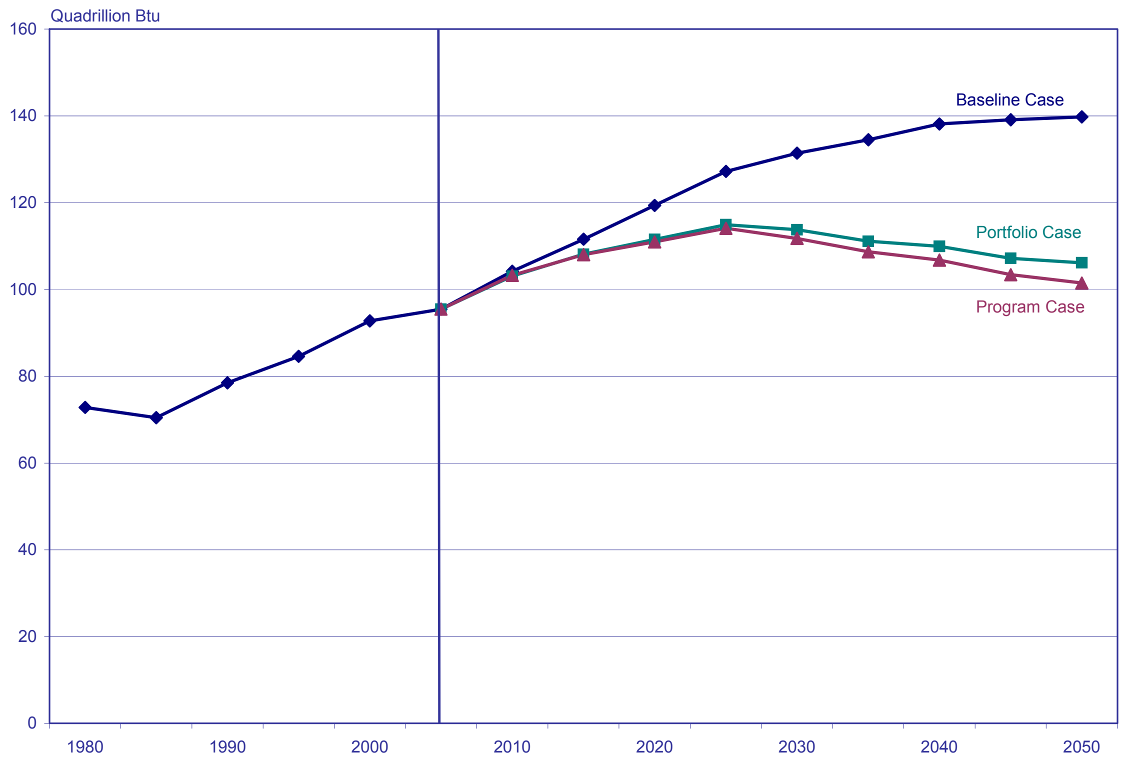

Figure 3.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

These estimates account for interactions among program results. While some program activities reinforce each other to produce larger benefits than would be evident from each program's individual efforts, programs compete for the same markets in other cases. For example, the various renewable technology programs compete in the electricity-generation market. In addition, activities being funded by some programs reduce the potential market for technologies being developed in other programs. As an example, reductions in electricity demand due to efficiency improvements reduce the size of the generation market and,

[9] See Chapter 1 for information on how EERE's "no-program" Baseline Case is developed.

therefore, the market opportunity for renewable-generation technologies. The overall effect of these interactions is to reduce estimated benefits by about 0.8 quads in 2025 compared to the sum of the individual program benefits; and to reduce estimated benefits by about 4.6 quads in 2050 compared to the sum of the individual program benefits (*i.e.*, Program Case, see **Figure 3.1**).

Economic Benefits: The energy savings resulting from these efficiency and renewable energy contributions are estimated to reduce annual consumer energy expenditures in 2025 by $123 billion (expressed in real 2002 dollars) relative to the baseline projection of $1,015 billion (**Figure 3.2**), or about 12 percent of the nation's expected energy bill.

While these energy bill savings appear to be large, they represent both reduced energy purchases and lower energy prices resulting from reductions in demand. They also exclude incremental costs to end users of acquiring the new technology, because the EIA NEMS model does not currently have the capability to determine this in all sectors of the economy. Lower energy demand dampens fuel costs and reduces the need for expensive new energy infrastructure expenditures. Lower energy prices improve affordability for all consumers, including those who make no additional efficiency or renewable investments as a result of EERE's activities.

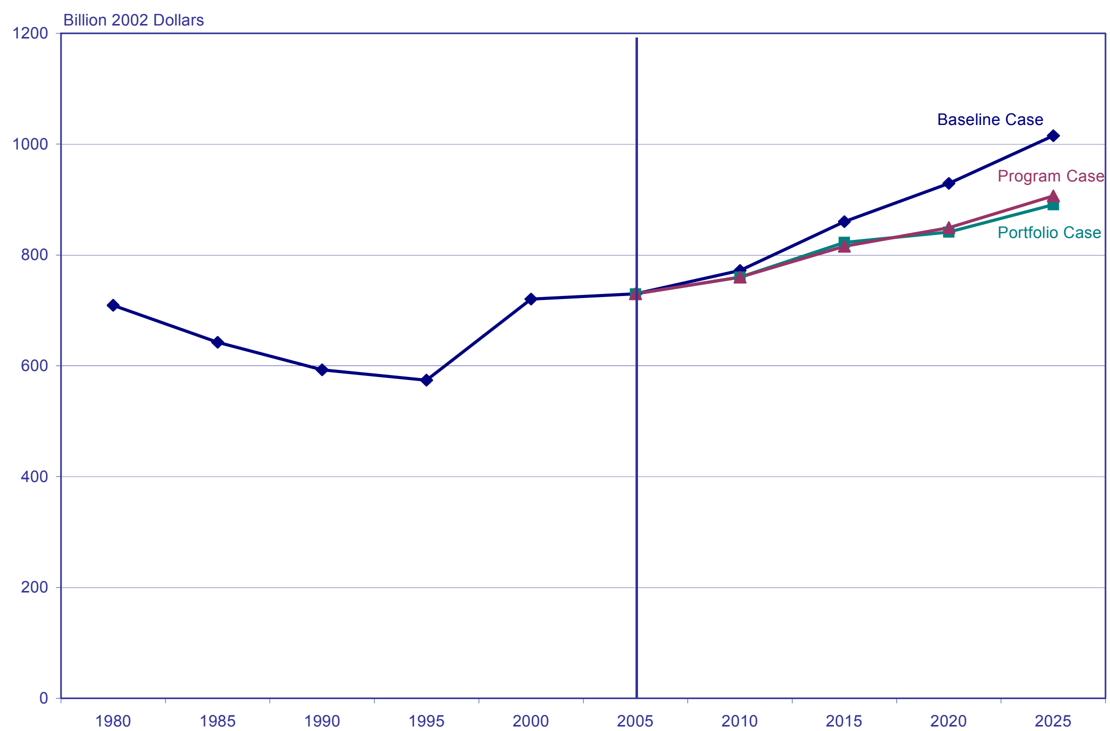

Figure 3.2. U.S. Total Energy Expenditure, 1980-2000, and Projections to 2025: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 3.4 and Table D1, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

The EERE portfolio also will reduce annual total system energy costs by $282 billion (in real 2002 dollars) in 2050 (**Figure 3.3**). This longer-term analysis is done using MARKAL-GPRA06, which includes the incremental costs to end users of acquiring the new technology.

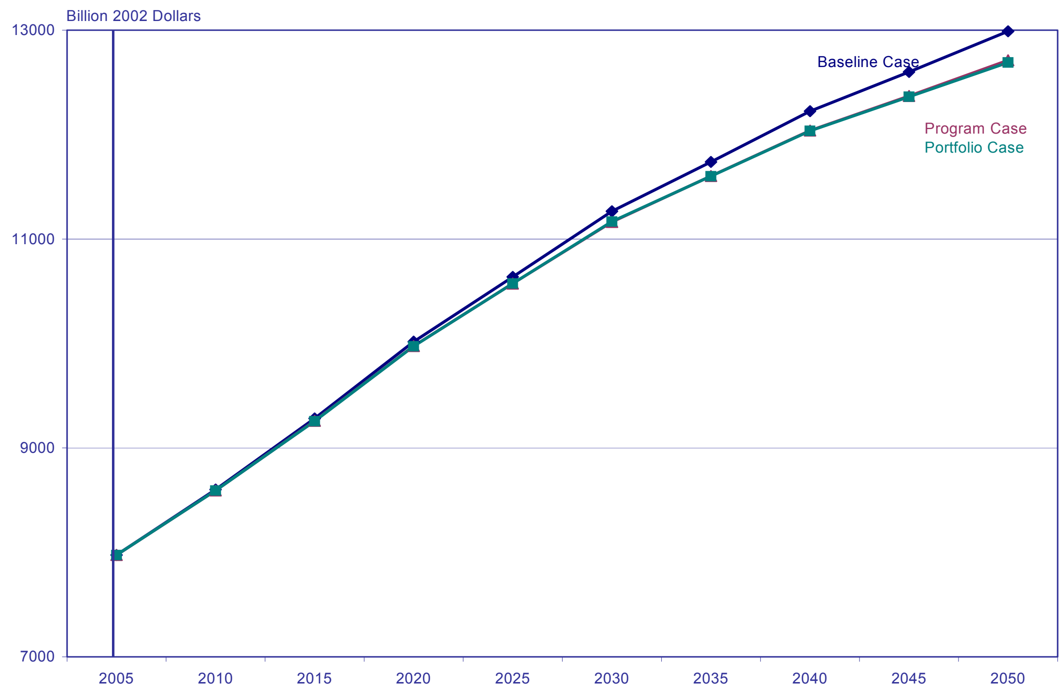

Figure 3.3. U.S. Total Energy-System Cost Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: MARKAL-GPRA06

Environmental Benefits: Annual carbon emissions are projected to be 262 million metric tons (carbon equivalent) less than the 2025 baseline projection of 2,219 million metric tons—a reduction of about 12 percent (**Figure 3.4**) or 45 percent of the expected increase from 2005 to 2025.[10] Annual carbon emissions are projected to be 699 million metric tons (carbon equivalent) less than the 2050 baseline projection of 2,621 million metric tons—a reduction of about 27 percent or 71 percent of the expected increase from 2005 to 2050.

Although not quantified here, EERE's portfolio contributes toward improved regional and local air quality through reduced SO_2 and NOx emissions from fossil energy consumption (SO_2 reductions in the utility sector are likely to lower permit prices rather than reduce net emissions). The portfolio also provides State and local governments with additional options for meeting Clean Air Act ambient air quality standards. For instance, the Clean Cities activity in the Weatherization and Intergovernmental Program facilitates local purchases of alternative-fuel vehicles.

[10] To meet the 2012 target under President Bush's Climate Change Initiative, emissions – from energy consumption – would need to be 1,754 mmtce (an 18 percent reduction). The Baseline projection is 1,843 mmtce, which is a 13.8 percent reduction in carbon intensity from 2002. With the EERE Portfolio, emissions are projected to be 1,806, or a 15.6 percent intensity reduction from 2002. The EERE Portoflio, therefore, is expected to contribute 43 percent of the reduction toward the goal.

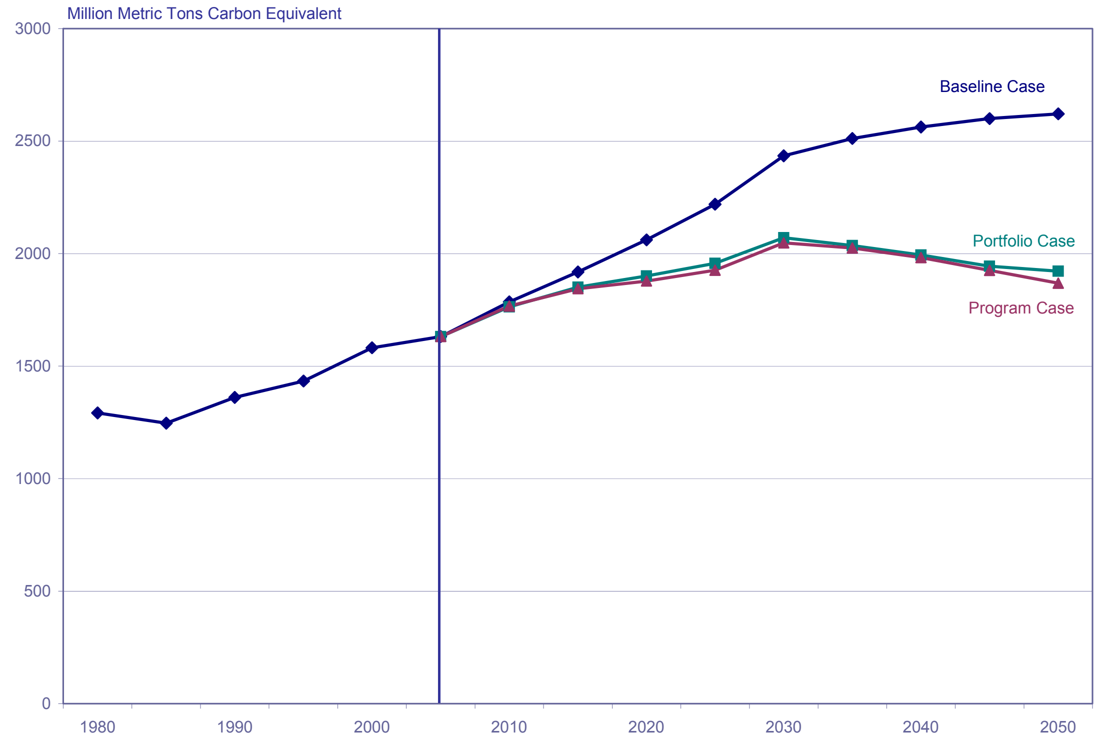

Figure 3.4. U.S. Carbon Emissions, 1980-2000, and Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

Security Benefits: The EERE portfolio is expected to reduce annual oil consumption by 2.3 mbpd from the 2025 baseline of 26 mbpd, or about 34 percent of expected growth in oil demand between 2005 and 2025 (**Figure 3.5**). The portfolio is expected to reduce oil consumption by 11 mbpd from the 2050 baseline of 30.5 mbpd (about 99 percent of expected growth in oil demand between 2005 and 2050). This results in declining oil consumption starting in 2030.

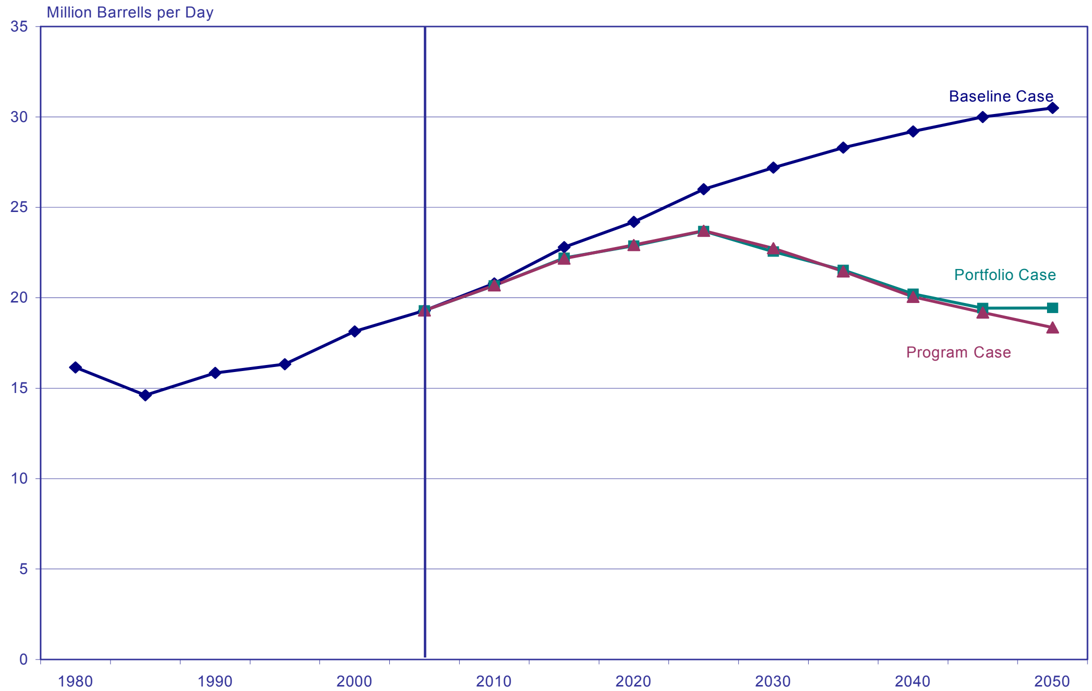

Figure 3.5. U.S. Oil Consumption, 1980-2000, and Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html. Data were converted from quads to mbpd using conversion factor of 1 quad = 0.472 mbpd.

While EERE's portfolio has elements that increase (as well as decrease) natural gas consumption; on balance, EERE's portfolio is expected to reduce annual natural gas consumption by about 1.8 quadrillion Btu from the baseline of 32.2 quadrillion Btu in 2025 and by 2.4 quadrillion Btu from the baseline of 36.6 quadrillion Btu in 2050 (**Figure 3.6**). While EERE does not estimate the portion of natural gas savings attributed to imported natural gas supplies, supplies from countries other than the United States and Canada may be the marginal sources of natural gas for meeting any future growth in demand.

EERE's technology programs also contribute to the security of the Nation's electricity supply by reducing central conventional power plant capacity additions. This is achieved through reduced demand for electricity (through improved efficiency or when coincident with renewable generation) and central renewable and distributed power additions. By 2025, EERE's portfolio is expected to reduce central conventional capacity additions by 137 gigawatts—by increasing central renewable and distributed power capacity by 144 gigawatts (some of which is intermittent and therefore displaces less conventional capacity). Increased efficiency reduces the need for 65 GWs of capacity (based on BT, Industrial, FEMP, and WIP programs, which do not take into account the integration effect in the Portfolio Case) (**Figure 3.7**). As shown in **Figure 3.8**, renewable energy capacity additions (central and distributed) are projected to grow by an additional 42 GW compared with the Baseline Case in 2025, and 137 GW compared with the Baseline Case in 2050.

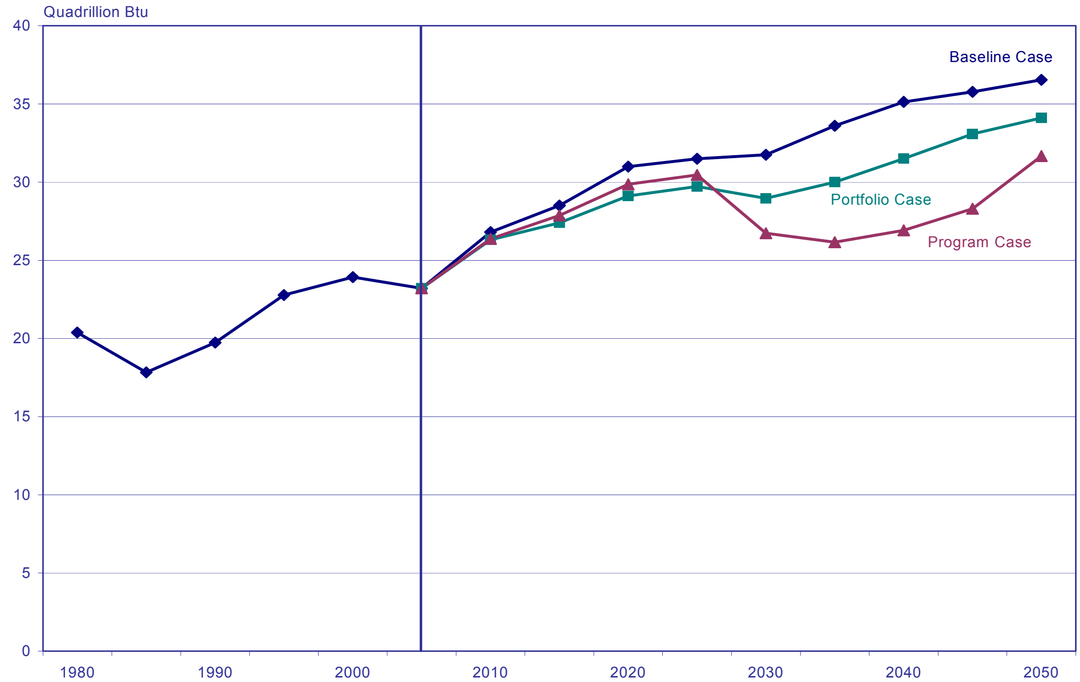

Figure 3.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

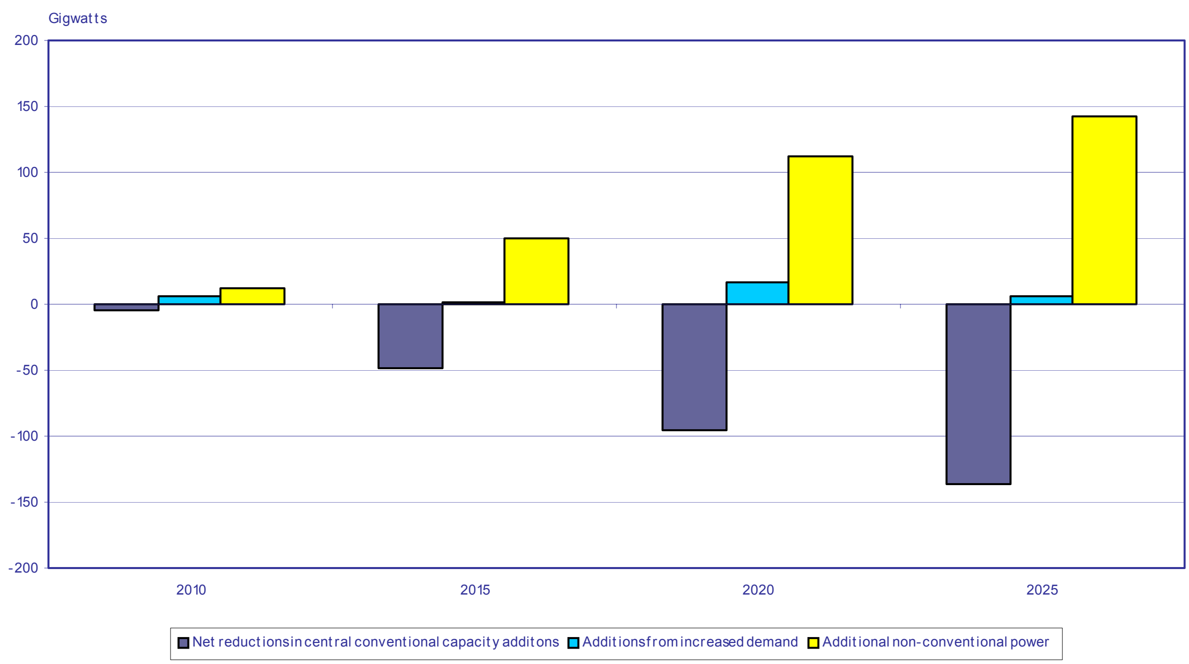

Figure 3.7. Impacts on Capacity Projections to 2025: Portfolio Case

Data Source: NEMS-GPRA06

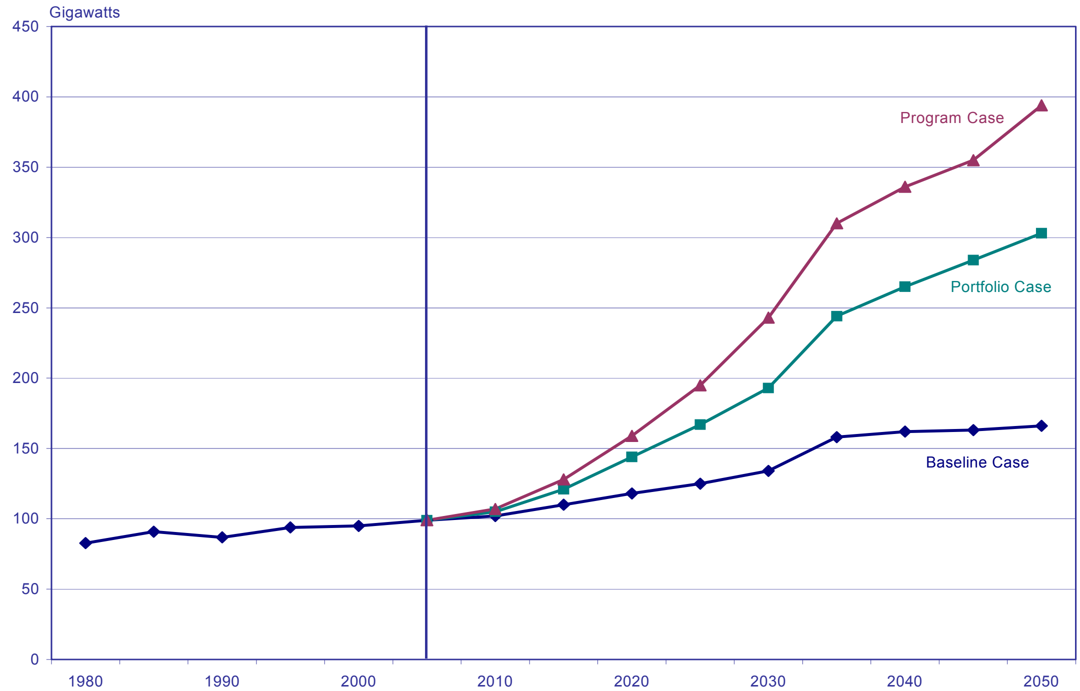

Figure 3.8. U.S. Renewable Energy Capacity, 1980-2000, and Projections to 2050: Baseline, Program, and Portfolio Cases

Data Source: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., October 2004), Table 8.11a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

Program Benefits

The remainder of this chapter is devoted to program-specific information, including program budget requests and benefits. See **Chapter 4** and **Chapter 5** for more specific program-level analysis. **Figure 3.9** displays the EERE program budget requests for FY 2006. The largest program budget is $310 million for the Weatherization and Intergovernmental Program (WIP), which includes $225.4 million for Low-Income Weatherization Assistance.

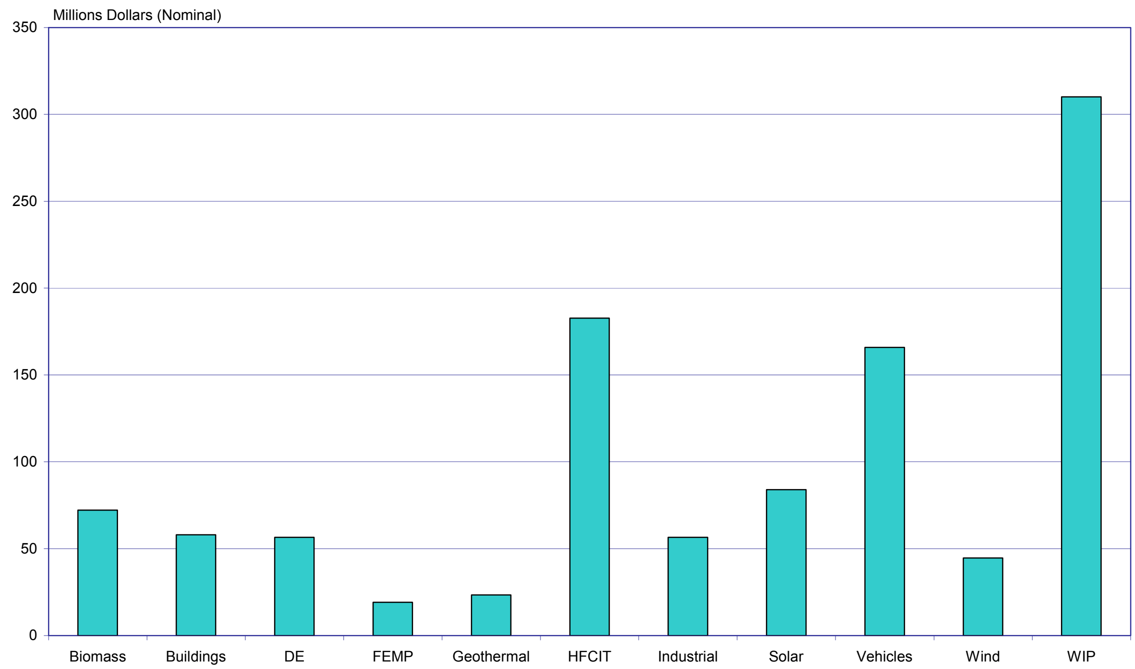

Figure 3.9. EERE Program FY 2006 Budget Requests

Source: Budget request from *FY 2005 Budget-in-Brief*, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy05_budget_in_brief.pdf.

The FY 2006 estimates of benefits for the individual EERE programs are shown for 2025 and 2050 in **Figures 3.10 through 3.16**. The benefits vary widely across EERE's programs, with each program providing a different level and mix of benefits. Often, individual programs target different types of benefits. Nonrenewable energy savings in 2025, for example, range from 0.06 quadrillion British thermal units (Btu) for the Federal Energy Management Program (FEMP) to 3.98 quadrillion Btu for the Vehicle Technologies Program (**Figure 3.10**). The differences in benefits result from a number of factors: (1) program size and target market; (2) time frames for program results and reported benefits; (3) primary types of benefits addressed by each program; (4) technical potential achievable within each program beyond the Baseline Case, and (5) ability to assess program goals or target markets with current capabilities. Note that these estimates do not reflect the relative performance risk associated with these program activities.

Several EERE programs are targeted toward benefits not well reflected in any of EERE's quantified benefits metrics. For instance, the Distributed Energy (DE) Program focuses on improving electricity reliability by developing electricity-generating capacity at or near the point of use (**Figure 3.16**). However, EERE does not currently have the capability of quantifying the level or value of improved reliability, or of reflecting the consumer value for reliability in estimated future market purchases. Similarly, the State Energy Grant Program funds the development of State energy plans, including energy emergency planning. This key component of homeland security is not reflected in any of the security metrics in this analysis. In the case of the Biomass Program, there has been a substantial redirection of the research toward integrated biorefineries that will produce a mix of high-value chemicals, as well as fuels such as ethanol and electric power. These are very complex systems, and EERE does not yet have an adequate modeling capability for this, as described in **Chapters 4 and 5**.

While incomplete, the results indicate both the range and approximate level of benefits available to the Nation from funding the efficiency and renewable investments in EERE's portfolio of programs. They indicate a potential for making better use of existing technologies and for accelerating technological advances to make significant changes in our energy markets, which can drive the Nation to a period of level energy consumption.

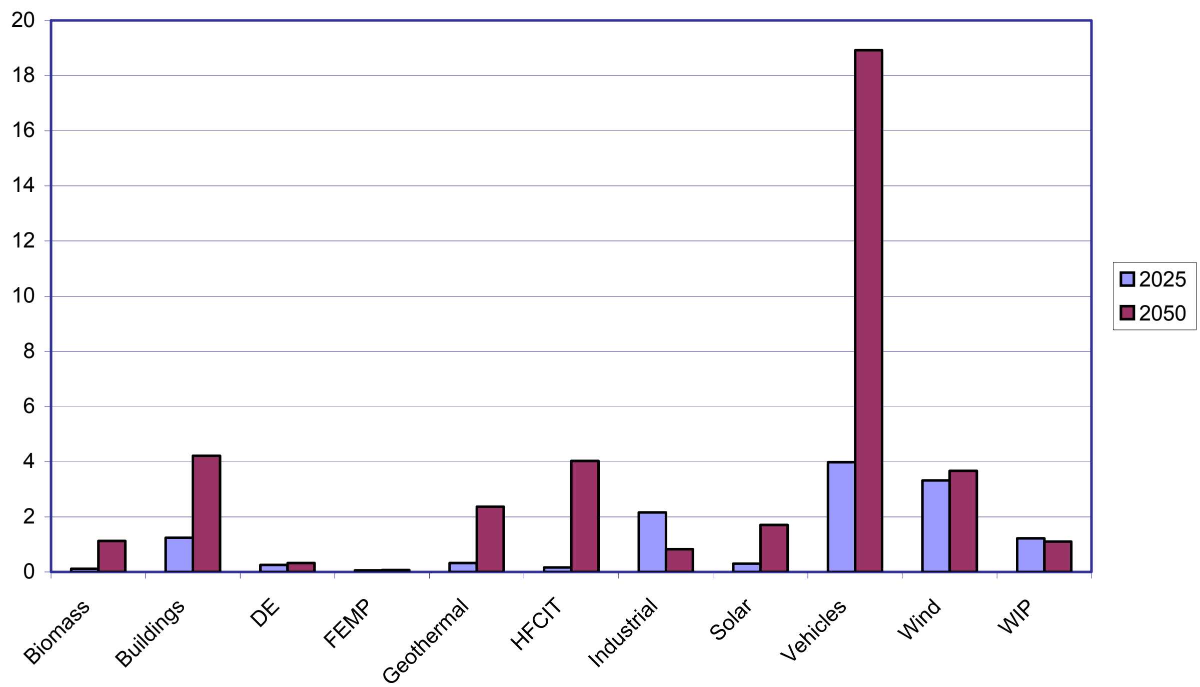

Figure 3.10. Annual Nonrenewable Energy Savings: 2025 and 2050 (quadrillion Btu)

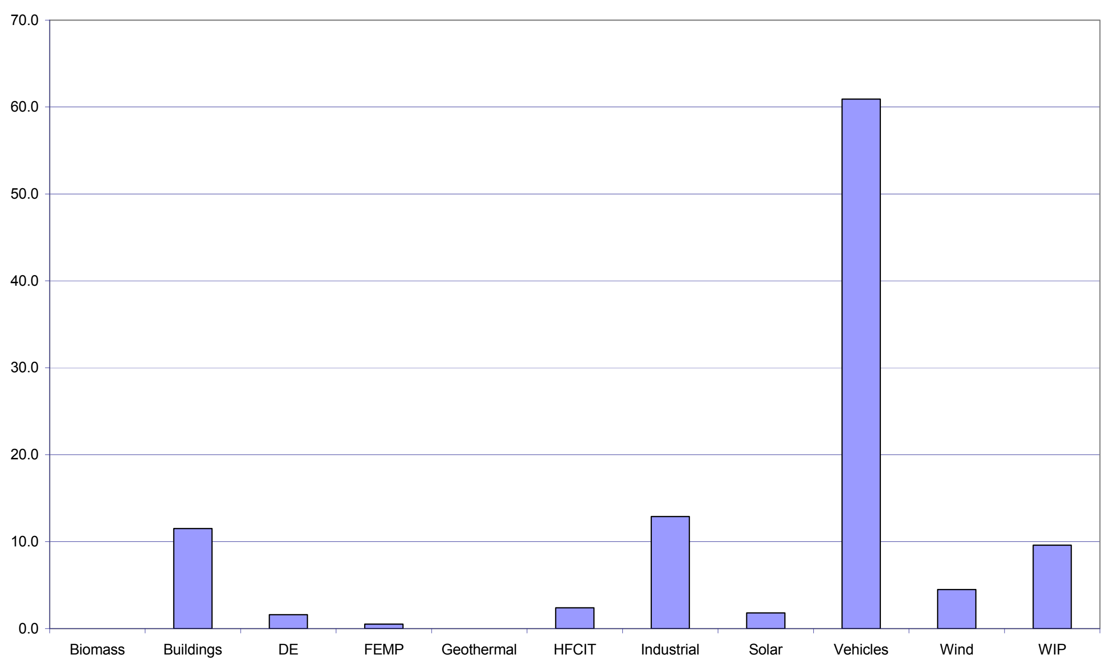

Figure 3.11. Annual Energy Expenditure Savings: 2025 (billion 2002 dollars)

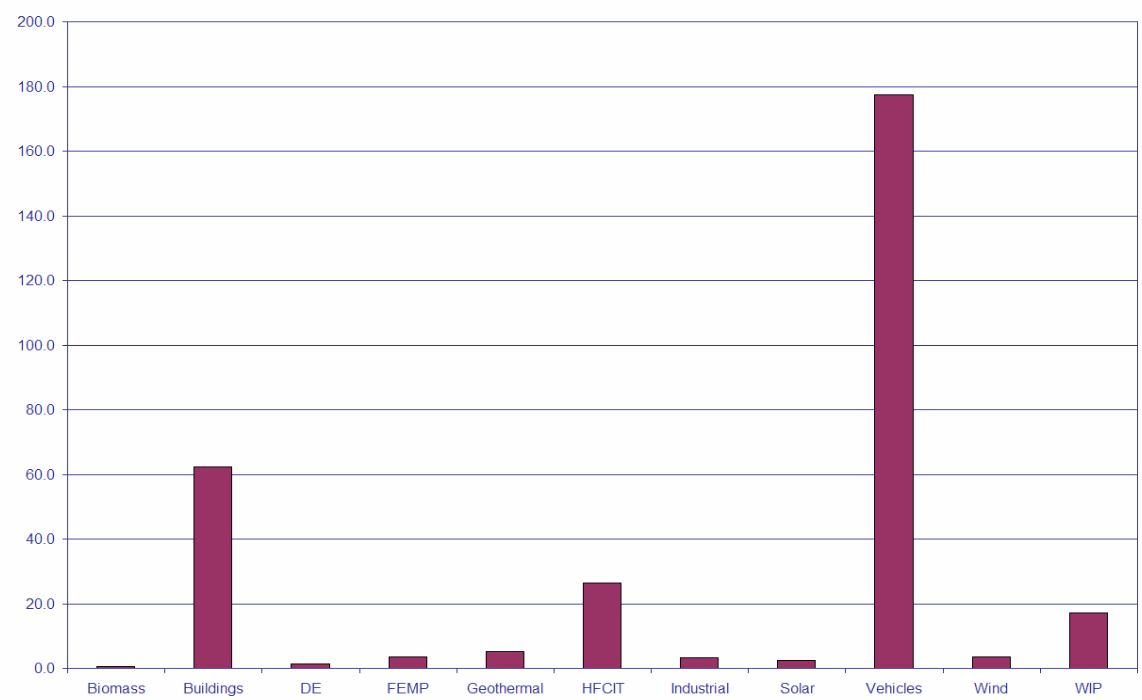

Figure 3.12. Annual Energy-System Cost Savings: 2050 (billion 2002 dollars)

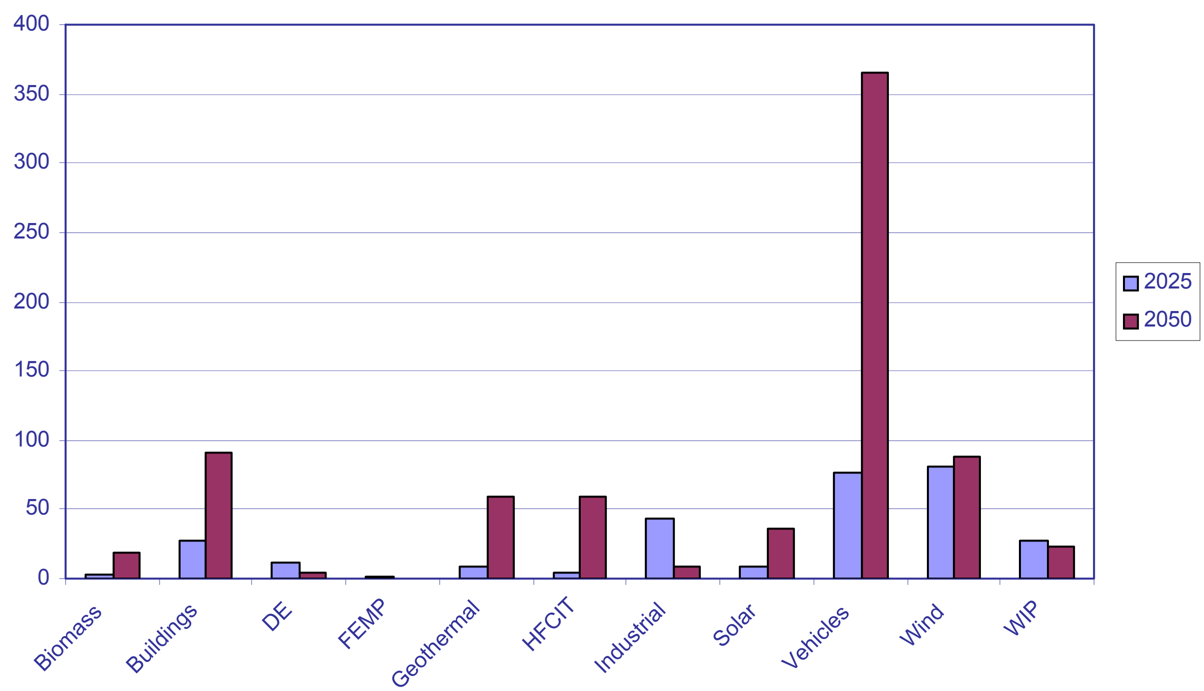

Figure 3.13. Annual Carbon Dioxide Savings: 2025 and 2050 (mmt carbon equivalent)

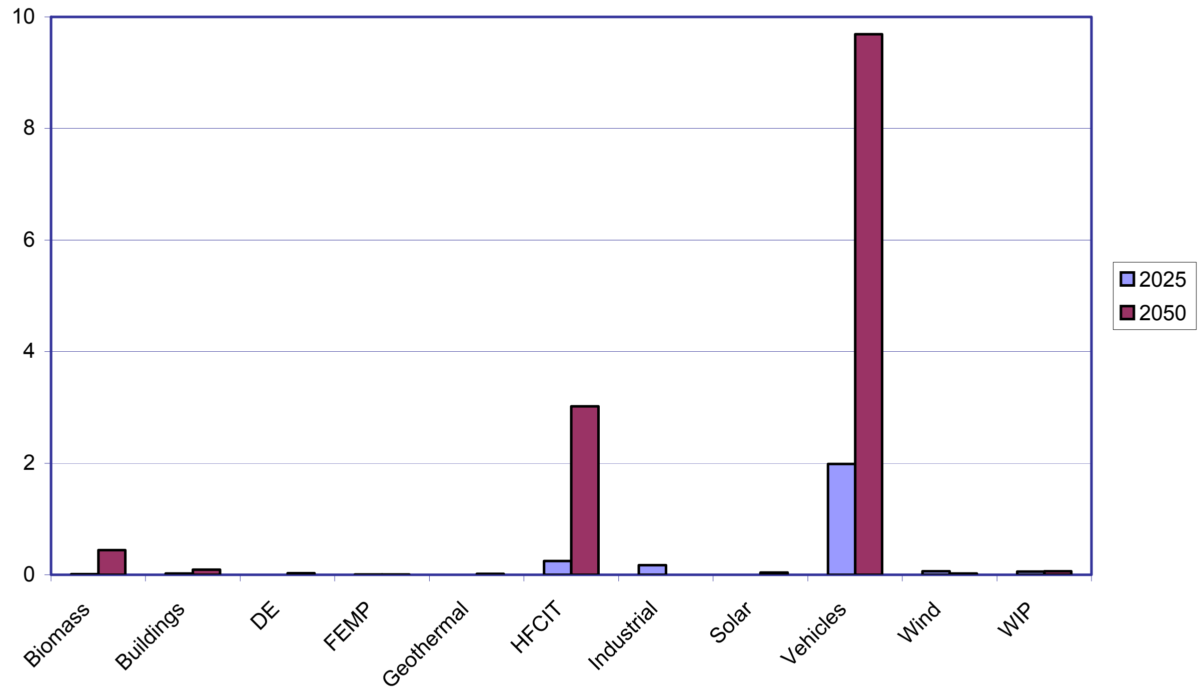

Figure 3.14. Annual Oil Savings: 2025 and 2050 (mbpd)

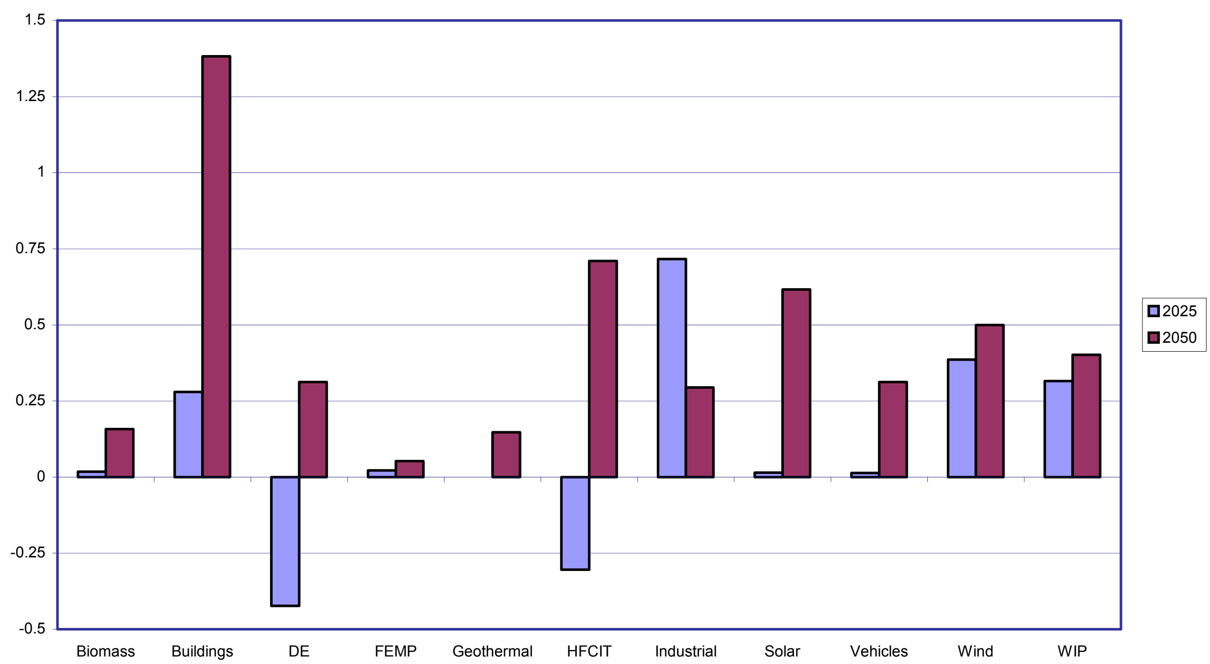

Figure 3.15. Annual Natural Gas Savings: 2025 and 2050 (quadrillion Btu)

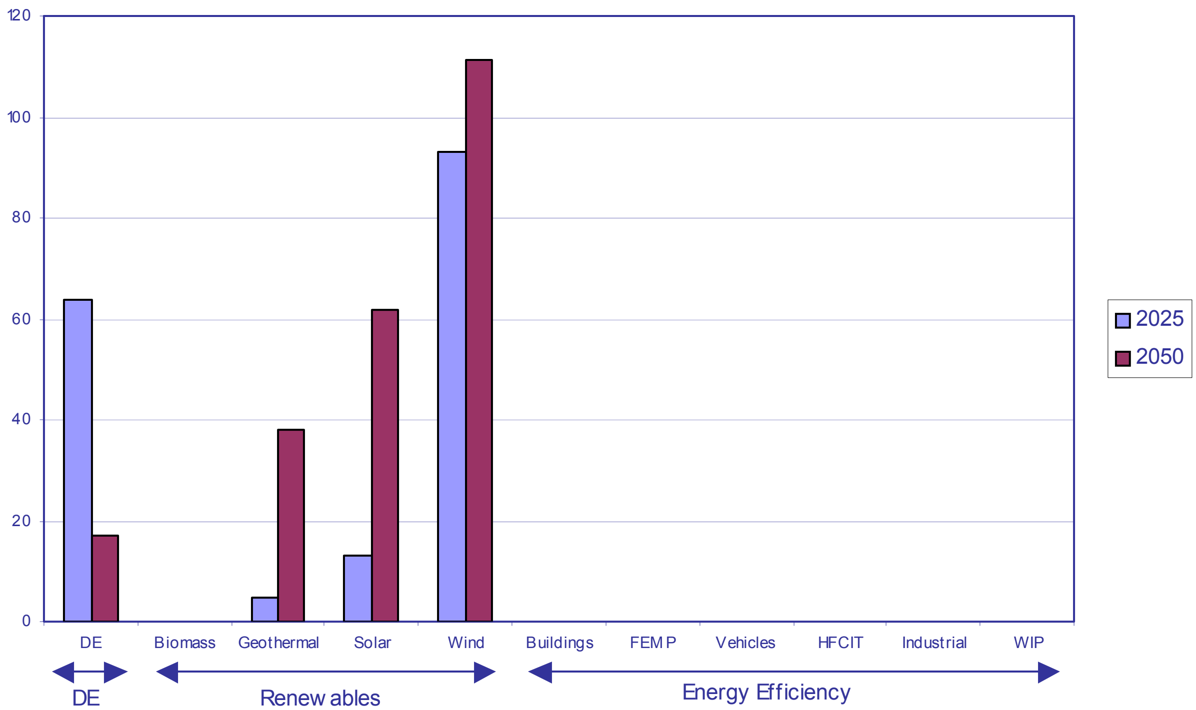

Figure 3.16. Annual Electric Generating Capacity – DE, Renewables, Energy Efficiency: 2025 and 2050 (gigawatts)

Note: Capacity for the DE Program includes gas-fired combined heat and power (CHP) systems in commercial and industrial applications and non-CHP grid support applications. Renewables include distributed and central station capacity. The Biomass Program does not create additional capacity because it is aimed at developing biomass refineries. The Buildings, FEMP, Vehicle Technologies, Industrial, and WIP programs do not create additional electric generating capacity because they are efficiency programs. Some of the efficiency programs do, however, reduce the need for additional capacity. The HFCIT Program includes fuel cell capacity.

CHAPTER 4

MIDTERM BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

The results of the **Step 2** program and market analyses are incorporated into NEMS-GPRA06 in the Program and Portfolio Cases to estimate the midterm (to 2025) benefits for each program and for EERE's overall portfolio. In some cases, NEMS-GPRA06 can directly utilize program performance goals (outputs). In other cases, analysts need to make adjustments to the program analyses when incorporating them in NEMS-GPRA06. This chapter describes the NEMS-GPRA06 analyses for each program. The appendices provide additional information on the inputs provided by each program.

Table 4.1 shows a breakdown by program of the two types of analytical tool employed in its benefits analyses—specialized "off-line" tools and NEMS-GPRA06. A description of EIA's NEMS model is provided in **Box 4.1** at the end of this chapter. Descriptions of the off-line tools are provided in the related program appendix.

Table 4.1. Program Benefits Modeling by Primary Type of Model Used and Activity Area

Program	Activity Area	Off-Line Tool	NEMS-GPRA06
Biomass	Bio-based Products	✓	
	Cellulosic Ethanol	✓	✓
Building Technologies	Technology R&D	✓	✓
	Regulatory Actions	✓	✓
	Market Enhancement	✓	
DE	DE		✓
FEMP	FEMP	✓	
Geothermal	Geothermal		✓
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		✓
	Production and Delivery	✓	
Industrial Technologies	R&D	✓	
	Deployment	✓	
Solar Energy Technologies	Solar Water Heaters		✓
	Photovoltaics	✓	✓
	Concentrated Solar Power		✓
Vehicle Technologies	Light Vehicle Hybrid and Diesel		✓
	Heavy Vehicles	✓	✓
Weatherization and Intergovernmental	Weatherization	✓	
	Domestic Intergovernmental	✓	
Wind and Hydropower Technologies	Wind		✓

Required off-line analysis can range from simple verification of program goals to an initial calculation of energy savings, depending on the treatment of the target market in NEMS-GPRA06 and the nature of the program. Analysts use specialized off-line tools to develop the inputs to NEMS-GPRA06 for each program case. The activity areas listed are groupings of activities within each program that share either technology or market features. They do not represent actual program-management categories.

Biomass Program

The goal of the Biomass Program is the development of biomass refineries (biorefineries), which produce a range of products including ethanol and/or other fuels, chemicals, materials, and/or power. The biorefinery concept allows the cost of production to be reduced through synergies associated with feedstock handling and processing, and the allocation of capital and fixed O&M costs across multiple products. The current analysis is based on two types of biorefineries. The first type produces chemicals and materials, but not fuels, and the second type produces ethanol fuel as the major output. Future analyses could include additional fuels that the program may identify in the longer term.

Bio-based products from nonfuel biorefineries: The use of biomass would displace the use of petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, NEMS-GPRA06 does not have sufficient detail within its representation of this industry to explicitly model bio-based products. Given the lack of a bio-based products sector in the model, analysts assessed energy savings off-line. The energy savings by fuel type (the largest share was petroleum feedstocks) were implemented in the integrated model, by subtracting the estimates from industrial energy consumption otherwise projected by NEMS-GPRA06. Analysts then used the model to compute the other benefits of primary energy savings, carbon emission reductions, and energy-expenditure savings.

Cellulosic ethanol from biorefineries dedicated to the production of ethanol, lignin-derived electricity, and chemical coproducts: EERE is sponsoring research aimed at reducing the cost of producing ethanol from cellulosic biomass.[1] The second type of biorefineries assumed in this analysis is one that focuses on producing ethanol, lignin-derived electricity, and a small quantity of chemical coproducts. Estimates of future cellulosic ethanol production costs in the *AEO2004* and the Baseline Case are comparable. The biomass-to-ethanol conversion efficiencies for both the Baseline and Program Cases reflect more updated information than the *AEO2004* assumptions. In the *AEO2004*, EIA assumed that the growth in projected production was constrained by a number of factors in addition to ethanol production costs. In the Baseline Case, EERE was more conservative in terms of constraining the growth in cellulosic ethanol production in the absence of EERE programs, with production at roughly one-fifth of the *AEO2004* values. EERE's biofuels analytic model, ELSAS Bioref, was used to estimate the growth of ethanol made from agricultural residues (such as corn stover) and other cellulosic biomass.[2] The two cellulosic ethanol estimates were combined and input into NEMS-GPRA06. Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline or corn ethanol in the ethanol blend market for gasoline. In the FY 2006 EERE mid-term benefits estimates, a large portion of the cellulosic ethanol displaces corn ethanol, which leads to fossil

[1] Cellulose and hemi-cellulose that can be converted to ethanol (and other chemicals, materials, and biofuels) are found in biomass such as agricultural residues (corn stover, wheat, and rice straw), mill residues, organic constituents of municipal solid wastes, wood wastes from forests, future grass, and tree crops dedicated to bio-energy production.

[2] For more information on the off-line analysis, see Appendix B.

energy and carbon emission savings based on recent EERE life-cycle analysis. Fossil energy requirements and carbon emissions to produce ethanol fuels were obtained from EERE's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model. The Biomass Program benefits shown in **Table 4.2** are the reductions in energy use and carbon emissions in the Program Case compared with the Baseline Case.

Table 4.2. FY06 Benefits Estimates for Biomass Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	ns	0.02	0.06	0.12
Cellulosic Ethanol Production (billion gallons/yr)	0.00	0.12	0.26	1.57
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	ns
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	0.4	1.6	2.6
Security				
Oil Savings (million barrels per day)	ns	0.00	0.01	0.01
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	ns	0.02
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Building Technologies Program

The activities of the Building Technologies Program can be classified into three general types: technology R&D, regulatory actions, and (to a far lesser extent) market enhancement.[3] The modeling approach and applicable end uses for the activities that comprise the Building Technologies Program are displayed in **Table 4.3**. Analysts model the technology R&D activities by modifying costs and efficiencies of the equipment and shell technology slates. Market-enhancement activities and some regulatory activities (such as buildings codes) are modeled using penetration rates and energy-savings estimates. A few R&D activities such as residential incandescent light fixtures were not modeled, because they represented a small segment of the market and are not explicitly represented within NEMS-GPRA06.

Technology R&D: The technology R&D activities seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The forecast benefits for these are measured by modifying the technology slates from those that are available in the Baseline Case to reflect the program goals. Building technologies in NEMS-GPRA06 are represented by end use. For most end uses, there are conversion technologies (*e.g.*, furnaces and water heaters) that use different fuels and that have several different levels of energy efficiency. The Baseline Case incorporates EIA's estimation of future technology improvement that is then modified in the Program Case.

[3] With the reorganization of EERE, the overwhelming majority of the market-enhancement activities are part of the Weatherization and Intergovernmental Program.

Residential shell technologies (such as windows or insulation) for new buildings are represented by several packages of technologies with different levels of improvements. Each package is characterized by a capital cost and heating and cooling load reductions. The commercial-sector shell measures are represented by window and insulation technologies that can be selected individually. EIA developed the residential methodology for the *AEO2001*, while OnLocation developed the commercial methodology for EERE.

Table 4.3. Modeling Approach for Building Technologies Program Activities

	Sector		End-Use					Modeling Approach		
Building Technology Project List	Resd	Comm	Heat	Cool	Water Heating	Lighting	Other	Energy Savings and Penetration Rates	Equipment Technology Costs and Efficiencies	Shell Technology Costs and Efficiencies
Residential Buildings Team										
Research and Development (Building America)	✓		✓	✓	✓	✓	✓			✓
Residential Building Energy Codes	✓		✓	✓				✓		
Commercial Buildings Team										
Commercial Research and Development		✓	✓	✓				✓		
Commercial Building Energy Codes		✓	✓	✓		✓		✓		
Standards										
Commercial Unitary AC/HP (EPAct)		✓	✓	✓					✓	
Distribution Transformers										
Analysis Tools and Design Strategies		✓	✓	✓				✓		
Appliances and Engineering Technologies										
Roof top AC		✓		✓					✓	
Can Lights	✓					✓				
R-Lamp	✓					✓				
Window Technologies										
Electrochromic Windows		✓	✓	✓		✓				✓
Superwindows	✓		✓	✓				✓		✓
Low-E Market Accpetance	✓	✓	✓	✓				✓		
Lighting Research and Development										
Lighting Controls		✓				✓		✓		
Solid State Lighting	✓	✓				✓			✓	
Refrigeration R&D										
Unitary DX System	✓	✓	✓	✓					✓	
Remote Fault Detection & Diagnostics	✓	✓	✓	✓					✓	
Commercial Refrigeration		✓							✓	
Ventilation Load Reduction		✓	✓	✓					✓	

The residential and commercial sectors are each represented by several building types within nine Census divisions. NEMS-GPRA06 computes end-use technology choice for each of these building types and geographic regions, based on the relative economics and estimations of consumer behavior for the technologies. The latter is important to replicate current technology market shares. In a few cases where NEMS-GPRA06 has insufficient detail for explicit technology representation, analysts computed market penetration using off-line tools, and the results were implemented with NEMS-GPRA06 through efficiency factors.

Regulatory activities: Regulatory activities include setting new appliance standards, based on the legislatively mandated schedule and encouraging state adoption of more stringent building codes.[4] Representing appliance standards is straightforward. In the year that the program expects the new standard to be implemented, all technologies that are less efficient than the standard are

[4] The outreach/deployment aspects of the codes process occur with funding provided by the Weatherization and Intergovernmental Program.

removed from the market and unavailable for consumer choice. The resulting energy savings depend on the difference in the level of efficiency of the standard compared to the technology that had been selected in the Baseline Case.

Market enhancement: Building-code development is primarily a regulatory activity, although it also involves outreach to encourage the various states to adopt new and stricter standards. Analysts make a spreadsheet computation of average savings using off-line estimates for the fraction of buildings within areas that adopt more stringent codes, as well as the heating, cooling, and lighting load reductions associated with the new levels of codes. The building shell packages in NEMS-GPRA06 are modified to produce the appropriate savings.

The Building Technologies Program results in energy savings primarily in four end-use categories: space heating, space cooling, water heating, and lighting. **Table 4.4** demonstrates the level of savings from each category. In 2025, cooling and space-heating end uses have the highest savings in residential buildings, while the lighting energy-use reduction is the largest in commercial buildings.

Table 4.4. Building Technologies Program Energy Savings by End Use

Energy Reduction	Residential				Commercial			
Percentage	2010	2015	2020	2025	2010	2015	2020	2025
Space Heating	0%	2%	3%	5%	0%	1%	2%	2%
Space Cooling	0%	2%	4%	8%	1%	2%	3%	2%
Water Heating	0%	0%	0%	0%	0%	0%	0%	0%
Lighting	0%	0%	0%	1%	0%	1%	2%	10%
Other	0%	0%	0%	0%	0%	0%	0%	0%

Analysts estimate the Building Technologies Program benefits (**Table 4.5**) within the integrated NEMS-GPRA06, so that the electricity-related primary energy savings are directly computed. In addition, the estimates include any feedbacks in the buildings or other sectors resulting from changes in energy prices that result from the reduced energy consumption.

Table 4.5. FY06 Benefits Estimates for Building Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.09	0.31	0.62	1.24
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	1.8	5.0	7.5	11.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1.6	6.3	13.6	28.4
Security				
Oil Savings (million barrels per day)	0.01	0.02	0.03	0.02
Natural Gas Savings (quadrillion Btu/yr)	0.05	0.10	0.14	0.28
Avoided Additions to Central Conventional Power (gigawatts)	ns	8	19	33
Total Electricity Capacity Avoided (cumulative gigawatts)	ns	9	19	36

Distributed Energy Program

The Distributed Energy (DE) Program encompasses many technologies and markets. The benefits were estimated by focusing on several segments of the distributed energy market: gas-fired combined heat and power (CHP) systems in commercial building and industrial applications, and non-CHP grid support applications. Distributed energy applications that are motivated by the need for electric reliability primarily will be systems that produce only electricity and are used in backup mode. In the program analysis, these are represented as grid-support DE for their similar technology characteristics, although the model treats them as though they are purchased by electric-power producers rather than electricity-consuming businesses. The value of these systems is difficult to capture in the GPRA benefits metrics. They do not provide significant energy or emissions savings, because they run for only a few hours per year and generally have similar or lower efficiencies than larger central-station peaking facilities. They do have the potential to contribute significantly to new electric power-generating capacity. The benefit estimates do not account for increased reliability and local Clean Air Act impacts on demand.

Combined heat and power systems produce both useful thermal heat and electricity. Their economics depend on the amount of thermal heat needed at the site, the electricity usage at the site, the price of the input fuel, and the value of the electricity. If the end-use customer is making the investment, the electricity value will depend on the customer-avoided purchases at the electricity retail price, and possibly the amount of excess electricity sold off-site at prevailing wholesale electricity prices. Using the average electricity price is a simplification that may overlook the requirement to continue paying some type of flat distribution charge, even though less electricity is purchased from the utility. If a vertically integrated electric utility is making the investment, the value is from avoided generation, and transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

The DE Program facilitates the development of the DE market by improving the technology characteristics (lowering costs, improving efficiency, and reducing environmental emissions) and by removing barriers to adoption and consumer acceptance. Thus, the benefits are estimated based on the impact of improved technology and greater market penetration.

Baseline adjustments: The *AEO2004* Reference Case includes significant DE technological advancement. The Baseline Case includes a modified set of technology characteristics that represented the absence of continued EERE programs. These modifications were made in all three areas in NEMS where distributed technologies are represented: commercial building combined heat and power (CHP), industrial CHP, and utility grid support. For most of the commercial and industrial CHP technologies, the baseline technology characteristics were assumed to be a 10-year lag of the program goals, therefore assuming the baseline technologies will catch up with the policy case in 10 years. The technology assumptions for commercial gas-fired chillers also were modified, and these chillers were assumed to be applicable to all building types; unlike in the *AEO2004,* where they can be used only in the larger building sizes.

The adoption rates of distributed technologies in commercial buildings were modified to reflect market data gathered by EERE on consumer adoption of energy efficiency projects as a function of payback time (**Figure 4.1**).[5] The NEMS-GPRA06 framework uses a cash-flow model to evaluate the DE technologies—CHP and photovoltaic (PV) systems—within the building sectors. For commercial buildings, debt and interest payments are computed over a loan period of 15 years along with associated taxes and tax benefits and assuming a 25 percent down payment. Annual fixed maintenance costs also are included. For the gas-fired CHP technologies, NEMS-GPRA06 computes fuel costs based on the delivered cost of natural gas and the technology efficiency. The value of the useful waste heat produced is netted against the fuel cost, based on the delivered natural gas price, the thermal efficiency of the CHP system, and the internal thermal load. The value of the electricity produced is then subtracted from these costs to determine the cash flow. The value of electricity is equal to the larger of the electricity produced and the internal electricity demand, multiplied by the delivered electricity price. Any electricity produced in excess of internal needs is assumed to be sold to the grid at the wholesale rate. The number of years until positive cash flow is reached determines the market share in new buildings. The market share for existing buildings is assumed to be a fraction of the share for new.

Under both the EIA and program assumptions, market share in new buildings decreases sharply as the number of years required to achieve positive cash flows increases. This reflects the high rates of return generally expected for energy-related projects by commercial-building owners. These shares apply to the fraction of commercial buildings assumed to be eligible for an installation of distributed CHP. The *AEO2004* eligibility fraction assumption of 30 percent was increased to 50 percent. These adoption rate changes were made in the Baseline Case as well as the Program Case.

Technology improvements: The program provided characteristics for distributed energy systems that reflect the program's research goals. These included commercial CHP systems (gas engines, gas turbines, gas microturbines), commercial gas-fired chillers, industrial CHP (five systems sizes for gas-fired engines and turbines), and grid-support DE (base and peaking).

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[5] ***Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project***. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.

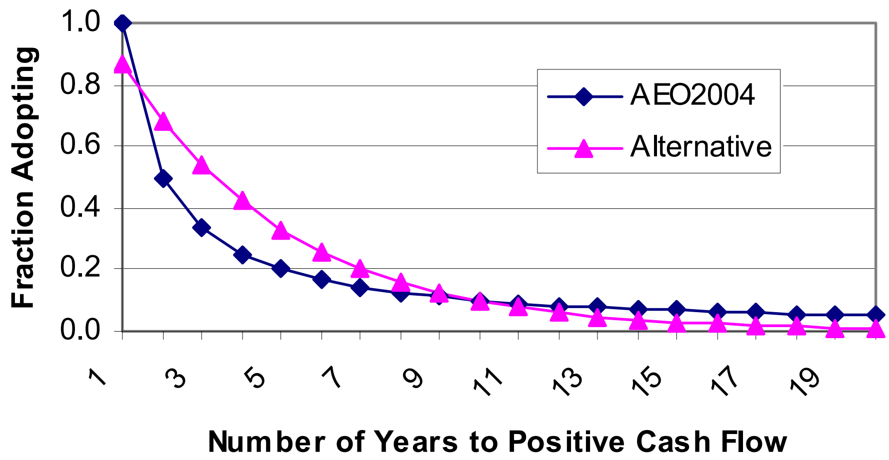

Figure 4.1. Commercial-Sector DG Adoption Rates

Because the thermal output of CHP cannot be used for absorption cooling within NEMS, analysts made an off-line adjustment based on an exogenous customer payback spreadsheet model that determines the impact of absorption cooling on customer payback. In addition, a set of exogenous savings was introduced to account for the potential impacts on end-use consumption of cooling energy savings from increased absorption penetration and increased heating consumption if not all the waste heat was available to meet both the heating and cooling loads.

Market enhancement: The DE Program's impact on consumer-adoption rates was represented by shifting the market adoption rates for industrial CHP systems (**Figure 4.2**). The effect is similar to reducing the acceptance criteria by a year or less. In addition, the penetration rate of the amount of economic potential that is implemented each year was increased from 5 percent to 10 percent for all sizes of gas turbine systems.

The incremental DE capacity that results from this representation of the DE Program activities is shown in **Table 4.6**, along with the projected total quantities. Of the 64 GW of incremental capacity by 2025, roughly 40 percent of the increase is expected to be industrial applications and 59 percent grid-support systems.

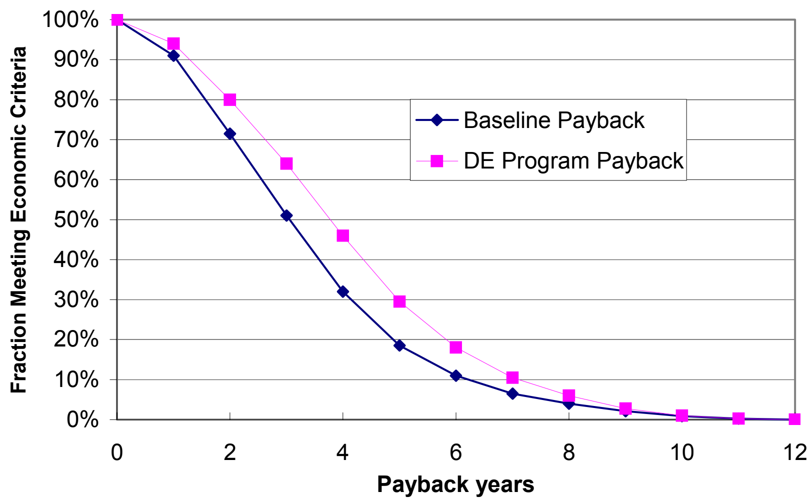

Figure 4.2. Industrial-Sector Combined Heat and Power Adoption Rates

In the Baseline Case, by 2025, the industrial sector is projected to satisfy roughly 20 percent of its total electricity demand with distributed generation. With the DER Program, the share increases to 31 percent.

Table 4.6. Distributed Energy Capacity (GW)

	2010	2015	2020	2025
AEO Base				
Buildings	1.6	1.9	2.4	3.5
Industry*	31.5	35.4	39.6	43.7
Electric Industry	0.5	2.4	7.6	12.4
Baseline Case				
Buildings	2.1	2.6	4.0	9.3
Industry*	30.8	34.7	41.1	48.2
Electric Industry	1.5	1.9	5.0	15.7
Benefits Case				
Buildings	2.1	3.3	4.9	9.8
Industry*	35.8	47.5	60.6	74.2
Electric Industry	3.3	22.4	37.6	53.1
Incremental Capacity				
Buildings	0.0	0.6	0.9	0.5
Industry*	5.0	12.8	19.5	26.0
Electric Industry	1.9	20.5	32.6	37.5
Total	6.9	33.9	52.9	63.9

* Excludes nontraditional, large qualifying facility cogenerators.

The DE Program benefits (**Table 4.7**) are projected within the integrated modeling framework, so that the impact of the program will be reflected in the rest of the energy system. As a result of increased investments in DE, electricity purchases from the commercial and industrial sectors are reduced, and additional electricity is sold wholesale to the grid. The central electricity-generation industry responds by reducing production from the most expensive plants operating in each region, and over time by building fewer central-station plants in the face of lower demand. Retirements are relatively unaffected, with only 3 GW of additional capacity retired by 2025 in the Program Case. Almost 60 GW of central-station investments are avoided by the additional DE. In the Baseline Case, about half of new central-station capacity additions from 2006 to 2025 are projected to be natural gas fired, and about three quarters of the avoided central-station investments are natural gas-fired turbines and combined-cycle plants. In total, distributed generation makes up roughly 15 percent of new capacity additions from 2006 to 2025 in the Baseline Case. This share increases to 36 percent in the Program Case.

The energy- and carbon emission-reduction benefits that stem from distributed generation are computed as the decrease in traditional central-station nonrenewable energy consumption and associated carbon emissions, net of the energy and emissions from the DE. The central-station generation reductions are from a mix of existing plants and avoided new plants. Over time, the facilities that are used in the Baseline Case become more efficient as the central station generation technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour.

Table 4.7. FY06 Benefits Estimates for DE (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.08	0.13	0.28	0.25
Generation (gigawatt-hours/yr)	37	106	161	210
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	1.6	2.9	ns	1.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	2.2	5.5	12.3	11.5
Security				
Oil Savings (million barrels per day)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	-0.01	-0.21	-0.42	-0.42
Avoided Additions to Central Conventional Power (gigawatts)	2	26	50	56
Program-Specific Electric Capacity Additions (cumulative gigawatts)	7	34	53	64

Federal Energy Management Program

The Federal Energy Management Program (FEMP) is an implementation program to increase the energy efficiency of Federal Government buildings, which account for about 5 percent of U.S. commercial-building energy consumption. FEMP activities support the installation of a variety of existing technologies, rather than focusing on the development of specific technologies, as do many other EERE programs. Because it encompasses a broad technological scope—while, at the same time, targeting a specific market segment—FEMP is difficult to model in an integrated framework such as NEMS-GPRA06. However, there is also less uncertainty associated with achieved energy savings because the program tracks changes in Federal energy consumption.

Delivered energy savings (estimated off-line) are used as inputs for the integrated modeling. These projected savings are subtracted from the Baseline Case for commercial-building energy consumption. Analysts use the model to compute the other benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings (**Table 4.8**).

Table 4.8. FY06 Benefits Estimates for FEMP (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.03	0.04	0.05	0.06
Economic				
Energy Expenditure Savings (billion 2002 dollars/yr)	0.2	0.3	0.4	0.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.5	0.7	0.9	1.2
Security				
Oil Savings (million barrels per day)	0.00	0.00	0.01	0.01
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.02	0.02	0.02
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Geothermal Technologies Program

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal-generation technologies, including both conventional and enhanced geothermal systems (EGS). Measuring the benefits involves projecting the market share for these technologies, based on their economic and environmental characteristics.

The NEMS-GPRA06 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner, due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources, each with a set of capital and operating and maintenance (O&M) costs. For the Program Case, an additional set of EGS sites were added to this slate.

Baseline adjustments: The EIA *AEO2004* Reference case includes a significant improvement in geothermal generation technology over time, similar to the program goals. To reflect what might occur without continued R&D funding, analysts reduced the cost reduction by half for the GPRA Baseline.

Technology improvements: The Geothermal Program was represented by reducing the capital and O&M costs for all hydrothermal geothermal sites, so that the average of the three lowest-cost sites matched the program cost goals. Separate program technology goals were provided for the added EGS sites. In addition, the program was assumed to reduce the risk associated with new geothermal development, and the Baseline Case limit on the size of annual developments per geothermal site was increased from 25 MW or 50 MW (depending on year) to 100 MW per year.

Table 4.9 shows the resulting additional geothermal capacity and generation, by region and for capacity by technology type. The greatest incremental capacity is in California (CAL) and the Northwest (NWP), with less in the Rocky Mountain area (RA). The primary energy, oil, and carbon emissions savings stem from geothermal power displacing fossil-fueled generation sources. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. **Table 4.10** shows the overall Geothermal Technologies Program benefits.

Table 4.9. Geothermal Capacity and Generation

	2010	2015	2020	2025
GPRA Base Capacity (GW)				
NWP	0.7	1.3	1.6	1.8
RA	0.5	0.7	0.7	0.8
CAL	2.7	3.1	3.5	3.9
Total	3.9	5.0	5.7	6.5
Conventional	3.9	5.0	5.7	6.5
EGS	0.0	0.0	0.0	0.0
Program Case Capacity (GW)				
NWP	1.1	2.1	2.7	3.7
RA	0.5	0.8	0.8	1.6
CAL	2.9	4.0	4.7	6.0
Total	4.5	6.9	8.2	11.4
Conventional	4.5	6.6	6.8	6.8
EGS	0.0	0.3	1.4	4.6
Total	4.5	6.9	8.2	11.4
Incremental Capacity (GW)				
NWP	0.4	0.8	1.1	1.9
RA	0.0	0.2	0.2	0.8
CAL	0.2	0.9	1.3	2.2
Total	0.6	1.9	2.5	4.9
Conventional	0.6	1.6	1.1	0.3
EGS	0.0	0.3	1.4	4.6
Total	0.6	1.9	2.5	4.9
Incremental Generation (BkWh)				
NWP	3	6	9	15
RA	0	1	1	6
CAL	1	7	10	17
Total	5	15	20	39

Table 4.10. FY06 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.01	0.09	0.16	0.33
Generation (gigawatt-hours/yr)	5	15	20	39
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	ns
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	1.9	3.9	8.4
Security				
Oil Savings (million barrels per day)	ns	0.01	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.02	0.02	ns
Avoided Additions to Central Conventional Power (gigawatts)	ns	1	2	3
Program-Specific Electric Capacity Additions (cumulative gigawatts)	1	2	3	5

Hydrogen, Fuel Cells, and Infrastructure Technologies Program

The Hydrogen, Fuel Cells, and Infrastructure Technologies Program is targeted toward the introduction of fuel cells for both stationary and vehicular applications, as well as the production and delivery of hydrogen at a reasonable price. NEMS-GPRA06 does not have a representation of hydrogen supply options.[6] Therefore, a simple assumption was used that all hydrogen through 2025 would be derived from natural gas. The hydrogen conversion process was assumed to be 75 percent efficient and yield a hydrogen price of $1.50 per gallon of gasoline equivalent (excluding taxes) when the natural gas price is $4 per MMBtu.

The stationary fuel cell research is focused on distributed proton-exchange membrane (PEM) fuel cells. The program goals for their capital costs and efficiencies were taken from the multiyear program plan (MYPP). The MYPP provides goals through 2010, and no further improvements were assumed. This conservative assumption most likely understates the benefits of these fuel cells. Analysts converted program technology goals into installed costs for combined heat and power systems in residential and commercial buildings.

The fuel cell vehicles were modeled along with the Vehicle Technologies Program. The success of fuel cell vehicles is predicated on some of the vehicular improvements being developed under the Vehicle Technologies Program, so the fuel cell vehicles could not be treated in isolation. Analysts modified the gasoline and hydrogen fuel cell vehicle costs and efficiencies to reflect the program goals (see the Vehicle Technologies Program description for more detail about the modeling of vehicle choice). In addition, hydrogen availability for vehicle refueling was assumed to be 10 percent by 2020 and 25 percent by 2025. The benefits associated with fuel cell vehicles were derived by comparing the amount of fuel cell vehicles from the case with “both Hydrogen and Vehicle Technologies” to the “Vehicle Technologies only” case. Analysts computed energy savings, oil savings, and carbon emission reductions, based on the incremental fuel cell vehicles assuming conventional gasoline vehicle displacement (**see Figure 4.2**). This leads to greater

[6] Hydrogen is represented within the refinery model of NEMS-H2, but for internal use only.

savings than a simple difference between the cases, while still having smaller savings than would be derived by comparing a fuel cell vehicles case with the Baseline Case. **Table 4.11** presents the overall benefits.

Table 4.11. FY06 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	ns	ns	ns	0.16
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	2.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	0.0	0.0	4.6
Security				
Oil Savings (million barrels per day)	ns	0.01	0.04	0.23
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	-0.01	-0.30
Avoided Additions to Central Conventional Power (gigawatts)	ns	1	ns	2
Program-Specific Electric Capacity Additions (cumulative gigawatts)	ns	1	ns	ns

Industrial Technologies Program

The Industrial Technologies Program covers primarily the energy-intensive basic materials processing industries, as well as some key technologies that are common across most industries, with the objective of increasing energy efficiency. These can be characterized in two categories, R&D and deployment. The R&D projects generally apply to specific industries or to specific technologies that cut across industries. The R&D projects seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The deployment projects seek to increase the adoption of existing, as well as new, energy-efficient technologies.

The heterogeneity of the program makes it difficult to represent the program activities explicitly through technologies in the NEMS-GPRA06 framework. Therefore, analysts perform an off-line analysis using detailed spreadsheet models, and use the resulting energy savings by fuel type to provide inputs into the integrated model. Because these programs cannot be modeled on an economic basis, analysts reduce the off-line energy savings by an “integration factor” before putting them into NEMS-GPRA06. This is to account for interactions among programs and feedback effects that could not be considered in their original estimation. The amount of the integration factor is based on how much program overlap or “integration” was captured by the off-line tools and is based on the expert judgment of the benefits analysis team. The crosscutting programs, including the Best Practices activity, were reduced by 10 percent. The Industries of the Future programs were not reduced because they are relatively specific and not likely to experience overlap with other industrial programs.

Analysts then run the fully integrated NEMS-GPRA06 to compute the benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings that are associated with the fuel-consumption reductions.

The resulting estimated primary savings are slightly lower than those targeted because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, the lower energy consumption causes lower energy prices (although the feedback is small), which causes energy consumption to be higher than it otherwise would have been, leading to slightly lower program savings (**Table 4.12**).

Table 4.12. FY06 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.25	0.80	1.77	2.16
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	2.2	11.2	16.9	12.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	4.7	14.8	34.7	44.4
Security				
Oil Savings (million barrels per day)	0.03	0.14	0.19	0.15
Natural Gas Savings (quadrillion Btu/yr)	0.12	0.30	0.64	0.72
Avoided Additions to Central Conventional Power (gigawatts)	ns	2	9	8
Total Electric Capacity Avoided (cumulative gigawatts)	1	3	8	11

Solar Energy Technologies Program

The Solar Energy Technologies Program develops both thermal-heat and electric-solar technologies. The solar water-heating component is focused on developing low-cost solar hot water and pool heaters to displace fossil-fueled or electric alternatives. Photovoltaics (PVs) are being improved for both distributed and central electricity generation applications, and the program is working to accelerate PV adoption through the Million Solar Roofs Initiative. The Concentrated Solar Power R&D activity is developing better technology for large-scale central electricity generation facilities that concentrates solar energy to produce electricity through a thermal process.

The benefits for solar water heat are represented within the residential module of NEMS-GPRA06. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical use. NEMS-GPRA06 was modified to add solar water heat as an option for new homes, and the algorithm governing water-heater replacements was modified so that solar water heaters could compete in a larger market. In the Program Case, the baseline assumptions were modified to reflect the program cost and performance goals. The costs were changed for both new and replacement water heaters.

Three changes were made to the representation of distributed PV systems in the Baseline and Program Cases. The size of the typical distributed PV installation was increased to 4 kW per home (from 2 kW) and to 100 kW per commercial building (from 25 kW) to reflect literature on recent installations. In addition, the fraction of eligible buildings was increased from 30 percent to 60 percent for homes and to 55 percent for commercial buildings. The California renewable energy credit program, which provides a PV credit of $4000/kW in 2003 declining by $400/kW per year, was included for the Pacific region. For the program case, the capital and O&M costs were modified to reflect the program's goals. The regional capacity factors in the Baseline Case were similar to those in the program's goals, so they were left unchanged.

The improved concentrated solar power (CSP) technology was represented by declining capital costs over time and higher capacity factors. The capital costs goals are higher than those used in the Baseline but represent systems with significantly more storage and therefore higher electrical output. A set of capacity factors by time periods within a year were computed by analysts to optimize the timing of solar output for each region within the bounds of the storage potential. The capacity factors and capital costs vary by region due to difference in solar insolation and resulting storage costs.

In addition to competing on an economic basis with other electricity-generation technologies, PVs may be constructed for their environmental benefits. PERI, using their Green Power Market Model, provided an estimate of PV capacity additions in response to the expanding green power markets in many places throughout the country. The projections for green power PV installations were combined with the Million Solar Roofs Initiative goals to determine the planned PV capacity additions that were incorporated into NEMS-GPRA06. **Table 4.13** shows the baseline, program case, and incremental capacity and electricity generation for the solar technologies.

Table 4.13. NEMS-GPRA06 Solar Capacity (GW) and Water Heaters

Solar Generation Technologies	2010	2015	2020	2025
GPRA Base				
Solar CSP	0.4	0.5	0.5	0.5
Central PV	0.2	0.2	0.3	0.4
Distributed PV	0.4	0.4	0.4	3.8
Total	1.0	1.1	1.2	4.7
Solar Program Case				
Solar CSP	0.4	0.5	0.5	2.2
Central PV	0.2	0.2	0.3	0.4
Distributed PV	1.2	3.0	6.5	15.2
Total	1.8	3.7	7.4	17.8
Incremental Capacity				
Solar CSP	0.0	0.0	0.0	1.7
Central PV	0.0	0.0	0.0	0.0
Distributed PV	0.8	2.6	6.2	11.4
Total	0.8	2.6	6.2	13.1

Incremental Generation (BkWh)				
Solar CSP	0.0	0.0	0.0	10.8
Central PV	0.0	0.0	0.0	0.0
Distributed PV	1.7	5.2	12.6	23.6
Total	1.7	5.2	12.6	34.4

Solar Water Heaters

	2010	2015	2020	2025
GPRA Base				
Million	0.61	0.81	1.04	1.40
Share (percent)	0.5%	0.6%	0.8%	1.0%
Solar Program Case				
Million	0.92	2.33	3.81	5.73
Share (percent)	0.8%	1.9%	2.9%	4.2%

Estimates of primary energy, oil, and carbon emissions savings result from displacement of energy use for water and pool heating, and from electricity demand reductions and PV and CSP generation. The savings associated with reduced conventional electricity requirements depend on which types of generating plants were built and operated in the Baseline Case. Over time, the mix of fuels and efficiencies of power generation vary; and, therefore, the energy savings will as well. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. Energy savings from water heaters also directly reduce energy expenditures. Overall benefits of the Solar Energy Technologies Program are shown in **Table 4.14**.

Table 4.14. FY06 Benefits Estimates for Solar Energy Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.01	0.05	0.12	0.30
Generation (gigawatt-hours/yr)	2	5	13	34
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	1.1	2.7	1.8
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.1	1.0	2.4	7.6
Security				
Oil Savings (million barrels per day)	ns	0.01	0.01	ns
Natural Gas Savings (quadrillion Btu/yr)	0.01	0.03	0.03	0.01
Avoided Additions to Central Conventional Power (gigawatts)	ns	2	4	9
Program-Specific Electric Capacity Additions (cumulative gigawatts)	1	3	6	13

Vehicle Technologies Program

The Vehicle Technologies Program consists of research on light-duty vehicle hybrid and diesel technologies, heavy vehicle engine/drivetrain and parasitic loss-reduction technologies, and lightweight materials for engines and vehicles. In addition, the program includes research in advanced petroleum and renewable fuels, the benefits of which are not modeled.

Light-duty vehicle hybrid and diesel technologies: This research aims to improve engine technologies in light-duty vehicles, which include passenger cars and light-duty trucks. NEMS-GPRA06 is used to compute benefits estimates for these activities through a process that estimates the penetration (sales) of the various technologies in the market for light-duty vehicles over time. The amount that each technology penetrates into the market determines the stock of these vehicles and the vehicle miles traveled (VMT) associated with each technology.

Heavy vehicle engine/drivetrain and parasitic loss reduction technologies: Heavy vehicles are those that have a gross weight (the weight when fully loaded) of 10,000 pounds or more. This program researches multiple technologies including engines/drivetrains, parasitics/accessories, aerodynamics, and hybrids. The benefits of this R&D activity are derived from penetration rates estimated by the Heavy Truck Energy Balance and Truck 2.0 models developed for the Vehicle Technologies Program, using efficiency and technology cost assumptions.

Lightweight materials for engines and vehicles: The lightweight materials developed under this R&D activity are used in both light and heavy vehicles. The effect of these materials are included in the projection of vehicle attributes and not modeled separately.

In the NEMS-GPRA06 integrating model, the light-duty vehicle (LDV) market consists of six car classes—mini-compact, subcompact, compact, midsize, large, two-seater—and six light-duty truck classes—small and large pickup, small and large van, small and large sport utility vehicle (SUV)—in nine Census divisions. For each vehicle type and class and for each region, a number of LDV technologies compete against each other in the market for vehicle sales. These include conventional gasoline, advanced combustion diesel, gasoline hybrids, diesel hybrids, gasoline fuel cell, hydrogen fuel cell, electric, natural gas, and alcohol. Each vehicle technology is represented by a number of characteristics that can change over the forecast time horizon and that influence the technology's acceptance in the marketplace (*i.e.*, its sales). These characteristics include the vehicle cost, the fuel cost per mile (a combination of the fuel price and the vehicle efficiency), the vehicle range, the operating and maintenance cost, the acceleration, the luggage space, the fuel availability, and the make and model availability. The NEMS-GPRA06 model also includes "calibration" coefficients to calibrate the model to historical data. The associated characteristics for all the alternative technologies are specified as relative to those for the conventional gasoline vehicle.

The model estimates the sales-penetration share of each technology in all of the vehicles, classes, and regions in each year of the forecast. The various characteristics of the technologies determine the technology's value to consumers and its acceptance in the marketplace, but each characteristic has a differing degree of influence.[7] The vehicle cost is generally the most

[7] The vehicle shares are sensitive to assumptions about consumer preference for each vehicle attribute. In the NEMS-GPRA06 transportation model, a different set of consumer-choice assumptions is made than those in the NEMS *AEO2004* transportation model, leading to different rates of technology adoption.

influential of the characteristics, certainly having a much stronger influence than luggage space, for example. The values of all the characteristics are combined to create an overall value. The technologies are competed against each other using a nested logit formulation. In a logit formulation, the relative size of the overall value for each technology determines the relative penetration shares for that technology. Technologies that have higher values are given greater sales shares, resulting in a distribution of consumer preferences rather than the technology with the highest "utility" receiving 100 percent of the market. The overall sales-penetration results are the sum of all the more disaggregated results.

In the FY 2006 benefits analysis, the Baseline Case for transportation programs is essentially the *AEO2004* Reference Case, which already includes some small amount of penetration for the program vehicle technologies. The Program Case uses the program technology characteristics, along with a variety of other assumptions relating to behavioral responses in the underlying logit formulation of the NEMS-GPRA06 model. These include moving away from the "calibration" coefficients over the forecast period (used by the model for a tie to history), and reworking the manner in which the make and model availability coefficients are used.

Using the fully integrated NEMS-GPRA06 model, the overall sales share for gasoline vehicles in 2025 falls from 81 percent in the Baseline Case to 40 percent in the Program Case (**Figure 4.3**). This decrease in share is due to the penetration of the alternative technologies. The overall share in 2025 for advanced combustion diesel increases from 5 percent to 25 percent, for gasoline hybrids from 5 percent to 18 percent, and for diesel hybrids from 1 percent to 12 percent.

These large vehicle sales shares for advanced technology vehicles in 2025, however, translate into much smaller shares of overall vehicle stocks and overall shares of vehicle miles traveled (VMT) for each technology. The stock shares depend on the share of sales over time, which only gradually increases for the alternative-technology vehicles, and the rate of vehicle replacement and growth. The total VMT for gasoline vehicles falls from 3,455 billion miles in 2025 to 2,667 (just over 60 percent of the VMT) between the two cases (**Figure 4.4**). The total VMT for advanced combustion diesel increases from 180 to 519 billion miles (12 percent), for diesel hybrids from 20 to 218 billion miles (5 percent), and for gasoline hybrids from 182 to 710 billion miles (16 percent).

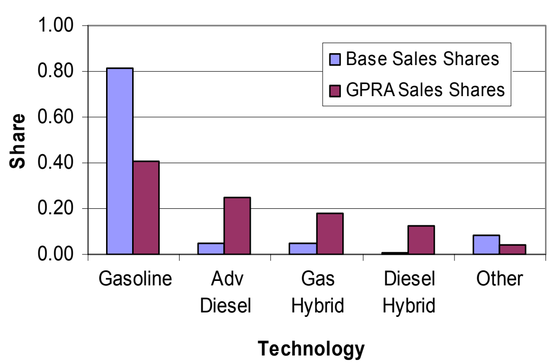

Figure 4.3. Sales Shares in 2025

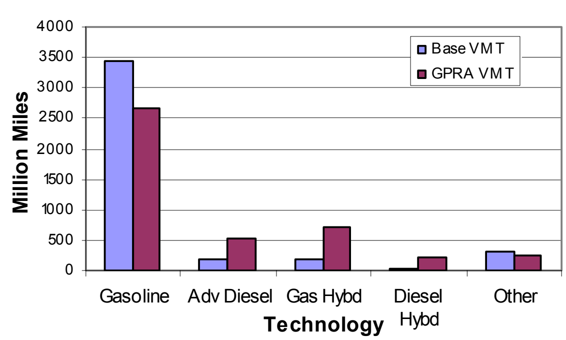

Figure 4.4. Vehicle Miles Traveled in 2025

The miles per gallon (MPG) for advanced combustion diesel and for hybrid vehicles is much greater than the MPG for conventional gasoline vehicles. As a consequence, since these advanced-technology vehicles are substituting for the conventional gasoline vehicles, there is a considerable amount of fuel savings.

In these fully integrated NEMS-GPRA06 model runs, the savings are typically somewhat less than if they were estimated in a transportation-only model, because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, reduced gasoline demand causes lower gasoline prices, which leads to an increase in travel and less-efficient vehicle purchases than would otherwise have occurred absent the price change. The rebound of gasoline consumption reduces the program savings. At the same time, energy-expenditure savings are greater. The small decreases in price apply to the total amount of fuel consumed and contribute significant additional expenditure savings. In addition, the "rebound" effect is also influenced by the fact that vehicles are more efficient, thereby reducing the cost to drive, causing more miles to be driven. **Table 4.15** presents the total program benefits, including those of heavy trucks.

Table 4.15. FY06 Benefits Estimates for Vehicle Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.09	0.73	2.12	3.98
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	7.3	31.4	60.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1.9	14.6	41.8	76.2
Security				
Oil Savings (million barrels per day)	0.04	0.32	0.90	1.80
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	ns	ns
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Weatherization and Intergovernmental Program

The Weatherization and Intergovernmental Program (WIP) encompasses a broad range of activities in virtually all demand sectors of the energy economy. These activities generally are comprised of market enhancement, rather than R&D. The major components include: International, Native American Renewable Initiative (also referred to as Tribal Energy), the Renewable Energy Production Incentive (REPI), Weatherization (Assistance), State Energy Program Grants, and Gateway Deployment (Energy Star, Clean Cities, Inventions and Innovations, Rebuild America, Energy Efficiency Information and Outreach, and Building Codes Training and Assistance). The FY 2006 benefits estimate methodologies vary by activity.

The international activities are currently outside the scope of the integrated modeling framework. The Native American renewable initiative also is not being modeled for this year. REPI provides payments to publicly owned utilities, such as municipal utilities or rural electric cooperatives, for electricity generation from renewable energy sources that is the public power equivalent of the production tax credit for investor-owned renewable generators. Analysts projected the amount of new renewable generation that is likely to be stimulated by future REPI payments. Almost all the new generation is expected to be wind, based on the eligibility criteria and past experience. Analysts then used the NEMS-GPRA06 benefits for the Wind Program to develop the benefits metrics for REPI based on the ratio of additional generation.

Weatherization and State Energy Program grants are implementation programs that lead to greater adoption of energy efficiency. They are represented in NEMS-GPRA06 by reducing energy consumption in the residential and commercial sectors, based on the program goals.

The Clean Cities subprogram is represented through an increase in alternative-fuel vehicles and an increase in dedicated ethanol (E85) vehicles and fuel usage. For the increase in alternative-fuel vehicles, analysts determined the cumulative number of expected vehicles participating in Clean Cities through off-line analysis. These were converted to annual vehicle sales and used as inputs into NEMS-GPRA06. The incremental sales were allocated to vehicle types, based on program information, although the fuel types in the model do not directly correspond in all cases. The largest share of vehicles are compressed natural gas, ethanol, and liquefied petroleum gas. Electric and methanol vehicle shares are small. For the portion of the program that encourages greater ethanol use, analysts determined the change in the fraction of vehicles using E85 over time and an increasing fraction of E85 use per vehicle. These were converted to overall fractions of E85 use and were then used as inputs to NEMS-GPRA06.

The Inventions and Innovation (I&I) subprogram savings estimates are based on numerous individual technologies receiving grants in the previous year, because this is the most recent year of award data available for analysis. For this analysis, the projects with the greatest expected energy savings are represented using specific technology characteristics or by targeting the energy-savings goals of the individual projects funded. The technologies include two inventions involving ethanol production, two types of buildings equipment, and one industrial process. The ethanol and industrial process inventions could not be modeled on an economic basis within NEMS-GPRA06, so the estimated off-line energy savings were used in the model after being discounted by 30 percent to 50 percent to reflect potential interactions with other EERE markets and technologies. In the building sector, the electrochromic windows reduce heating and cooling loads. Based on an analysis performed by PNNL,[8] the windows were modeled in NEMS-GPRA06 based on technology cost and efficiency characteristics. The humidity-control invention was modeled using an assumption of air-conditioning savings in homes with commercial applications and in the markets where humidity control is important.

Analysts represented the Energy Star activities of Gateway Deployment by modifying the consumer-behavior coefficients, indicating how consumers trade first-cost expenditures for annual energy savings. The program goals for market penetration were used to determine the degree of change of these parameters. For the compact fluorescent bulb (CFL) activities, the target market share was defined as the fraction of lighting demand rather than the fraction of bulbs, in order to reflect that CFLs are most likely to be installed in high-use fixtures.

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[8] See Appendix K on the Weatherization and Intergovernmental Program analysis.

Other buildings energy-related activities, including Building Codes and Rebuild America, were represented in NEMS-GPRA06 based on an offline analysis of penetration rates and efficiency improvements. Overall benefits for WIP are shown in **Table 4.16**.

Table 4.16. FY06 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.34	0.61	0.97	1.22
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	4.6	10.4	11.9	9.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	6.3	12.3	21.0	27.2
Security				
Oil Savings (million barrels per day)	0.03	0.08	0.08	0.05
Natural Gas Savings (quadrillion Btu/yr)	0.20	0.20	0.26	0.31
Avoided Additions to Central Conventional Power (gigawatts)	1	9	16	15
Total Electric Capacity Avoided (cumulative gigawatts)	7	11	12	14

Wind Technologies Program

The wind component of the Wind Technologies Program seeks to reduce the cost—and improve the performance—of wind generation. The FY 2006 benefits are based primarily on projecting the market share for wind technologies, based on their economic characteristics.

Representation of Wind: The NEMS-GPRA06 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Unlike the *AEO2004* version of NEMS, NEMS-GPRA06 characterizes wind by three wind classes, which each have their own capital costs and resource cost multipliers. For example, wind turbines being developed by the program for use in Class 4 winds are expected to be more expensive, but deliver more electricity per unit of capacity. The regional resource cost multipliers act to increase costs as more of a wind class is developed in a region, and development may move to the next most cost-effective wind class. The same resource multipliers are used as in the *AEO2004*, although they are applied at the class level rather than for the entire regional resource. NEMS-GPRA06, as in the *AEO2004*, assumes that the capacity value of wind diminishes with greater wind capacity in a region. Finally, another constraint on the growth of wind-resource development is how quickly the wind industry can expand before costs increase due to manufacturing bottlenecks. The *AEO2004* assumption that a cost premium is imposed when new orders in a year are 20 percent higher than in the highest of the previous 10 years was maintained in the Program Case[9] (see **Table 4.17**).

[9] In the *AEO2004,* all generation technologies face similar premiums associated with rapid growth.

The baseline characterization of wind capital costs and capacity factors were modified to reflect a more consistent view relative to the program goals. The Baseline costs were raised slightly and distinguished between Class 5 and 6 versus Class 4 costs. The more significant change was an increase in capacity factors for all three wind classes. This reduced the benefits attributed to the program, but presents a better representation of the impact of the program's R&D.

NEMS-GPRA06 also includes a representation of offshore wind that it not in the AEO2004 version. The offshore wind is represented as a distinct technology that competes with all other generation technologies. It is characterized in a similar manner as onshore wind, with three wind classes, but also has a distinction between shallow and deep-water sites. The constraints on intermittent generation and rapid growth apply similarly to offshore as to onshore wind development. The offshore wind does not have the regional resource cost multipliers because there is insufficient data on how they might apply.

Analysts represented the Wind Program R&D activities by reducing the capital and O&M costs and increasing the performance of wind capacity to match the program cost goals. In addition to competing on an economic basis with other electricity-generation technologies, wind capacity may be constructed for its environmental benefit. PERI, using their Green Power Market Model, provided an estimate of wind capacity additions in response to the expanding green power markets in many places nationwide. Analysts incorporated the projections for green power wind installations into NEMS-GPRA06 as planned capacity additions. These are quite small relative to the economic additions selected within the model.

Table 4.18 provides the estimates of primary energy, oil, and carbon emissions savings stemming from wind and hydropower displacing fossil-fueled generation sources. Analysts measure the energy-expenditure savings as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

Table 4.17. Wind Capacity (GW)

		2010	2015	2020	2025
AEO Base		7.9	9.5	12.0	14.0
GPRA Baseline					
Onshore	Class 6	6.1	6.5	6.5	6.5
	Class 5	4.9	6.2	6.7	7.4
	Class 4	0.1	0.1	0.1	0.2
	Subtotal	11.1	12.8	13.3	14.2
Offshore	Class 7	0.0	0.4	1.2	1.4
	Class 6	0.0	0.0	0.0	0.0
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	0.4	1.2	1.4
Total	Total	11.1	13.2	14.5	15.6
Wind Program Case					
Onshore	Class 6	6.1	10.8	11.3	11.3
	Class 5	7.8	16.5	18.7	20.7
	Class 4	0.1	14.4	36.3	37.6
	Subtotal	13.9	41.7	66.4	69.6
Offshore	Class 7	0.0	1.9	16.7	37.2
	Class 6	0.0	0.0	1.7	2.1
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	1.9	18.4	39.2
Total	Total	13.9	43.6	84.8	108.8
Incremental Capacity					
Onshore	Class 6	0.0	4.3	4.8	4.8
	Class 5	2.8	10.3	12.1	13.2
	Class 4	0.0	14.2	36.2	37.4
	Subtotal	2.8	28.8	53.0	55.4
Offshore	Class 7	0.0	1.5	15.5	35.8
	Class 6	0.0	0.0	1.6	2.0
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	1.5	17.2	37.8
Total	Total	2.8	30.3	70.2	93.2

Table 4.18. FY06 Benefits Estimates for Wind Technologies Program (NEMS-GPRA06)

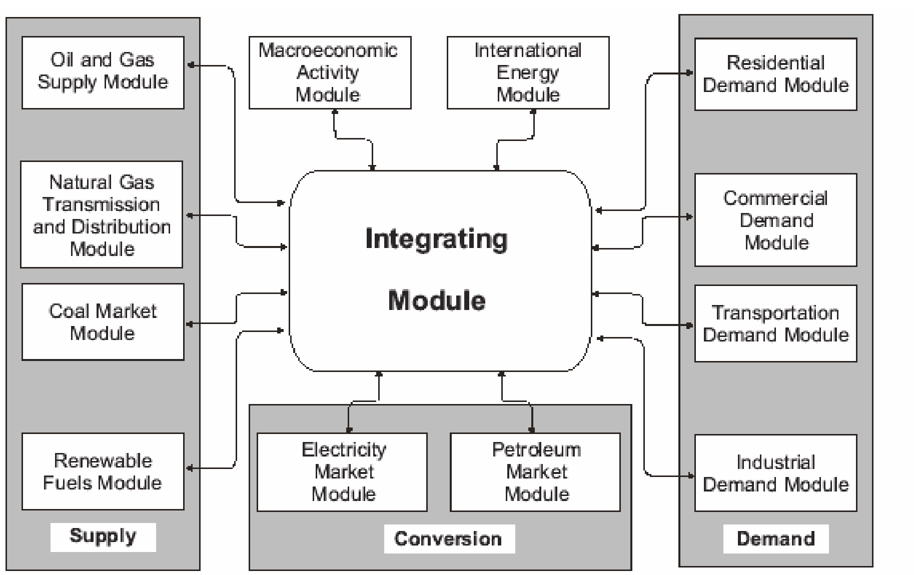
Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Non-Renewable Energy Savings (quadrillion Btu/year)	0.04	0.84	2.29	3.32
Generation (gigawatt-hours/year)	11	120	298	416
Economic				
Energy Expenditure Savings (billion 2000 dollars/year)	ns	5.2	6.8	4.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/year)	0.9	18.0	52.4	80.6
Security				
Oil Savings (million barrels per day)	ns	0.06	0.07	0.06
Natural Gas Savings (quadrillion Btu/year)	0.01	0.24	0.52	0.39
Avoided Additions to Central Conventional Power (gigawatts)	1	9	19	24
Program-Specific Electric Capacity (cumulative gigawatts)	3	30	70	93

Box 4.1—EIA's National Energy Modeling System (NEMS)*

The National Energy Modeling System (NEMS) is an energy-economy modeling system of U.S. energy markets for the midterm period through 2025. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE). As described in the GPRA Baseline section, the NEMS-GPRA06 version of the model used for the EERE GPRA analysis includes minor modifications to the standard EIA NEMS.

NEMS is designed as a modular system. Four end-use demand modules represent fuel consumption in the residential, commercial, transportation, and industrial sectors; subject to delivered fuel prices, macroeconomic influences, and technology characteristics. The primary fuel supply and conversion modules compute the levels of domestic production, imports, transportation costs, and fuel prices that are needed to meet domestic and export demands for energy; subject to resource base characteristics, industry infrastructure and technology, and world market conditions. The modules interact to solve for the economic supply and demand balance for each fuel. Because of the modular design, each sector can be represented with the methodology and the level of detail (including regional detail) that is appropriate for that sector.

A key feature of NEMS is the representation of technology and technology improvement over time. Five of the sectors—residential, commercial, transportation, electricity generation, and refining—include extensive treatment of individual technologies and their characteristics, such as the initial capital cost, operating cost, date of availability, efficiency, and other characteristics specific to the sector. Technological progress results in a gradual reduction in cost and is modeled as a function of time in these end-use sectors. In addition, the electricity sector accounts for technological optimism in the capital costs of first-of-a-kind generating technologies and for a decline in cost as experience with the technologies is gained both domestically and internationally. In each of these sectors, equipment choices are made for individual technologies as new equipment is needed to meet growing demand for energy services or to replace retired equipment. In the other sectors—industrial, oil and gas supply, and coal supply—the treatment of technologies is more limited, due to a lack of data on individual technologies. In the industrial sector, only the combined heat and power and motor technologies are explicitly considered and characterized. Cost reductions resulting from technological progress in combined heat and power technologies are represented as a function of time as experience with the technologies grows. Technological progress is not explicitly modeled for the industrial motor technologies. Other technologies in the energy-intensive industries are represented by technology bundles, with technology possibility curves representing efficiency improvement over time. In the oil and gas supply sector, technological progress is represented by econometrically estimated improvements in finding rates, success rates, and costs. Productivity improvements over time represent technological progress in coal production.



* Most of this description is taken from *The National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003.

CHAPTER 5

LONG-TERM BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

This chapter provides an overview of the modeling approach used in MARKAL-GPRA06 to evaluate the benefits of EERE R&D programs and technologies. The program benefits reported in this section result from comparisons of each Program Case to the Baseline Case, as modeled in MARKAL-GPRA06.

The Baseline Case used to evaluate the impact of the EERE portfolio was benchmarked to EIA's *Annual Energy Outlook 2004* (*AEO2004*) for the period between 2000 and 2025. To the extent possible, the same input data and assumptions were used in MARKAL-GPRA06 as were used to generate the *AEO2004* Reference Case. For example, the macroeconomic projections for GDP, housing stock, commercial square footage, industrial output, and vehicle miles traveled were taken from the *AEO2004*. At the sector level, both supply-side and demand-side technologies were characterized to reflect the *AEO2004* assumptions, in cases where the representation of technologies is similar between MARKAL (MARKet ALlocation) and the National Energy Modeling System (NEMS). The resulting projections track closely with the *AEO2004* at the aggregate level, although they do not match exactly at the end-use level. For the period after 2025, various sources were used to compile a set of economic and technical assumptions. For instance, the primary economic drivers of GDP and population were based on the real GDP growth rate from the Congressional Budget Office's *Long-Term Budget Outlook* and population growth rates from the Social Security Administration's 2003 *Annual Report* to the Board of Trustees. **Appendix A** provides a more complete discussion of the MARKAL-GPRA06 Baseline Case.

For each EERE R&D program, analysts make modifications to the characteristics of the technologies involved to generate a Program Case. Program Cases also may include technologies not available in the Baseline Case. The modifications made to the model parameters and attributes of a technology depend on the nature of the program. They directly affect the technology's competitiveness and market deployment presented in the model.

Table 5.1 provides a breakdown by program of the two types of analytical methods employed in EERE's long-term benefits analyses—specialized "off-line" tools and MARKAL-GPRA06. The activities listed are groupings of activities within each program that share either technology or market features. They do not represent actual program-management categories. A description of the MARKAL model is provided in **Box 5.1** at the end of this chapter. Descriptions of the off-line models are provided in the related program appendix. It is important to note that the off-line analysis served to feed appropriate parameters and other factors into MARKAL-GPRA06, which was then run for all the programs. The indication that the Industrial Technologies Program (or other program areas) was modeled using off-line tools should not be interpreted to mean that the Industrial Technologies Program was not included in the MARKAL-GPRA06 modeling, or that the results of the Industrial Technologies Program analysis are not impacted by the MARKAL-GPRA06 modeling.

Table 5.1. Long-Term Benefits Modeling by Primary Type of Model Used and Activity Area

Program	Activities	Off-Line Tools	MARKAL-GPRA06
Biomass	Bio-based Products	✓	
	Cellulosic Ethanol	✓	
Buildings Technologies	Residential Sector	✓	✓
	Commercial Sector	✓	✓
DE	DER / CHP		✓
FEMP	FEMP	✓	
Geothermal	Geothermal		✓
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		✓
	Production		✓
Industrial Technologies	R&D	✓	
	Deployment	✓	
Solar Energy Technologies	Solar Water Heaters		✓
	Photovoltaics	✓	✓
Vehicle Technologies	Light-Vehicle Hybrid and Diesel		✓
	Heavy Trucks		✓
Weatherization and Intergovernmental	Weatherization	✓	
	Domestic Intergovernmental	✓	
Wind Technologies	Wind		✓

The following sections summarize how each EERE R&D program is formulated in MARKAL-GPRA06. In many cases, analysts convert the technological data and their projected market potentials in each program directly to MARKAL-GPRA06 input. When this is not feasible, the quantitative analyses undertaken in **Step 2** are used, in part, to generate the Program Cases.

Biomass Program

The goal of the Biomass Program is the development of biomass-based refineries (biorefineries), which produce a range of products including cellulosic ethanol and/or other fuels, chemicals, materials, and/or electricity. The biorefinery concept allows the cost of production to be reduced through synergies associated with feedstock handling and processing, and the allocation of capital and fixed O&M costs across multiple products. For the current analysis, we modeled two types of biorefineries. The first type produces chemicals and materials, but not fuels, and the second type produces ethanol fuel as the major output. Future analyses may include additional fuels that the program identifies in the longer term.

Bio-based products: At this early stage of biorefinery R&D, the output and cost of the nonfuel biorefineries (producing only chemicals and materials) are not yet well defined. Program goals are estimated off-line and represented in MARKAL-GPRA06 as reductions in petroleum and natural gas demand for feedstocks. Off-line projections of the use of petroleum and natural gas as chemical feedstock are represented in a highly aggregated manner and include changes in fuel requirements for process heat. The off-line energy savings for displaced feedstocks and changes in process heat are represented in the MARKAL-GPRA06 model as a conservation curve in the amounts shown in **Table 5.2**.

Table 5.2. Bio-based Products Energy Savings by Year

	2010	2020	2030	2040	2050
Natural Gas (TBtu/yr)	1.13	3.53	11.68	35.66	71.54
Coal (TBtu/yr)	-0.15	-0.47	-1.56	-4.75	-9.54
Electricity (Billion kWh/yr)	-0.15	-0.47	-1.56	-4.75	-9.54
Distillate (TBtu/yr)	1.13	3.53	11.68	35.66	71.54
Oil Feedstock (TBtu/yr)	2.75	8.62	28.54	87.17	174.86
Total (TBtu/yr)	**4.70**	**13.60**	**45.03**	**137.51**	**275.85**

Corn and cellulosic ethanol: EERE is sponsoring research aimed at reducing the cost of producing ethanol from cellulosic biomass.[1] The second type of biorefineries assumed in this analysis is one that focuses on the production of ethanol, lignin-derived electricity and a small quantity of chemical coproducts. In the Biomass Program Case, the conversion of corn fiber and residual starch to ethanol becomes available for dry mills beginning in 2012 and yields a 20 percent increase in a dry mill's ethanol output. Corn stover-to-ethanol technology becomes available in 2018, whereas sugar-based biorefineries producing ethanol as a major product, along with high-value coproducts, from corn stover and other cellulosic wastes and residues, become available in 2024. Currently, the MARKAL-GPRA06 model lacks sufficient technical detail to properly capture beneficial qualities of ethanol, such as octane enhancement; or the regional detail to model niche markets in agricultural states where ethanol/gasoline blends may compete on an even basis with traditional gasoline. Therefore, estimates of future ethanol demand from biomass-specific models (e.g., ELSAS Bioref) are used for both the Baseline and Program Cases. **Table 5.3** depicts the production of cellulosic and corn ethanol set in MARKAL-GPRA06, which reflects corn and cellulosic ethanol's penetration if program cost goals are met.

Table 5.3. Projected Ethanol Demand (million gallons/year)

	2000	2010	2020	2030	2040	2050
Corn	1,600	3,733	4,018	3,644	3,531	3,531
Corn Fiber & Residual Starch	0	0	340	474	459	459
Cellulosic	0	0	0	3,600	9,000	13,200
Total	**1,600**	**3,733**	**4,357**	**7,718**	**12,990**	**17,190**

The benefits of the Biomass Program derived in MARKAL-GPRA06 (**Table 5.4**) are the results of direct substitution of biomass-based energy for fossil fuels. Bio-based products reduce the demand for petroleum feedstocks. Cellulosic ethanol displaces an increasing fraction of the gasoline used in light-duty vehicles (LDVs) in later periods. The reduction in fossil fuel consumption at high marginal cost generates savings both in carbon emissions and energy-system costs.

[1] Cellulose and hemi-cellulose that can be converted to ethanol (and other chemicals, materials, and biofuels) are found in biomass such as agricultural residues (corn stover, wheat, and rice straw), mill residues, organic constituents of municipal solid wastes, wood wastes from forests, future grass and tree crops dedicated to bio-energy production.

Table 5.4. FY06 Benefits Estimates for Biomass Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.05	0.23	0.71	1.13
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	0.0	0.2	0.5	0.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1	4	12	19
Security				
Oil Savings (mbpd)	0.05	0.09	0.29	0.40
Natural Gas Savings (quadrillion Btu/yr)	-0.08	0.02	0.06	0.16

Building Technologies Program

MARKAL-GPRA06 models technologies and activities in the Buildings Program based on two general types of activities: technology R&D and regulatory actions.

Technology R&D: New and improved technologies are introduced into MARKAL-GPRA06 by modifying the technology slates that are available in the Baseline Case. These modifications are accomplished by changing any (or all) of the following three parameters to reflect program goals: the date of commercialization, capital cost, and efficiency. Building technologies for which these parameters can be characterized to meet specific building service demands include end-use devices such as heating burners, air conditioners, and water heaters. In instances where the market potentials of a technology were estimated off-line, a maximum initial market penetration rate was imposed, combined with an annual growth rate limit to replicate these potentials in MARKAL-GPRA06.

Technologies that lower service demand (*e.g.*, building shell technologies, lighting controls) are modeled in MARKAL-GPRA06 as conservation supply steps. Each supply step is characterized by capital cost, load-reduction potentials expressed as upper bounds of market penetration, consumer's hurdle rate, and technology lifetime. These conservation steps reduce the market size or load demand for end-use devices. In the Buildings Program Case, these newly introduced technologies compete with the baseline technologies for market share. For example, in future time periods, the size of the market for commercial air conditioning is the projected total heat in trillion Btus to be removed from the service areas. The new investment opportunity in that time period is the difference between the projected service demands in that period and the vintage capacities carried over from the previous period.

Technologies such as solid-state lighting, although available in the Baseline Case, do not have a market share initially because of their high consumer hurdle rate (44 percent). These hurdle rates are lowered to 18 percent when running the Buildings Technology Case to reflect consumer acceptance of these products with improved performance.[2] The 18 percent is an empirical value based on observed consumer responses, but is much higher than would be observed if consumers were minimizing life-cycle costs. Although the future market potential of new lighting technologies is great due to the relatively short life of the equipment, the penetration of these technologies modeled in MARKAL-GPRA06 is limited to a sustainable growth path that generates a potential market penetration path consistent with the program goals.

Regulatory activities: Analysts represent new appliance standards and building codes in MARKAL-GPRA06 as either new technologies or energy-conservation supply steps. In the time period that a new standard becomes effective, the model removes technologies with efficiency below the set standard from the market. Regulatory activities primarily affect the performance of new energy products for a specific end-use product purchased by consumers in future markets. The overall impact of the Buildings Program, therefore, depends on the size of these markets. MARKAL-GPRA06 determines the size of these markets by dynamically keeping track of the turnover of capital equipment and deriving the new investment needed to meet projected energy service demands. Because some end-use devices (*e.g.*, heating equipments) have a long service lifetime, the stock turnover constraints modeled in MARKAL-GPRA06 limit near-term energy savings.

In MARKAL-GPRA06, energy savings are achieved when a more efficient and economic (on a life-cycle basis) end-use device is selected to substitute for a conventional device competing in the same market. For example, a 20 Watt (W) CFL can replace a 75W incandescent light bulb and provide the same level of lighting service, but uses much less electricity. The total market potential for this substitution in a future time period, however, is constrained by the investment opportunity established in MARKAL-GPRA06.

While the Building Technologies Program conducts research on a variety of technologies and applications, the three activities with the highest potential in the GPRA06 analysis are Solid State Lighting, Residential and Commercial Unitary DX System, and Building America. For solid-state lighting, the Building Technologies Program is conducting research to improve the efficiency and reduce the cost of the lamps. Unitary DX Systems research aims to double the efficiency of both residential and commercial space cooling and heat pump technologies with only a 10 percent increase in cost (by 2020).

The goal of the Build America Program is to improve efficiency of new and existing homes through research, development, demonstrations, and technology transfer strategies using the whole buildings approach. This program was modeled as a series of three conservation curves for residential space heating and cooling demands. The first conservation curve represents the incremental cost to reduce energy consumption by 20 percent, while the next two supply curves represent the incremental cost to reduce energy consumption by a further 20 percent and 10

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[2] The hurdle rates in MARKAL-GPRA06 include factors to reflect both the interest rate available to consumers, as well as behavioral and risk premiums that are implicit in consumer decisions. Behavioral premiums would reflect a documented consumer bias towards choosing reduced up-front investment costs over longer-term operating cost savings. The behavioral premium also incorporates agency issues where the decision maker would not benefit from long-term operating costs and, thus, would make decisions based primarily on initial capital costs. Risk premiums would apply to new, unfamiliar products that are presumed to be less desirable to consumers due to the lack of familiarity or a track record of successful application. Also, risk premiums would be appropriate for modeling situations where technologies may appear to be cost effective on paper, but are not chosen by consumers for reasons such as convenience, styling or lack of availability.

percent, respectively. The technology assumptions for these activities are shown in **Tables 5.5, 5.6**, and **5.7**.

Table 5.5. Solid-State Lighting Technologies

	2010	2020	2030	2040	2050
Efficacy (lumens/watt)	60	118	153	162	162
Price ($/kilolumen)	$126.93	$9.91	$4.09	$4.00	$4.00

Table 5.6. Residential and Commercial Unitary DX System Technologies

	2010	2015	2020	2025
Incremental Cost (percent)	100%	89%	64%	10%
Incremental Efficiency (percent)	100%	100%	100%	100%

Table 5.7. Building America Building Shell Cost Assumptions (2001$/MMBtu)

	2010	2015	2020
North			
Step 1	$21.2	$15.9	$10.7
Step 2	$196	$147	$98
Step 3	$258	$194	$129
Midwest			
Step 1	$29	$22	$15
Step 2	$240	$180	$120
Step 3	$240.7	$180.6	$120.4
South			
Step 1	$30	$22	$15
Step 2	$279.9	$209.9	$140.0
Step 3	$353	$265	$176
West			
Step 1	$18.2	$13.6	$9.1
Step 2	$211	$158	$106
Step 3	$215	$161	$107

For information on the other Technologies Program inputs, please refer to **Appendix C.**

Tables 5.8 and 5.9 depict the projected delivered energy savings by demand and fuel generated from the use of more efficient end-use devices and cost-effective conservation measures covered under the Buildings Program.

In addition to the reduction in delivered primary energy, the reduction in electricity demand in buildings also leads to the reduction in gas-fired generation capacity, as well as fuel used for generation. Furthermore, building code and envelop improvements reduce both the demand for delivered energy and the required output capacity of end-use devices, such as furnaces or air conditioners. Thus, consumers see both a reduction in their energy bills, as well as reduced capital costs for end-use appliances. This is another factor attributable to the overall reduction in energy-system cost in addition to direct energy savings.

Table 5.8. Residential Delivered Energy Savings by Demand and Fuel (trillion Btu/year)

	2010	2020	2030	2040	2050
Reduction by Service Demand					
Space Heating	42	284	502	660	641
Space Cooling	20	69	132	169	201
Water Heating	0	0	-1	-16	-28
Lighting	0	11	56	148	279
Other	0	0	0	0	0
Total	**62**	**364**	**690**	**961**	**1,093**
Reduction by Fuel					
Petroleum	1	37	92	124	131
Natural Gas	35	243	380	410	252
Coal	0	2	0	1	0
Electricity	27	82	218	425	710
Total	**62**	**364**	**690**	**961**	**1,093**

Table 5.9. Commercial Delivered Energy Savings by Demand and Fuel (trillion Btu/year)

	2010	2020	2030	2040	2050
Reduction by Service Demand					
Space Heating	0	38	42	42	36
Space Cooling	3	24	44	36	30
Ventilation Equipment	5	19	41	26	2
Water Heating	0	0	0	0	0
Lighting	3	61	201	435	781
Other	0	0	0	0	0
Total	**11**	**141**	**327**	**539**	**849**
Reduction by Fuel					
Petroleum	6	38	18	13	-1
Natural Gas	-12	-18	-41	-37	-30
Coal	0	0	0	0	0
Electricity	16	120	350	562	879
Total	**11**	**141**	**327**	**539**	**849**

Table 5.10. FY06 Benefits Estimates for Building Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	1.3	2.4	3.5	4.2
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	12.8	28.7	43.3	62.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	23	45	64	92
Security				
Oil Savings (mbpd)	0.06	0.06	0.10	0.08
Natural Gas Savings (quadrillion Btu/yr)	0.81	1.42	2.26	1.38
Electricity Capacity Avoided (gigawatts)	24	62	76	108

Distributed Energy Program

The Distributed Energy (DE) Program covers distributed generation technologies (DG) and combined heat and power (CHP). The program focuses on the improvement of these technologies (higher efficiency, lower cost, and lower emissions) and removal of market barriers for consumer acceptance.

The DE Program Case in MARKAL-GPRA06 is formulated by the introduction and performance improvements in industrial and commercial sector combined heat and power technologies and a 1 MW distributed electric utility generator to meet local peaking demands. All of these technologies are modeled explicitly as decentralized systems in MARKAL-GPRA06 and do not require transmission and distribution for their electricity or heat output; and, therefore, avoid the associated costs and electricity losses. Implicitly, this improves the electric reliability at the end-use locations—although this value to consumers is not reflected in the model representation of consumer choices.

The overall efficiencies and capital costs used to characterize these technologies are assumed to become more favorable due to R&D achievements expected from the DE Program. The assumptions for commercial, industrial, and distributed electric utility technologies are shown in **Tables 5.11**, **5.12** and **5.13,** respectively.

Table 5.11. Commercial Sector Distributed Generation Technology Assumptions

	2005	2010	2015	2020	2025
200 kW Gas Engine					
Installed Cost (2001$/kW)	$1,112	$793	$729	$729	$729
Electric Efficiency	32%	39%	39%	39%	39%
Overall Efficiency	88%	92%	92%	92%	92%
1 MW Gas Turbine					
Installed Cost (2001$/kW)	$1,781	$1,653	$1,597	$1,542	$1,514
Electric Efficiency	23%	28%	28%	28%	28%
Overall Efficiency	77%	84%	84%	84%	84%
100 kW Micro Turbine					
Installed Cost (2001$/kW)	$1,595	$1,317	$1,212	$1,212	$1,212
Electric Efficiency	30%	36%	37%	38%	39%
Overall Efficiency	71%	80%	81%	81%	81%

Table 5.12. Industrial Sector Distributed Generation Technology Assumptions

	2005	2010	2015	2020	2025
1 MW Internal Combustion Engine					
Installed Cost (2001$/kW)	$914	$643	$592	$592	$592
Overall Heat Rate (Btus/kWh)	9,871	8,066	8,066	8,066	8,066
Overall Efficiency	71%	75%	75%	75%	75%
3 MW Internal Combustion Engine					
Installed Cost (2001$/kW)	$909	$639	$588	$588	$588
Overall Heat Rate (Btus/kWh)	9,538	7,797	7,797	7,797	7,797
Overall Efficiency	69%	73%	73%	73%	73%

1 MW Gas Turbine					
Installed Cost (2001$/kW)	$1,881	$1,881	$1,881	$1,881	$1,881
Overall Heat Rate (Btus/kWh)	15,580	12,030	12,030	12,030	12,030
Overall Efficiency	65%	73%	73%	73%	73%
5 MW Gas Turbine					
Installed Cost (2001$/kW)	$986	$932	$879	$827	$773
Overall Heat Rate (Btus/kWh)	12,344	9,721	9,721	9,721	9,721
Overall Efficiency	67%	75%	75%	75%	75%
10 MW Gas Turbine					
Installed Cost (2001$/kW)	$900	$860	$821	$778	$738
Overall Heat Rate (Btus/kWh)	11,551	9,084	9,084	9,084	9,084
Overall Efficiency	69%	77%	77%	77%	77%
25 MW Gas Turbine					
Installed Cost (2001$/kW)	$776	$747	$717	$694	$664
Overall Heat Rate (Btus/kWh)	9,817	7,679	7,679	7,679	7,679
Overall Efficiency	70%	78%	78%	78%	78%
40 MW Gas Turbine					
Installed Cost (2001$/kW)	$688	$677	$667	$650	$640
Overall Heat Rate (Btus/kWh)	9,146	7,119	7,119	7,119	7,119
Overall Efficiency	72%	81%	81%	81%	81%
100 MW Combined Cycle					
Installed Cost (2001$/kW)	$677	$667	$658	$645	$635
Overall Heat Rate (Btus/kWh)	6,894	6,400	6,400	6,400	6,400
Overall Efficiency	70%	84%	85%	85%	86%

Table 5.13. Electric Utility Distributed Peaker Technology Assumptions

	2005	2010	2015	2020	2025
Installed Cost (2001$/kW)	$523	$641	$631	$621	$621
Heat Rate (Btus/kWh)	10,169	8,348	8,298	8,249	8,249
Variable O&M (mills/kWh)	19.8	15.9	15.9	15.9	15.9

In addition to the GPRA Scenario technology assumption changes, the Baseline Case assumptions for these technologies were changed from those used to create the 2004 AEO projection. The Baseline Case assumptions for distributed technologies were changed such that the cost and efficiency of these distributed generation technologies would achieve the same levels in the DE GPRA Scenario with a 10-year delay. Thus, the Baseline Case assumptions for the industrial sector 1MW gas engine technology in 2025 would be the same as the GPRA Scenario assumptions for 2015. This assumption change results in increased penetration of distributed generation technologies in the Baseline Case, relative to the penetration of these technologies using the 2004 AEO cost and efficiency assumptions. The MARKAL-GPRA06 results show accelerated market penetration of DE technologies relative to the Baseline Case. However, by 2050 the incremental installed capacity is diminished and is primarily the result of cumulative capacity investment. The installed distributed generation capacity is shown in **Table 5.14.**

Table 5.14. Installed Distributed Generation Capacity by Sector and Case (gigawatts)

	2010	2020	2030	2040	2050
Baseline Scenario					
Buildings	2	5	15	28	29
Industry	33	43	54	67	78
Electric Utility	1	11	36	82	72
Total	**36**	**59**	**105**	**177**	**179**
GPRA Scenario					
Buildings	2	5	12	26	27
Industry	35	49	62	75	80
Electric Utility	1	15	46	97	88
Total	**37**	**69**	**121**	**198**	**195**
Increase					
Buildings	0	0	-3	-1	-1
Industry	1	6	9	8	2
Electric Utility	0	4	10	14	16
Total	**1**	**10**	**16**	**21**	**16**

With the increase in distributed generation capacity, MARKAL-GPRA06 directly reduces the investment in central gas and coal-fired generators. On the demand side, the heat generated from CHP further reduces fuel use for space and water heat in buildings, and for process steam in industrial applications. The higher overall efficiency (combined heat and power with no transmission loss) of these technologies results in long-term benefits in energy savings, energy-system costs, and carbon emission reductions (**Table 5.15**).

Table 5.15. FY06 Benefits Estimates for DE Program (MARKAL-GPRA06)

Annual Benefits	**2020**	**2030**	**2040**	**2050**
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.4	0.4	0.5	0.3
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	1.3	2.1	1.3	1.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	8	10	10	4
Security				
Oil Savings (mbpd)	0.08	0.03	0.05	0.03
Natural Gas Savings (quadrillion Btu/yr)	0.05	0.03	0.13	0.31
Capacity (gigawatts)	11	20	22	17
Total Displaced Need for New Electric Capacity (gigawatts)	9	25	22	17

Federal Energy Management Program

The Federal Energy Management Program (FEMP) aims to improve the overall energy efficiency in Federal Government buildings. As a deployment program, FEMP utilizes a broad spectrum of existing technologies and practices for achieving its goal. Therefore, it does not provide specific technological information in relating costs and energy savings under its activities. The program has a well-documented track record and provided estimates of future savings based on past results and current budgets. The savings by specific energy type projected by the program through the year 2030 are depicted in **Table 5.16**. For the period after 2030, the amount of energy displaced was held constant.

Table 5.16. FEMP Annual Energy Savings Projections

Year	Direct Electricity Displaced (billion kWh/yr)	Direct Natural Gas Displaced (billion CF/yr)	Direct Petroleum Displaced (million barrels/yr)	Direct Coal Displaced (million short tons/yr)
2006	0.45	1.37	0.11	0.022
2007	0.85	2.82	0.20	0.048
2008	1.22	4.29	0.30	0.071
2009	1.61	5.61	0.40	0.094
2010	2.01	6.88	0.49	0.115
2015	2.41	10.78	0.73	0.171
2020	2.98	13.80	0.97	0.220
2025	3.61	16.59	1.18	0.264
2030	4.09	19.63	1.38	0.307

In order to quantify the broader benefits of these savings in MARKAL-GPRA06, a single energy-conservation supply curve was modeled in the FEMP Case to reduce the energy service demands in "miscellaneous" commercial energy demand. The conservation curve was set to reflect the program's estimated delivered energy savings as shown in **Table 5.16**. Further adjustments were made to the case to roughly match the level of delivered energy savings for each fuel type.

The reduction in commercial energy demand effectively leads to lower investment in future capacity of demand devices servicing the Federal buildings, resulting in lower energy use in these devices. The reduction in electricity demand also leads to a slight drop in the electric generation by gas-fired power plants. FEMP also directly reduces fossil fuels used in commercial (government) buildings. The long-term systemwide benefits are provided in **Table 5.17**.

Table 5.17. FY06 Benefits Estimates for FEMP (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.06	0.08	0.07	0.06
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	2.4	3.5	3.5	3.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1	1	0	0
Security				
Oil Savings (mbpd)	0.00	0.00	0.00	0.01
Natural Gas Savings (quadrillion Btu/yr)	0.06	0.06	0.05	0.05

Geothermal Technologies Program

The main goals of the Geothermal Technologies Program are to reduce the cost of conventional geothermal technologies and to develop Enhanced Geothermal Systems (EGS) as a new source of electricity generation.

The Geothermal Technologies Program Case formulated in MARKAL-GPRA06 reflects the program goals for both conventional systems and EGS. For conventional geothermal systems, analysts changed the capital and operating and maintenance (O&M) costs to reflect program goals. However, EGS represents a new geothermal resource not represented in the MARKAL-GPRA06 model's reference case scenario. The program identified three types of potential geothermal reservoirs:

- Type I. Improvement prospects in existing commercial reservoirs
- Type II. Identified reservoirs with suboptimal characteristics
- Type III. Prospective sites that are not currently identified as hydrothermal prospects

Due to program activities, the capital and O&M costs of EGS systems are projected to decline. **Table 5.18** shows the estimated capital and O&M costs for the three types of EGS systems for 2000 and 2050.

The EGS sites projected under the program are grouped into a set of supply steps, and the discount rate of these technologies is set at 8 percent (instead of 10 percent for the power generation-sector average) to reflect the accelerated depreciation schedule permitted by the Internal Revenue Service for renewable-generation technologies. The EGS systems are modeled as centralized base-load generation.

Table 5.18. EGS Generation Assumptions

		2000 Cost		2050 Cost	
EGS Type	Projected Resource MWe	Capital Cost 2002$/kW	O&M 2002$/kW/yr	Capital Cost 2002$/kW	O&M 2002$/kW/yr
I	3,400	$2,486	$155	$949	$51
II	25,000	$2,859	$179	$1,091	$59
III	60,000	$3,232	$202	$1,233	$67

Geothermal plants compete directly with fossil fuel-based plants for both electricity generation and meeting peak power requirements. In MARKAL-GPRA06, EGS becomes more competitive, as its higher capital cost is offset by increased fossil fuel costs for gas and coal-fired generators, which increase during the projection period as overall fuel demand increases.

The improvements in capital and O&M costs lead to increased market penetration for conventional geothermal-generation capacity. Furthermore, EGS capacity, which was not available in the Baseline Case, shows significant market penetration between 2020 and 2050. **Table 5.19** shows both Baseline Case and Geothermal Technologies Program Case capacity, while **Table 5.20** shows geothermal power generation for both cases.

Table 5.19. Total Geothermal Capacity by Type (gigawatts)

	2000	2010	2020	2030	2040	2050
Baseline Case						
Conventional	2.9	3.9	7.7	8.2	11.4	10.9
EGS	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.9**	**3.9**	**7.7**	**8.2**	**11.4**	**10.9**
Geothermal Program Case						
Conventional	2.9	4.3	9.4	11.2	13.5	12.9
EGS	0.0	0.0	1.0	8.0	23.4	36.1
Total	**2.9**	**4.3**	**10.4**	**19.1**	**36.9**	**49.0**
Increase						
Conventional	0.0	0.4	1.7	3.0	2.1	1.9
EGS	0.0	0.0	1.0	8.0	23.4	36.1
Total	**0.0**	**0.4**	**2.7**	**11.0**	**25.5**	**38.0**

Table 5.20. Total Geothermal Power Generation by Type (billion kilowatt hours/year)

	2000	2010	2020	2030	2040	2050
Baseline Case						
Conventional	22	30	59	62	87	83
EGS	0	0	0	0	0	0
Total	**22**	**30**	**59**	**62**	**87**	**83**
Conventional	22	33	71	85	103	98
EGS	0	0	8	68	199	307
Total	**22**	**33**	**80**	**153**	**302**	**405**
Increase						
Conventional	0	3	13	23	16	15
EGS	0	0	8	68	199	307
Total	**0**	**3**	**21**	**90**	**215**	**322**

The projected market penetration of geothermal generation technologies in MARKAL-GPRA06's Geothermal Technologies Program Case directly displaces both natural gas and coal-fired generation beginning in 2010. The long-term benefits are shown in **Table 5.21**.

Table 5.21. FY06 Benefits Estimates for Geothermal Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.23	0.82	1.89	2.36
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	0.3	1.4	3.9	5.2
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	5	16	38	59
Security				
Natural Gas Savings (quadrillion Btu/yr)	0.13	0.43	0.98	0.15
Capacity (gigawatts)	3	11	25	38

Hydrogen, Fuel Cells, and Infrastructure Technologies Program

The Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) Program conducts research and development activities in hydrogen production, storage, and delivery; and transportation and stationary fuel cells. On the demand side, the program's activities focus on the introduction of fuel cells for both stationary and mobile applications. On the supply side, the program goal is to lower the production cost of hydrogen to a competitive level against petroleum products.

The representation of the Hydrogen, Fuel Cells, and Infrastructure Technologies Program in MARKAL-GPRA06 requires representation of fuel cell vehicles and transportation markets, hydrogen production and distribution infrastructure, and stationary fuel cell applications.

Fuel cell vehicles and transportation markets: Fuel cell vehicles are projected to compete with traditional petroleum and hybrid-electric vehicles for market share in the light-duty vehicle and commercial light truck markets. In MARKAL-GPRA06, analysts measure energy service demands for road transportation in vehicle miles traveled (VMT). Projected VMTs are taken directly from the *Annual Energy Outlook 2004* and extended past 2025, based on historical relationships between passenger and commercial VMTs and population and economic growth. Projected VMTs for cars, light trucks, and commercial light trucks are shown in **Table 5.22**.

Table 5.22. LDV and Commercial Light Truck Vehicle Miles Traveled (billion VMTs/year)

	2000	2010	2020	2030	2040	2050
Total Light-Duty Vehicles	2,355	3,041	3,768	4,507	5,086	5,277
Cars	1,498	1,686	2,007	2,415	2,600	2,568
Light Trucks	857	1,355	1,761	2,092	2,485	2,709
Commercial Light Trucks	69	79	101	129	157	167

For each time period, these demands are met by a mix of vehicle types selected by the model on the basis of total life-cycle costs. The vehicle type is characterized for each model year it is available for purchase. The Baseline Case cost and efficiencies of these vehicles were derived from the *AEO2004* assumptions, with cost and efficiency improvements extrapolated after 2025.

For the Hydrogen Program Case, capital costs, operation and maintenance costs, and fuel efficiency goals were provided by the HFCIT Program for hydrogen fuel cell vehicles from 2015 to 2050. As with the Vehicle Technologies Program, these were provided as ratios to conventional gasoline-powered vehicles of the same vintage. For example, a 2020 hydrogen-fuel cell passenger car with a cost ratio of 1.07 and an efficiency ratio of 2.54 would cost 7 percent more than the average 2020 traditional gasoline passenger car and have 154 percent higher fuel economy. The cost and efficiency assumptions for passenger cars, sport utility vehicles (SUVs), and commercial light trucks are shown in **Table 5.23**.

Table 5.23. Cost and Efficiency Assumptions for Fuel Cell Vehicles

	2010	2020	2030	2040	2050
Passenger Cars					
Cost Ratio to Conventional	n.a.	1.07	1.05	1.045	1.04
Efficiency Ratio to Conventional	n.a.	2.54	3.03	3.03	3.03
SUVs & Commercial Light Trucks					
Cost Ratio to Conventional	n.a.	1.07	1.05	1.045	1.04
Efficiency Ratio to Conventional	n.a.	2.49	2.96	2.96	2.96

Hydrogen production and distribution infrastructure: The HFCIT Program conducts research on developing cost-effective hydrogen production technologies from distributed natural gas reformers, as well as a variety of renewable sources, including biomass. For the Hydrogen Case, analysts modeled five hydrogen production technologies: distributed natural gas reformers, central natural gas reformers, central coal gasification, central biomass gasification, and central electrolytic production. Other renewable hydrogen-production technologies were not modeled, due to a greater degree of uncertainty in their costs. Nuclear hydrogen production technologies were also not represented in the MARKAL-GPRA06 model. We expect that more hydrogen production technologies will be modeled in future GPRA analysis, as the data becomes available.

Carbon sequestration pathways were available for central coal and natural gas hydrogen production. However, because no carbon policies were assumed, producers would not have an economic incentive to incur the incremental cost to sequester carbon generated from hydrogen production activities and, thus, no carbon was sequestered in this Program Case.

HFCIT Program goals were used to estimate capital and O&M costs and production efficiencies for distributed natural gas reformers and central biomass gasifiers and electrolytic production technologies. Assumptions for central coal and natural gas production technologies were adapted from *Hydrogen Production Facilities Plant Performance and Cost Comparisons, Final Report*.[3] The infrastructure requirements and operating costs for the widespread distribution of hydrogen vary widely by distance and method. As a simplifying assumption, a flat cost of $5.28 per MMBtu—or $0.65 per gallon of gasoline equivalent (gge)—was assumed for hydrogen distribution costs based on published data from NREL.[4] (Please note that one kilogram of hydrogen is roughly equivalent in energy content to one gallon of gasoline, and is often referred to as a gallon of gasoline equivalent (gge).) As with production technologies, we will be enhancing the representation of the distribution and fueling costs for hydrogen in future analysis

[3] *Hydrogen Production Facilities Plant Performance and Cost Comparisons, Final Report*, March 2002, prepared for NETL by Parsons Infrastructure and Technology Group.

[4] Amos W.A., Lane J.M., Mann M.K., and Spath P.L. *Update of hydrogen from biomass – determination of the delivered cost of hydrogen*, NREL, 2000.

as data becomes available. **Table 5.24** shows projected hydrogen costs by cost component for the Hydrogen Program Case.

(Please note that due to market factors affecting feedstock costs, the projected costs may not match HFCIT Program goals.).

Table 5.24. Hydrogen Production Costs by Technology and Component (2002 $/gge)

Central Coal								
Unit Costs	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Capital Costs				$0.49	$0.49	$0.49	$0.49	$0.49
O&M				$0.27	$0.27	$0.27	$0.27	$0.27
Feedstock Costs				$0.24	$0.24	$0.24	$0.26	$0.27
Plant Gate				$1.00	$1.01	$1.01	$1.03	$1.03
Distribution, Storage & Tax				$1.07	$1.07	$1.07	$1.07	$1.07
Total				$2.06	$2.06	$2.07	$2.08	$2.09
Distributed Natural Gas Reformer								
Unit Costs	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Capital Costs		$0.43	$0.43	$0.43	$0.43	$0.51		
O&M		$0.57	$0.57	$0.53	$0.55	$0.54		
Feedstock Costs		$1.02	$0.95	$0.90	$0.99	$1.11		
Plant Gate		$2.01	$1.95	$1.87	$1.96	$2.14		
Tax		$0.40	$0.40	$0.40	$0.40	$0.40		
Total		$2.42	$2.35	$2.27	$2.37	$2.55		
Central Natural Gas Reformer**								
Unit Costs	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Capital Costs				$0.16	$0.16	$0.16	$0.16	$0.16
O&M				$0.09	$0.08	$0.08	$0.08	$0.08
Feedstock Costs				$0.94	$0.96	$1.08	$1.09	$1.18
Plant Gate				$1.20	$1.21	$1.32	$1.33	$1.42
Distribution, Storage & Tax				$1.07	$1.07	$1.07	$1.07	$1.07
Total				$2.25	$2.28	$2.39	$2.39	$2.49
Central Biomass								
Unit Costs	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Capital Costs			$1.02	$0.99	$0.98	$0.98	$0.96	$0.96
O&M			$0.31	$0.31	$0.31	$0.31	$0.31	$0.31
Feedstock Costs			$0.33	$0.33	$0.33	$0.33	$0.33	$0.33
Plant Gate			$1.66	$1.63	$1.61	$1.61	$1.60	$1.60
Distribution & Storage*			$0.66	$0.66	$0.66	$0.66	$0.66	$0.66
Total			$2.33	$2.29	$2.29	$2.29	$2.27	$2.27
Central Electrolytic Production**								
Unit Costs	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Capital Costs				$0.12	$0.12	$0.12	$0.12	$0.12
O&M				$0.29	$0.29	$0.29	$0.29	$0.29
Feedstock Costs				$1.87	$2.18	$2.07	$2.06	$2.02
Plant Gate				$2.29	$2.60	$2.49	$2.47	$2.43
Distribution, Storage & Tax				$0.66	$0.66	$0.66	$0.66	$0.66
Total				$2.96	$3.26	$3.15	$3.14	$3.10

* Note: Hydrogen produced from biomass was assumed to receive preferential tax treatment.
** Central electrolytic and natural gas reformer production technologies did not penetrate in the Hydrogen Case. The above costs are based on a separate model run where this technology was required to produce.

Stationary fuel cell applications: In addition to use in vehicles, fuel cells also may be used for distributed electric generation. The HFCIT Program provided cost and performance goals for a 5kW CHP residential fuel cell system and a 200kW CHP commercial fuel cell system. The cost and performance parameters are shown in **Tables 5.25 and 5.26**

Table 5.25. 5 kW Residential Combined Heat and Power System Assumptions

Year	CHP System Efficiency	Electrical Efficiency	Thermal Recovery Efficiency	Equip. Cost (2002 $/kW)	Maint. Cost (2002$/kW-yr)
2005	68%	29%	54%	$2,274	$261
2010	72%	32%	59%	$1,780	$182
2015	72%	32%	59%	$1,780	$166
2025	72%	32%	59%	$1,780	$166

Table 5.26. 200 kW Commercial Combined Heat and Power System Assumptions

Year	CHP System Efficiency	Electrical Efficiency	Thermal Recovery Efficiency	Equip. Cost (2002 $/kW)	Maint. Cost (2002$/kW-yr)
2005	68%	29%	54%	$1,908	$229
2010	72%	36%	56%	$1,414	$127
2015	72%	36%	56%	$1,414	$127
2025	72%	36%	56%	$1,414	$127

Unlike other program cases, analysts ran the Hydrogen Program Case with both HFCIT and Vehicle Technologies Program assumptions. The rationale for this change is that the hydrogen fuel cell vehicle assumptions provided by the HFCIT Program assume that the Vehicle Technologies Program's hybrid systems and materials technologies R&D activities are successful. The market penetration of hydrogen fuel vehicles is somewhat limited by the increased competition from more-advanced hybrid vehicles. The market shares for LDVs are shown in **Table 5.27**.

Table 5.27. Light-Duty Vehicle Market Shares for the Hydrogen Case (% of VMT)

	2000	2010	2020	2030	2040	2050
Gasoline	99%	95%	78%	47%	14%	2%
Advanced Gasoline	0%	2%	7%	15%	10%	0%
Gasoline Hybrid	0%	4%	13%	27%	55%	79%
Diesel Hybrid	0%	0%	1%	5%	7%	1%
Hydrogen	0%	0%	1%	6%	14%	18%
Diesel & Other	1%	0%	0%	0%	0%	0%

Because the Hydrogen Program Case was run with both Hydrogen and Vehicle Technologies Programs' assumptions, analysts could not perform the calculation of benefits through the direct comparison of the Hydrogen Program Case and the Baseline Case. Instead, analysts based the calculation of oil and carbon benefits for the Hydrogen Program on the relative fuel/carbon intensities per vehicle miles traveled (VMTs) of hydrogen fuel cell vehicles.

To determine petroleum savings, analysts calculated the average consumption of petroleum products per billion vehicle miles traveled (oil intensity) for light-duty vehicles and commercial light trucks in the Baseline Case. Analysts then multiplied the Baseline Case oil intensity by the VMTs traveled by hydrogen fuel cell vehicles in the Hydrogen Program Case to estimate how much oil would be consumed if these VMTs were traveled by traditional gasoline vehicles. These calculations are shown in **Table 5.28**.

Table 5.28. Calculation of Petroleum Savings

	2010	2020	2030	2040	2050
Baseline Case Oil Intensities (TBtu/billion VMT)					
Light-Duty Vehicles	6.48	5.94	5.70	5.47	5.30
Light Trucks	10.26	9.35	8.89	8.77	8.14
Hydrogen Vehicle (VMTs/yr)					
Light-Duty Vehicles	0	40	271	725	1,009
Light Trucks	0	0	4	21	55
Petroleum Savings (TBtu/yr)					
Light-Duty Vehicles	0	238	1,543	3,967	5,344
Light Trucks	0	0	36	182	446
Total	**0**	**238**	**1,579**	**4,150**	**5,790**
Total (million barrels per day)	**0.00**	**0.11**	**0.75**	**1.96**	**2.74**

Carbon emission reductions accounted for both the reduced carbon emissions from burning gasoline, as well as increases in carbon emissions from the production of hydrogen, assuming no sequestration. If the hydrogen is produced at central facilities and the resulting carbon is sequestered, then the carbon savings will be accordingly larger in the projections below. These calculations are shown in **Table 5.29**.

Table 5.29. Calculation of Carbon Emission Reduction

	2010	2020	2030	2040	2050
Decreased CO2 Emissions from Decline in Gasoline Consumption					
Decrease in Gasoline Consumption (TBtu/yr)	0	5	30	77	103
Carbon Intensity of Gasoline (MT of Carbon per MMBtu)	0.0	0.0	0.7	3.5	8.6
Decline in Carbon (MMT/yr)	**0.0**	**4.6**	**30.5**	**80.2**	**112.0**
CO2 Emissions from Hydrogen Production					
Production of Hydrogen (TBtu/yr)	0.0	1	9	36	49
Carbon Intensity of Hydrogen (MT of Carbon per MMBtu)	0.0	0.0	0.2	1.6	3.9
Increase in Carbon (MMT/yr)	**0.0**	**1.4**	**9.6**	**37.6**	**52.4**
Net decrease in Carbon Emissions (MMT/yr)	**0.0**	**3.2**	**20.9**	**42.7**	**59.6**

The carbon intensity of hydrogen varies significantly, because of the varying carbon content and market shares of the feedstocks used to produce hydrogen. Hydrogen production by feedstock is shown in **Table 5.30**. It should be noted that this analysis was conducted with a single-region MARKAL-GPRA06 model, and that the price of feedstocks and distribution costs are based on national averages. There is significant variation in regional fuel costs in the United States, and it is likely that during the development of a hydrogen infrastructure, these differences would lead to a greater diversity of hydrogen-production technologies than shown below. Furthermore, this analysis was conducted with only a subset of the full range of hydrogen-production technologies. Thus, this analysis may be biased toward hydrogen production from coal. Future efforts are planned to correct for these modeling limitations.

Table 5.30. Hydrogen Production by Feedstock (% of total hydrogen production)

	2015	2020	2025	2030	2035	2040	2045	2050
Central Coal	0%	0%	0%	32%	53%	77%	79%	81%
Remote Natural Gas	0%	100%	85%	46%	28%	10%	0%	0%
Central Natural Gas	0%	0%	0%	0%	0%	0%	0%	0%
Central Biomass	0%	0%	15%	22%	19%	13%	21%	19%

Overall, the Hydrogen, Fuel Cells, and Infrastructure Technologies Program reduces gasoline consumption in the transportation sector through the deployment of hydrogen fuel cell LDVs and commercial light trucks (**Table 5.31**). Furthermore, the reduction in petroleum consumption leads to reduced carbon emissions. However, as noted above, these reductions in carbon emissions are partly offset due to carbon emissions from the production of hydrogen. The reductions in total energy-system costs arise from both the reduction in petroleum imports, as well as associated refining and distribution capacity. However, this is offset somewhat by the cost of establishing the hydrogen-production and -distribution infrastructure.

Table 5.31. FY06 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.09	1.04	3.03	4.32
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	-0.8	1.5	11.2	26.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	3	21	43	60
Security				
Oil Savings (mbpd)	0.11	0.75	1.96	2.73
Natural Gas Savings (quadrillion Btu/yr)	-0.04	-0.27	0.29	0.71

Industrial Technologies Program

The Industrial Technologies Program (ITP) covers a wide range of technologies, industries, and end-use applications. The overall goal of this program is to increase energy efficiency through R&D, as well as the deployment of new and improved technologies. The heterogeneity of the program's R&D activities makes it difficult to represent program activities explicitly in the MARKAL-GPRA06 framework. Instead, the projected ITP goals by various industries were aggregated into MARKAL-GPRA06 industrial energy-use demand categories as a set of conservation supply curves. Because this approach does not reflect economic competition nor interaction among program technologies, analysts reduced the off-line energy savings by an "integration factor" before these supply curves were constructed and input into the model (**Table 5.32**). The amount of the integration factor is based on how much program overlap or "integration" was captured by the off-line tools. The reduction is based on the expert judgment of the benefits analysis team.

Table 5.32. Industrial Program Integration Factors

Subprogram	Integration Factor
Industries of the Future	0%
Crosscutting R&D	10%
Industrial Assessment Centers	10%
Best Practices	0%

The potential savings represented in these conservation measures yield an overall reduction in delivered energy consumption, as shown in **Table 5.33**.

The reduction in electricity demand also leads to the reduction in coal and gas-based generation. Both conservation and reduction in electricity demand result in less investment in end-use devices and electric-generation capacity on the supply side (**Table 5.34**).

Table 5.33. Delivered Energy Savings in the Industrial Sector (trillion Btu/year)

	2010	2015	2020	2025	2030	2040	2050
Petroleum	44	103	140	110	112	90	-48
Natural Gas	135	422	990	1,166	1,062	399	173
Coal	4	29	54	79	105	105	62
Electricity	39	132	243	275	314	172	53
Heat	1	2	11	-19	0	-53	0
Renewable	0	0	0	0	0	0	0
Subtotal	222	687	1,438	1,612	1,593	713	239
Petrochemicals	5	31	86	84	69	38	12
Total	**227**	**718**	**1,524**	**1,696**	**1,662**	**751**	**251**

Table 5.34. FY06 Benefits Estimates for Industrial Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	2.07	2.26	1.26	0.45
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	13.6	15.7	9.8	3.2
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	34	42	23	8
Security				
Oil Savings (mbpd)	0.11	0.09	0.06	-0.01
Natural Gas Savings (quadrillion Btu/yr)	1.48	1.26	0.77	0.29
Displaced Capacity (gigawatts)	11	20	9	2

Solar Energy Technologies Program

The Solar Energy Technologies Program covers solar water-heating technologies, photovoltaic (PV)-based electricity generation and central solar thermal generation with energy storage. The program goal is to lower the cost and improve performance of these technologies.

The Solar Energy Technologies Program Case includes characterization of several solar water heaters with backup systems and PV systems for electricity generation. Analysts base the characterization of solar water heaters for households on the capital cost reductions and reduced reliance on backup fuels as projected in the program objectives. The use of backup fuels is modeled as the percentage of total use. Thus, a 2020 solar water heater would rely on its backup fuel for 45 percent of the time. Analysts assume the efficiency of the backup system to be the efficiency of the least-expensive traditional water heater of the same vintage. Because the MARKAL-GPRA06 model assumes that homes will utilize the same fuel for water heat that is used for space heat, it was assumed that solar water heaters could use natural gas, electricity, and heating oil as the backup fuel.

Analysts modeled both centralized and decentralized PV power and central solar thermal systems. The capital cost and O&M costs for both units are reduced to meet program goals. In addition, analysts set the discount rates of these technologies at 8 percent (instead of the industrial average of 10 percent) to reflect the accelerated depreciation schedule available for renewable-generation technologies. The total installed capacity of the decentralized units reflects the Million Solar Roofs installation goals for reducing end-use electricity demand from the central grid. Analysts model the centralized PV-generating systems to compete with conventional fossil fuel-based power plants. The cost and performance characteristics of the Solar Energy Technologies Program Case for water heaters, PV systems, and central thermal stations are shown in **Table 5.35**.

Solar photovoltaic capacity increases dramatically over the Baseline Case (**Table 5.36**). By 2050, the Solar Energy Technologies Program Case shows an additional 36.5 GW of photovoltaic capacity over the Baseline Case. Additionally, the Solar Energy Technologies Program Case shows an additional 25.4GW of central solar thermal generation. By 2050, the improved PV and thermal technologies generate an incremental 268 billion kWh of generation over the Baseline Case (**Table 5.37**).

Table 5.35. Solar Energy Technologies Program Assumptions

Photovoltaics

	Central Generation		Residential Buildings		Commercial Buildings	
Year	Installed Price (2002$/kW)	O&M (2002$/kW)	Installed Price (2002$/kW)	O&M (2002$/kW)	Installed Price (2002$/kW)	O&M (2002$/kW)
2005	$4,845	$51	$9,828	$170	$5,707	$170
2010	$3,178	$34	$6,224	$40	$4,362	$40
2015	$2,615	$22	$4,844	$28	$3,667	$28
2020	$2,054	$10	$3,464	$16	$2,912	$16
2025	$1,741	$9	$2,783	$10	$2,697	$10
2030	$1,596	$9	$2,567	$9	$2,481	$9
2035	$1,450	$8	$2,352	$9	$2,266	$9
2040	$1,374	$7	$2,235	$8	$2,214	$8
2050	$1,349	$7	$2,131	$7	$2,110	$7

Central Solar Thermal

Year	Installed Price (2002$/kW)	O&M (2002$/kW)	Annual Capacity Factor
2005	$5,031	$69	53%
2010	$3,565	$45	65%
2020	$2,501	$26	72%
2025	$2,234	$22	72%
2030	$2,024	$20	72%
2035	$1,909	$19	72%
2040	$1,855	$19	72%
2050	$1,825	$19	72%

Solar Water Heaters

Vintage	Installed Cost	Backup Fuel Use
2000	$2,844	50%
2010	$1,524	45%
2020	$1,320	40%
2030	$1,180	36%
2040	$2,844	33%

Table 5.36. Solar-Generation Capacity by Case and Type (gigawatts)

	2000	2010	2020	2030	2040	2050
Baseline Case						
Central PV	0.0	0.2	0.3	0.4	0.4	0.4
Distributed PV	0.1	1.6	4.8	14.6	25.2	26.3
Central Thermal	0.3	0.5	0.9	1.0	0.8	0.5
Total	**0.4**	**2.2**	**6.0**	**16.0**	**26.4**	**27.3**
Solar Program Case						
Central PV	0.0	0.1	0.1	0.1	1.0	1.0
Distributed PV	0.1	1.7	6.7	17.2	36.1	62.3
Central Thermal	0.3	0.5	2.5	9.4	19.7	25.9
Total	**0.4**	**2.2**	**9.3**	**26.7**	**56.8**	**89.1**
Increase						
Central PV	0.0	-0.1	-0.3	-0.4	0.6	0.6
Distributed PV	0.0	0.1	1.9	2.6	11.0	35.9
Central Thermal	0.0	0.0	1.6	8.4	18.9	25.4
Total	**0.0**	**0.0**	**3.2**	**10.6**	**30.4**	**61.9**

Table 5.37. Solar-Generation by Case and Type (Billion kWh)

	2000	2010	2020	2030	2040	2050
Baseline Case						
Central PV	0.0	0.4	0.8	0.5	0.9	0.9
Distributed PV	0.2	3.9	12.1	36.4	62.8	65.8
Central Thermal	1.1	1.7	3.0	3.5	2.7	1.8
Total	**1.3**	**6.0**	**15.9**	**40.5**	**66.5**	**68.5**
Solar Program Case						
Central PV	0.0	0.2	0.2	0.1	2.5	2.5
Distributed PV	0.2	4.1	16.8	42.9	90.2	155.5
Central Thermal	1.1	1.7	14.3	62.0	133.9	178.4
Total	**1.3**	**5.9**	**31.2**	**105.0**	**226.6**	**336.5**

	2000	2010	2020	2030	2040	2050
Increase						
Central PV	0.0	-0.2	-0.7	-0.5	1.6	1.6
Distributed PV	0.0	0.2	4.7	6.5	27.4	89.7
Central Thermal	0.0	0.0	11.3	58.5	131.2	176.7
Total	**0.0**	**0.0**	**15.3**	**64.5**	**160.2**	**268.0**

Central and distributed PV and central thermal generation technologies in the Solar Energy Technologies Program Case directly displace central gas and coal-fired generation capacity. However, because of the PV technologies' lower availability factor and reduced contribution to peak power supply, the total gas and coal capacity replaced is less than the installed solar capacity. Benefits estimates for the Solar Energy Technologies Program are shown in **Table 5.38.**

Table 5.38. FY06 Benefits Estimates for Solar Energy Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.18	0.56	1.23	1.71
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	0.4	1.7	2.5	2.3
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	4	11	23	36
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.10	0.29	0.71	0.62
Capacity (gigawatts)	3	11	30	62

Vehicle Technologies Program

The Vehicle Technologies Program[5] consists of Hybrid Systems R&D, Advanced Combustion R&D, Heavy Systems R&D, and Materials Technologies R&D. The general goal of these R&D activities is to improve the efficiency and lower the cost of road vehicles.

Energy-service demands for road transportation are measured in vehicle miles traveled (VMT). Projected VMTs are taken directly from the *Annual Energy Outlook 2004 (AEO 2004)* and extended past 2025, based on historical relationships between passenger and commercial VMTs, and population and economic growth. Projected VMTs for cars, light trucks[6], commercial light trucks,[7] and heavy trucks are shown in **Table 5.39**.

[5] The Vehicle Technologies Program is run by the Office of FreedomCAR and Vehicle Technologies.
[6] Light trucks include trucks with a gross vehicle weight under 8,500 pounds and may include pickups, vans, or sport utility vehicles (SUVs).
[7] Commercial light trucks are light trucks with a gross vehicle weight between 8,500 and 10,000 pounds and may include pickups, vans, or SUVs.

Table 5.39. Projected Vehicle Miles Traveled by Vehicle Class (billion VMTs/year)

Vehicle Class	2000	2010	2020	2030	2040	2050
Light-Duty Vehicles	2,355	3,041	3,768	4,507	5,086	5,455
Cars	1,498	1,686	2,007	2,415	2,600	2,502
Light Trucks	857	1,355	1,761	2,092	2,485	2,953
Commercial Light Trucks	69	79	101	129	157	176
Heavy Trucks	207	242	313	392	461	506

For each time period, these demands are met by a mix of vehicle types, selected by the model on the basis of total life-cycle costs. The vehicle type is characterized for each model year that it is available for purchase. The Baseline Case cost and efficiencies of these vehicles were derived from the *AEO2004* assumptions, with cost and efficiency improvements extrapolated for periods after 2025.

For the Vehicle Technologies Program Case, the costs and efficiencies for hybrid (HEV) and advanced diesel vehicles were changed for passenger cars, sport utility vehicles (SUVs), commercial light trucks, and commercial heavy trucks. These changes reflect the results of the fuel combustion, hybrid systems, and materials R&D activities. Alternate cost and efficiency assumptions were provided for gasoline and diesel hybrid vehicles, as well as advanced diesel engines for use in passenger cars, SUVs, and commercial light trucks for the period 2010 to 2050. Cost and efficiency assumptions for advanced diesel and diesel hybrid Class 3-6 trucks and advanced diesel Class 7-8 trucks also were provided for the period 2010 to 2050. The cost and efficiency assumptions were provided from the off-line analysis as ratios to conventional gasoline or diesel internal combustion engine-powered vehicles of that vintage.

For example, a 2020 gasoline-hybrid passenger car with a cost ratio of 1.05 and an efficiency ratio of 1.96 would cost 5 percent more than the average 2020 traditional gasoline passenger car and have 96 percent better fuel economy. MARKAL does not currently distinguish the different heavy truck classes and usage profile (i.e. short haul vs. long haul). For the Vehicle Technologies Program Case, the analysts created a single advanced truck technology based on the cost and efficiency assumptions and market shares for the different truck classes and usage profile that were calculated in the off-line analysis. The cost and efficiency assumptions for passenger cars, SUVs, and commercial light trucks are shown in **Table 5.40**, while **Table 5.41** shows these assumptions for heavy trucks.

Table 5.40. Cost and Efficiency Assumptions for Light-Duty Vehicles

	2010	2020	2030	2040	2050
Passenger Cars					
Cost Ratio to Conventional in Same Year					
Advanced Gasoline	1.01	1.02	1.03	1.02	1.01
Gasoline HEV	1.07	1.05	1.03	1.02	1.02
Advanced Diesel	1.05	1.03	1.03	1.02	1.02
Diesel HEV	1.10	1.08	1.06	1.04	1.03
Efficiency Ratio to Conventional in Same Year					
Advanced Gasoline	1.01	1.09	1.25	1.25	1.25
Gasoline HEV	1.50	1.96	2.22	2.22	2.22
Advanced. Diesel	1.40	1.60	1.80	1.80	1.80
Diesel HEV	1.60	2.05	2.36	2.36	2.36

	2010	2020	2030	2040	2050
Light Trucks and SUVs					
Cost Ratio to Conventional in Same Year					
Advanced Gasoline	1.01	1.03	1.03	1.02	1.01
Gasoline HEV	1.07	1.05	1.03	1.02	1.02
Advanced Diesel	1.04	1.03	1.02	1.02	1.02
Diesel HEV	1.10	1.08	1.06	1.04	1.03
Efficiency Ratio to Conventional in Same Year					
Advanced Gasoline	1.05	1.23	1.37	1.37	1.37
Gasoline HEV	1.40	1.85	2.00	2.00	2.00
Advanced Diesel	1.35	1.50	1.70	1.80	1.80
Diesel HEV	1.50	1.90	2.13	2.13	2.13

Table 5.41. Cost and Efficiency Assumptions for Heavy Trucks*

	2010	2020	2030	2040
Class 7-8 – Diesel				
Efficiency Ratio – Short Haul	1.30	1.45	1.45	1.45
Efficiency Ratio – Intermediate Haul	1.50	1.61	1.61	1.61
Efficiency Ratio – Long Haul	1.50	1.76	1.76	1.76
Cost Ratio	1.23	1.10	1.05	1.05
Class 3-6 – Diesel				
Efficiency Ratio	1.02	1.37	1.37	1.37
Cost Ratio	1.12	1.04	1.04	1.04
Class 3-6 – Diesel Hybrid				
Efficiency Ratio	1.70	1.70	1.70	1.70
Cost Ratio	1.42	1.12	1.06	1.06

* Note: Ratios are compared to conventional vehicles in the same year.

The oil savings generated from the Vehicle Technologies Program are attributable to the market penetration of more efficient LDVs and heavy trucks. **Table 5.42** shows the market shares for traditional gasoline and alternative light-duty vehicles for the Vehicle Technologies Program Case, while **Table 5.43** shows transportation-sector petroleum consumption for the Baseline and Vehicles Technologies Program Case.

The reduction in transportation-sector petroleum consumption (**Table 5.44**) is due to both increased market share and fuel efficiency of alternative vehicles, particularly hybrid-electric vehicles. The reductions in total energy-system costs arise from both the reduction in petroleum imports, as well as associated refining and distribution capacity.

Table 5.42. Light-Duty Vehicle Market Shares for the Vehicles Technologies Program Case (% of total fleet)

	2000	2010	2020	2030	2040	2050
Gasoline	99%	95%	79%	53%	25%	9%
Advanced Gasoline	0%	2%	7%	15%	12%	0%
Gasoline Hybrid	0%	4%	13%	27%	55%	89%
Diesel Hybrid	0%	0%	1%	5%	7%	2%
Diesel & Other	1%	0%	0%	0%	0%	0%

Table 5.43. Petroleum Consumption by Vehicle Class and Case (trillion Btu/year)

	2000	2010	2020	2030	2040	2050
Baseline Case						
Light-Duty Vehicles	15,725	19,697	22,376	26,234	28,768	29,871
Commercial Light Trucks	788	811	944	1,129	1,333	1,383
Heavy Trucks	4,236	5,102	6,458	7,677	8,805	9,456
Vehicle Technologies Program Case						
Light-Duty Vehicles	15,725	19,564	21,169	21,431	18,583	15,527
Commercial Light Trucks	788	794	763	682	728	776
Heavy Trucks	4,236	5,091	5,949	5,879	6,377	6,680
Savings						
Light-Duty Vehicles	0	133	1,207	4,803	10,185	14,344
Commercial Light Trucks	0	16	181	447	605	608
Heavy Trucks	0	11	509	1,798	2,428	2,776
Total Transportation Sector	**0**	**160**	**1,897**	**7,047**	**13,218**	**17,728**

Table 5.44. FY06 Benefits Estimates for Vehicle Technologies Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	2.01	7.67	14.17	18.92
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	2.1	28.4	94.6	177.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	38	148	272	365
Security				
Oil Savings (mbpd)	0.97	3.59	6.59	8.77
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.03	0.16	0.31

Weatherization and Intergovernmental Program

The Weatherization and Intergovernmental Program (WIP) Case formulated in MARKAL-GPRA06 focuses on deployment programs that have an impact on the energy consumption in the residential sector and vehicle fuel use. Projected program goals of the Weatherization Assistance Program, State Energy Program, Rebuild America, and Code Training and Assistance are transformed into conservation-supply curves that reduce the heating and cooling loads in households benefiting from these programs. Other deployment programs aimed at promoting individual technologies were either modeled by adjusting the technologies discount rate or by applying lower bounds on the technology investment based on off-line analysis.

Table 5.45 depicts the projected funds and program goals of the Weatherization Assistance Program used to develop the MARKAL-GPRA06 input. Analysts distributed the aggregated market potentials for Weatherization Assistance Program energy savings in proportion to household savings in the four MARKAL-GPRA06 residential regions: Northeast, Midwest, South, and West.

Table 5.45. Weatherization Assistance Program Projected Budget and Goals[8]

Year	Cost per House	No. Houses Weatherized[9]	Annual Total Houses Weatherized	SITE Energy Savings (TBtu/yr)	Single-Family Home Savings (TBtu/yr)	Mobile Home Savings (TBtu/yr)	Multi-family Home Savings (TBtu/yr)
2006	$2,390	189,650	189,650	5.93	3.80	1.19	0.95
2010	$2,444	184,267	934,764	29.21	18.70	5.84	4.67
2015	$2,458	182,983	1,849,681	57.76	36.97	11.55	9.24
2020	$2,458	182,983	2,764,599	86.31	55.24	17.26	13.81
2025	$2,458	182,983	2,744,752	85.64	54.81	17.13	13.70
2030	$2,458	182,983	2,744,752	85.64	54.81	17.13	13.70

As with the Weatherization Assistance Program, the State Energy Program, Rebuild America, Inventions and Innovations, and Code Training and Assistance energy savings goals were transformed into conservation-supply curves that reduce the heating and cooling loads in households benefiting from these programs. However, due to the potential overlap in target markets for these programs, the projected energy savings were reduced by 30 percent. For more information about these programs and projected savings, please refer to **Appendix K.** Analysts modeled the Clean Cities Program by applying lower bounds on the investment of alternative-fueled vehicles based on program estimates of market penetration, as shown in **Table 5.46**.

Table 5.46. Projection of Baseline Case and Clean Cities Program Case Alternative-Fueled Vehicles (number of vehicles on the road)

	Cumulative No. of Vehicles	Type of Fuel	% of Fleet
2010	423,178	Natural Gas	44%
2015	474,185	LPG	17%
2020	676,235	Ethanol	34%
2025	856,370	Electric	4%

Tables 5.47 and 5.48 depict the energy savings by end-use demand and fuel type in the residential and commercial sectors respectively, while **Table 5.49** reports the reduction in energy consumption in the industrial sector due to the I&I Program.

Table 5.47. Delivered Energy Demand Reductions in the Residential Sector (trillion Btu/year)

	2010	2020	2030	2040	2050
Reductions by Demand Service					
Space Heating	53	138	165	162	154
Space Cooling	2	9	22	21	20
Water Heating	1	2	-2	0	1
Lighting	40	168	201	188	133
Other	0	0	0	0	0
Total	**96**	**317**	**386**	**371**	**308**
Reduction by Fuel					
Petroleum	0	0	1	0	-16
Natural Gas	87	132	150	158	144
Coal	1	0	0	-1	1
Electricity	8	185	235	215	179
Total	**96**	**317**	**386**	**372**	**308**

[8] See Appendix K for additional documentation on these goals.
[9] Includes homes weatherized using leveraged state and local funds.

Table 5.48. Delivered Energy Demand Reductions in the Commercial Sector (trillion Btu/year)

	2010	2020	2030	2040	2050
Reductions by Demand Service					
Space Heating	19	34	40	35	33
Space Cooling	4	10	11	9	8
Water Heating	3	4	6	5	5
Lighting	24	70	99	99	99
Other	0	0	0	0	0
Total	**50**	**117**	**157**	**148**	**144**
Reduction by Fuel					
Petroleum	5	0	0	5	0
Natural Gas	13	31	25	1	5
Coal	0	0	6	7	7
Electricity	32	87	126	141	132
Total	**50**	**117**	**157**	**154**	**144**

Table 5.49. Delivered Energy Demand Reductions in the Industrial Sector (trillion Btu/year)

	2010	2020	2030	2040	2050
Petroleum	3	0	4	8	61
Natural Gas	16	97	127	130	66
Coal	0	0	0	0	0
Electricity	3	31	31	31	31
Total	**22**	**128**	**162**	**169**	**158**

The reduction in electricity demand in residential space conditioning and lighting also leads to the reduction in gas-based generation in the long run. Both conservation and reduction in electricity demand result in fewer investments in end-use devices and electric-generation capacity on the supply side. This is another factor attributable to the overall reduction in energy-system cost and carbon emissions, in addition to direct energy savings (**Table 5.50**).

Table 5.50. FY06 Benefits Estimates for Weatherization and Intergovernmental Program (MARKAL-GPRA06)

Annual Benefits	**2020**	**2030**	**2040**	**2050**
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	1.23	1.43	1.29	1.10
Economic				
Energy System Cost Savings (billion 2002 dollars/yr)	11.6	15.8	17.1	17.1
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	22	29	24	23
Security				
Oil Savings (mbpd)	0.02	0.03	0.03	0.06
Natural Gas Savings (quadrillion Btu/yr)	0.85	0.66	0.80	0.40
Displaced Capacity (gigawatts)	12	21	17	16

Wind Technologies Program

The Wind Program R&D aims to reduce capital and O&M costs and improve capacity factors for wind turbines. The program goals are represented in the MARKAL-GPRA06 model by changing the capital and O&M costs and capacity factors for wind turbines to coincide with the program goals as represented in **Table 5.51**.

Table 5.51. Wind-Power Assumptions

	2010	2020	2030	2040	2050
Capital Costs with Contingency Factor (2002 $/kW)					
Onshore					
Class 6	893	819	788	767	746
Class 5	893	819	788	767	746
Class 4	982	893	866	856	840
Shallow Offshore					
Class 6	1,129	1,070	1,016	989	962
Class 4	1,129	1,070	1,016	989	962
Deep Offshore					
Class 7	1,723	1,177	1,024	977	945
Class 6	1,723	1,177	1,024	977	945
Class 4	1,723	1,177	1,024	977	945
Fixed O&M Cost (2002 $/kW/year)					
Onshore	20.0	15.0	13.8	13.2	12.8
Shallow Offshore	47.0	38.0	36.0	34.0	32.0
Deep Offshore	49.3	41.0	39.0	37.0	36.0
Capacity Factor					
Onshore					
Class 6	50%	51%	52%	52%	52%
Class 5	44%	46%	46%	46%	46%
Class 4	40%	47%	48%	48%	48%
Shallow Offshore					
Class 6	45%	50%	50%	50%	50%
Class 4	36%	40%	40%	40%	40%
Deep Offshore					
Class 7	55%	60%	60%	60%	60%
Class 6	45%	50%	50%	50%	50%
Class 4	36%	40%	40%	40%	40%

The discount rate for wind generators is set at 8 percent (instead of the utility average of 10 percent) to reflect the accelerated depreciation schedule available for renewable-generation technologies. Wind generators are modeled as centralized plants to compete with fossil fuel-based plants.

The improvements in wind turbines result in a significant increase in installed wind generation capacity over the Baseline Case. Total wind generation increases due to both the increase in total installed capacity and the increase in capacity factors. The change in wind capacity and generation is shown in **Table 5.52**.

Table 5.52. Total Wind Capacity and Generation

	2000	2010	2020	2030	2040	2050
Wind Capacity (GW)						
Reference Case						
Onshore	2.5	7.8	13.5	12.8	18.6	14.8
Offshore	0.0	0.2	1.7	4.9	9.3	13.2
Total	**2.45**	**8.01**	**15.13**	**17.66**	**27.96**	**27.97**
GPRA Scenario						
Onshore	2.5	10.9	37.5	80.9	112.6	112.6
Offshore	0.0	0.2	1.7	4.9	11.7	26.5
Total	**2.5**	**11.1**	**39.2**	**85.7**	**124.3**	**139.1**
Increase						
Onshore	0.0	3.0	24.0	68.0	94.0	97.8
Offshore	0.0	0.0	0.0	0.0	2.4	13.3
Total	**0.0**	**3.0**	**24.0**	**68.0**	**96.3**	**111.1**
Wind Generation (Billion kWh)						
Reference Case						
Onshore	10	31	57	55	83	66
Offshore	0	1	8	24	49	71
Total	**10**	**32**	**65**	**79**	**132**	**137**
GPRA Scenario						
Onshore	10	46	171	372	519	521
Offshore	0	1	10	28	69	156
Total	**10**	**47**	**180**	**400**	**588**	**677**
Increase						
Onshore	0	14	114	316	436	455
Offshore	0	0	1	5	20	85
Total	**0**	**14**	**115**	**321**	**457**	**540**

In the Wind Technologies Program Case, wind generation directly displaces gas-fired and coal-based generation. However, because of wind's lower availability and reduced contribution to peak, the total gas and coal generation capacity replaced is less than the wind capacity installed. The estimated benefits for the Wind Program are shown in **Table 5.53**.

Table 5.53. FY06 Benefits Estimates for Wind Program (MARKAL-GPRA06)

Annual Benefits	2020	2030	2040	2050
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	1.14	2.81	3.71	3.66
Economic				
Energy-System Cost Savings (billion 2002 dollars/yr)	1.2	1.2	3.4	3.7
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	21	60	73	87
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.67	1.09	1.99	0.50
Capacity (gigawatts)	24	68	96	111

Box 5.1—The MARKAL Model

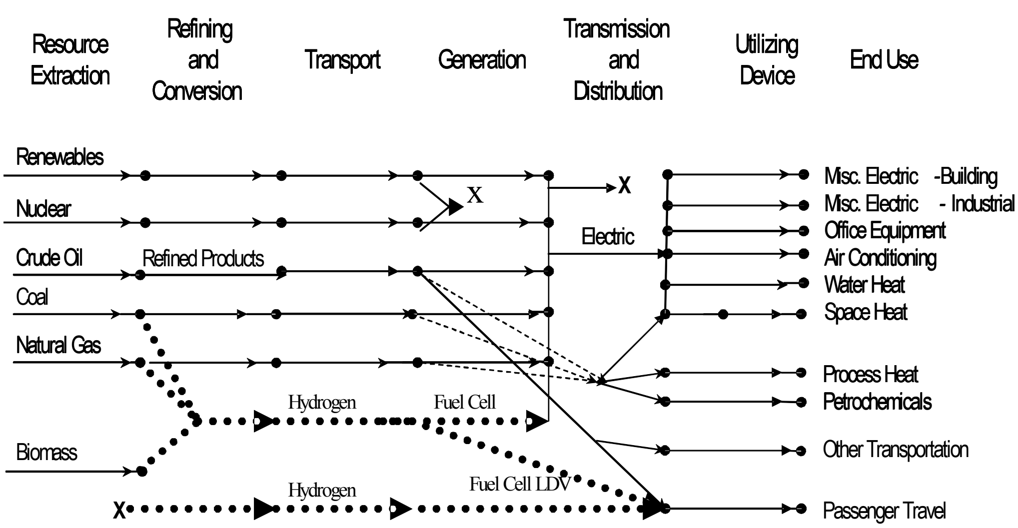
The U.S. MARKAL model is a technology-driven linear optimization model of the U.S. energy system that runs in five-year intervals over a 50-year projection period. MARKAL provides a framework to evaluate all resource and technology options within the context of the entire energy/materials system, and captures the market interaction among fuels to meet demands (*i.e.*, competition between gas and coal for electric generation). The model explicitly tracks the vintage structure of all capital stock in the economy that produces, transports, transforms, or uses energy.

In MARKAL, the entire energy system is represented as a network, based on the reference energy system (RES) concept. The RES depicts all possible flows of energy from resource extraction, through energy transformation, distribution, and transportation; to end-use devices that satisfy the demands of useful energy services (e.g., vehicle miles traveled, lumen-second in lighting). **Figure 5.2** illustrates a simplified RES in graphical form. The U.S. MARKAL has detailed technical representations of four end-use sectors (residential, commercial, industrial, and transportation), as well as fossil fuel and renewable resources, petroleum refining, power generation, hydrogen production, and other intermediate conversion sectors. Cross comparisons of MARKAL outputs provide detailed technical and economic information to use in estimating the programs' benefits.

Technology choice in the MARKAL framework is based on the present value of the marginal costs of competing technologies in the same market sector. On the demand side, the marginal cost of demand devices is a function of levelized capital cost, O&M cost, efficiency, and the imputed price of the fuel used by these devices. For a specific energy-service demand and time period, the sum of the energy-service output of competing technologies has to meet the projected demand in that period. The relative size of the energy-service output (market share) of these technologies depends not only on their individual characteristics (technical, economic, and environmental), but also on the availability and cost of the fuels (from the supply side) they use. The actual market size of a demand sector in a future time period depends on the growth rate of the demand services and the stock turnover rate of vintage capacities. MARKAL dynamically tracks these changes and defines future market potentials. Another factor considered in MARKAL, which affects the market penetration of a specific demand device, is the sustainability of the expansion in the implied manufacturing capacity to produce these devices. For EERE R&D programs that have independently projected the market potentials of their technologies, an initial market penetration (combined with an annual growth rate limit) was imposed in MARKAL to replicate these potentials for assessing the benefits of these technologies.

On the supply side, technology choice made in MARKAL is based on the imputed price of the energy products and the marginal cost of using these products downstream in the demand sectors. The cost of resource input for production (exogenously projected in MARKAL) such as imported oil prices and cost of biomass feedstock, together with the characteristics of supply technologies (including electricity generation) determine the market share of a particular fuel type (including renewables) and the technology that produces it. The supply-demand balance achieved for all fuels under the least energy-system cost represents a partial equilibrium in the energy market.

Figure 5.1. An Illustrative Reference Energy System



Appendix A – GPRA06 Benefits Estimates: MARKAL and NEMS Model Baseline Cases

MARKAL Baseline Case Assumptions and Projections

Economic and Demographic Assumptions

The reference case projection used to evaluate the impact of the EERE portfolio was benchmarked to EIA's *2004 Annual Energy Outlook* (AEO) for the period between 2000 and 2025. To the extent possible, the same input data and assumptions were used in MARKAL as were used to generate the AEO reference case. For example, the macroeconomic projections for GDP, housing stock, commercial square footage, industrial output, and vehicle miles traveled were taken from the AEO. At the sector level, both supply-side and demand-side technologies were characterized to reflect the AEO assumptions, in cases where the representation of technologies is similar between MARKAL and the National Energy Modeling System (NEMS). The resulting projections track closely with the AEO at the aggregate level, although they do not match exactly at the end-use level. For the period after 2025, various sources were drawn upon to compile a set of economic and technical assumptions. The primary economic drivers of GDP and population were based on the real GDP growth rate from the Congressional Budget Office's *Long-Term Budget Outlook* and population growth rates from the Social Security Administration's *2003 Annual Report* to the Board of Trustees.

In the reference case, GDP is projected to increase at an average annual rate of 2.8 percent 2000 to 2025, and then slow to an average annual rate of 2.2 percent from 2025 to 2050. The population growth rate is projected to decline from an average annual rate of 0.9 percent between 2000 and 2025 to 0.5 percent from 2025 to 2050. The reference case macroeconomic assumptions are shown in **Table 1.**

Table 1. Reference Case Macroeconomic and Demographic Assumptions

												Annual Growth Rates		
	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'00-'25	25-'50	'00-'50
GDP (Bill. 2002$)	$10,163	$11,502	$13,479	$15,592	$17,900	$20,478	$23,169	$26,023	$29,014	$32,021	$35,267	2.8%	2.2%	2.5%
Population (Million)	275.7	296.8	309.3	321.9	334.6	347.5	359.4	370.4	378.8	384.9	390.4	0.9%	0.5%	0.7%
Total Households (Million)	105.2	113.7	119.8	126.1	132.0	137.8	143.8	148.1	151.5	153.9	156.2	1.1%	0.5%	0.8%
Commercial Floorspace (Bill. sq ft)	68.5	77.6	83.8	89.9	95.9	101.8	108.0	114.1	120.2	126.0	131.9	1.6%	1.0%	1.3%
Industrial Production (2000=100)	100	99	113	128	146	166	186	207	229	250	274	2.0%	2.0%	2.0%
Light Duty Vehicle Miles Traveled (Bill. VMT)	2,355	2,709	3,041	3,409	3,768	4,173	4,507	4,829	5,086	5,277	5,455	2.3%	1.1%	1.7%

Assumptions on Energy Prices

Table 2 shows projected energy prices for the reference case. Natural gas prices are projected to drop between 2000 and 2005, and then increase at nearly 1 percent per year from 2005 to 2025 before increasing amounts of arctic gas and LNG imports limit the average annual increase to 1.3 percent from 2025 to 2050. Crude oil prices are also projected to drop between 2000 and 2005, increase at average annual rates of 0.8 percent between 2005 and 2025, and 0.8 percent per year thereafter.

Average mine mouth coal prices are projected to continue to decline by about 0.2 percent a year between 2000 and 2025, due to increasing productivity gains and a continued shift to less labor intensive Western coal production. However, coal prices are projected to increase at an average rate of 1 percent per year after 2025, due to increased demands, gradually increasing mine depths and a saturation of labor productivity gains.

Table 2. Reference Case Energy Prices

												Annual Growth Rates		
2002 $s	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'00-'25	25-'50	'00-'50
World Oil Price ($/bbl)	$28.61	$22.95	$24.15	$24.98	$26.25	$26.89	$28.03	$28.80	$29.94	$31.15	$32.42	-0.2%	0.8%	0.3%
Natural Gas Wellhead Price ($/Mcf)	$3.71	$3.49	$3.38	$4.30	$4.19	$4.17	$3.92	$4.36	$5.10	$5.31	$5.79	0.5%	1.3%	0.9%
Coal Minemouth Price ($/short ton)	$17.30	$17.20	$16.65	$16.27	$16.17	$16.54	$17.43	$17.88	$18.89	$19.96	$21.18	-0.2%	1.0%	0.4%
Average Wholesale Electricity Price (¢/kWh)	4.0¢	4.4¢	4.9¢	5.7¢	6.0¢	5.7¢	4.3¢	5.3¢	5.0¢	5.1¢	5.1¢	1.4%	-0.4%	0.5%

Primary Energy Consumption

As a result of slightly increasing energy prices, technology improvements, and shifts within the economy, energy demand is projected to increase more slowly than GDP. As shown in **Table 3**, total primary energy use is projected to increase at a rate of 1.3 percent per year from 2000 to 2025, and at an average annual rate of 0.4 percent between 2025 and 2050. By 2050, total primary energy consumption is projected to reach 152 quadrillion Btus (quads). Overall, the energy consumption to GDP ratio is projected to decline by 1.6 percent per year from 2000 to 2050, while total carbon emissions increase by 1.4 percent per year over the same period.

Table 3. Primary Energy Consumption, Energy Intensity and Carbon Emissions

												Annual Growth Rates		
	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'00-'25	25-'50	'00-'50
Petroleum	39.8	40.9	44.9	48.5	51.3	54.8	57.6	59.9	61.9	63.4	64.6	1.3%	0.7%	1.0%
Natural Gas	22.0	24.1	26.6	29.0	30.8	31.5	31.8	33.6	35.1	35.8	36.6	1.4%	0.6%	1.0%
Coal	22.4	23.5	25.4	26.5	28.3	31.3	33.5	34.3	35.1	35.6	35.9	1.3%	0.5%	0.9%
Nuclear	8.1	8.4	8.4	8.6	8.6	8.6	8.5	6.6	6.0	4.2	2.7	0.2%	-4.5%	-2.2%
Renewables	6.5	7.6	8.0	8.9	9.5	9.8	10.1	11.5	11.7	11.9	12.1	1.7%	0.9%	1.3%
Total Primary Energy	**98.8**	**104.4**	**113.3**	**121.4**	**128.6**	**136.0**	**141.5**	**145.9**	**149.8**	**151.0**	**151.8**	**1.3%**	**0.4%**	**0.9%**
Energy/GDP (Thos. Btu/ '01$ GDP)	9.8	9.1	8.4	7.8	7.2	6.6	6.1	5.6	5.2	4.7	4.3	-1.6%	-1.7%	-1.6%
Carbon Emissions (MMT)	1,594	1,678	1,840	1,965	2,089	2,236	2,346	2,435	2,512	2,562	2,600	1.4%	0.6%	1.0%

Crude oil's share of total energy consumption is projected to increase from 40 percent in 2000 to nearly 43 percent in 2050. The natural gas share is projected to grow from 22 percent to 24 percent over the same period. Coal generation is projected to increase slightly from a 23 percent share in 2000 to nearly 24 percent in 2050. Almost all existing nuclear generation capacity is assumed to retire between 2025 and 2050. However, 29 GW of new nuclear capacity is projected to be added between 2025 and 2050. The share of renewable energy is also projected to be relatively stable at between seven and eight percent throughout the projection period.

As the MARKAL reference case projection was calibrated to the *2004 Annual Energy Outlook*, the natural gas supply assumptions are more pessimistic than in the 2003 AEO. By 2050, LNG imports and Arctic gas supplies account for 38 percent of gas supply. **Figure 1** shows natural gas supplies by source for the reference case.

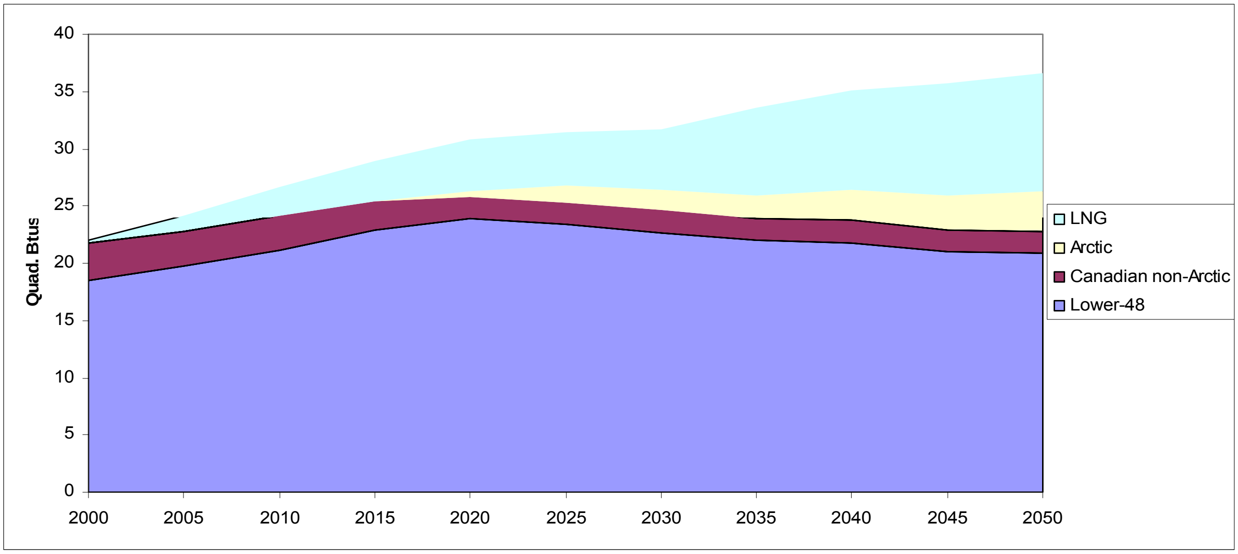
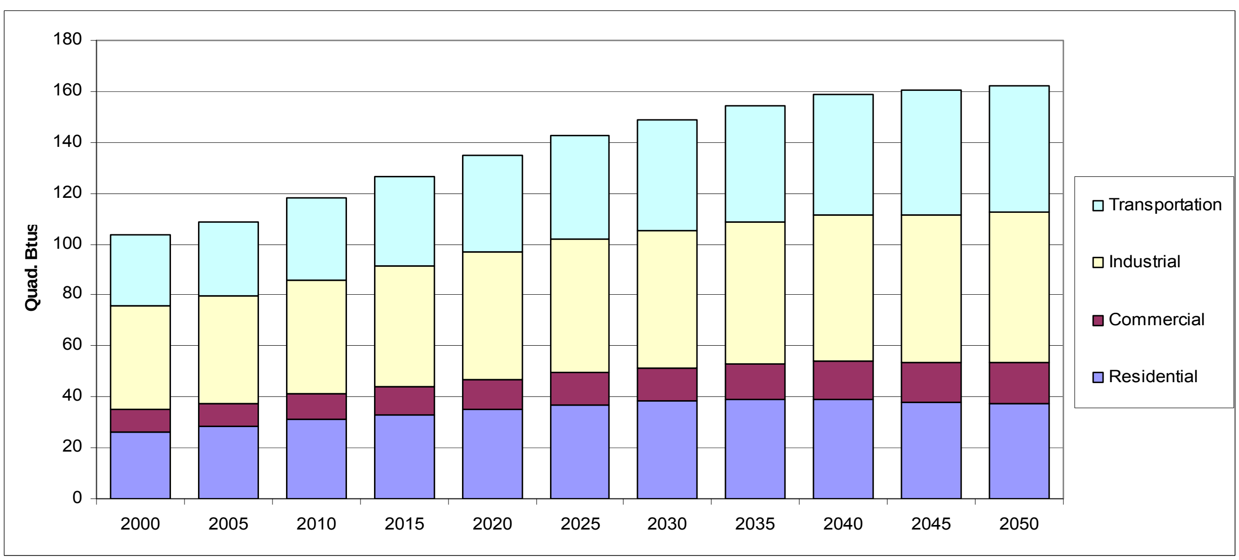


Figure 1. Reference Case Natural Gas Supply by Source

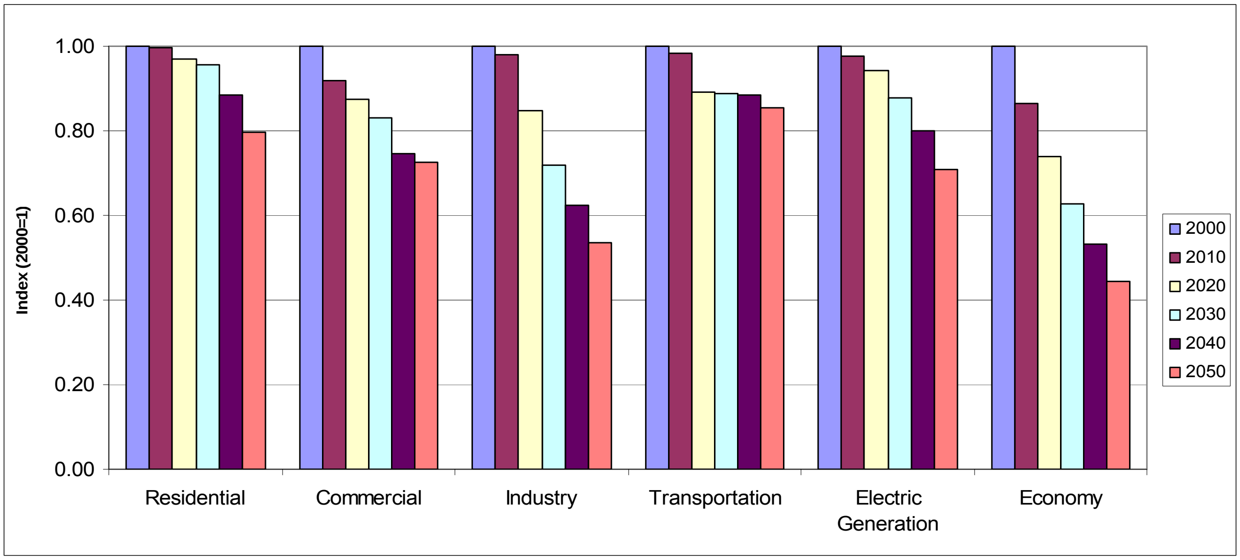
End-Use Energy Demand

The sectoral breakout of energy use, shown in **Figure 2**, demonstrates that transportation energy demand is projected to increase most rapidly, at 1.2 percent per year, from 2000 to 2050; while residential and industrial energy demand increases most slowly, at 0.7 percent per year. Commercial energy demand is projected to grow at a rate of 1.1 percent per year. The growth rates in energy consumption are a function of the opposing trends of increasing end-use energy service demand and improvements in the efficiency of technologies that satisfy this demand, as well as macroeconomic shifts toward less energy-intensive industries. This phenomenon is best illustrated by examining the energy intensity of the economy. **Figure 3** shows the relative energy intensity for different end-use and conversion sectors and the economy as a whole.



Note: consumption totals include electric generation and distribution losses

Figure 2. Energy Consumption by Sector



Note: Residential index is primary energy excluding misc. use per household; Commercial index is primary energy use excluding office equipment and misc. appliances per square foot; Industrial index is total primary energy per unit output; Transportation index is LDV primary energy per mile traveled; Electricity index is non-renewable average heat rate; and Economy index is total primary energy per unit GDP.

Figure 3. Relative Energy Intensity by Sector

As shown in **Figure 3**, our reference case projection indicates that the energy intensity of the economy (which we've defined as total primary energy consumption per $ of GDP) is projected to fall by more than half by 2050. This decrease reflects both a continued shift toward a service-based economy, as well as increases in energy technology efficiency. End-use efficiencies are projected to increase throughout the economy over the projection period as new, more efficient capital stocks are purchased to replace existing equipment and to meet new demand. The reference case technology database includes technologies that are expected to become available in the future, as well as those that are currently on the market. For example, more efficient electric heat pumps and light-duty vehicles are assumed to become available throughout the projection period. The technical and economic data associated with these technologies are derived from a variety of sources, but rely most heavily on the NEMS database.

The residential energy intensity index shows significant improvements in energy use per household. However, the residential index excludes "miscellaneous demands," the fastest growing segment of residential energy demand. The miscellaneous demand category includes electric devises such as home computers, TVs, microwave ovens, as well as devices such as gas lamps and swimming pool heaters. Because these service demands are growing faster than the sector as a whole, their energy use per household actually rises over time. Thus, the inclusion of miscellaneous demands in the calculation of residential energy intensity would obscure the efficiency gains being made in other residential service demands.

The commercial energy intensity index shows significant improvements in energy use per square foot. However, as with the residential sector, this calculation excludes the fastest growing demand categories; office equipment and miscellaneous commercial appliances. The inclusion of these demand categories would result in relatively constant commercial energy demand per square foot.

The industrial-sector efficiency index shows dramatic declines in energy intensity due to a shift from energy-intensive industries to nonenergy-intensive manufacturing, as well as improvements in process efficiency. Between 2005 and 2050, nonenergy-intensive manufacturing output is expected to grow at twice the rate as energy intensive industrial output. This shift in output exaggerates the decline in energy intensity. However, in the transportation sector, consumer preferences for more powerful engines and a continued shift from passenger cars to SUVs, limit gains in overall efficiency.

On an individual technology basis, there are several important trends in the reference case technology assumptions. Although most technologies' capital costs are assumed to remain constant at their current level in real terms, the costs of a few key technologies are projected to decline over time. These include gas combined cycle, integrated coal gasification, and renewable technologies, such as wind and PV. Most of these technologies also show improvements in their heat rates or performance (e.g. capacity factor) between 2000 and 2050.

In the power-generation sector, the efficiency of nonrenewable generation is expected to increase as older, less efficient fossil steam units retire and new high efficiency gas combined cycle and IGCC capacity is built. Electric generation by type is shown in **Figure 4**. Natural gas-fired generation is projected to increase its share of total generation from about 16 percent to 28 percent over the projection period. Coal-fired generation remains the largest source of electricity at 53 to 58 percent of total generation. Due to significant retirements of existing nuclear capacity, the share of nuclear generation falls from 21 percent to 3 percent of generation in the projection period. Renewable generation is relatively constant at about 10 percent of total generation.

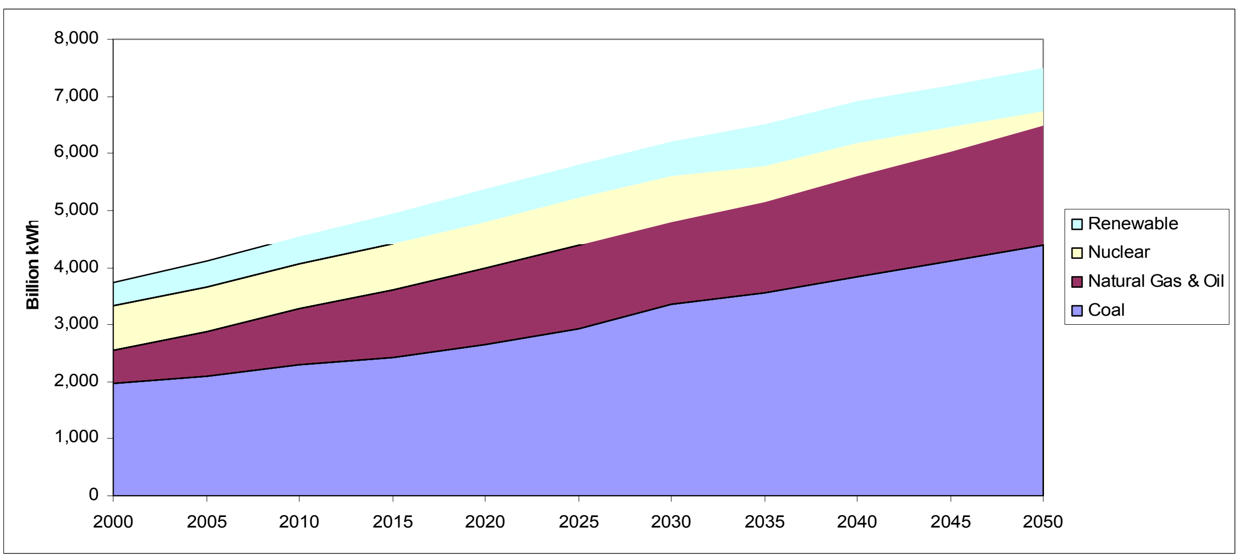


Figure 4. Electricity Generation by Type: Reference Case

While both natural gas and coal-fired generation show increased efficiency, fossil fuel use for electric generation increases by 78 percent during the projection period. Such an increase in coal and natural gas demand for power generation is dependant on the availability of these resources. However, potential reduction in supply, such as changes in the outlook in natural gas supply, would necessitate a significant change fuels used for electric generation.

NEMS Baseline Case Assumptions and Projections

Overview
The Office of Energy Efficiency and Renewable Energy (EERE) programs use integrated energy models to analyze the benefits expected from successful implementation of individual programs and the EERE portfolio as a whole. The use of integrated models provides a consistent economic framework and incorporates the interactive effects among the various programs. Feedback and interactive effects result from (1) changes in energy prices resulting from lower energy consumption, (2) the interaction between supply programs affecting the mix of generation sources and the end-use sector programs affecting the demand for electricity, and (3) additional savings from reduced energy production and delivery.

A modified version of the National Energy Modeling System (NEMS)[1] was one of the models used for this benefits analysis. NEMS is an integrated energy model of the U.S. energy system that was developed by the Energy Information Administration (EIA) for forecasting and policy analysis purposes. NEMS currently provides projection capability to the year 2025 and so is used for the midterm benefits analysis. The latest version of NEMS available at the time of the benefits analysis was used as the starting point. This is a slightly updated version from *Annual Energy Outlook 2004* (AEO2004) that was used by EIA for a set of service reports[2]. Several modifications were made to the model by EERE to enhance its ability to represent the EERE programs. The modified version of the model is referred to as NEMS-GPRA06.

GPRA 2006 Baseline
The first step in the benefits analysis process is to establish an appropriate Baseline Case. The EERE Baseline Case is a projection intended to represent the future U.S. energy system without the effect of EERE programs. This Baseline Case assures that program benefits are estimated based on the same initial forecasts for economic growth, energy prices, and levels of energy demand. It also assures that these initial assumptions are consistent with each other; e.g., that the level of electricity demand expected under the economic growth assumptions could be met at the electricity price assumed. It provides a basis for assessing how well renewable and efficiency technologies might be able to compete against future, rather than current, conventional energy technologies (e.g., more efficient central power generation). Finally, it helps assure that underlying improvements in efficiency and renewable energy are not counted as part of the benefits of the EERE programs.

The most recent Annual Energy Outlook Reference Case is used as the starting point for the developing the base case.[3] The Energy Information Administration (EIA) Annual Energy Outlook (AEO) Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy (e.g., to reflect the availability of new appliances), technology improvements that might improve the efficiency of energy use, and changes in energy resource production costs, including renewable energy.

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[1] The National Energy Modeling System: An Overview 2003, March 2003, DOE/EIA-0581(2003).
[2] Analysis of S. 1844, the Clear Skies Act of 2003; S. 843, the Clean Air Planning Act of 2003; and S. 366, the Clean Power Act of 2003" available at http://www.eia.doe.gov/oiaf/servicerpt/csa/pdf/sroiaf(2004)05.pdf. The reference case is similar to the AEO2004.
[3]As described above, the updated NEMS produces similar reference case projections as the Annual Energy Outlook 2004 with Projections to 2025, January 2004, DOE/EIA-0383 (2004). See http://www.eia.doe.gov/oiaf/archive/aeo04/pdf/0383(2004).pdf.

Current energy market policies, such as state Renewable Portfolio Standards, which facilitate the development and adoption of these technologies, are included in the Base Case. This approach ensures that EERE's benefits estimates do not include expected impacts of such policies. Neither the EIA Reference Case nor the EERE Base Case includes any changes in future energy policies.

The Baseline is constructed starting with EIA's *Annual Energy Outlook* Reference Case and then any identifiable effects of EERE programs already included are removed. For example, EIA's estimate of rooftop photovoltaic installations resulting from the Million Solar Roofs Initiative were removed for the EERE Baseline. The *AEO2004* assumption of roughly constant hydroelectric capacity over time was modified to reflect the expectation that without more environmentally benign turbine designs some reduction in hydro capacity would occur as a result of relicensing requirements. The maximum growth rates for cellulosic ethanol production were reduced by a factor of 5 because growth of this new industry is expected to be very slow without EERE program involvement.

The AEO forecast includes technology improvements in all areas of energy demand and supply and identifying what portion is due to EERE programs is extremely difficult. For GPRA06, selected technology changes were made where the AEO appeared to already incorporate the EERE program goals. Technology assumptions that were modified for the Baseline include cost and efficiency improvements in distributed combined heat and power (CHP) technologies that were assumed to be delayed without an ongoing DEER program. In addition, the two composite distributed generation technologies in the electricity generation sector were modified to reflect baseline values for gas turbines, microturbines, and gas engines. The *AEO2004* includes a significant improvement in geothermal generation technology over time, similar to the program goals. To reflect might what might occur without continued R&D funding, analysts reduced the cost reduction by half for the GPRA Baseline.

There are a few EERE technologies that are either not represented in the *AEO2004* Reference Case or their improvement is less than anticipated by the program in the absence of EERE programs. These technology assumptions were also modified for the GPRA06 Baseline. In commercial lighting, an advanced electrodeless fluorescent technology was replaced with a baseline projection of solid-state lighting characteristics. The efficiency of absorption cooling in commercial buildings was assumed to increase slightly, rather than remain constant over time. Offshore wind technology characteristics were added, and the onshore wind characteristics were modified. The onshore capital costs were increased slightly. More importantly the capacity factors for each wind class were assumed to be higher than in the AEO2004, although lower than the program goals.

A few other modifications were made to reflect EERE program assumptions or updated information about energy markets. These changes affect both the Baseline and the Benefits Cases. The size of typical PV systems was increased to 4 kW in residential and 100 kW in commercial buildings to reflect recent PV installation experience and trends. The maximum market for PV systems was increased from 30 percent to 55 percent in the commercial sector and to 60 percent for residential PVs. Similarly, the maximum market share for gas-fired distributed generation technologies was increased from 30 percent to 50 percent in the commercial sector. California PV credits were incorporated in the Pacific region. Solar water heat was added to the slate of technologies for new homes, and the share of the replacement market in which it can compete was increased from 20 percent to 50 percent. The conversion efficiency of cellulosic ethanol was reduced because EIA's assumption appeared too optimistic.

Table 4. Summary of Baseline Changes from the AEO2004

	AEO2004	Preliminary GPRA06 Baseline Case
Representation of EERE Technology Characteristics		
Million Solar Roofs	0.4 GW installed 2005 to 2025	Removed
Photovoltaic system costs	Significant improvement	Slower rate of improvement
Hydroelectric capacity	Roughly constant hydro capacity and generation	2.2 GW reduction for 2010 to 2025
Cellulosic ethanol production	0.6 billion gallons annually by 2025	0.12 billion gallons annually by 2025
DG technology improvement	Significant improvement	Slower rate of improvement
Commercial absorption cooling efficiency	Constant over time	Increase 20 percent by 2020
Wind	30 to 44 percent capacity factors depending on wind class and year	34 to 50 percent capacity factors depending on wind class and year
Geothermal	Significant improvement	Half the rate of improvement
Energy Market Updates		
PV system size	2 kW residential, 25 kW commercial	4 kW residential, 100 kW commercial
PV maximum market share	30 percent for both residential and commercial	60 percent for residential and 55 percent for commercial
CHP commercial building maximum share	30 percent	50 percent
Commercial absorption cooling	Included in only 5 building types	Included in all 11 building types
California PV subsidy	Not included	Included for residential systems
Solar water heat	Maximum 20 percent replacement market	New and up to 50 percent replacement market
Cellulosic conversion efficiency	90 to 103 gallons of ethanol per dry ton of biomass	82 to 101 gallons of ethanol per dry ton of biomass
Structural Changes		
Wind module	One capital cost and resource multiplier for all wind classes No offshore wind technology	Capital costs and resource multipliers by wind classes Offshore wind
Commercial shell efficiency	Index	Technology representation
Commercial DG algorithms		Market share and stock accounting modified

In a few cases, structural changes were made to improve the model's representation of markets important to EERE technologies. The wind module was modified, so that each of the three wind classes is treated more discretely with separate capital costs and resource multipliers. Offshore wind was added as another technology option with resources available in the coastal regions and the regions around the Great Lakes. The shell indices in the commercial module were replaced with a technology choice algorithm necessary for later representation of EERE shell technologies. In addition, alterations to the distributed generation algorithm in the building modules were made to reflect the DEER program's market adoption data, to account for buildings that have already installed a DG technology in prior years, and to allow greater than an annual 0.5 percent adoption in existing buildings. Absorption cooling was allowed to compete in all commercial building types, rather than only a subset as in the AEO2004.

A summary of these modifications is provided in **Table 4**. Greater detail can be found in the individual program appendices.

In the Baseline projections oil prices are projected to fall from 2004 and then gradually rise through 2025, as shown in **Figure 5**. Natural gas prices are projected to fall more gradually through 2010 and then increase through 2025. Coal prices, on the other hand, are projected to be relatively constant in real terms with a very slight decline. Electricity prices are projected to experience a slight decrease through 2010.

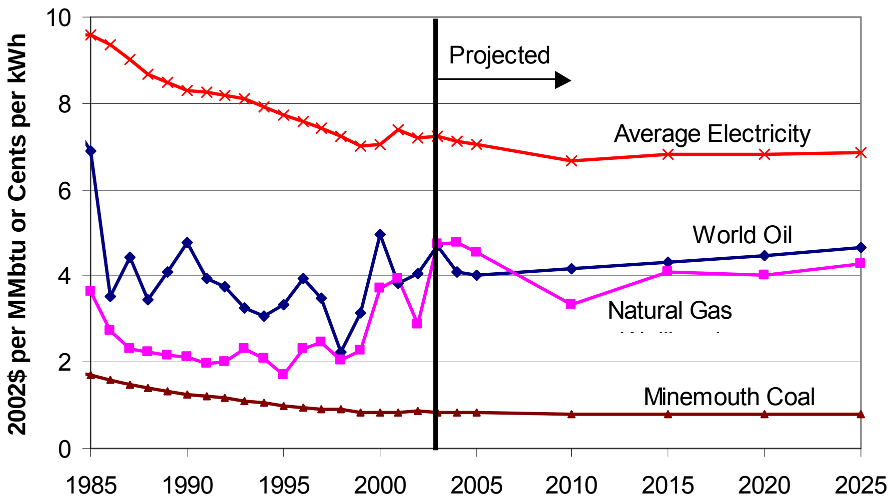

Figure 5. Projected Energy Prices

The resulting Baseline Case projects a 33 percent increase in conventional energy demand from 2005 to 2025[4]. Energy efficiency and renewable energy improvements, however, contribute toward a 25 percent reduction in conventional energy intensity (energy used per dollar of GPD produced) over the same period (Figure 2).[5] Between 2005 and 2025, renewable energy technology improvements result in increases in electric generation in central and distributed applications (in billions of kWh) of 35 for wind, 30 for geothermal, 36 for biomass, 2 for municipal solid waste, 8 for photovoltaics, and 0.4 for solar thermal.

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[4] Very similar to the AEO2004.

[5] Energy-intensity changes result from a mix of structural changes in the economy (e.g., growing service sector) and efficiency improvements. Two recent EERE-sponsored studies provide additional background on understanding the sources of changes to our energy intensity: Ortiz and Sollinger, *Shaping Our Future by Reducing Energy Intensity in the U.S. Economy; Volume 1: Proceedings of the Conference* (2003, Rand Corporation) and Bernstein, Fonkych, Loeb, and Loughran, "State-Level Changes in Energy Intensity and their National Implications (2003, Rand Corporation).

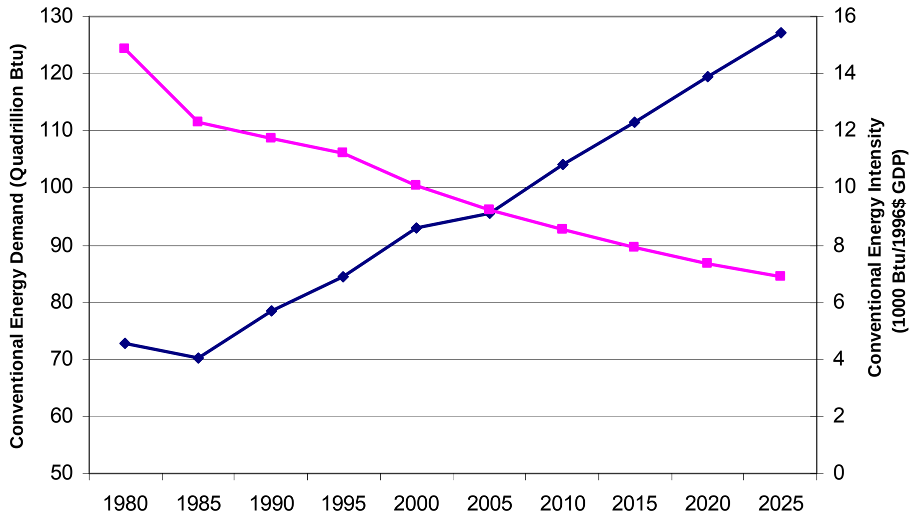

Figure 6. U.S. Conventional Energy Demand and Energy Intensity

EERE NEMS-GPRA06 Baseline Case Tables

Table 1. Total Energy Supply and Disposition Summary
(Quadrillion Btu per Year, Unless Otherwise Noted)

The Worksheet was generated by ftab
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	2010	2015	2020	2025
Production				
Crude Oil & Lease Condensate	12.60	11.71	10.52	9.81
Natural Gas Plant Liquids	3.18	3.21	3.43	3.46
Dry Natural Gas	21.74	22.23	24.13	24.58
Coal	25.00	26.10	28.13	30.71
Nuclear Power	8.38	8.52	8.57	8.57
Renewable Energy 1/	7.16	7.83	8.34	8.83
Other 2/	0.89	0.79	0.81	0.84
Total	78.94	80.39	83.94	86.80
Imports				
Crude Oil 3/	24.64	29.60	31.49	34.15
Petroleum Products 4/	5.64	6.09	8.21	10.08
Natural Gas	5.71	6.88	7.47	8.18
Other Imports 5/	0.95	1.05	1.12	1.18
Total	36.95	43.63	48.28	53.59
Exports				
Petroleum 6/	2.15	2.17	2.13	2.16
Natural Gas	0.81	0.79	0.80	0.72
Coal	0.89	0.80	0.74	0.55
Total	3.85	3.76	3.67	3.43
Discrepancy 7/	0.32	0.46	0.46	0.54
Consumption				
Petroleum Products 8/	44.29	48.56	51.65	55.41
Natural Gas	26.80	28.51	30.99	32.24
Coal	24.97	26.27	28.47	31.34
Nuclear Power	8.38	8.52	8.57	8.57
Renewable Energy 1/	7.16	7.83	8.34	8.83
Other 9/	0.11	0.11	0.07	0.03
Total	111.72	119.80	128.09	136.42
Net Imports - Petroleum	28.14	33.52	37.56	42.08
Prices (2001 dollars per unit)				
World Oil Price ($ per bbl) 10/	24.17	25.07	26.02	27.00
Gas Wellhead Price($ / Mcf) 11/	3.43	4.20	4.14	4.39
Coal Minemouth Price ($ / ton)	16.69	16.63	16.69	16.56
Aver. Electricity (cents / Kwh)	6.68	6.83	6.82	6.84

1/ Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy. See Table A18 for selected nonmarketed residential and commercial renewable energy.
2/ Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
3/ Includes imports of crude oil for the Strategic Petroleum Reserve.
4/ Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
5/ Includes coal, coal coke (net), and electricity (net).
6/ Includes crude oil and petroleum products.
7/ Balancing item. Includes unaccounted for supply, losses, gains, net storage withdrawals, heat loss when natural gas is converted to liquid fuel, and heat loss when coal is converted to liquid fuel.
8/ Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum-based liquids for blending, such as ethanol.
9/ Includes net electricity imports, methanol, and liquid hydrogen.
10/ Average refiner acquisition cost for imported crude oil.
11/ Represents lower 48 onshore and offshore supplies.

Table 2. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2010	2015	2020	2025
Energy Consumption				
Residential				
Distillate Fuel	0.92	0.88	0.83	0.79
Kerosene	0.11	0.11	0.10	0.09
Liquefied Petroleum Gas	0.56	0.58	0.61	0.64
Petroleum Subtotal	1.59	1.57	1.55	1.51
Natural Gas	5.71	5.87	6.15	6.32
Coal	0.01	0.01	0.01	0.01
Renewable Energy 1/	0.40	0.40	0.41	0.40
Electricity	4.86	5.19	5.57	5.92
Delivered Energy	12.57	13.05	13.68	14.16
Electricity Related Losses	10.43	10.85	11.34	11.79
Total	23.00	23.89	25.03	25.95
Commercial				
Distillate Fuel	0.63	0.65	0.67	0.69
Residual Fuel	0.13	0.13	0.13	0.13
Kerosene	0.02	0.02	0.02	0.02
Liquefied Petroleum Gas	0.10	0.10	0.10	0.10
Motor Gasoline 2/	0.05	0.05	0.05	0.05
Petroleum Subtotal	0.92	0.95	0.97	0.99
Natural Gas	3.56	3.73	4.01	4.28
Coal	0.10	0.10	0.10	0.10
Renewable Energy 3/	0.10	0.10	0.10	0.10
Electricity	5.02	5.61	6.21	6.78
Delivered Energy	9.70	10.49	11.39	12.24
Electricity Related Losses	10.78	11.71	12.65	13.51
Total	20.47	22.21	24.03	25.75
Industrial 4/				
Distillate Fuel	1.18	1.27	1.34	1.43
Liquefied Petroleum Gas	2.36	2.53	2.74	2.95
Petrochemical Feedstocks	1.35	1.43	1.54	1.63
Residual Fuel	0.21	0.23	0.22	0.23
Motor Gasoline 2/	0.16	0.17	0.18	0.19
Other Petroleum 5/	4.40	4.72	4.96	5.17
Petroleum Subtotal	9.66	10.36	10.98	11.59
Natural Gas 6/	8.62	9.13	9.94	10.76
Lease and Plant Fuel 7/	1.34	1.37	1.51	1.55
Natural Gas Subtotal 6/	9.96	10.50	11.46	12.31
Metallurgical Coal	0.65	0.59	0.53	0.47
Steam Coal	1.43	1.45	1.47	1.48
Net Coal Coke Imports	0.01	0.00	0.00	0.01
Coal Subtotal	2.09	2.04	1.99	1.96
Renewable Energy 8/	2.00	2.26	2.48	2.70
Electricity	3.83	4.16	4.46	4.81
Delivered Energy	27.54	29.32	31.37	33.38
Electricity Related Losses	8.24	8.68	9.08	9.58
Total	35.78	38.00	40.45	42.96

1/ Includes wood used for residential heating. See Table A18 estimates of nonmarketed renewable energy consumption for geothermal heat pumps, solar thermal hot water heating, and solar photovoltaic electricity generation.
2/ Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
3/ Includes commercial sector electricity cogenerated by using wood and wood waste, landfill gas, municipal solid waste, and other biomass. See Table A18 for estimates of nonmarketed renewable energy consumption for solar thermal hot water heating and solar photovoltaic electricity generation.
4/ Fuel consumption includes consumption for combined heat and power, which produces electricity and other useful thermal energy.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Includes consumption for combined heat and power; excludes consumption by nonutility generators.
7/ Represents natural gas used in the field gathering and processing plant machinery.
8/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass; includes combined heat and power, both for sale to the grid and for own use.

Table 2. Energy Consumption by Sector and Source (Continued)

	2010	2015	2020	2025
Transportation				
Distillate Fuel 9/	6.43	7.27	8.04	8.94
Jet Fuel 10/	3.93	4.36	4.69	4.91
Motor Gasoline 2/	19.94	21.80	23.37	25.31
Residual Fuel	0.79	0.80	0.82	0.83
Liquefied Petroleum Gas	0.06	0.07	0.08	0.09
Other Petroleum 11/	0.26	0.27	0.30	0.32
Petroleum Subtotal	31.41	34.58	37.30	40.40
Pipeline Fuel Natural Gas	0.72	0.73	0.84	0.87
Compressed Natural Gas 19/	0.06	0.08	0.10	0.12
Renewable Energy (E85) 12/	0.00	0.00	0.00	0.00
Liquid Hydrogen 20/	0.00	0.00	0.00	0.00
Electricity	0.09	0.10	0.11	0.12
Delivered Energy	32.27	35.49	38.35	41.51
Electricity Related Losses	0.19	0.21	0.22	0.24
Total	32.46	35.70	38.58	41.75
Electric Generators 15/				
Distillate Fuel	0.22	0.52	0.30	0.37
Residual Fuel	0.50	0.59	0.55	0.55
Petroleum Subtotal	0.72	1.10	0.85	0.92
Natural Gas	6.80	7.59	8.43	8.34
Steam Coal	22.77	24.12	26.36	29.27
Nuclear Power	8.38	8.52	8.57	8.57
Renewable Energy/Other 16/	4.66	5.07	5.35	5.62
Electricity Imports 17/	0.11	0.11	0.07	0.03
Total	43.43	46.51	49.64	52.74
Total Energy Consumption				
Distillate Fuel	9.37	10.59	11.18	12.22
Kerosene	0.16	0.15	0.14	0.13
Jet Fuel 10/	3.93	4.36	4.69	4.91
Liquefied Petroleum Gas	3.07	3.28	3.54	3.77
Motor Gasoline 2/	20.14	22.02	23.60	25.55
Petrochemical Feedstocks	1.35	1.43	1.54	1.63
Residual Fuel	1.64	1.75	1.72	1.74
Other Petroleum 13/	4.64	4.97	5.23	5.47
Petroleum Subtotal	44.29	48.56	51.65	55.41
Natural Gas	24.74	26.40	28.63	29.81
Lease and Plant Fuel 7/	1.34	1.37	1.51	1.55
Pipeline Natural Gas	0.72	0.73	0.84	0.87
Natural Gas Subtotal	26.80	28.51	30.99	32.24
Metallurgical Coal	0.65	0.59	0.53	0.47
Steam Coal	24.31	25.68	27.94	30.86
Net Coal Coke Imports	0.01	0.00	0.00	0.01
Coal Subtotal	24.97	26.27	28.47	31.34
Nuclear Power	8.38	8.52	8.57	8.57
Renewable Energy 18/	7.16	7.83	8.34	8.83
Electricity Imports 17/	0.11	0.11	0.07	0.03
Total	111.72	119.80	128.09	136.42

2/ Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
7/ Represents natural gas used in the field gathering and processing plant machinery.
9/ Diesel fuel containing 500 parts per million (ppm) or 15 ppm sulfur.
10/ Includes only kerosene type.
11/ Includes aviation gas and lubricants.
12/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
13/ Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.
15/ Includes consumption of energy by electricity-only and combined heat and power (CHP) plants whose primary business is to sellelectricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.
16/ Includes conventional hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes net electricity imports.
17/ In 1999 approximately 70 percent of the U.S. electricity imports were provided by renewable sources (hydroelectricity); EIA does not project future proportions for the fuel source of imported electricity.
18/ Includes hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, wind, photovoltaic and solar thermal sources. Includes ethanol components of E85; excludes ethanol blends (10 percent or less) in motor gasoline. Excludes net electricity imports and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal hot water heaters.
19/ Includes natural gas for hydrogen production.
20/ Hydrogen is not reported separately but rather as the fuel feedstock. See note 19.

Table 3. Energy Prices by Sector and Source
(2001 Dollars per Million Btu, Unless Otherwise Noted)

	2010	2015	2020	2025
Residential	14.24	14.92	14.92	15.24
Primary Energy 1/	8.16	8.71	8.62	8.88
Petroleum Products 2/	9.89	10.38	10.88	11.30
Distillate Fuel	7.81	8.04	8.38	8.54
Liquefied Petroleum Gas	13.85	14.46	14.82	15.21
Natural Gas	7.69	8.28	8.07	8.32
Electricity	23.39	23.83	23.62	23.67
Commercial	13.81	14.58	14.73	15.00
Primary Energy 1/	6.49	7.03	6.98	7.22
Petroleum Products 2/	6.33	6.51	6.83	7.00
Distillate Fuel	5.45	5.63	6.00	6.16
Residual Fuel	4.13	4.27	4.41	4.55
Natural Gas 3/	6.66	7.30	7.14	7.40
Electricity	20.51	21.03	21.07	21.15
Industrial 4/	6.47	6.96	7.15	7.39
Primary Energy	5.14	5.62	5.82	6.06
Petroleum Products 2/	6.83	7.11	7.56	7.80
Distillate Fuel	5.68	5.82	6.24	6.41
Liquefied Petroleum Gas	9.67	10.26	10.66	11.11
Residual Fuel	3.74	3.88	4.03	4.17
Natural Gas 5/	4.09	4.82	4.74	5.01
Metallurgical Coal	1.96	1.90	1.84	1.77
Steam Coal	1.57	1.56	1.55	1.52
Electricity	13.52	13.91	13.98	14.07
Transportation	10.52	10.54	10.58	10.75
Primary Energy	10.49	10.51	10.56	10.72
Petroleum Products 2/	10.49	10.51	10.56	10.72
Distillate Fuel 6/	10.16	10.18	10.10	10.14
Jet Fuel 7/	5.76	5.83	6.09	6.32
Motor Gasoline 8/	11.88	11.87	11.91	12.06
Residual Fuel	3.60	3.73	3.87	4.02
Liquefied Petroleum Gas9/	14.92	15.42	15.54	15.86
Natural Gas 10/	8.26	9.04	8.89	9.08
Ethanol (E85) 11/	17.21	17.79	18.58	18.98
Electricity	19.76	20.39	20.06	19.91

1/ Weighted average price includes fuels below as well as coal.
2/ This quantity is the weighted average for all petroleum products, not just those listed below.
3/ Excludes independent power producers.
4/ Includes combined heat and power.
5/ Excludes uses for lease and plant fuel.
6/ Diesel fuel containing 500 parts per million (ppm) or 15 ppm sulfur. Price includes Federal and State taxes while excluding county and local taxes.
7/ Kerosene-type jet fuel. Price includes Federal and State taxes while excluding county and local taxes.
8/ Sales weighted-average price for all grades. Includes Federal, State, and local taxes.
9/ Includes Federal and State taxes while excluding county and local taxes.
10/ Compressed natural gas used as a vehicle fuel. Price includes estimated motor vehicle fuel taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).

Table 3. Energy Prices by Sector and Source (Continued)

	2010	2015	2020	2025
Average End-Use Energy	10.25	10.61	10.70	10.91
Primary Energy	8.23	8.53	8.62	8.84
Electricity	19.58	20.02	20.00	20.06
Electric Generators 12/				
Fossil Fuel Average	1.94	2.16	2.12	2.12
Petroleum Products	4.28	4.57	4.73	4.96
Distillate Fuel	4.94	5.06	5.50	5.68
Residual Fuel	3.99	4.14	4.32	4.48
Natural Gas	4.11	4.80	4.72	4.97
Steam Coal	1.22	1.22	1.21	1.22
Average Price to All Users 13/				
Petroleum Products 2/	9.57	9.65	9.84	10.04
Distillate Fuel	8.93	8.95	9.14	9.24
Jet Fuel	5.76	5.83	6.09	6.32
Liquefied Petroleum Gas	10.61	11.19	11.56	11.97
Motor Gasoline 8/	11.88	11.87	11.91	12.06
Residual Fuel	3.78	3.93	4.08	4.23
Natural Gas	5.30	5.95	5.80	6.06
Coal	1.24	1.24	1.23	1.24
Ethanol (E85) 11/	17.21	17.79	18.58	18.98
Electricity	19.58	20.02	20.00	20.06
Non-Renewable Energy Expenditures by Sector (billion 2001 dollars)				
Residential	173.21	188.68	198.03	209.69
Commercial	132.57	151.57	166.22	182.12
Industrial	133.93	153.11	168.24	185.97
Transportation	331.85	366.20	396.91	436.69
Total Non-Renewable Expenditures	771.56	859.55	929.40	1014.47
Transportation Renewable Expenditures	0.03	0.04	0.05	0.07
Total Expenditures	771.59	859.59	929.46	1014.53

11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).

12/ Includes all electric power generators except combined heat and power, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.

13/ Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Table 4. Electricity Supply, Disposition, Prices, and Emissions
(Billion Kilowatthours, Unless Otherwise Noted)

	2010	2015	2020	2025
Generation by Fuel Type				
Electric Power Sector 1/				
Power Only 2/				
Coal	2170	2313	2581	2934
Petroleum	67	109	79	82
Natural Gas 3/	644	797	922	943
Nuclear Power	803	816	821	821
Pumped Storage/Other	-9	-9	-9	-9
Renewable Sources 4/	400	421	437	452
Distributed Gen (Natural Gas)	1	1	2	7
Non-Utility Gen for Own Use	-37	-37	-37	-37
Total	4039	4411	4796	5192
Combined Heat and Power 5/				
Coal	33	33	33	33
Petroleum	1	5	2	2
Natural Gas	177	163	162	150
Renewable Sources	4	4	4	4
Non-Utility Gen for Own Use	-24	-24	-24	-24
Total	191	181	178	166
Net Available to the Grid	4230	4592	4974	5357
End-Use Sector Generation 6/				
Combined Heat and Power				
Coal	21	21	21	21
Petroleum	12	15	18	18
Natural Gas	108	129	176	235
Other Gaseous Fuels 7/	9	11	12	13
Renewable Sources 4/	39	45	50	54
Other 8/	11	11	11	11
Total	201	233	289	354
Other End-Use Generators 9/	5	5	5	12
Generation for Own Use	-158	-175	-206	-251
Total Sales to the Grid	47	63	88	114
Net Imports	33	31	21	8

1/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.
2/ Includes plants that only produce electricity.
3/ Includes electricity generation from fuel cells.
4/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other biomass, solar, and wind power.
5/ Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report NAICS code 22).
6/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors.
7/ Other gaseous fuels include refinery and still gas.
8/ Other includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.
9/ Other end-use generators include small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

Table 4. Electricity Supply, Disposition, Prices, and Emissions (Continued)

	2010	2015	2020	2025
Electricity Sales by Sector				
Residential	1423	1522	1632	1734
Commercial	1470	1644	1820	1986
Industrial	1124	1219	1306	1409
Transportation	26	29	32	35
Total	4043	4414	4790	5165
End-Use Prices 10/ (2001 cents per kilowatthou				
Residential	8.0	8.1	8.1	8.1
Commercial	7.0	7.2	7.2	7.2
Industrial	4.6	4.7	4.8	4.8
Transportation	6.7	7.0	6.8	6.8
All Sectors Average	6.7	6.8	6.8	6.8
Prices by Service Category 10/ (2001 cents per kilowatthour)				
Generation	4.2	4.4	4.4	4.5
Transmission	0.6	0.7	0.7	0.7
Distribution	1.9	1.8	1.7	1.7
Emissions				
Sulfur Dioxide (million tons)	9.64	9.01	8.95	8.95
Nitrogen Oxide (million tons)	3.47	3.58	3.65	3.72
Mercury (tons)	52.39	53.21	54.18	54.46

10/ Prices represent average revenue per kilowatthour.

Table 5. Electricity Generating Capacity
(Gigawatts)

	2010	2015	2020	2025
Electric Power Sector 2/				
Power Only 3/				
Coal Steam	302.0	316.9	352.9	402.4
Other Fossil Steam 4/	102.1	98.6	97.1	94.9
Combined Cycle	126.2	158.0	177.0	195.5
Combustion Turbine/Diesel	128.0	146.5	160.6	170.5
Nuclear Power 5/	100.6	102.1	102.6	102.6
Pumped Storage	20.3	20.3	20.3	20.3
Fuel Cells	0.1	0.1	0.1	0.1
Renewable Sources 6/	98.2	102.0	104.7	108.0
Distributed Gen (Nat Gas) 7/	1.5	1.9	5.0	15.7
Total	878.9	946.4	1020.4	1110.1
Combined Heat and Power 8/				
Coal Steam	5.2	5.2	5.2	5.2
Other Fossil Steam	1.1	1.1	1.1	1.1
Combined Cycle	32.9	32.9	32.9	32.9
Combustion Turbine/Diesel	5.4	5.4	5.4	5.4
Renewable Sources	0.3	0.3	0.3	0.3
Total	44.9	44.9	44.9	44.9
Total Electric Power Industry	923.8	991.3	1065.2	1154.9
Cumulative Planned Additions 9/				
Coal Steam	1.1	1.1	1.1	1.1
Other Fossil Steam	0.0	0.0	0.0	0.0
Combined Cycle	43.5	43.5	43.5	43.5
Combustion Turbine/Diesel	8.1	8.1	8.1	8.1
Nuclear Power	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0
Fuel Cells	0.1	0.1	0.1	0.1
Renewable Sources	4.3	4.6	4.7	4.8
Distributed Generation	0.0	0.0	0.0	0.0
Total	57.1	57.4	57.5	57.6
Cumulative Unplanned Additions 9/				
Coal Steam	2.5	18.0	55.3	105.9
Other Fossil Steam	0.0	0.0	0.0	0.0
Combined Cycle	6.2	38.1	57.0	75.6
Combustion Turbine/Diesel	8.8	27.9	44.2	55.6
Nuclear Power	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0
Renewable Sources	4.4	7.9	10.5	13.7
Distributed Generation	1.5	1.9	5.0	15.7
Total	23.4	93.7	172.0	266.4
Cumulative Total Additions	80.5	151.1	229.5	324.0
Cumulative Retirements 10/				
Coal Steam	7.4	8.0	9.2	10.4
Other Fossil Steam	28.5	32.0	33.5	35.7
Combined Cycle	1.7	1.7	1.7	1.7
Combustion Turbine/Diesel	10.8	11.4	13.5	15.1
Nuclear Power	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0
Renewable Sources	0.1	0.1	0.1	0.1
Total	48.5	53.2	58.1	62.9

1/ Net summer capacity is the steady hourly output that generating equipment is expected to supply to system load (exclusive of auxiliary power), as demonstrated by tests during summer peak demand.

2/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

3/ Includes plants that only produce electricity. Includes capacity increases (uprates) at existing units.

4/ Includes oil-, gas-, and dual-fired capacity.

5/ Nuclear capacity reflects operating capacity of existing units, including 4.3 gigawatts of uprates through 2025.

6/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other biomass, solar and wind power.

7/ Primarily peak-load capacity fueled by natural gas.

8/ Includes combined heat and power plants whose primary business is to sell electricity and heat to the public

Table 5. Electricity Generating Capacity (Continued)

	2010	2015	2020	2025
End-Use Sector Generators 11/				
Combined Heat and Power				
Coal	4.1	4.1	4.1	4.1
Petroleum	1.6	2.0	2.3	2.4
Natural Gas	17.6	20.4	26.8	34.8
Other Gaseous Fuels	2.2	2.4	2.6	2.7
Renewable Sources	5.6	6.7	7.5	8.3
Other	0.3	0.3	0.3	0.3
Total	31.5	35.9	43.7	52.7
Other End-Use Generators 12/	0.0	0.0	0.0	0.0
Renewable Sources	1.4	1.4	1.4	4.8
Cumulative Additions 9/				
Combined Heat and Power	6.0	10.4	18.2	27.2
Other End-Use Generators	0.2	0.2	0.2	3.6

9/ Cumulative additions after December 31, 1999.
11/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors.
12/ Other end-use generators include small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

Table 6. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2010	2015	2020	2025
Residential				
Petroleum	29.9	29.5	28.9	28.1
Natural Gas	82.2	84.5	88.6	91.0
Coal	0.3	0.3	0.3	0.3
Electricity	244.7	258.3	277.2	298.3
Total	357.0	372.6	395.0	417.7
Commercial				
Petroleum	18.1	18.7	19.1	19.5
Natural Gas	51.3	53.7	57.8	61.6
Coal	2.5	2.5	2.5	2.5
Electricity	252.7	279.0	309.0	341.7
Total	324.6	354.0	388.4	425.3
Industrial 1/				
Petroleum	100.1	106.6	111.6	116.8
Natural Gas 2/	141.6	149.2	162.9	175.1
Coal	53.1	51.7	50.6	49.8
Electricity	193.2	206.8	221.8	242.4
Total	487.9	514.5	546.9	584.1
Transportation				
Petroleum 3/	599.5	660.1	712.1	771.5
Natural Gas 4/	11.2	11.8	13.6	14.3
Other 5/	0.0	0.0	0.0	0.0
Electricity	4.5	4.9	5.4	6.1
Total 3/	615.1	676.8	731.2	791.8
Total by Delivered Fuel				
Petroleum 3/	747.6	814.9	871.7	935.9
Natural Gas	286.1	299.2	322.8	341.9
Coal	55.9	54.6	53.4	52.6
Other 5/	0.0	0.0	0.0	0.0
Electricity	695.1	749.1	813.5	888.5
Total 3/	1784.7	1917.8	2061.4	2219.0
Electric Power Sector 6/				
Petroleum	14.9	22.7	17.7	19.0
Natural Gas	97.9	109.3	121.4	120.0
Coal	582.2	617.1	674.5	749.5
Total	695.1	749.1	813.5	888.5
Total by Primary Fuel 7/				
Petroleum 3/	762.5	837.6	889.3	954.9
Natural Gas	384.1	408.6	444.2	462.0
Coal	638.1	671.6	727.9	802.1
Other 5/	0.0	0.0	0.0	0.0
Total 3/	1784.7	1917.8	2061.4	2219.0

1/ Fuel consumption includes energy for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public.
2/ Includes lease and plant fuel.
3/ This includes international bunker fuel, which by convention are excluded from the international accounting of carbon dioxide emissions. In the years from 1990 through 1998, international bunker fuels accounted for 25 to 30 million metric tons carbon equivalent of carbon dioxide annually.
4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
5/ Includes methanol.
6/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Does not include emissions from the nonbiogenic component of municipal solid waste because under international guidelines these are accounted for as waste, not energy.
7/ Emissions from the electric power sector are distributed to the primary fuels.

Appendix B – GPRA06 Biomass Program Documentation

1. Introduction

This appendix discusses the assumptions and methods employed in the biomass benefits analysis that is part of the fiscal year 2006 GPRA benefits analysis for all of the Department of Energy's Energy Efficiency and Renewable Energy (EERE) research and deployment programs. The biomass benefits analysis focuses on the benefits of future achievements by the program and excludes retrospective benefits and benefits resulting from industry's own initiative and funding.

The major program focus is to enable integrated biorefineries producing a slate of products including fuels, chemicals, materials, and/or heat and power. The heat and power may be for internal biorefinery use, but may also be sold externally. Biorefineries process biomass into these products using biochemical processes (such as hydrolysis of biomass to sugars followed by fermentation of sugars to fuels and/or chemicals) or thermochemical processes (such as gasification of biomass to syngas followed by conversion of syngas to fuels or chemicals). Biorefinery configurations may vary as a function of site-specific conditions, including feedstock availability and price, local and regional market demand, and other factors. In addition to facilitating the development of future biorefineries, the program is collaborating with existing ethanol plants in evaluating the feasibility of enhancing their economic viability through increasing their ethanol output. This can be achieved with technology that converts the fibrous component of the corn kernels to ethanol, and, in the process, also convert the starch that is tightly bound by this fiber and so far, not available for conversion to ethanol in existing corn ethanol plants ("residual starch"). As an interim step leading to future biorefineries, the program is working with ethanol production plants (which are less-advanced, limited-capability biorefineries) on near-term technologies aimed at increasing the ethanol that these plants can produce from their traditional feedstock (corn kernels), while enhancing the value of the plants' non-ethanol coproducts such as animal feed additives.

In recent years, the National Renewable Energy Laboratory's (NREL) design of a cellulosic ethanol plant has been a primary source of data for estimates of costs and environmental effects related to the conversion of lignocellulosic feedstock to fuels. With respect to nonfuel products, the Cargill Dow Company is operating the first U.S. bio-based plastics plant in Blair, Nebraska, with the feedstock being the starch from corn kernels. This analysis is consequently based on the concept of enhanced corn ethanol plants with the added production of corn fiber ethanol, residual starch ethanol, and eventually stover-based ethanol, and two interim concepts of biorefineries. The two concepts are "Ethanol Biorefineries" (E-biorefineries) that produce primarily ethanol and a small volume of high value coproducts (chemicals and materials), and "nonfuel biorefineries" that produce chemicals and/or materials, but not fuels. The Biomass Program is conducting midterm and long-term research, development and demonstration (RD&D) that will lead to better defined integrated biorefinery concepts. Because it will take some time for RD&D work to bear fruit, this analysis does not include the benefits that could be estimated once the integrated biorefinery concepts are defined and, therefore, likely underestimates the probable benefits of the program.

A biorefinery industry is expected to result in biomass displacing most petroleum and natural gas feedstocks traditionally used in the production of fuels, chemicals, and materials. The biorefinery concept allows the cost of production to be reduced through synergies associated with feedstock handling and processing, and the allocation of capital and fixed O&M costs across multiple products. While the current analysis assumes that ethanol is the major output of E-biorefineries, future analyses could include additional fuels that the program may identify in the longer term.

The E-biorefinery is envisioned to biochemically process cellulosic biomass into ethanol (the lignin residues from this process are used to make electricity that will be sold externally, reducing the net ethanol cost) and a small quantity of nonfuel chemicals whose economic benefits were modeled as a "credit" that reduces the ethanol production cost. EERE used the Ethanol Long Range Systems Analysis Spreadsheet with Biorefinery Advantages (ELSASBioref) to integrate ethanol supply/demand data with biorefinery synergy credit and "current law" tax incentives to estimate market penetration for ethanol. EERE used these results as input to the NEMS-GPRA06 and MARKAL-GPRA06 models to estimate benefits.

In view of the large number of potential chemical products and materials that could be produced from biomass, this analysis did not assume specific nonfuel products, but instead assumed a category of "generic/composite" product for which EERE made assumptions based on a wide range of possible bio-based products (polymers, solvents, etc.).

Bio-Based Products from Nonfuel Biorefineries

The FY2006 analysis focuses on the benefits associated with a generic/composite bio-based product rather than specific products. This approach was adopted because there are too many potential bio-based chemicals and materials, and the markets for those are quite diverse, unlike transportation fuels where a few commodities account for most of the national market.

Target Markets for Nonfuel Biorefineries

A wide variety of chemicals and materials could potentially be produced at nonfuel biorefineries. Sugar and starch products derived through fermentation and thermochemical processes include alcohols, acids, starch, xanthum gum, and other products. Oil- and lipid- based products include fatty acids, oils, alkyd resins, glycerine, and a variety of vegetable oils. Gum and wood chemicals include tall oil, alkyd resins, rosins, pitch, fatty acids, turpentine, and other chemicals. Cellulose derivatives, fibers and plastics include products derived from cellulose, including cellulose acetate (cellophane) and triacetate, cellulose nitrate, alkali cellulose, and regenerated cellulose. Industrial enzymes are used as biocatalysts for a variety of biochemical reactions in the production of starch and sugar, alcohols, and oils; and are also used in laundry detergents, tanning of leathers and textile sizing.

Some of these chemicals and materials represent end products, while others represent "intermediates" used in the production of other products. The potential target markets are even more diverse than the list of potential products. Therefore, EERE did not characterize or analyze specific target markets for this benefits analysis.

Key Factors in Shaping Market Adoption for Nonfuel Biorefineries

Price will be the key factor in market adoption of products from nonfuel biorefineries. Most of these chemical and material products are commodity-based; and, as such, price will be the over-riding factor in their penetration of their respective markets. In view of the "generic products" approach, meaningful comparisons of prices or other market factors for biobased products with competing hydrocarbon-based products are not possible.

Methodology and Calculations for Nonfuel Biorefineries

The methodology was based on an "averaged" bio-based product. EERE averaged the energy-use profile from the FY 2004 GPRA estimates to estimate the FY 2006 GPRA profile for the average generic bio-based product. The profile, which included a wide range of products (polymers, solvents, and other chemicals and materials), was averaged by summing the energy savings from the FY 2004 analyses and dividing the total by the volume of products it represented. The result is approximately 20,000 Btus of fossil energy displaced per pound of bio-based product, with the displaced energy distributed between feedstock and processing requirements. This is conservative because it does not include the use of biomass for on-site energy generation, which would result in even greater fossil energy displacement. Starch/cellulose-based products will involve handling dilute aqueous streams throughout the production process, requiring considerable electricity for processes such as separation and purification. This fact and the conservative approach previously noted account for the negative electricity saving coefficient in **Table 2.**

Based on the Biomass Program's plans, bio-based products will enter the market with the first starch-based biorefinery starting up in 2007. The program's experts assumed that the annual starch-based growth rate will be approximately 8% to 9% for the first 28 years, and gradually decrease to nearly 6% after 2035. They also assumed technical challenges will delay market entry for cellulose-based products until 2018, and that the annual growth rate for cellulosic products will be approximately 11% through 2030, 8.5% for 2031-2037, 6.5% for 2038-2044, and 5.5% for 2045 and thereafter. Initially high growth rates moderate as the industry matures, consistent with what one can observe in other industries.

Table 1 shows the growth of bio-based products from nonfuel biorefineries.

Table 1. FY 2006 Bio-Based Products from Nonfuel Biorefineries (Billion pounds per year)

Year	2020	2025	2030	2035	2040	2045	2050
Products from starch	0.61	0.96	1.44	2.12	2.91	3.99	5.20
Products from cellulose	0.28	0.47	0.79	1.19	1.68	2.30	3.02

Table 2 presents energy-related input that the program's analysts provided to the EERE integrating models in the FY 2005 analysis, which serves as the basis for the current analysis[1].

**Table 2. FY 2005 Input to Integrating Models –
Energy Savings for Bio-based Products
(Energy-saving coefficients per billion lbs of bioproducts)**

Natural Gas	T Btu/billion lbs	4.5
Coal	T Btu/billion lbs	-0.6
Electricity	B kWh/billion lbs	-0.6
Distillate Oil	T Btu/billion lbs	4.5
Feedstock	T Btu/billion lbs	11

Ethanol and Bio-Based Products from Enhanced Corn Ethanol Plants and E-Biorefineries

The discussion in this section will focus on describing target markets and technical characteristics used in the analysis of the market penetration and benefits attributable to enhanced corn ethanol plants and E-biorefineries.

Target Markets for Corn Ethanol Plants and E-Biorefineries

Corn ethanol plants, both dry mills and wet mills (to learn more about these plants, use search feature at www.ethanolrfa.org), currently use corn kernels (no cellulosic feedstock) to produce ethanol and some coproducts such as animal feed additives (both dry and wet mills), or corn oil and high-fructose corn syrup (wet mills). Ethanol Biorefineries, or E-biorefineries, will use cellulosic biomass to produce ethanol fuel, high-value specialty chemicals and materials, and combined heat and power. The analysis for this type of biorefinery is limited to the benefits associated with ethanol because they will comprise most of the benefits of E-biorefineries. Thus, this analysis included only ethanol used as a transportation fuel for light-duty vehicles (passenger vehicles, mostly). While it is possible to envision an E-biorefinery using both cellulosic biomass and corn kernels as feedstock, it is outside the scope of this benefits analysis.

In 2004, U.S. ethanol fuel production reached approximately 3.4 billion gallons, an increase of 21% from the previous year. As of October 2004, 81 ethanol plants were producing and 11 additional plants were under construction. Ethanol competes in transportation fuel markets for light-duty vehicles. In 2003, the U.S. prime supplier sales volume of motor gasoline was approximately 134 billion gallons[2].

EERE targets ethanol technology for the gasoline additive market in the midterm and as a gasoline substitute/additive in the longer term. In 2003, approximately 99% of the ethanol consumed in the United States was for the gasoline additive market and 1% was for use as a gasoline substitute.[3] In 2004, the majority of the ethanol consumed in the additive market is used as an oxygenate component (additive) for gasoline, and the remainder is used as a gasoline additive to improve octane in conventional gasoline. Within the oxygenate market, in early 2004, methyl-tertiary-butyl-ether (MTBE) and ethanol each provided approximately 50% of the volume. However, ethanol is expected to take a much larger share of this market because MTBE has been or is being phased out in many states due to environmental concerns (see discussion of MTBE later in this section for additional detail).

The Clean Air Act requires a minimum level of oxygen content in both reformulated gasoline (RFG) and oxygenated gasoline. RFG, which is required in ozone nonattainment areas, and oxygenated gasoline, which is required in carbon monoxide (CO) nonattainment areas, are not the same. Ethanol competes with MTBE in both of these oxygenate market segments. Most of the MTBE (and an increasing share of ethanol) are used in RFG, which is the most important market segment for oxygenates. Both ethanol and MTBE are used in the smaller oxygenated gasoline market segment, with ethanol being the dominant oxygenate. In a third market segment, ethanol is blended with conventional gasoline to make gasohol, which is primarily marketed in the Midwest. Gasohol consists of 90% gasoline and 10% ethanol by volume, with the ethanol serving as an octane enhancer and gasoline extender.

After adjusting for its Federal excise tax exemption, the price of ethanol has historically tracked with the price of gasoline, whereas MTBE is normally priced at a premium relative to gasoline. However, MTBE used to be the oxygenate of choice in RFG for most refiners outside the Midwest because of its wider availability, more favorable blending characteristics for summer Reid Vapor Pressure, and ease of distribution. When blended into gasoline, ethanol raises the vapor pressure of the mixture, while adding MTBE to gasoline has only a minor effect on vapor pressure. Because ethanol absorbs water, which is typically present in small quantities in the U.S. petroleum products pipeline system, ethanol and ethanol blends are not routinely shipped via pipeline. Consequently, ethanol is shipped by rail, truck, and/or barge to distribution terminals, where it is blended into gasoline. MTBE is blended into gasoline at the refinery, and MTBE blends do not require any special handling compared with gasoline that has no MTBE.

MTBE is currently the subject of environmental concern in several communities, due to its leakage and contamination of groundwater. It imparts a turpentine odor to water at low concentrations. There have been several efforts at the national level to completely phase out MTBE's use in gasoline. At this time, these efforts have not succeeded. Eighteen states, however, have issued their own limits on MTBE use. The states that have enacted MTBE bans account for more than 60% of historical MTBE consumption.

The 2003 production level for ethanol was 2.81 billion gallons per year. The consumption of MTBE in 2002 was approximately 4 billion gallons, but MTBE consumption has been declining as California, New York, Connecticut and other states transitioned from MTBE to ethanol. A national ban on MTBE would increase the demand for ethanol because ethanol, like MTBE, is a high-octane content, virtually sulfur-free additive that reduces toxic air emissions. Ethanol also will help solve the problem of fuel volume loss that would accompany an MTBE ban because oxygenates such as MTBE (or ethanol or other oxygenates), when blended in gasoline, also are used by the automobile engine as a fuel. Reformulated gasoline typically contains 11% MTBE.

Vehicle fleets provide additional demand for ethanol fuel. These include alternative-fuel vehicles that have been either modified or manufactured to accommodate the use of E85 (85% ethanol and 15% gasoline) or E95 (95% ethanol and 5% gasoline). Many of these vehicles are flexible-fuel vehicles, enabling their use with gasoline or E85. The vehicle fleet market is dominated by government agencies, but also includes fleets owned by corporate entities and other organizations (taxi cabs, utilities, airport authorities, etc.). The use of green fuels in

Federal Government fleets is driven largely by the alternative-fuel vehicle requirements under the Energy Policy Act (EPACT) of 1992. The market penetration of E85 has been much lower than for E10 because (1) only a limited number or vehicles can use E85 (and fleet rules under EPACT do not necessarily require the use of alternative fuels in these vehicles), (2) E85 is generally more costly than gasoline on an energy-equivalent basis, and (3) the required investment for refueling infrastructure is greater for E85 and E95 than for E10.

In the longer term, once production technology improvements achieve cost parity between ethanol and gasoline, ethanol will compete directly with gasoline in broader automotive fuel markets. In this instance, the growth of ethanol consumption eventually will become limited by the availability of biomass feedstocks, rather than by ethanol market demand.

Baseline Technology Improvements for E-Biorefineries

The degree to which this technology would progress in the absence of EERE's biomass R&D has not been studied. Alternatively, EERE evaluated the technical and market barriers to the development of E-Biorefineries using cellulosic feedstock, and concluded that without Federal investment in RD&D, the cellulosic ethanol industry would grow at only 20% of the rate postulated in the EIA Reference Case for the Annual Energy Outlook 2004. The rationale for this conclusion is industry's reticence to underwrite cellulosic ethanol research because of its risk and cost. For example, for a decade, the enzyme industry failed to show interest in partnering with EERE to develop low-cost enzymes for cellulosic ethanol production. Only in 2000-2001 did they make the strategic decision to become key players in the development of the new ethanol industry. Feedstock collection infrastructure is another critical area in which industry has neglected to invest in the development of new technology. Sustained public/private collaboration continues to be needed before cellulose-based chemicals and ethanol can become competitive.

Baseline Market Acceptance for E-Biorefineries

Gasoline is a mix of both high- and lower-value petroleum-based components, with the high-value components comprising only a small fraction of the total volume. With current ethanol tax incentives and ethanol's value to refiners due to its environmental and octane characteristics, corn-based ethanol is competitive with the small fraction of high-value petroleum-based constituents of gasoline that give gasoline acceptable octane and emissions levels. Therefore, a small amount of ethanol (10% or less) can be blended with 90% or more gasoline to produce a fuel that is competitive with conventional gasoline. However, blending ethanol with gasoline in higher concentrations becomes less competitive because a gallon of ethanol has only two-thirds the energy of a gallon of gasoline, and it cannot compete with gasoline on an energy-equivalent basis.

Ethanol is already widely used in gasoline and accepted as a component of transportation fuel in the target market. As the technology for producing cellulosic ethanol matures in the longer term, the retail value of cellulosic ethanol will become competitive with gasoline on an energy basis. At that point, fuel markets will likely accept nearly pure ethanol such as E85 because of its environmental characteristics and indigenous supply basis. Increases in market penetration for ethanol will also be affected by competition from other alternative transportation fuels and success in overcoming the lack of an established nationwide E85 transportation and distribution infrastructure. Eventually, increases in market penetration may be constrained by the availability of feedstock, rather than market demand.

Key Factors in Shaping Market Adoption for E-Biorefineries

Price - The price of biomass-based fuels is sensitive to biomass feedstock costs, the decrease in net ethanol production costs resulting from integration with bio-based products in a biorefinery, and prices of competing fuels, such as gasoline. The previous section discussed the value of ethanol in the low-blend market (E10) versus the high-blend market (E85 or higher blends).

Nonprice Factors – These include vehicle compatibility, infrastructure requirements, key consumer preferences/values, manufacturing factors, and policy factors.

Vehicle Compatibility - In the E10 market, virtually all gasoline vehicles can use this low-blend ethanol gasoline mixture. For high blends such as E85, automobile manufacturers have considerable experience in producing vehicles that meet the Environmental Protection Agency's requirements, due to a few million flex-fuel vehicles that have been sold in the United States; these include models of the Ford Taurus, Chevrolet S10 pickup truck, GMC Sonoma pickup truck, Isuzu Hombre pickup truck, Chrysler Voyager minivan, Dodge Caravan minivan, Chevrolet Silverado, and other models.

Infrastructure Requirements - A 2002 study[4] on logistics barriers, sponsored by EERE, foresees no major infrastructure barriers to a substantial expansion of the ethanol industry in the scenarios it analyzes, which include substantial movement of ethanol among and within different regions of the country by several different modes of transport. The study reveals that a large number of investments in transportation, storage, terminalling, and retailing are possible without encountering significant "growing pains."

Although petroleum terminal improvements anticipated by the study represent significant capital investments for terminal operators, they amount to less than 1 cent per gallon of new ethanol volume on an amortized basis. In addition, with some assurance of increased throughput volumes at terminals (such as that provided by a Federal renewable fuel standard), terminal operators could be expected to make the improvements.

The volume of product anticipated to be moved by railroad and river barge is a very small fraction of products moved by these industries. Furthermore, both the rail freight car-building industry and the barge-building industry have the capacity to build equipment that would keep pace with the increasing ethanol shipments from new plants.

There are also operational strategies the ethanol industry could employ that would mitigate risk of supply disruptions caused by logistical glitches. Additional inventory levels at terminals and other storage locations could act as a cushion against delayed shipments and help ensure the smooth functioning of a growing market.

While the study did not find any serious logistical impediments to expansion of the ethanol industry, it did identify two areas of potential concern that merit further study. These are the availability of Jones Act/OPA90-compliant vessels and barge movement in some areas of the U.S. inland waterway system as a result of vessel retirements.

Ships that are used to transport ethanol are subject to various regulations and requirements. The Merchant Marine Act of 1920, otherwise known as the Jones Act, requires that all ocean or waterway transportation from one U.S. port to another U.S. port be moved in a vessel built in the United States, owned by a U.S. person or corporate entity, manned by a certified U.S. crew and registered in the United States (U.S. flagged). Tankers meeting these specifications are known as Jones Act tonnage.

Vessels carrying petroleum products between U.S. ports are also subject to the Oil Pollution Act of 1990 (OPA90). This would include ethanol because ethanol is normally transported after having been "denatured," with the addition of a small quantity of a petroleum product such as gasoline. OPA90 requires the use of double-hulled vessels and further requires the retirement of single-hulled vessels from petroleum product service by certain dates, based on their manufacture or rebuild date.

Key Consumer Preferences/Values - Both E10 and E85 are likely to penetrate the market more easily in the Midwest where ethanol already is a familiar fuel. In addition, if the trend of increasing public awareness and environmental concern continues, this could become a significant positive factor in consumer choice in fuel markets in other regions outside of the Midwest.

Manufacturing Factors - Cellulosic ethanol is envisioned as a major product – but not the only one – from a biorefinery. While various biorefinery configurations are possible, the two fundamental platforms are fermentation (sugar-based) and gasification (syngas-based). EERE is working with private industry to further develop these platforms, from which a host of fuels and chemicals may be derived. Initial plants will cost more in view of the perceived technical risks. As experience is gained with new plants, costs for each subsequent plant will decrease as a result of lessons learned and lower cost of capital associated with reduced risk. The Biomass Program has historically focused more on the fermentation platform for cellulosic ethanol, as this path was seen as a logical extension of the more mature starch-based ethanol process. Consequently, NREL and its subcontractors have extensively analyzed the process economics of the fermentation pathway. Because the focus on the syngas-based biorefinery is relatively new, our understanding of this pathway is not as developed as our understanding of the sugar-based pathway. For this reason, our analysis was limited to the sugar-based pathway.

Policy Factors - In estimating the rate of market adoption, the analysis is based on the continuation of existing laws, regulations and policies (such as the ethanol tax incentive) and continuing USDA and DOE investment in biomass technologies RD&D at current levels, consistent with the Biomass R&D Act of 2000.

Methodology and Calculations for E-Biorefineries

Inputs to Base Case - Tables 3 and 4 show the results of the E-biorefinery analysis documented in this report, which serve as input to the integrated benefits analyses. NEMS-GPRA06 analysis extends through 2025, while MARKAL-GPRA06 analysis extends through 2050. The methodology employed to derive these inputs is described below.

Table 3. FY 2006 Ethanol from Corn Ethanol Plants and E-Biorefineries (Billion gallons per year)

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Starch-Based Ethanol	3.42	3.73	3.97	4.02	3.92	3.64	3.53	3.53	3.53	3.53
Cellulosic Ethanol from Corn Fiber			0.088	0.34	0.51	0.47	0.46	0.46	0.46	0.46
Cellulosic Ethanol from Corn Stover, Other Wastes, and Energy Crops					1.20	3.60	6.20	9.00	10.2	13.2
Total	3.42	3.73	4.05	4.36	5.63	7.71	10.2	13.0	14.2	17.2

Table 4. FY 2006 Bio-Based Products from E-Biorefineries

Year	2024	2025	2030	2035	2040	2045	2050
Products as % of cellulosic ethanol by weight	1.0	3.0	3.0	5.0	5.0	7.0	7.0
Products from cellulose in billion lbs. per year	0.05	0.24	0.71	2.05	2.97	4.72	6.11

In **Table 3**, corn ethanol growth through 2050 is based on our latest assessment of the industry, not assuming a Renewable Fuels Standard because this has not been enacted in 2004. For cellulosic ethanol based on corn fiber conversion, a near-term technology being developed by the program and industry partners, we assumed success for dry mills only. While the other type of ethanol plants, wet mills, may also succeed in deploying this technology, the benefits from wet mills are not considered in order to make the estimates more conservative. The volume of cellulosic ethanol from corn fiber includes the ethanol resulting from converting the fiber in the corn kernel and the residual starch that can be converted once liberated from the fiber. The total increment in ethanol output would equal 20% of the current dry mill's ethanol output. As previously stated, future E-biorefineries are assumed to use cellulosic biomass such as corn stover and energy crops, and not the corn kernel or its fiber as feedstock.

Also in **Table 3**, cellulosic ethanol estimates from corn stover, other cellulosic wastes, and energy crops resulted from a market equilibrium analysis that competes ethanol versus petroleum constituents in the low-blend fuel market (E10) and versus corn ethanol. Future biorefineries will produce chemical coproducts from biomass along with the main ethanol output stream to enhance their economic viability. **Table 4** shows the fraction of bio-based products produced in E-biorefineries from cellulosic feedstock.

Technical Characteristics - The E-biorefinery analysis is based on a plant whose main product is fuel ethanol with coproduction of high-value bio-based products and electricity. This results in a reduced cost of ethanol due to the allocation of costs across several products. NREL has designed a narrowly defined biorefinery, i.e., a cellulosic ethanol plant whose products are ethanol and electricity generated from biomass wastes. To be conservative in the current biorefinery analysis, EERE estimated that bio-based coproducts reduce ethanol costs further by a modest 3% to 5%. This estimate will be refined when better data are available as a result of additional R&D and analysis.

The analysis is for a biorefinery with a total throughput of 2,000 dry metric tons of feedstock per day and with a conversion efficiency increasing from approximately 70 gallons of ethanol per dry U.S. ton of feedstock currently to 95 in 2050, as a result of technological advances.

Technical Potential - The biomass feedstock resources discussed here do not include wood waste and black liquor waste from paper mills, an important but captive resource – these resources are typically used within the forest and paper products industry. Under favorable R&D outcome and market scenarios, the upper bound for ethanol supply from U.S. biomass is estimated at 35 billion gallons per year, based strictly on feedstock availability. The farm-gate price and supply relationship for biomass used in the ELSASBioref model (for near-term conditions) are presented in **Table 5.**

Table 5. Farm-gate Biomass Quantities Supplied vs. Price Range Excluding Mill Residues and Black Liquor (Million dry tons per year)

Feedstock	up to $20/dt	up to $30/dt	up to $40/dt	up to $50/dt
Forest Residues	0	12	20	70
Agricultural Crops Residues	0	1	65	80
Potential Energy Crops	0	0	80	187
Other Wastes	0	17	25	35
Total	0	30	190	372

The total is 190 million dry tons per year at prices up to $40 per dry ton, and 372 million dry tons per year at up to $50 per dry ton, before adding transportation costs to the biorefinery. To be realistic, some of the future energy crops are assumed to be used in non-biorefinery applications. Therefore, only 66 percent of energy crops will count toward EERE's benefits. Likewise, some of the forest and agricultural residues and other wastes will be used for fiber products and other non-biorefinery applications. The fraction of each feedstock available for use in biorefineries is shown below.

While forest residues and some of the "other wastes" may not be optimal for sugar-based ethanol production, we recognize that future syngas-based fuels production may use forest residues and certain "other wastes" as feedstock. Therefore, this analysis is not deemed to be overly optimistic in spite of the assumption that biorefineries are sugar-based.

Transportation costs ranging from $7.50 to $15.0 per dry ton (depending on hauling distance) were added to farm-gate prices to account for hauling to the biorefinery. After adding these costs and applying the factors shown in **Table 6**, the near-term supply as a function of price per dry ton at the biorefinery gate is shown in **Table 7**.

Table 6. Fraction of Total Feedstock Assumed To Be Available To Biorefineries

Feedstock	Fraction
Forest Residues	0.4
Agricultural Crops Residues	0.7
Potential Energy Crops	0.66
Other Wastes	0.6

Table 7. Biorefinery-gate Quantities Supplied vs. Price Range Excluding Mill Residues and Black Liquor (Million dry tons per year after transportation)

Feedstock	Up to $27.50/dry ton	Up to $40.00/dry ton	Up to $52.50/dry ton	Up to $65.00/dry ton
Agricultural Crops Residues	0	0.7	45	56
Potential Energy Crops	0	0	53	123
Forest and Other Wastes	0	15	23	49
Total	0	16	121	228

The annual quantity available for ethanol production, at up to $65 per dry ton (including costs of transportation to the biorefinery), has been reduced from 372 to 228 million dry tons after applying the reduction factors from **Table 6**. In the longer term (2040, for example), crop yields increasing at the rate of 1% per year will result in additional feedstock as shown in **Table 8**.

Table 8. Long-term Biorefinery-Gate Supply vs. Prices Excluding Mill Residues and Black Liquor (Million dry tons per year after transportation)

Feedstock	Up to $27.50/dry ton	Up to $40.00/dry ton	Up to $52.50/dry ton	Up to $65.00/dry ton
Agricultural Crops Residues	0	1	68	83
Potential Energy Crops	0	0	78	184
Forest and Other Wastes	0	15	23	49
Total	0	16	169	316

At approximately 93 gallons of ethanol per dry ton of feedstock, the potential supply in the long term is 29 billion gallons per year. This potential would increase significantly with appropriate incentives such as those aimed at reducing carbon emissions.

Expected Market Uptake - Although the proposed Renewable Fuels Standard (RFS) is expected by many to be enacted, this analysis is limited to existing policies and does not include consideration of the RFS. Corn ethanol is projected to continue to expand as a result of various states' phase-outs of MTBE, but only to approximately 4 billion gallons/year by 2014 compared with approximately 5 billion gallons/year under the proposed RFS. Future cellulosic ethanol capacity will slowly replace corn ethanol capacity as the new technology becomes more and more competitive relative to corn ethanol. The tables show corn ethanol continuing at a fairly stable level through 2050.

The Biomass Program estimates that, beginning in 2012, corn ethanol plants will deploy the technologies for processing corn fiber, a cellulosic feedstock, into ethanol. This would be in addition to their continuing production of ethanol from corn starch. Beginning in 2018, a number of the ethanol plants will also convert corn stover to ethanol, if R&D is successful. Beginning in 2024, the first E-biorefineries producing ethanol as a major product (along with high-value coproducts) from biomass wastes and residues will be completed and begin operation. Note that a number of nonfuel biorefineries would have started producing before 2024, as described in the previous section on bio-based products analysis. Eventually energy crops (e.g., fast growing grasses) will supply the biorefineries to augment the residues.

The analytic tool ELSASBioref was used to estimate ethanol market penetration for cellulosic ethanol, including from corn stover, energy crops and other cellulosic residues, but excluding corn fiber and residual starch. The market penetration of corn fiber and residual starch-based ethanol, small quantities in comparison with the other cellulosic ethanol, was determined exogenously with input from the Biomass Program experts. The following section describes ELSASBioref and its use for this analysis.

Methodological Approach - Biomass ethanol market penetration analysis was accomplished through the integration of the results of various analyses conducted primarily by national laboratory personnel and their subcontractors. ELSASBioref served as the integrating tool. The following discussion provides a brief overview of ELSASBioref and the integration methodology.

Integration of Component Analyses - The four principal components integrated with the ELSASBioref tool are corn feedstock and conversion cost and performance estimates, cellulosic feedstock supply curve information, cellulosic ethanol conversion technology data, and ethanol demand curve information. These components are described in greater detail in the following sections.

ELSASBioref is a spreadsheet-based economic equilibrium analysis tool that integrates these four sets of data – along with additional technical, economic, and policy variables – to derive ethanol supply and demand curves and estimate market penetration (see **Figure 1** depicting the input and output).

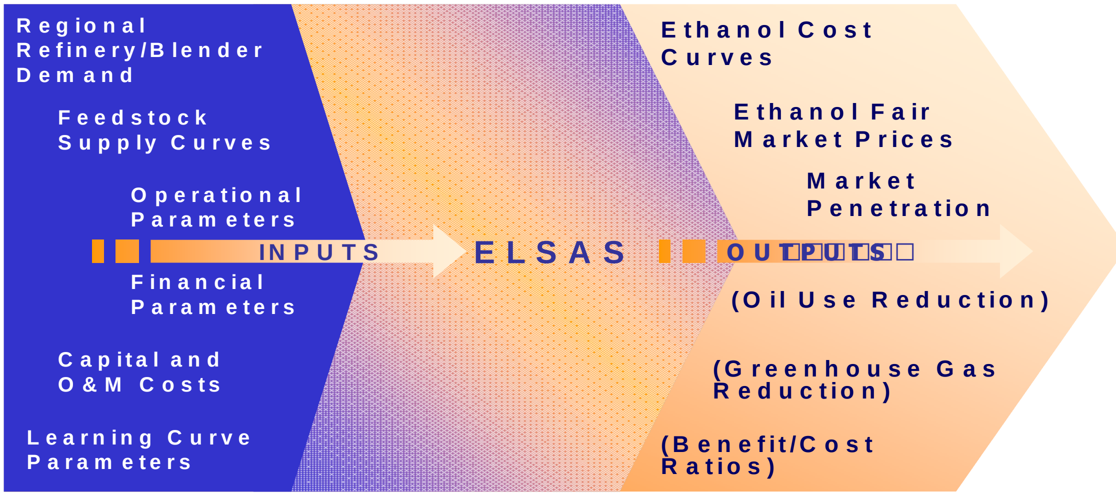

Figure 1. ELSASBioref Input and Output Parameter Categories

The model uses cost projections provided by NREL's design team to characterize the enzyme-based technology used to convert cellulosic feedstocks to sugars and eventually ethanol. The model combines this data with cellulosic feedstock supply data to generate the cost and incremental supply of ethanol available for a given year.

For the last year in each five-year increment (to 2050), ELSASBioref balances supply and demand of ethanol by establishing a market-clearing price. For supply levels greater than the amount of corn starch-based ethanol production, the marginal cost of ethanol supply at each five-year increment is determined by cellulosic ethanol production costs and feedstock costs. Feedstock costs may increase with increasing demand in accordance with supply curves provided by experts at Oak Ridge National Laboratory.

Quantities demanded at different prices are represented in a demand curve for ethanol. For the last year in each five-year increment, supply and demand are balanced through a market-equilibrium price. The production of starch-based ethanol for that year is subtracted from the total demand for ethanol to calculate the total volume of cellulosic ethanol produced. Quantities of cellulosic ethanol produced in the first four years in the five-year increment are determined by interpolation. This process of determining market-equilibrium quantities and prices is performed for each five-year increment to 2050.

Additional details regarding the three primary data-input components and their treatment within ELSASBioref are presented below.

EERE provided estimates of growth rates for conventional corn starch based ethanol supply, and these were incorporated as additional input data in the ELSASBioref model.

Cellulosic Feedstock Supply - Oak Ridge National Laboratory (ORNL) developed cellulosic feedstock supply curves with the aid of BIOCOST[5], POLYSYS[6], and other regionally detailed models. The feedstock supply-curve information shows quantities of different categories of cellulosic feedstocks available at different prices and time periods. This information is used by ELSASBioref at a national level of aggregation. The current GPRA case uses ORNL data reported by Arthur D. Little Inc[7]. These data were modified based on more recent ORNL work on agricultural residue availability and cost[8].

Within ELSASBioref, cellulosic feedstock costs are adjusted to include transportation charges from the farm gate to the conversion facility, and feedstock supplies are allocated among different competing uses as described above in the Technical Potential section. In addition, the analysis assumes that agricultural residues and bio-energy crops will increase at an annual rate of 1% during the analysis period, due to increasing agricultural productivity. This assumption yields a total U.S. feedstock supply in 2040 approaching 316 million dry tons of agricultural residues, forest wastes, energy crops and other biomass wastes, after excluding potential competing uses.

Ethanol Conversion Costs - NREL, which is partnering with industry and universities to develop competitive ethanol production technologies, provided estimates of cellulosic ethanol production costs (other than feedstock-related costs) on a per-gallon basis. The NREL estimate of the efficiency of converting feedstock into ethanol is input as a function of date, namely the number of gallons per dry ton of feedstock increases in the future as a result of R&D success. This allows the ORNL-provided feedstock costs to be presented on a per-gallon basis and added to the NREL non-feedstock costs to obtain the cost of producing a gallon of cellulosic ethanol.

Ethanol Demand - Demand curves for ethanol (for use as a blending component with gasoline) are developed by ORNL refinery modelers. The value of ethanol to refiners is based on its blending characteristics including octane rating, toxics dilution, sulfur dilution, effect on Reid vapor pressure in summer reformulated gasoline, etc. The refinery model ORNL-RYM uses this value along with crude oil and gasoline price projections, public policy variables, and numerous technical and economic factors relating to oil refinery operations. For a given set of input assumptions, the ORNL analysis generates quantities of ethanol demanded by refineries for blending with gasoline at different prices. Procedures were developed to modify RYM outputs to different world oil price scenarios. Ethanol transportation costs also are used in the analysis.

Benefits Estimation - The factors used by NEMS-GPRA06 and MARKAL-GPRA06 for calculating reductions in fossil energy use and carbon emissions were derived from the EERE Environmental Benefits Model GREET. The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model is maintained by Argonne National Laboratory and is widely used within EERE, by industry, universities, and other government agencies. GREET contains characterizations of several biomass feedstock sources, including herbaceous and woody biomass, corn, and soybeans. GREET models many transportation fuels and vehicle technologies and includes representations of major electricity generation sources. GREET can compare energy and emission changes for alternative technologies, relative to a base technology in a unified and consistent way.

Sources

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Appendix C – GPRA06 Building Technologies (BT) Program Documentation

Introduction

Table 1 outlines the activities characterized for the GPRA06 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.

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.

Table 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: Controls
		Solid State Lighting
	Space Conditioning & Refrigeration R&D	Refrigeration R&D: Unitary DX System
		Refrigeration R&D: Ventilation Load Reduction
		Refrigeration R&D: Commercial Refrigeration
		Refrigeration R&D: Remote Fault Detection and Diagnostics
	Appliances & Emerging Technologies R&D	Appliances & Emerging Tech R&D: Roof Top AC
		Appliances & Emerging Tech R&D: Recessed Can Lights
		Appliances & Emerging Tech R&D: R-Lamp
	Building Envelope R&D: Window Technologies	Window Technologies: Electrochromic Windows
		Window Technologies: Superwindows
		Window Technologies: Low-E Market Acceptance
	Analysis Tools and Design Strategies	Analysis Tools and Design Strategies
Equipment Standards and Analysis	Equipment Standards and Analysis	Standards: Commercial Unitary AC/HP
		Standards: Distribution Transformers

1.0 Residential Buildings Integration

The long-term goal of Residential Buildings Integration is to develop cost-effective designs for net Zero Energy Buildings (ZEB)—houses that produce as much energy as they consume on an annual basis—by 2020.

1.1 Residential Building Energy Codes

1.1.1 Target Market

Project Description. The Residential Building Energy Codes project improves the minimum or baseline energy efficiency of new residential buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for residential buildings. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. Federal, state, and local jurisdictions then adopt and implement these upgraded federal and 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.

Market Description. The market includes new residential low-rise buildings three stories or less in height and all additions and renovations to buildings requiring code permits.

Size of Market. Each year, nearly 1.6 million residential building permits are issued, approximately 80% of which are single-family dwellings. Although not all jurisdictions currently have energy efficiency building codes in place, the Pacific Northwest National Laboratory (PNNL) estimates that about half of 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 could 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 FY06, the percentage of potential savings, in the first year 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 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.

1.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL 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).

This corresponds to a total incremental cost of approximately $120 million in 2010, $285 million in 2020, and $300 million in 2030.

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

- 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.

1.1.3 Methodology and Calculations

Inputs to Base Case. With respect to codes, it is indeterminate as to whether potential future code improvements are incorporated into the National Energy Modeling System (NEMS) base case. The NEMS-GPRA06 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 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-GPRA06 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. Only an estimate of potential future codes is included in the GPRA estimates. Therefore, PNNL did not provide inputs to change the base case assumptions for the program markets.

Technical Characteristics. The FY 2006 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 2000 edition of the International Energy Conservation Code (IECC) code (to comply with Section 304 of the Energy Conservation and Production Act), and 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 2000) with variations in climate by states (and differences among states) in their adoption and enforcement of building codes. This discussion uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology.

The principal difference between the 1995 Model Energy Code and the IECC 2000 involves the solar heat gain requirements for windows and increased thermal resistance requirements for ducts in unconditioned spaces. Based on a series of simulations for various U.S. locations, the percentage reduction in cooling load was estimated to be about 15%. This requirement increases the heating load by a small amount, about 2% nationally. The requirement itself is restricted to the southern tier of states. The GPRA estimates were partly based on states' accelerated schedule of adoption of the IECC 2000 and 2003 codes. Through the efforts of the Building Energy Codes project, 31 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of three years nationwide.

The IECC's ongoing activities were assumed to lead to more stringent residential standards in the future. The Department of Energy (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 IECC standard assumed to become available in the latter part of the current decade. Based on discussions with EERE-Building Technologies (BT) staff, PNNL assumed that the results of these upgrades were to reduce heating and cooling loads in new residential structures by 10%. Without these activities, PNNL assumed that the same standard would be adopted, on average, three years later.

Relationship to WIP. EERE's efforts to support building codes covers two aspects: 1) the development of new codes with greater stringency or ease of enforcement and 2) activities to improve the compliance with codes and to accelerate adoption of the most recent codes by states and localities. The development of new codes is supported by the Building Technologies Program, and efforts to improve compliance and accelerate adoption are supported in the Weatherization and Intergovernmental Program (WIP). The methodology to develop the total effect from these two EERE programs is integrated. The documentation below discusses both aspects of EERE activities with regard to energy codes.

More explicitly for modeling purposes, the GPRA energy savings estimates for BT (in regard to codes) is restricted to the development of a single new national residential code, expected to be published in the latter part of the current decade. However, with the ongoing efforts to promote adoption and compliance, the impact of the published code would be modest. However, without development of a new code, activities to promote adoption and compliance would be meaningless. Thus, the issue becomes assignment of savings from future code between the BT and WIP programs. In the GPRA estimates for 2006, 50% of the savings attributable to accelerated adoption and increased compliance of the new code were allocated to the BT program.

Expected Market Uptake. The project's activities also were assumed to improve compliance rates for codes currently adopted by states and localities, as well as future building codes. Compliance increases through better familiarity with the codes, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for various standards as discussed above. Compliance with the several key provisions in the IECC 2001 and 2003 (compared with the 1995 Model Energy Code) was expected to be higher from the outset. On average, compliance was estimated to be 68% in the year of the adoption. By 2010, compliance rates were assumed to increase to 69% without the project and 74% with the project. For homes that do not comply with the standard, only half of the incremental energy savings were assumed to be achieved by adopting IECC 2001 or 2003.

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 85% at the time of adoption, increasing to 90% with the effect of the project after the first 10 years.

1.2 Research and Development: Building America

1.2.1 Target Market

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% in additional energy savings through the use of integrated onsite power systems.[a] 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.

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 2006, however the impacts on existing homes were not modeled for the FY 2006 effort.

Size of Market[4]: Each year about 1.2 million new housing units are built. In 2002, 976,000 new single-family homes were built. These units are primarily owner occupied.

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. PNNL assumed that Building America activities would not occur without DOE funding; therefore, no acceleration of market acceptance was modeled.

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

1.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preference/Values – Nonenergy Benefits. The cost and performance characteristics were used to model this project in NEMS-GPRA06/MARKAL-GPRA06. The following nonenergy characteristics were not considered in the model:

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

1.2.3 Methodology and Calculations

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

a 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) savings per home. Added to this are the energy savings, accrued in that year, for Building America homes built in previous years, beginning in 2006.

Incremental costs for whole-building energy savings were developed with Navigant Consulting's Residential Optimization Model (Version 5.7). Cost increments were developed for three levels of percentage savings from the baseline: -40%, -60%, and -70%. PNNL 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 EERE, namely appliance standards, building codes, and Energy Star homes. Thus, the savings percentages with Building America are translated to 20%, 40%, and 50% of the baseline unit.

The ROM simulations were conducted for four cities: Minnesota, Boston, Atlanta, and Phoenix (see **Table 2**). Population weights to develop a national average were assigned in rough fashion (see **Table 3**). Because the NEMS shell module only treats heating and cooling, the energy savings from the inputs shown in **Table 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 would be roughly three times that shown in the model (i.e., 1.00/0.30 = 3.33). These other savings would occur in lighting, water heating, and other appliances in homes building to Building America criteria. The challenge for the integrated modeling effort is to try to incorporate these additional savings, with a link to the number of homes using shell package four or five (as shown in **Table 4**).

The Building America program is assumed to result in cost reductions in various residential technologies. 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 10%, falling by an additional 10% every five years.

Table 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 3. Population Weights and Incremental Costs for Representative Cities

City	Weight	Incremental Costs, Building America 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 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

PNNL refined the target market to reflect new home sale prices because homes built with renewable energy technologies will be targeting the higher-end housing market. Based on U.S. Census[6,7] data, PNNL assumed that high-end homes would be represented by those new homes that sold for at least $200,000 in the South and West regions (about 45% of new homes sold in those regions) and Northeast and Midwest regions (about 48% of new homes sold in those regions).

The fundamental premise leading to wide adoption is that existing technologies and 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, while shaving summer peak loads and thereby alleviating some of the need to expand the grid to accommodate system summer peaks. With much improved load characteristics, DOE expects zero-net energy houses through 2007 to receive slightly lower electric rates or utilize time of use (TOU) rates, and by 2020 will have a zero electric bill in return for zero summer peak loads[5].

Estimates do not include potential applications to manufactured homes or in existing buildings – both project goals – as cost estimates for these targeted areas are not yet available. Developers are assumed to be more likely to negotiate for favorable electrical service with local utilities –

based on the zero-net energy home concept. Energy savings resulting from adoption by smaller spec builders and one-off builders are not captured but could be significant if utilities offer a renewable energy rate to all homeowners.

1.2.4 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) 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) Annual Energy Outlook (AEO) 2003, Department of Energy, Energy Information Administration.
(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."

2.0 Commercial Buildings Integration

The long-term goal of this subprogram is to develop cost-effective designs for commercial buildings that produce as much energy as they use on an annual basis. Research will focus on reducing total energy use in a commercial building by 60% to 70%.

2.1 Commercial Building Energy Codes

2.1.1 Target Market

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.

Market Description. The market includes new commercial and multifamily high-rise (above three stories) buildings and all additions and renovations to commercial buildings requiring code 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 FY06, the percentage of potential savings, in the first year of the single future code, was assumed to be approximately 20% for envelope measures and 30% for lighting measures without the project.

Baseline Market Acceptance. The FY 2006 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2001 editions of ASHRAE 90.1-1999(4) standard (to comply with Section 304 of the Energy Conservation and Production Act), and the future development of more stringent building energy codes. Through the efforts of the Building Energy Codes project, 21 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

2.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL 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.

- Improved environment and more comfortable buildings.
- Lower utility bills
- 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.

2.1.3 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-GPRA06 base case. The NEMS-GPRA06 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., IECC 2003) is included in the GPRA forecast of savings. The GPRA savings estimates for WIP also include a portion of the impact of changes in building codes that are anticipated within approximately the next 10 years. (A portion of the savings from increased stringency of future codes is also allocated to the Building Technologies Program). Therefore, PNNL did not provide inputs to change the base case assumptions for the 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. This BT program works with the Training and Assistance for Codes project within the Office of Weatherization and Intergovernmental Programs, which funds the development of core materials (such as compliance tools and training materials) and provision of training and financial and technical assistance for states to update and implement their building energy codes. Benefits cannot be clearly allocated to either project, thus the benefits estimated are a function of both training and deployment as well as development of the commercial building energy codes and standards.

Savings estimates for commercial codes are based on increased stringency from the combined impact of the forthcoming ASHRAE 90.1-2004 code and the "next" code assumed to be published in 2007. For FY06, future codes (up through 2010) are assumed to achieve a total reduction of 18% in electricity and a 10% reduction in natural gas as compared to 90.1-1999, based on a series of simulations for various U.S. locations. Benefits for FY 2006 were assumed to be allocated according to the ratio of actual funding levels.

The project impacts energy consumption through two primary avenues: 1) developing and supporting code changes to improve the minimum energy-efficiency requirements for commercial and multifamily high-rise buildings and 2) providing technical and financial assistance to states to update and implement their building energy codes. The latter includes developing tools that can ease the adoption of new codes and through their use, can support improvements in compliance and enforcement of code provisions. Tools take the form of code compliance software, computer-based training tools for building energy codes, and tools for implementing noncomputer-based codes.

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. Support 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 2006 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2001 editions of ASHRAE 90.1(4) standard (to comply with Section 304 of the Energy Conservation and Production Act), and 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 principal differences between the ASHRAE 90.1-1989, 90.1-1999, and 90.1-2001[5] standards relate to requirements for better windows, reduced installed wattage for lighting, and more efficient heating and cooling equipment. The savings from improved equipment are not included in the project's savings estimates, because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Based on a series of simulations that include various U.S. locations and that were developed specifically to evaluate the two ASHRAE standards (often referred to as the "determination" study[6]), the average reduction in site energy use was estimated to be about 3.5% or 2 MMBtu/sq ft. The GPRA estimates were partly based on states' accelerated adoption schedule of the ASHRAE 90.1-1999 and 90.1-2001 standards. Through the efforts of the Building Energy Codes project, 21 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

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, assumed 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. Many states adopting this standard by 2010 also depends on the project's continuing activities to assist states in the adoption (and compliance) process. Without these activities, the analysis assumed that the same standard would be adopted, on average, six years later.

The project activities also were assumed to improve compliance rates for codes currently adopted by states and localities, as well as future building codes. Compliance is increased through increased familiarity with the codes, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance is effectively measured as the percentage of potential savings moving from one code to the next. Compliance rates estimated between the existing code (assumed to be 90.1-1989) and a code based on ASHRAE 90.1-1999; and between 90.1-1999 and a new code discussed above.

Without the program, the percentage of potential savings is assumed to be modest, as the program is directed toward software tools and training that facilitate adherence to the code. In this case, on average, PNNL estimated the percentage of potential energy savings for envelope measures to be about 20% in the year of adoption. Ten years later, the percentage of potential energy savings is assumed to increase to approximately 50%. For lighting, these percentages were 30% and 55%, respectively. With the program, the percentage of potential energy savings is expected to be higher at the outset and increase more rapidly. For envelope measures, the initial potential savings is about 70%, increasing to about 95% 10 years later. For lighting measures, the initial percentage of savings is 80%, again increasing to about 95% years later.

Expected Market Uptake. As part of work for an unpublished analysis of the historical impacts of Building Energy Codes in August 2003, the assumptions regarding the acceleration effect of the program were modified (e.g., program activities leading to states adopting codes more rapidly than they would have otherwise). In general, the states were classified into groups that: 1) immediately adopted the ASHRAE 90.1-1989 code, 2) would have adopted within five years without the building codes project, or 3) would have adopted within 10 years without the building codes project. 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 three years for the forthcoming ASHRAE 90.1-2004 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. This modified set of assumptions increases the overall estimate of the future energy savings impact from the program.

2.1.4 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.
(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 Technology Research and Development

2.2.1 Target Market

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. [b]

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

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

relatively higher energy use intensities such as assembly, education, food service, food sales, lodging, mercantile and service, and office buildings.

Baseline Technology Improvements. For this analysis, PNNL did not suggest any changes in technology improvements, apart from the 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. PNNL used the curve related to design products to model this project.

2.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.
Cost of Conventional Technology[(4)]: Average of $101/ft^2 for the targeted new commercial and multifamily; $0 for existing buildings.
Cost of BT Technology[(5)]: $103.00/ft^2 for new commercial and multifamily; $3/ ft^2 (2001 to 2009), increasing to $4/ ft^2 (2010 to 2030) for existing buildings.
Incremental Cost[(5)]: 2% above base for new buildings; $3/ ft^2 (2005 to 2009), increasing to $4/ ft^2 (2010 to 2030) 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.

2.2.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented in the 2004 PNNL report, *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (Elliott et al 2004).

Technical Characteristics. 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 and by 30% in existing buildings.[c]

[c] 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.

Expected Market Uptake. The market penetration goal[3] is to accelerate the penetration of high-performance building designs, such that 60% of new commercial and multifamily construction (**Figure 1**) and 20% of existing construction incorporates the products supported by this project by 2020 (**Figure 2**). Penetration curves were developed based on market diffusion curves developed by PNNL[6]. PNNL assumed that this project accelerates the adoption of relevant energy-savings products, technologies and designs by 10 years.

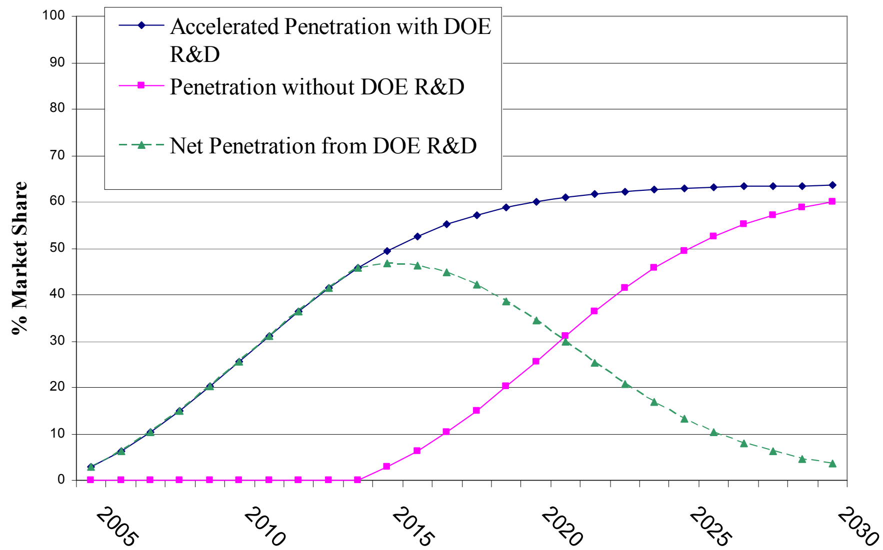

Figure 1. Market-Penetration Curve for Commercial R&D Project Targeting New Buildings

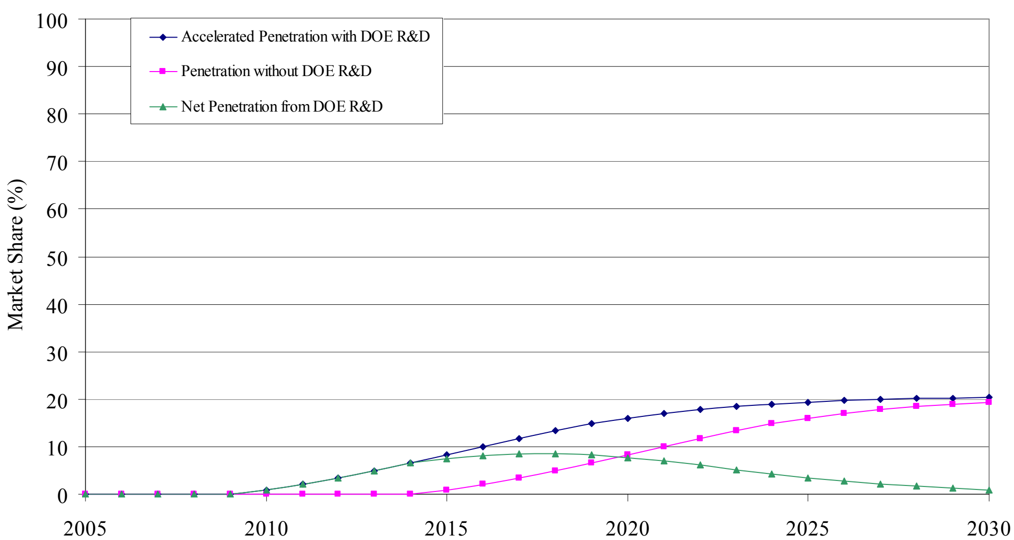

Figure 2. Market-Penetration Curve for Commercial R&D Project Targeting Existing Buildings

2.2.4 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

As legislatively mandated, BT will pursue energy efficiency standards for appliances and building equipment, setting higher standards where technologically feasible and economically justified.

3.1 Commercial Unitary AC/HP Standards

3.1.1 Target Market

Project Description. DOE is required by the Energy Policy and Conservation Act and its amendments to consider national energy conservation standards for certain commercial unitary air conditioners and heat pumps.

Market Description: The market includes all residential and commercial equipment covered by the appropriate legislation.[1,2]

Size of Market: The market size includes all applicable residential and commercial equipment in the market to which legislation applies (ovens/ranges and medical equipment, for example, are not covered).

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

3.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental investment costs were developed assuming a nine-year payback period on investment (i.e., an annual energy cost savings of $1 implies an initial investment of $9)[d]. This

[d] Screening Analysis for EPACT-Covered Commercial HVAC and Water Heating Equipment (PNNL-1223). P. D-12. Payback period for Upgrade Group relative to EPCA 1992 for Central Air Source AC Units, >= 65K, < 135 kBtu/h

corresponds with a total incremental investment cost of approximately $200 million in 2005, $1 billion in 2010, $1.4 billion 2020, and $600 million in 2030.

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

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

3.1.3 Methodology and Calculations

Technical Characteristics. For FY 2006, the energy savings from commercial equipment standards activities were based primarily on a PNNL screening analysis conducted in late 1999 and early 2000(3) to provide preliminary estimates of the potential energy savings from updated commercial equipment standards. PNNL used the spreadsheet developed for this study to estimate the energy savings from various levels of standards for nearly 40 types of equipment covered by the Energy Policy Act (EPAct). The spreadsheet results were used to identify technologies that could achieve significant energy savings beyond the efficiency levels set in the recent ASHRAE 90.1-1999 publication.(4)

Based on the spreadsheet EPACT_SA.XLS (essentially identical to the spreadsheet installed on the BT Web site for public comment subsequent to the EPAct screening analysis), the tables below summarize the efficiency assumptions and energy savings results for technologies that EERE-BT will further analyze. The key assumptions and results were summarized for 12 cooling technologies the **Table 5** and for boilers and a high-capacity instantaneous water heater in the **Table 6.** Cumulative savings, shown in the last column in both tables, were based on the savings from the effective date of the standards through 2030.

Table 5. Key Assumptions and Results for Cooling Products

Equipment Category	Efficiency (SEER and EER)*			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
3-Phase Single Package, Air Source Air Conditioning, <65 kBtu/h	9.7	12.0	2005	4.6	21.0	26.5	396.0
3-Phase Single Package, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	1.2	3.1	3.4	60.2
3-Phase Split, Air Source Air Conditioning, <65 kBtu/h	9.7	11.0	2005	0.9	4.1	5.2	78.1
3-Phase Split, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	9.1	24.0	26.5	463.0
Central, Water Source Heat Pump, >17 and <65 kBtu/h	9.3	12.5	2008	1.5	7.1	11.1	146.9
Central, Air Source Air Conditioning, >=65 and <135 kBtu/h	8.9	11.0	2008	5.5	25.0	31.6	471.6

Central, Air Source Air Conditioning, >=135 and <240 kBtu/h	8.5	11.0	2008	5.4	24.6	31.0	463.1
Packaged Terminal Air Conditioning, 7-10 kBtu/h	8.6	10.8	2008	0.4	1.8	2.2	33.3
Packaged Terminal Air Conditioning, 10-13 kBtu/h	8.1	10.2	2008	0.6	2.6	3.3	49.5
* SEER = seasonal energy efficiency ratio; EER = energy efficiency ratio.							

Table 6. Key Assumptions and Results for Boilers and a High-Capacity Instantaneous Water Heater

Equipment Category	Efficiency (SEER and EER)			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
Pkg'd Boilers, Gas, 400 kBtu/h, Hot Water	75%	78%	2008	0.2	0.9	1.7	19.7
Pkg'd Boilers, Gas, 800 kBtu/h, Hot Water	75%	78%	2008	0.4	2.0	3.7	43.0
Pkg'd Boilers, Gas, 1500 kBtu/h, Hot Water	75%	78%	2008	0.1	0.7	1.2	14.2
Pkg'd Boilers, Gas, 3000 kBtu/h, HW	75%	80%	2008	0.2	0.7	1.3	15.2
Pkg'd Boilers, Gas, 400 kBtu/h, Steam	72%	76%	2008	0.1	0.6	1.1	12.6
Pkg'd Boilers, Gas, 800 kBtu/h, Steam	72%	76%	2008	0.4	1.6	3.0	34.5
Pkg'd Boilers, Gas, 1500 kBtu/h, Steam	72%	79%	2008	0.3	1.2	2.3	26.7
Pkg'd Boilers, Gas, 3000 kBtu/h, Steam	72%	80%	2008	0.2	0.9	1.7	19.2
Instantaneous Water Heaters, 1000 kBtu/h	80%	83%	2008	1.0	4.4	5.6	83.3

3.2 Distribution Transformers

3.2.1 Target Market

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.

BT conducts the program that develops equipment energy conservation standards and has overall responsibility for rulemaking activities for distribution transformers in fulfillment of the law.

The first step in developing energy-conservation standards was the secretarial determination in 1997 that, "Based on its analysis of the information now available, the department has determined that energy conservation standards for transformers appear to be technologically feasible and economically justified, and are likely to result in significant savings" 62 FR 54809 (October 22, 1997).

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

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

3.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL 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). This corresponds to a total incremental investment of approximately $580 million in 2010, $780 million in 2020, and $230 million in 2030.

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

- Reduced CO_2 and SO_X emissions

3.2.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL[(7)].

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).[(5)] The analysis assumed the following:

- Average savings of 140 watts per unit
- A transformer sales forecast (see **Table 5**).
- 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.

PNNL assumed that the distribution transformer standard would not go into effect until 2008, based on an internal schedule indicating that the final rule would be issued May 2005, with the standard going into effect three years later.[6] 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 7. Distribution Transformer Market Penetration

Year	Transformer Sales Forecast
2005	1,422,000
2006	1,452,000
2007	1,485,000
2008	1,521,000
2009	1,549,000
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 Sources

(1) National Appliance Energy Conservation Act of 1987, Public Law 100-12.
(2) Energy Policy Act of 1992, Public Law 102-486.
(3) Somasundaran, S. et al. 2000. *Screening Analysis of EPAct-Covered Commercial HVAC and Water Heating Equipment*. PNNL-13232, Pacific Northwest National Laboratory, Richland, Washington.
(4) ASHRAE 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(5) DOE Draft ANOPR Analysis for Distribution Transformers Rulemaking, January 6, 2004.
(6) Internal DOE schedule tracking document for David Garman, Aug. 29, 2003
(7) 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.

4.0 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

4.1.1 Target Market

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 nonsoftware 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.

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]: PNNL assumed that this project accelerates the introduction and market penetration of the advanced building energy tools and design strategies by 10 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. PNNL assumed 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. For this analysis, PNNL did not suggest any changes in technology improvements, apart from the 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 by PNNL(5). The study suggested several generic penetration curves based on the type of equipment of interest. PNNL used the curve related to design products to model this project.

4.1.2 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, with the idea that the private sector can use these algorithms, codes, and modules and design a suitable 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).

4.1.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL(5).

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.[e]

Expected Market Uptake(3). The market penetration goal is to accelerate the penetration of high-performance building design, such that 50% of new commercial and multifamily construction and 30% of existing construction incorporates the products supported by this

[e] 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.

project by 2020. PNNL assumes that this project accelerates the adoption of relevant energy-savings products, technologies and designs by 10 years. The market penetration is shown in **Figure 3**.

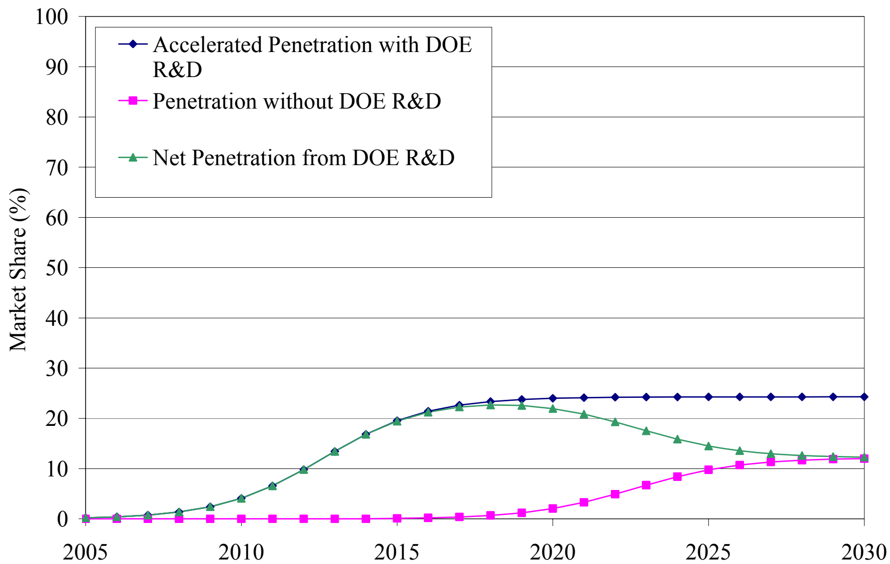

Figure 3. Market-Penetration Curve for Analysis Tools and Design Strategies

4.1.4 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

4.2.1 Target Market

Project Description. This project helps manufacturers and utilities commercialize highly efficient appliances and equipment by providing the following assistance:

- Technology procurement to bring new technologies to market (late developmental work).

- Independent third-party evaluation and verification of highly efficient technologies using field studies and demonstrations increase market share of emerging technologies and Energy Star technologies with very low market penetration.
- R&D on appliances not covered by other projects but offering significant energy-savings potential.

Market Description: The market includes residential and commercial building technologies, with emphasis on appliances, water heating, lighting, and building equipment.

Size of Market: The market size depends on the selected equipment:
- **Rooftop Air Conditioners:** One of the most widely used technologies with greatest commercial space conditioning energy use; more than a million tons sold in 1998.
- **Residential Can Lights:** An estimated 22 million incandescent can fixtures sold in 2001.
- **Reflector CFLs (R-lamps):** Nearly 125 million parabolic/reflector lamps sold to the residential market.

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

4.2.2 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:
- Reduced carbon emissions
- Dehumidification provided by heat-pump water heater.
- Reduced lamp replacement frequency with R-CFLs and CFL cans.

4.2.3 Methodology and Calculations

Rooftop Air Conditioning

The intent of the rooftop air conditioner project is to use competitive procurements of large numbers of units to stimulate the production of high-efficiency equipment. The immediate goal is to get high-efficiency equipment installed in buildings owned by the federal government and other state and local agencies.

With this long-term goal in mind, PNNL provided costs of high efficiency roof top air conditioners to be used in the NEMS-GPRA06 commercial model to reflect the principal influence of this project. In NEMS-GPRA06, three air conditioners are specified in the rooftop category—a baseline unit (energy efficiency ratio of 8.9), a moderate efficiency unit (energy efficiency ratio of 10.2) and a high-efficiency unit (energy efficiency ratio of 14.7). No subgroups are distinguished by capacity (e.g., 65 to 135 kBtu/hr vs. 135 to 240 kBtu/hr).

For this analysis, the incremental cost was reduced by 40%, based on project goals. Given the proportion of the market assumed in the NEMS-GPRA06 to display high discount rates in the selection of equipment, this cost reduction yielded a 4 to 12% penetration of the higher efficiency units through the projection period. By 2025, the proportion of the total rooftop air conditioning stock using the higher efficiency units is about 11%.

Market Introduction: No acceleration of market acceptance was modeled because the impact was determined to be negligible. Because the technology has only modest penetration (10%) by 2020 and only a few percent by 2010, assuming that this project accelerated market acceptance would not have a significant impact over the analysis period.

Performance Target: An efficiency increase from 10.3 to 11.0 energy efficiency ratio for 65 to 135 kBtu/hr and from 9.7 to 10.8 for 135 to 240 kBtu/hr.

Lifetime: 15 years.

Residential Can Lights

The intent of this project is to develop a recessed can light fixture that uses compact fluorescent lamps rather than incandescent.

Market Introduction: These projects were assumed to accelerate the introduction of these technologies into the marketplace by seven years.

Performance Target: Assumed efficacy of 37.5 lumens/watt[f]. Actual project requirements should be similar to other programs; here, efficacy is expected to improve by a factor of 2.5, while R-lamps are expecting an improvement factor of 3.33 and Energy Star CFLs are looking to an improvement factor of 3.42.

Installed Cost: Incremental cost above incandescent cans is $24/can in 2006 declining to $20/can by 2011.

Lifetime: 30 years.

R-Lamps

The intent of this project is to develop a floodlight or spotlight (lamps using reflector surfaces) that can utilize a screw-base compact fluorescent lamp rather than an incandescent lamp.

Market Introduction: These projects were assumed to accelerate the introduction of these technologies into the marketplace by five years.

Performance Target: Assumed efficacy of 36 lumen/watt[g]. Actual project requirements should be similar to Energy Star (within WIP), as **Table 8** shows.

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[f] Actual efficacy is lower than this value. The value of 37.5 assumes an existing technology value of 15 lumens/watt; actual incandescent can lights have efficacies significantly lower than this. However, BESET currently assume all incandescent lighting to have an efficacy of 15 lumens/watt. The proposed technology, which has the same lumen output as the current technology, is rated at 26W, while the existing incandescent technology is rated at 65W. Hence 15 * 65 / 26 = 37.5.

[g] Weighting the Energy Star targets 58% for less than 20W and 42% for 20W or more (58% of incandescent lamps in homes have Wattages less than 75W and 42% of incandescent lamps in homes have Wattages 75W and greater[(1)]) yields an average lumens/watt of 36. The comparison incandescent lamp, EPACT 65W R-lamp, has approximately 700 lumens or 10.8 lumens/watt.

Table 8. Performance Targets for R-Lamps

Lamp Power (watts) and Configuration	Minimum Efficacy: Lumens/watt*
Reflector Lamp:	
Lamp power <20	33
Lamp power >=20	40
* Based on initial lumen date.	

Installed Cost: Initial cost is about $7/compact fluorescent lamp reflector lamp; which represent an initial incremental cost of about $5/unit in 2006 which declines to $1.50/unit by 2020.

Lifetime: 8,000 hours

4.2.4 Sources

(1) Estimated from http://enduse.lbl.gov/Info/LBNL-39102.pdf, p.19.
(2) Gordon, K.L., and M.R. Ledbetter. 2001. *Technology Procurement Screening Study*. Pacific Northwest National Laboratory, Richland, Washington.
(3) The Freedonia Group, Inc. 1999. *Lamps in the United States to 2003*. Cleveland, Ohio. (See the following sections: "Introduction," "Executive Summary," "Market Environment," "Supply and Demand," "Incandescent Lamps," "Electrical Discharge," and "Lamp Markets.")

4.3 Envelope Research and Development

4.3.1 Target Market

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 differ from commercial, and new construction and renovation/retrofit are different, and because all performance is strongly influenced by climate and orientation, developing 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 the tools to select and optimize 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.

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. For this analysis, PNNL did not suggest any changes in technology improvements, apart from the EIA baseline.

4.3.2 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:

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

4.3.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL(2).

Electrochromic Windows(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 exploring 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.

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

Performance Parameters: Performance parameters for Electrochromic Windows are presented in **Table 9**.

Table 9. 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 10**). Commercial lighting savings are estimated to be 5% in all regions.

Table 10. 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

Installed Cost:—Incremental 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

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 PNNL assumed that the DOE project would accelerate market acceptance by 10 years. See penetration curves in **Figures 4 through 7**.

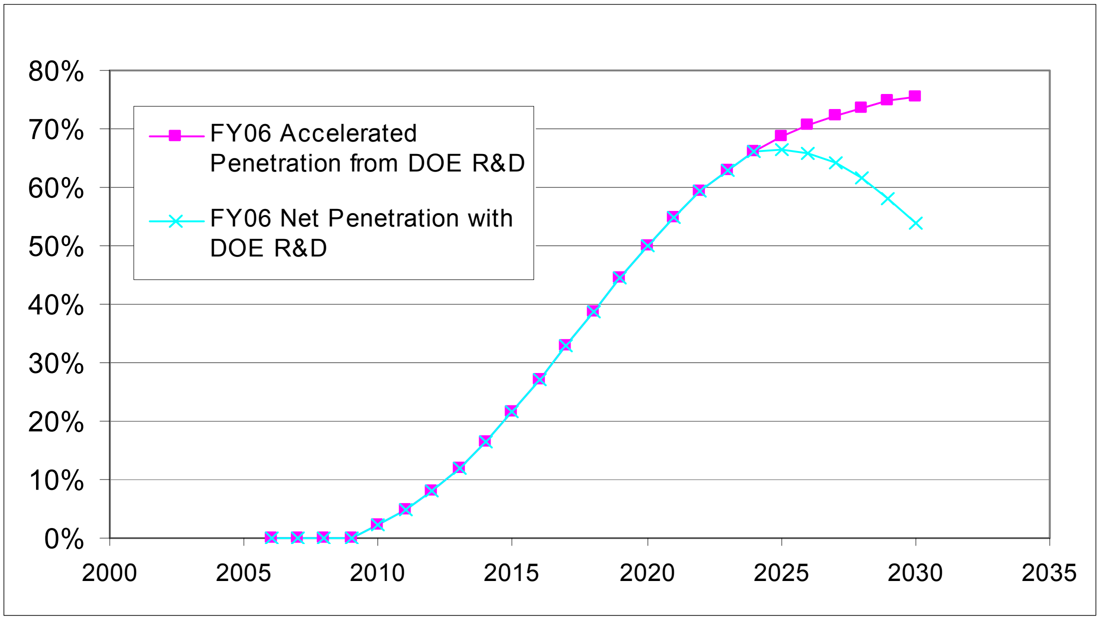

Figure 4. Electrochromic Windows – New Commercial Buildings Percent of Sales

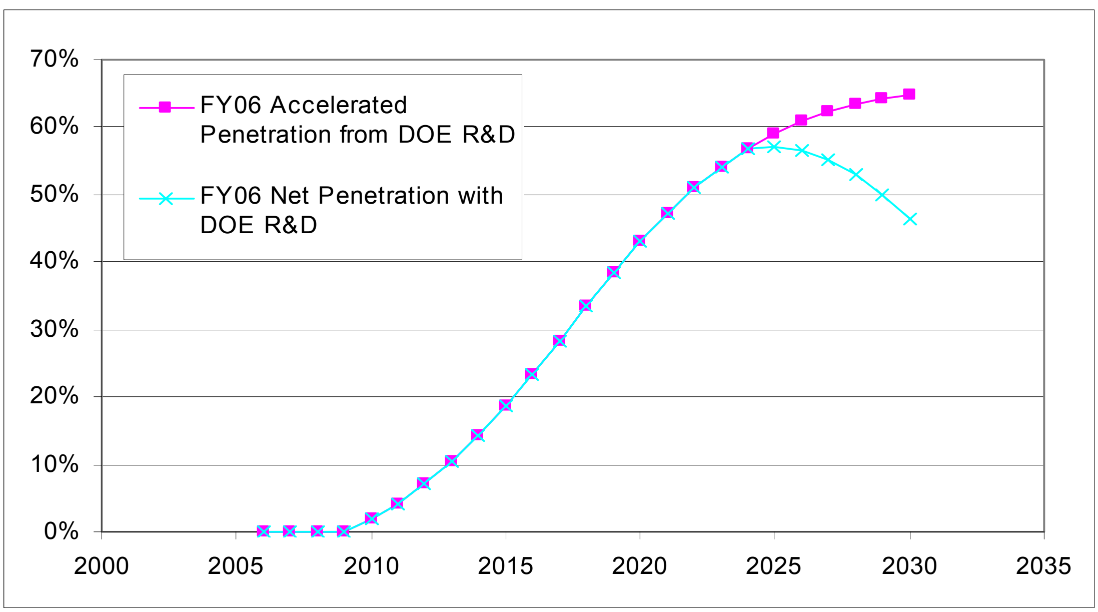

Figure 5. Electrochromic Windows – Existing Commercial Buildings Percent of Sales

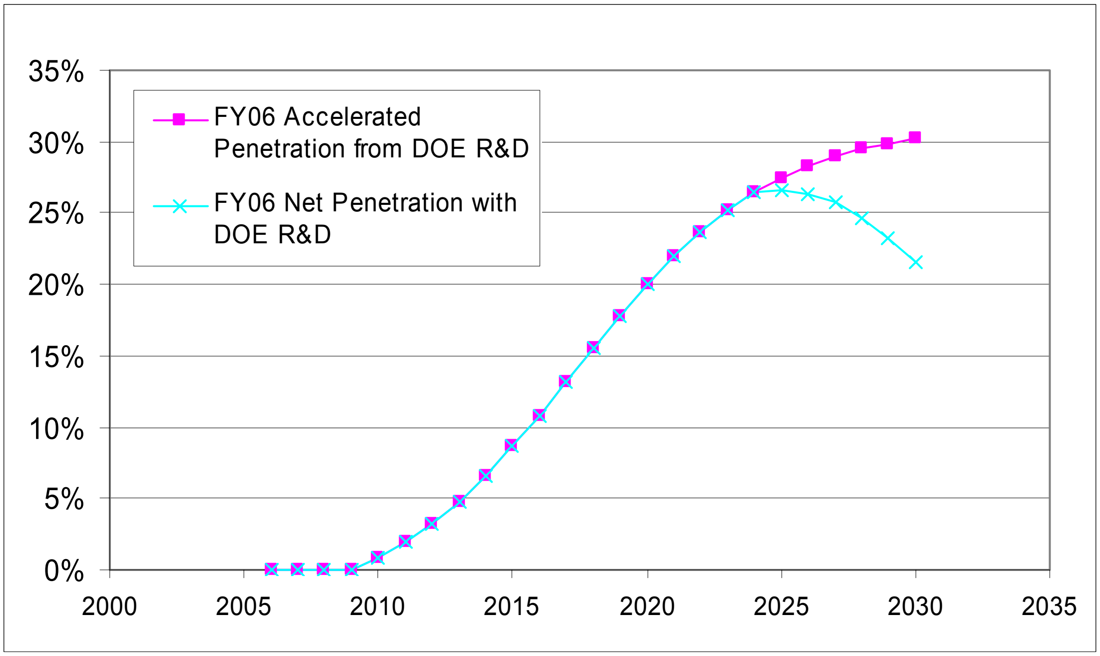

Figure 6. Electrochromic Windows – New Residential Buildings Percent of Sales

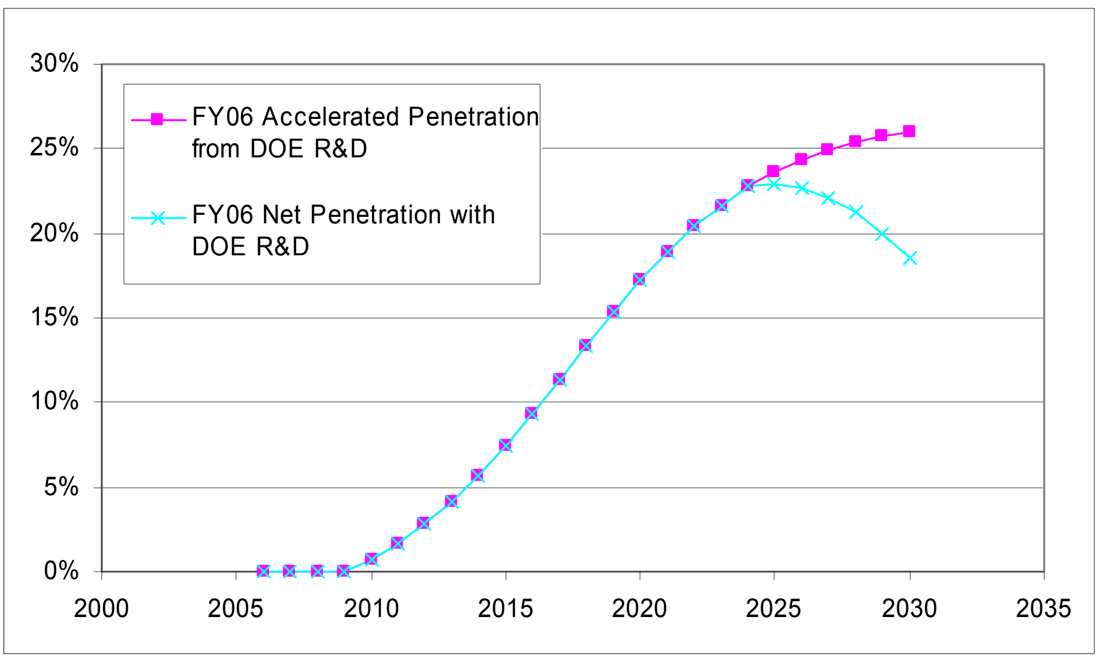

Figure 7. Electrochromic Windows – New Commercial Buildings Percent of Sales

Superwindows[(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.

Technical Characteristics

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

Performance Parameters: Superwindows have maximum U-value and SHGC 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 is as follows in **Table 11**.

Table 11. 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 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 12**.

Table 12. 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 13**).

Table 13. 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

Installed Cost:—Incremental Cost Over Low-e Double-Pane Windows

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

Lifetime: 30 years

Expected Market Uptake. The goal is to obtain 65% of window sales in new buildings and 33% in existing 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 sales attributable to DOE, as PNNL assumed that the DOE project would accelerate market acceptance by 10 years. See penetration curves in **Figures 8 and 9**.

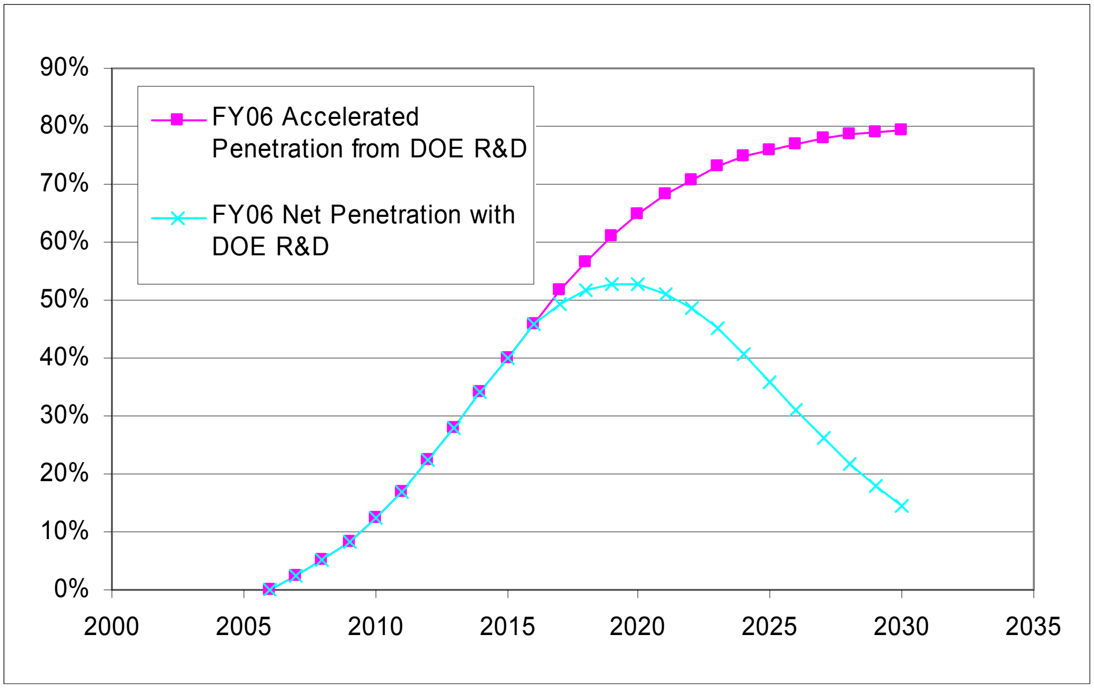

Figure 8. Superwindows – New Residential Buildings Percent of Sales

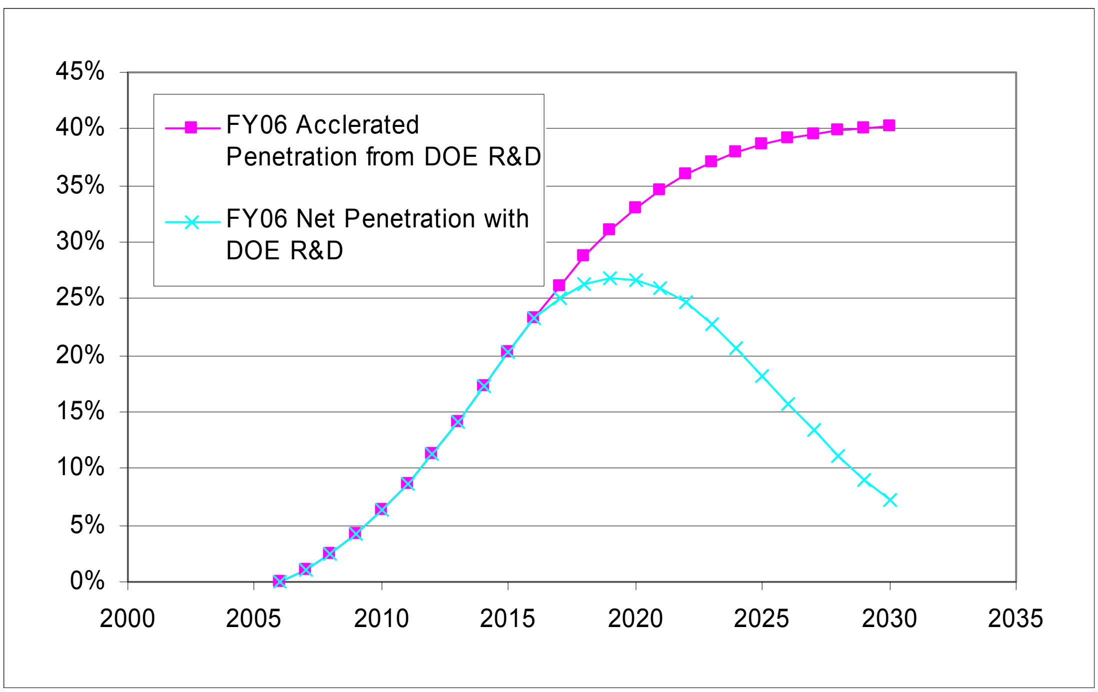

Figure 9. Superwindows – Existing Residential Buildings Percent of Sales

Low-Emissivity Glass Acceptance[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 FY05 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 (funded under the Weatherization and Intergovernmental Program), 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.

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

Methodology and Calculations

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 14**.

Table 14. 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 15**.

Table 15. 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 16**).

Table 16. 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[(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 PNNL assumed that the DOE project would accelerate market acceptance by 10 years. The penetration rates are shown in **Figures 10 and 11**. For Low-e Market Acceptance/ Energy Star Windows, PNNL assumed that these projects would accelerate the acceptance of this technology in the marketplace by 10 years.

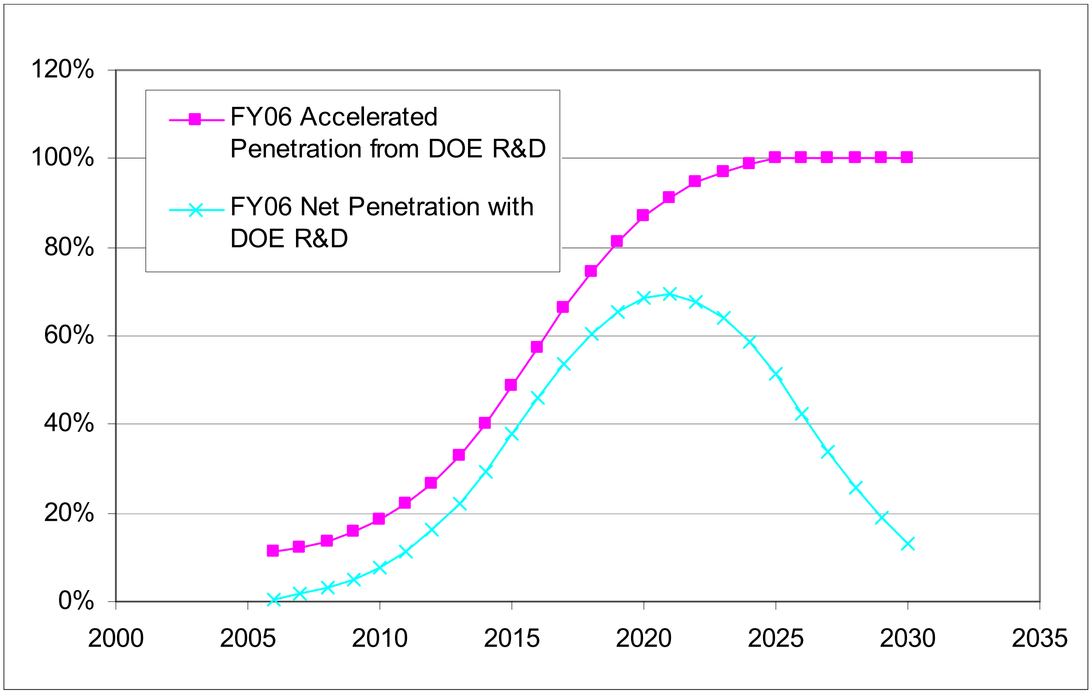

Figure 10. FY06 Low-e Windows – Commercial Buildings Percent of Sales

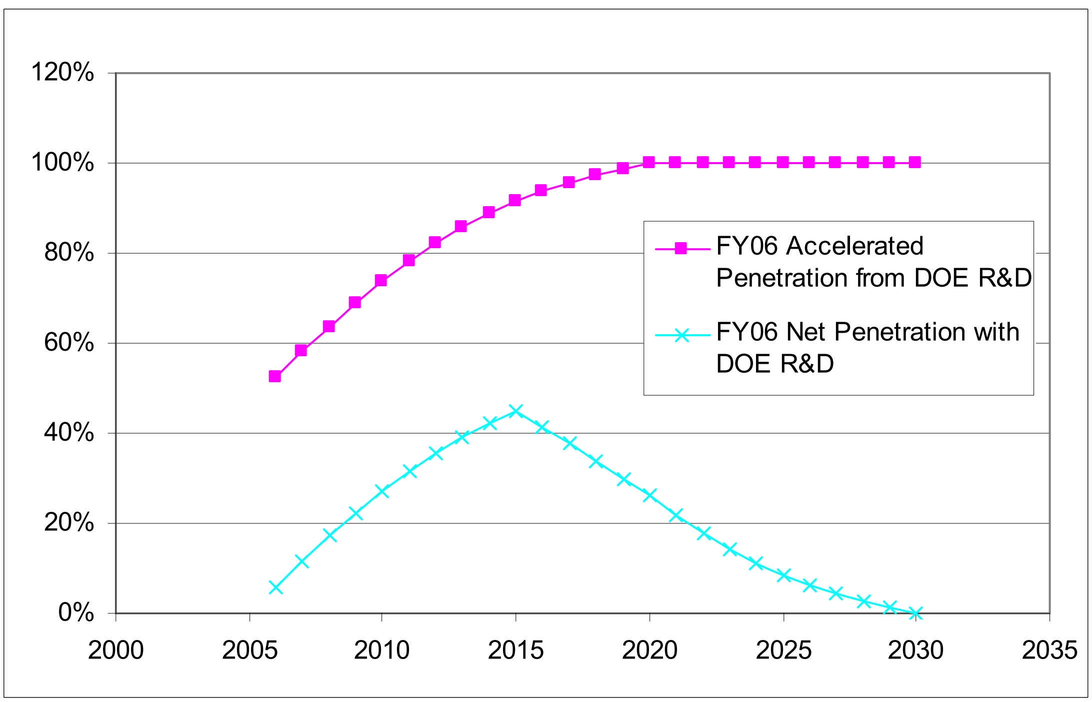

Figure 11. FY06 Low-e Windows – Residential Buildings Percent of Sales

4.3.4 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 Lighting Research and Development

4.4.1 Lighting Controls

4.4.1.1 Target Market

Project Description. The Lighting R&D project develops and accelerates the introduction of advanced lighting technologies.

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

Size of Market: Lighting consumes 26% (3.9 quad) 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. For this analysis, PNNL did not suggest any changes in technology improvements, apart from the EIA baseline.

4.4.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL 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
- Responds to an industry-initiated collaborative.

4.4.1.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL[(3)].

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 2006, 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. PNNL 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.

4.4.1.4 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.

4.4.2 Solid State Lighting

4.4.2.1 Target Market

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.

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.[h]

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

4.4.2.2 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
- Responds to industry-initiated collaborative.

4.4.2.3 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 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)] by A.D. Little for BT in early 2001; the study used some of the basic assumptions in the white paper[(2)] in developing some scenarios related to solid-state lighting.

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 four major groups: 1) incandescent CFL (point source), 2) 4-foot fluorescent, 3) 8-foot fluorescent, and 4) high-intensity point source (outdoor lighting). Solid-state lighting was assumed to penetrate the first three market groupings.

Given the cost 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.

[h] According to a recent 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.

Table 17 summarizes the cost and performance inputs for the solid state lighting technologies used in NEMS-GPRA06 for FY 2006.

Table 17. Solid-State Lighting Cost and Efficiency Assumptions – FY 2006 GPRA

Year	Efficacy (lumens/watt)	Price ($/klm)
2005	45	160.80
2006	45	160.80
2007	45	160.80
2008	50	152.35
2009	55	141.11
2010	60	126.93
2011	66	110.21
2012	72	92.00
2013	78	73.79
2014	84	57.07
2015	90	42.89
2016	96	31.65
2017	102	23.20
2018	108	17.11
2019	113	12.84
2020	118	9.91
2021	123	7.93
2022	128	6.60
2023	132	5.72
2024	136	5.13
2025	140	4.75
2026	143	4.49
2027	146	4.32
2028	148	4.21
2029	151	4.14
2030	153	4.09

4.4.2.4 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) A.D. Little. 2001. *Energy Savings Potential of Solid State Lighting in General Lighting Applications*. Prepared for DOE's Office of Building Technology, State and Community Programs by A.D. Little, Cambridge, Massachusetts.

4.5 Space Conditioning and Refrigeration R&D

4.5.1 General Target Market

Project Description(1). Over the next five years, space-conditioning activities will focus on the following areas:

1. Developing and demonstrating low-cost, commissioning and remote fault detection and diagnostics systems for HVAC systems, including commercial rooftop and residential systems. These packages aid in commissioning, and can continuously monitor performance and detect faults such as charge leakage, economizer malfunction, heat exchanger fouling, burner condition, and controls malfunctions. New sensor, electronics, and software technologies that leverage wireless networks, mobile computers, and the Internet, will be implemented to provide user-friendly, low-cost systems. Potential DOE regulations may ensure factory installation of these systems, and DOE efficiency standards may address efficiency degradation over time.
2. Developing technologies such as intelligent wireless controls, and low cost thermal storage to reduce peak electricity demand from HVAC.
3. Because future efficiency gains in HVAC systems will flow increasingly from electronic components, R&D will focus on leveraging advances in electronics, controls and low cost computing power to improve system efficiency. Examples of possible research topics include: development of variable speed motor and drive technologies with low applied costs, using adaptive/fuzzy logic controls to enhance comfort and indoor environmental quality while reducing energy consumption, providing real-time feedback to consumers on energy consumption in order to change usage patterns, optimizing operations based on outdoor and occupancy conditions, or developing modules to be integrated with HVAC systems that can respond to price and peak demand signals.
4. Developing low-cost, high efficiency unitary air conditioners and heat pumps, especially in the lower capacities needed for ZEH, and in larger commercial systems where the market does not currently focus on part load efficiency. A key element of this effort will involve reducing the cost of components to improve part-load efficiency (e.g. variable speed motors and drives, new concepts for modulating compressors).
5. Commercializing low-nergy approaches to reduce ventilation loads, such as natural or hybrid ventilation; pre-cooling with cool, dry nighttime air (with integrated energy storage); demand control ventilation that is simple to implement, widely accepted, and cost-effective; and low-cost air-leaning technologies that allow a reduction in ventilation rates.
6. Creating products and identifying practices that substantially reduce distribution losses through better duct installation and sealing techniques, reduction in losses in partially conditioned spaces, and consideration of novel distribution approaches, and evaluating the energy savings potential of ductless systems.

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

4.5.2 Unitary DX System

4.5.2.1 Target Market

Project Description[1]. Develop prototypes for two-three concepts that have the long-term potential to reduce annual HVAC energy consumption by 50%, with a modest installed cost premium over conventional systems.

Market Description. Residential and Commercial Buildings.

Market Introduction: 2007; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.

4.5.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Installed cost initially will be double the cost of conventional systems, declining to less than 10% greater than conventional systems by 2025.

4.5.2.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL[3].

Technical Characteristics. 50% reduction in heating and cooling over conventional systems.

Expected Market Uptake. This activity targets all residential cooling equipment and heat pumps, and all commercial DX cooling equipment and heat pumps.

4.5.3 Ventilation Load Reduction

4.5.3.1 Target Market

Project Description. The objective of this project is to apply advanced technologies to reduce ventilation energy used in commercial buildings, including both fan energy and conditioning of outside air, by 50% in the long term.

Market Description: Commercial buildings.

Market Introduction: 2007; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.

4.5.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Installed cost will be 15%-20% greater than conventional systems

4.5.3.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL [3].

Technical Characteristics. 50% reduction in ventilation and 50% reduction in the conditioning (heating and cooling) of outside air (i.e., make-up air)

4.5.4 Commercial Refrigeration

4.5.4.1 Target Market

Project Description. DOE is working to improve the efficiency of refrigerated display cases and developing methods of recovering reject heat for space conditioning. This project was modeled as an advanced supermarket refrigeration system that would target heating, cooling, and refrigeration end-use loads in the commercial food sales sector. The heating and cooling reductions occur because commercial refrigeration equipment draws a large amount of heat from the conditioned space, which must be made up by the heating equipment. In addition, heat energy can be recovered and used by the heating equipment, thus reducing the heating energy consumption and cost. These end uses comprise about 66% of total building, 67% of electric, and 61% of total natural gas end-use energy consumption.[2]

Displaced Technology: Conventional refrigeration equipment in food-sales buildings.

Performance Target: Reduced energy for building HVAC and refrigeration equipment during the next 15 to 20 years, specifically at least 15% for supermarket refrigeration and HVAC while reducing refrigerant needed. For FY 2006, PNNL assumed an overall 22.5% reduction in HVAC end-use energy consumption.

Market Description: All commercial food-sales buildings.

Market Introduction: 2004; PNNL assumed this project would accelerate the introduction of this technology into the marketplace by 10 years.

4.5.5 Remote Fault Detection and Diagnostics

4.5.5.1 Target Market

Project Description[1]. This project will develop and demonstrate low-cost commissioning and remote fault detection and diagnostics (FDD) systems for unitary HVAC systems, including commercial rooftop and residential systems.

Market Description. Residential and commercial space conditioning equipment.

Market Introduction: 2008 (Commercial), 2009 (Residential); this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.

4.5.5.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. $50-100 increase in cost per piece of equipment

4.5.5.3 Methodology and Calculations

Inputs to Base Case. The base case was developed based on an assortment of sources, including AEO 2003, CBECS 95, RECS 97, and several other sources, all of which are documented by PNNL [3].

Technical Characteristics. 20% reduction in Cooling and Heating (heat pumps and integrated gas heating – i.e., rooftop package units).

Expected Market Uptake. The market penetration goal is to enter the commercial market in 2008 with 10% penetration by 2010 and 50% penetration by 2015; and to enter the residential market in 2009 with 10% penetration by 2011 and 50% penetration by 2015.

4.5.6 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) Belzer, D.B and L.E. Wrench. 1997. *End-Use Consumption Estimates for U.S. Commercial Buildings, 1992*. PNNL-11514, Pacific Northwest National Laboratory, Richland, Washington.
(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.

Appendix D – GPRA06 Distributed Energy Program Documentation

Program Objective

The major programs modeled for DE include:

Industrial Gas Turbines
Advanced Microturbines
Gas-Fired Reciprocating Engines
Thermally Activated Technologies
Distributed Energy Systems Applications Integration
Cooling Heating and Power Integration
The Technology Base – (Advanced Materials and Sensors is not modeled directly because its benefits are represented in the other programs).

Methodology and Calculations

Because the time horizon of the *Annual Energy Outlook 2004* Reference Case (AEO-4 case) version of the National Energy Modeling System (NEMS) is 2025, and the goals of Distributed Energy (DE) programs are relatively short term, the approach taken in this GPRA cycle is that most of the outputs are captured before that date. However, DE programs are part of a wider effort to transform the power system from its current highly centralized form to a more robust decentralized paradigm, a transformation with a longer time horizon than NEMS-GPRA provides, and are not readily represented in the NEMS-GPRA framework.

Distributed generation (DG) appears in multiple modules (roughly corresponding to subsectors of the full energy sector, i.e. utility, commercial, etc.), which hinders DE program's representation in NEMS-GPRA. Further, only a limited number of technology slots are available to represent a broad array of equipment types, sizes, and configurations. For example, the reciprocating engines in the commercial sector all have combined heat and power (CHP) heating (but not cooling) capability, while those in the utility sector do not, while in some instances, engines without CHP might be attractive in the commercial sector and vice-versa. Proper representation of DE program goals includes an accurate representation of DE's technology-advancement targets, while accounting for the limitations of NEMS. Therefore, in addition to changing input assumptions relative to the AEO-4 version of NEMS, other *fixes* to perceived limitations or omissions are also appropriate in both the base and program cases.

Inputs to Base Case

Expectations of improvements in technologies embedded in the AEO-4 reference case, which presuppose existence of DE programs, need to be eliminated from the base case (referred to as the baseline) for comparisons with achievement of program goals (referred to as the program case). Two full sets of forecast scenarios are actually needed, *with* and *without* DE programs in place; and the AEO-4 case is likely, although not certain, to fall between the two. In the FY 2006

GPRA (GPRA06), the baseline case generally corresponds to a 10-year lag of the program case, though there are exceptions as described below. Estimation of the benefits of the programs is based on a comparison of the *baseline* and *program* scenarios. In this analysis, both scenarios were effectively estimated together as two deviations from the AEO-4 case, so they are presented together in the following section.

NEMS-GPRA Inputs

NEMS-GPRA input specifications follow by program, and all are summarized in **Table 3**. Inputs for each program are briefly described in the following sections. As a general rule, no modifications are made to NEMS-GPRA input data prior to 2006, consistent with the notion that FY 2006 benefits begin in year 2006.

The AEO-4 case and prior GPRA forecasts were compared with the National Renewable Energy Laboratory's (NREL) and Gas Technologies Institute's Technology Characterizations (TeChars) for three technologies: microturbines, gas engines, and industrial gas turbines. When program goals were not available from the program office, technology cost and electrical efficiency inputs are derived both from the TeChars and from DE program goals.[1]

NEMS-GPRA often contains multiple sizes of each DE technology, yet the program goals are typically provided for a single representative unit size. As a result, the technology inputs for baseline and program cases are scaled using the TeChars to correspond to the units represented in NEMS-GPRA. This analysis assumes the DE program goal data represent a 1 MW gas engine, 5 MW gas turbine, and 100 kW microturbine, which are then scaled to accommodate the various sizes. For clarification, a summary table of technology type, module, and nameplate capacities represented in the GPRA06 case is included in **Table 1**.

Table 1. Summary of Technology Size Representation by Module

Technology Type	Module	Representative Size in NEMS
Gas Turbine	Commercial	1 MW
	Industrial	1 MW, 5 MW, 10 MW
	EMM	2 MW*
Microturbine	Commercial	100 kW
Gas Engine	Commercial	200 kW
	Industrial	800 kW, 3 MW
	EMM	1 MW*

* The 1 MW peak-load and 2 MW base-load units in the EMM module are composite plants made up of various technologies, a portion of which are gas engines and gas turbines, respectively.

While many of the technology inputs reflect the achievement of DE program goals by 2012, the exact replication of this time frame is not always possible because of certain model constraints. For example, technological progress for the commercial module absorption chiller, an additional technology not explicitly characterized by size, is limited to a step-function advance, and input

[1] Goldstein, Larry, Bruce Hedman, Dave Knowles, Steven I. Freedman, Richard Woods, and Tom Schweizer, (November 2003). "Gas-Fired Distributed Energy Resource Technology Characterizations," NREL/TP-620-34783.

values are specified in years 2000, 2005, and 2020. **Figure 12** represents this limitation. For this reason, it is not always possible to exactly replicate program goals in NEMS-GPRA.

Industrial Gas Turbines

Gas turbine sizes in NEMS-GPRA range from 1 to 40 MW, appearing explicitly in the commercial and industrial demand modules, and as part of a composite plant in the utility electricity market module (EMM), where this plant is represented by a mix of different technologies and is defined generically as either a base-load or peak-load system. The industrial-sector turbines cover a wide size range, but proposed inputs to the GPRA06 process focus on the 1 MW-, 5MW-, and 10 MW-size systems. Although larger turbines are not the focus of the program, the 25 MW and 40 MW gas turbines in the industrial sector are also modified in order to maintain consistency across the various sized turbines. The commercial sector contains a single representative turbine sized at 1 MW. The inputs for the commercial turbine were scaled to 1 MW using the 5 MW representative size gas turbine input data and the TeChars difference between these two units. The baseline and program case inputs for the commercial sector correspond to the 1 MW system shown in **Figures 1-3**. Also, a portion of the 2 MW base-load EMM generator is represented as a 1 MW gas turbine, which is discussed in a later section.

The *baseline* input values for industrial gas turbines reflect a 10-year lag from the program electrical and combined efficiencies. There is no cost difference between baseline and program cases, which are kept at the AEO-4 levels.

The *program* input values represent an improvement in electrical efficiency by 2006. Again, costs are kept at AEO-4 levels. The combined efficiency changes reflect target levels for 2006 and 2008, scaled to the various sized turbines using the TeChars difference from the 5 MW unit and kept flat thereafter. The main objective of this program currently is efficiency and performance improvement and NOx and CO emissions reduction; but, because emissions reductions are not reported metrics, forecasts for these improvements are not included here.

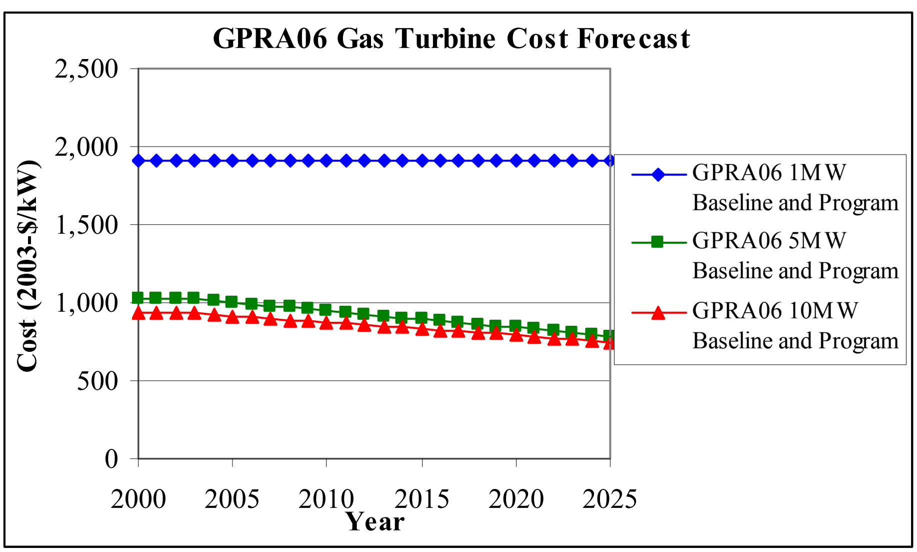

Figure 1. Industrial Gas Turbine Installed Cost

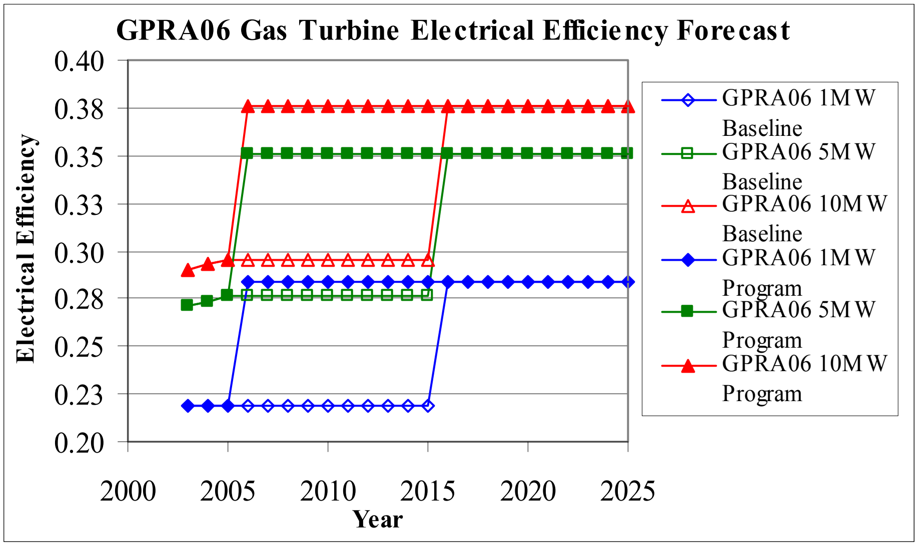

Figure 2. Industrial Gas Turbine Electric Efficiency

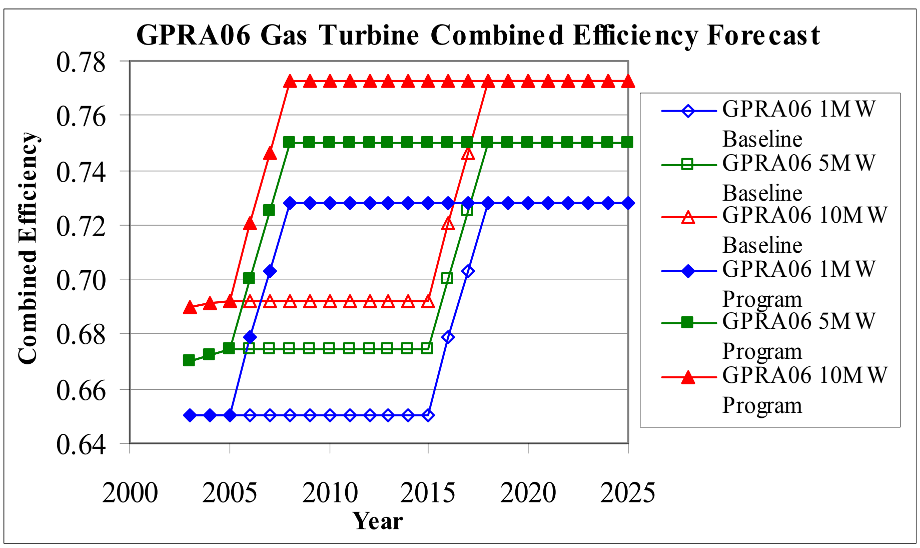

Figure 3. Industrial Gas Turbine Combined Efficiency

Advanced Microturbines

Microturbines occur only in the commercial module as a representative 100 kW system. Input data are therefore directly applied to this system without any scaling of different-sized units.

The *baseline* input values for costs, electricity conversion efficiency, and combined efficiency shown in **Figures 4-6**, respectively, represent a 10-year lag of the program input assumptions.

The *program* input values for cost are a 25% improvement from 2000 to 2008 with a continued trend through 2012. Costs therefore fall from $1,926/kW in 2000 to $1,231/kW by 2012 and are flat thereafter.

Because the AEO-4 microturbine electrical efficiency matches the TeChars projection, the program case assumes the AEO-4 with the baseline set to a 10-year lag of the program. Combined efficiency values are scaled to agree with the combined efficiency target provided for a 5 MW turbine using the relative difference between these two units in the TeChars publication. The combined efficiency reaches 71% by 2008 and is flat thereafter.

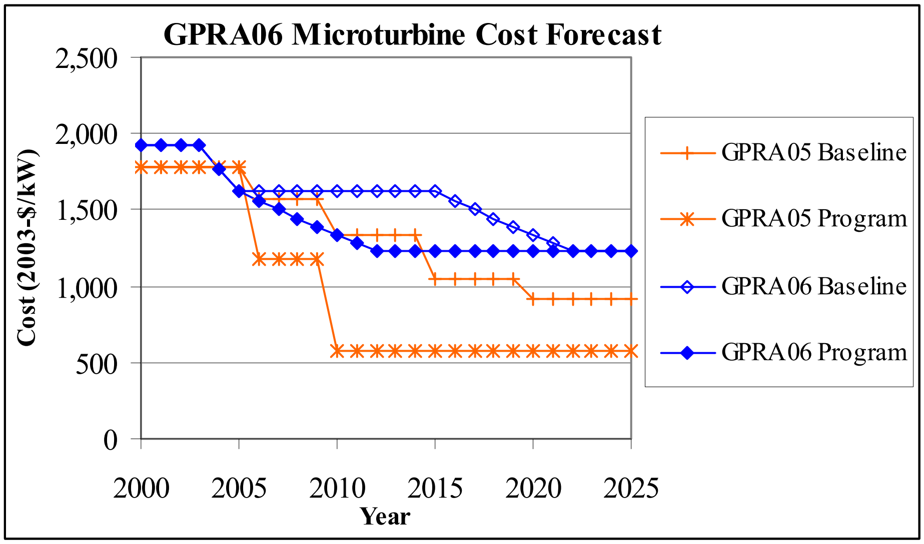

Figure 4. Microturbine Installed Cost

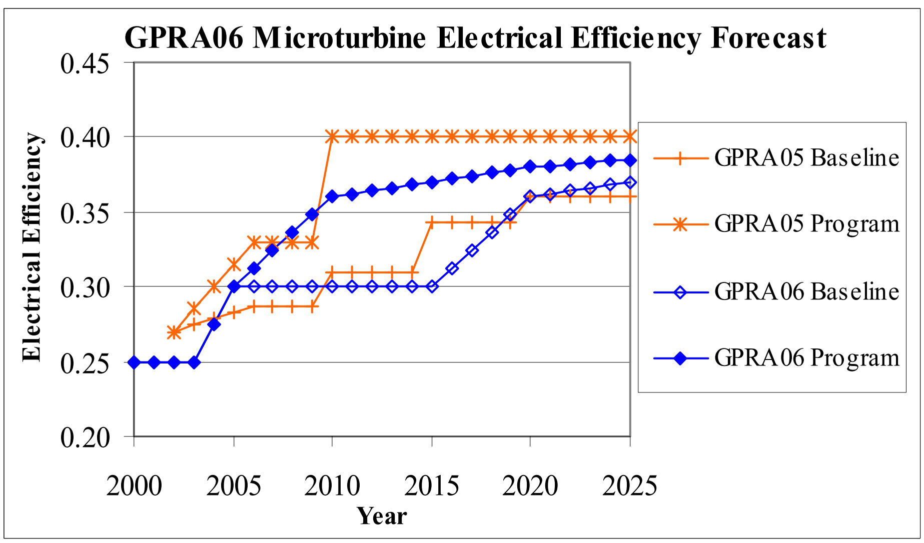

Figure 5. Microturbine Electric Efficiency

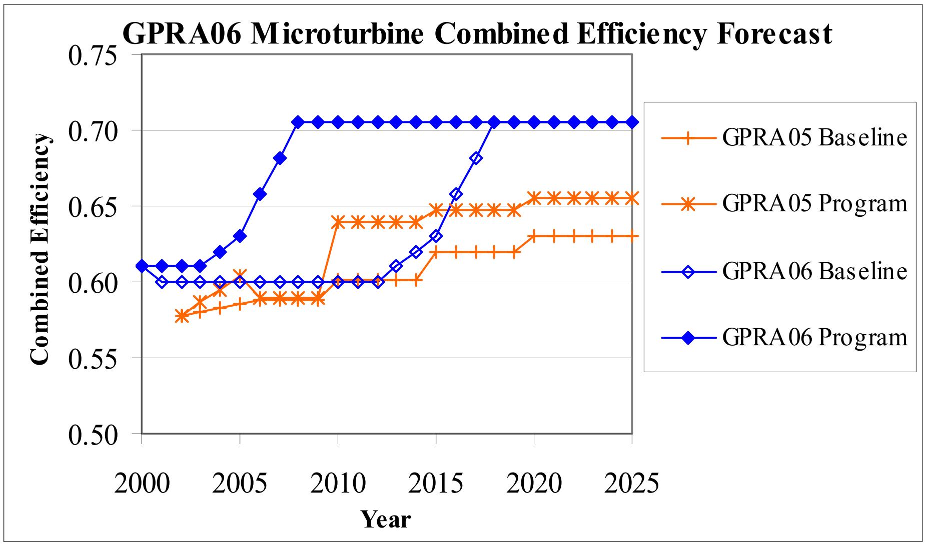

Figure 6. Microturbine Combined Efficiency

Gas-Fired Reciprocating Engines

Gas engines appear in several modules in NEMS, in both CHP and simple-cycle configurations, but only one or two marker models represent the wide range of available engines (see **Table 1**). The limited number of available technology slots, together with the maturity and clear attractiveness of gas engines in many configurations, makes the choice of inputs for this technology somewhat complex.[2] The commercial module has a marker 200 kW CHP-enabled unit, the industrial module has 800 kW and 3 MW CHP-enabled units, and the 1 MW unit that appears in the EMM also partially represents a simple-cycle gas engine as a composite plant for various technologies

The *baseline* input values for costs (see **Figure 7**), electricity conversion efficiency (see **Figure 8**), and combined efficiency (see **Figure 9**) are a 10-year lag from the program goal assumptions.

The *program* input values for the commercial and industrial engines are scaled from the inputs provided for a typical engine assumed to be 1 MW in size. However, the 800 kW engine in the industrial sector is represented by the 1 MW technology characteristics. The cost is represented as a 25% improvement from 2000 to 2008 with a continued trend through 2012, and flat thereafter. The electrical efficiency value for a 1 MW gas engine is assumed to be 42% by 2008, the cost is $601/kW by 2012, and the combined efficiency is 75% by 2008 and flat thereafter. The 200 kW commercial gas engine and 3 MW industrial gas engine are scaled from these targets using the relative difference in cost, electrical and combined efficiency in the TeChars.

[2] Heat recovery can be from exhaust gas or jacket coolant, and a promising CHP application is absorption- cycle cooling, which is non-existent in NEMS-GPRA.

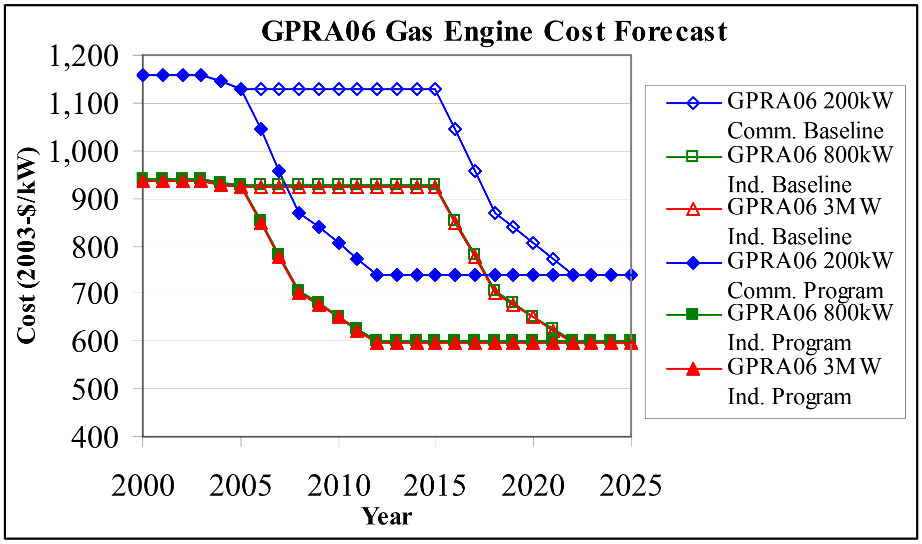

Figure 7. Gas Engine Installed Cost

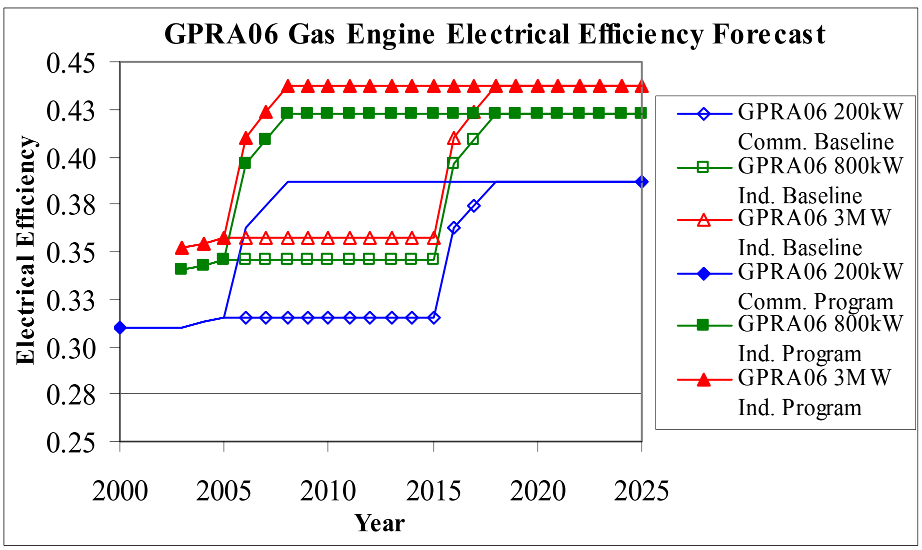

Figure 8. Gas Engine Electric Efficiency

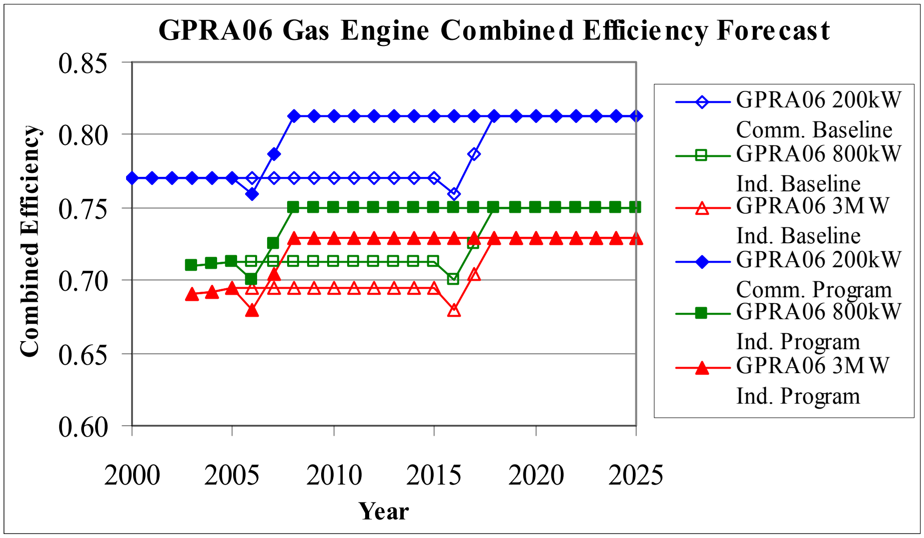

Figure 9. Gas Engine Combined Efficiency

Technology Representation in the Utility Sector (Electricity Market Module)

The EMM contains two generic DG technologies: a 2 MW base-load system and a 1 MW peak-load system, neither with CHP capability. Baseline and program representation of these technologies correspond to a projection based on a composite of various technologies. The 1 MW peak-load system's assumed composition is 80% gas engine and 20% microturbine from 2010 onward. The 2 MW base-load system assumes a make up of 20% gas engine, 20% gas turbine, 20% microturbine, and 40% fuel cell from 2010 onward. These modified weightings are taken from a study by Joe Iannucci of Distributed Utility Associates.[3] The technology characteristics of the gas engine, gas turbine and microturbine in these two composite plants are replaced with the 1 MW gas engine, 5 MW gas turbine, and 100 kW microturbine assumptions, respectively, to match the baseline and program goals. For the baseline, the EMM systems do not assume a 10-year lag of the program. Instead, separate trajectories for the baseline and program cases based on the Iannnucci study are assumed. **Figure 10** shows the cost trajectory and **Figure 11** illustrates the modified heat rate assumptions.

Although CHP applications may be attractive to utilities, DG systems in the EMM do not include heat-recovery components, and therefore projected technology costs are slightly lower.

[3] "Assessing Market Acceptance and Penetration for Distributed Generation in the United States", Distributed Utility Associates, June 1999.

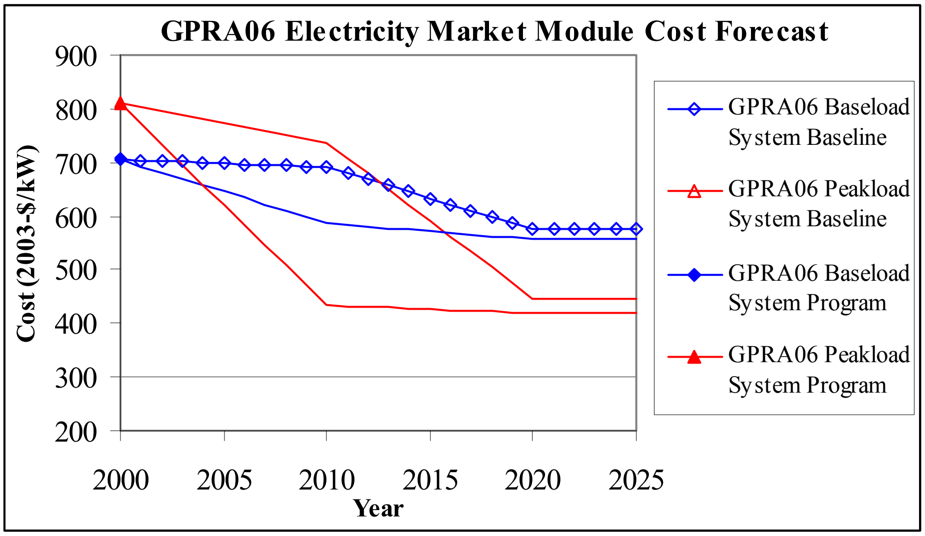

Figure 10. Electricity Market Module Installed Cost

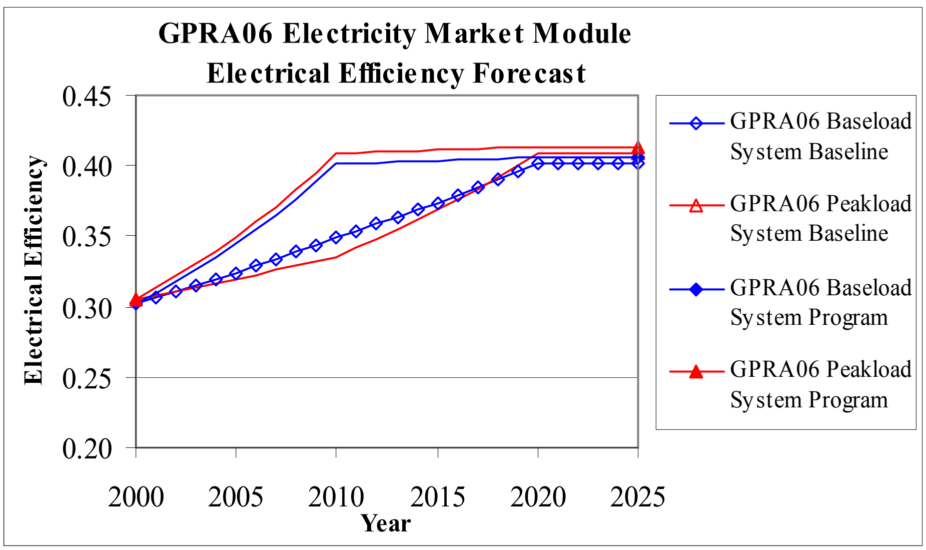

Figure 11. Electricity Market Module Electrical Efficiency

Advanced Materials

No separate inputs to represent this program are proposed. The benefits of this activity are represented in the preceding technology-development activities.

Thermally Activated Technologies

DE's thermally activated technologies program includes direct-fired absorption chiller technologies and desiccant dehumidification systems. Only the former are represented here as changes applied to gas-fired absorption chillers in the commercial technology input file.

The NEMS-GPRA commercial module represents the commercial building stock using 11 representative building types. Of these, the commercial technology input file restricts gas-fired absorption chillers from being installed in the following building types: food sales, food service, small office, warehouse, and other. These restrictions are removed for both the baseline and program cases to allow systems to be installed in all buildings.

The assumptions for the program case inputs include: cost-improvement data taken from Resource Dynamics' study of integrated energy systems[4] with future cost values (2005+) available in 2010; double-effect chillers are approximately 1.5 times the cost of single-effect chillers; and technology costs correspond to 50–100 cooling ton[5] range. **Table 2** and **Figure 12** shows the cost and COP assumptions for this technology.

The *baseline* case, based on a double-effect chiller introduced in 2020, uses cost assumptions from the AEO-4 with improvement in year 2020 and modest COP improvements in 2005 and again in 2020.

The *program* case is based on a double-effect chiller introduced in 2005 represented as an improvement to the cost and COP with further COP improvement in 2020. The cost improvement is introduced in 2005.

Table 2. GPRA06 Inputs for DE's Thermally Activated Technologies Program

	Baseline Case			Program Case		
Year	COP	Cost ($/kBtu/hr)	Cost ($/cooling ton)	COP	Cost ($/kBtu/hr)	Cost ($/cooling ton)
2000	1.0	78.75	945	1.0	78.75	945
2005	1.2	78.75	945	1.3	50.00	600
2010	1.2	78.75	945	1.3	50.00	600
2020	1.3	50.00	600	1.4	50.00	600

[4] LeMar, P. (August 2002). "Integrated Energy Systems (IES) for Buildings: A Market Assessment," Resource Dynamics.
[5] *1 cooling ton is equal to 12,000 Btu/hr or approx 3.5 kW thermal.*

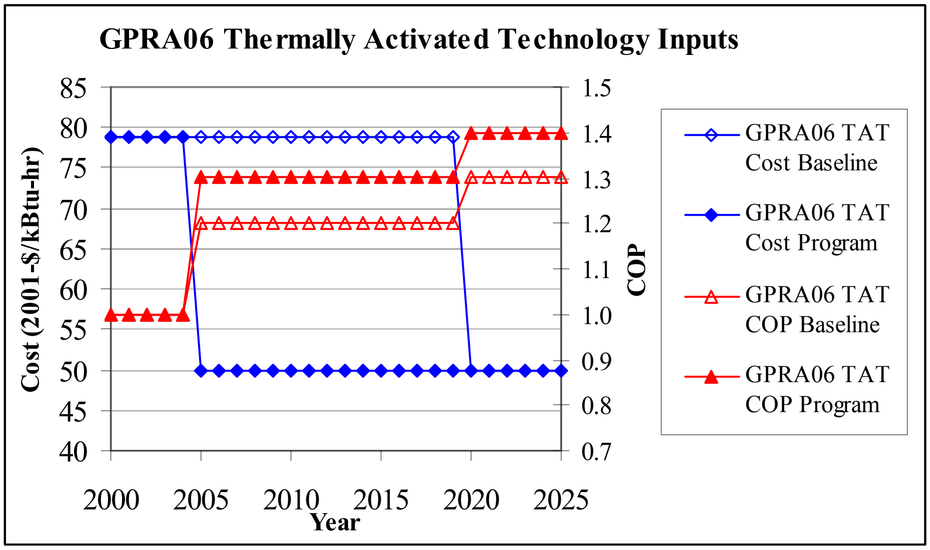

Figure 12. Thermally Activated Cooling Technology Inputs

Distributed Energy Systems Applications Integration

The Distributed Energy Systems Applications Integration (DESAI) Program strives to accelerate adoption of DG technologies in certain sectors, especially among the existing building market (i.e. through retrofits). The NEMS model calculates DG adoption in *existing* buildings as a predetermined fixed share of the adoption in *new* buildings, and that share is set at 0.5% in the AEO-4 Reference Case. Because the retrofit market is the primary target of the DESAI Program, the outputs are represented by an increase in the cap on the share of existing commercial sites that can adopt DG.

The *baseline* input values are achievements of cost and efficiency targets by 2020. The existing building adoption rate is 0.5% of new buildings, equivalent to the AEO-4 value.

The *program* input values increase the share of existing buildings eligible to adopt DG from 0.5% to 10% of new buildings.

As part of the DG adoption logic fixes described in Section 9, additional changes to the new building adoption parameter were made in addition to the DESAI Program representation.

Cooling Heating and Power Integration

This program develops improved CHP packages and otherwise supports the market penetration of CHP technologies, including indirect-fired absorption chillers. Because NEMS-GPRA does not have a representation of indirect-fired absorption chillers, this program is represented by a proxy improvement in the payback period of the prime mover technology equivalent to the economic benefit of using 25% of the generator waste heat for a cooling end use.

The *baseline* input values are a 10-year lag of the program input values.

The *program* input values are a target 70% combined efficiency level in 2006 and 75% level in 2008 assumed to represent a typical 1 MW gas engine or 5 MW gas turbine. The target was scaled using the TeChars to the various sized CHP capable technologies in the industrial and commercial sectors. Additionally, a commercial module customer payback adjustment is also made to incorporate the added benefits of absorption cooling capability in gas engines and microturbines. The corresponding energy savings from enhanced absorption cooling deployment are also adjusted as impacts to commercial end-use consumption. This adjustment also increases heating consumption if not all the waste heat is available to meet the load.

DG Adoption Logic Fixes

Two fixes were made to the DG adoption logic of new buildings in the commercial sector of NEMS-GPRA for both baseline and program cases. The adoption algorithm for DG in new buildings caps the maximum market adoption rate (the *penparm* parameter*)* at 30% for a one-year payback level. The NEMS cap on adoption rates for different paybacks (max *pen)* decays as an inverse function at a rate of 1/years to positive cash flow, and this decay is known as the payback acceptance function (shown as equation 1 below).

$$\max pen = \frac{penparm}{payback} \quad (1)$$

This approach severely disfavors technologies with paybacks that are moderate but still quite acceptable to many building owners—such as in the three- to six-year range—while it allows smaller adoption at very long paybacks, such as 15 years.

First, the cap for new buildings with a one-year payback (represented by the *penparm* parameter) is raised from 30% to 50%. A similar change was made in the GPRA05 analysis.

Second, the payback acceptance function is changed from an inverse decay function to one based on data of observed customer adoption of energy efficiency projects as a function of simple payback time[6]. These data are shown below for buildings in the institutional sector (n=768) and commercial buildings in the private sector (n=108).

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[6] *Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project*. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.

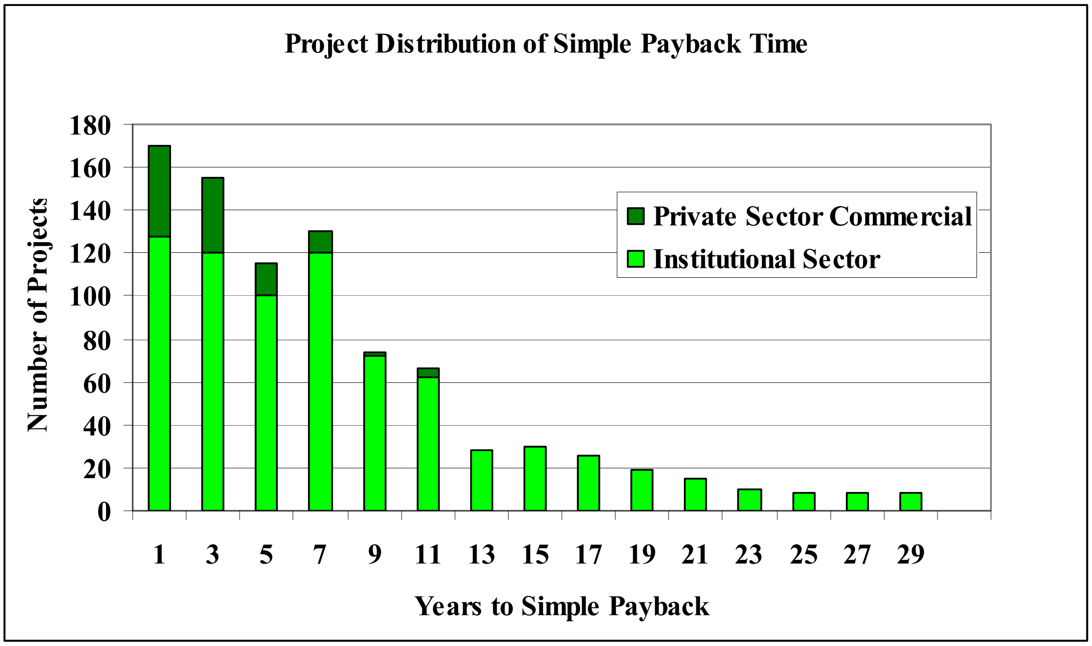

Figure 13. Distribution of Years to Simple Payback

To determine a decay function for the max *pen* based on this data set, the percentage of potential adopters from the total sample for each given payback year is calculated. It is assumed that for a given payback year, all of the adopters in that year and all adopters of projects with shorter payback periods would adopt, i.e. all columns are summed to the right in **Figure 13**. These data show that the relationship between the project payback period and the number of buildings that adopt the project is approximately linear for a payback between 1 and 11 years, and then falls off sharply at years 13 and higher. For example, all adopters of projects with 29-year paybacks also would adopt projects with 27-year paybacks, 25-year paybacks, etc. The resulting customer-acceptance curve is shown in **Figure 14**, along with the mathematical representation of the revised curve for input to NEMS-GPRA and the current equation used in the AEO-4. **Figure 14** shows that a maximum of 100% will adopt, and this represents 100% of the sample size; however, in NEMS-GPRA, the percentage of the total population that actually will adopt is scaled down using the *penparm* parameter (set at 50% for GPRA06), as discussed above.

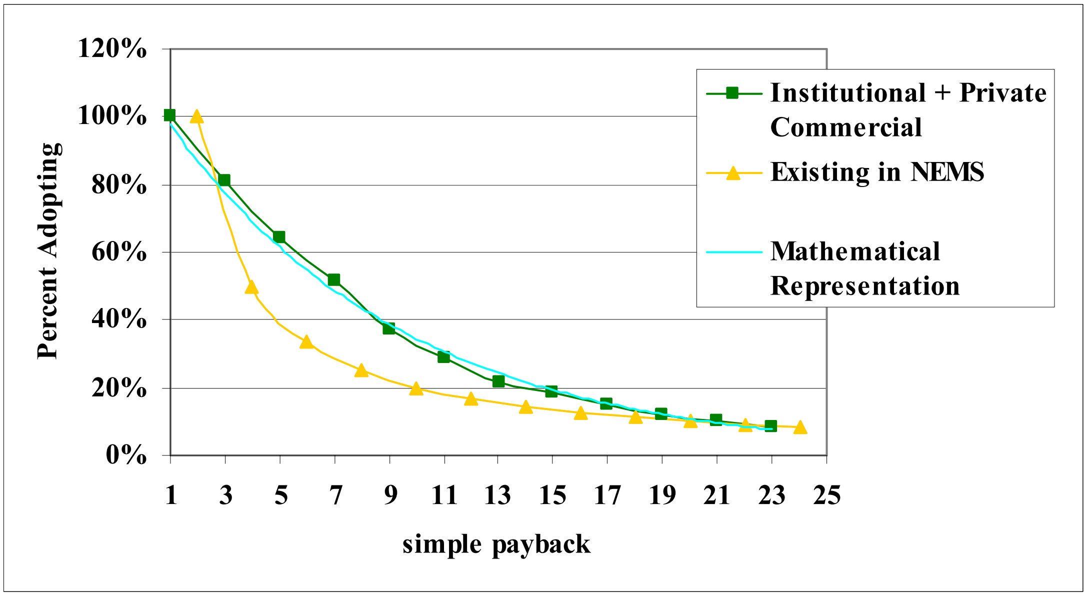

Figure 14. Decay Function of the Maxpen

NEMS-GPRA uses the number of years to positive cash flow[7], and not simple payback, as the primary metric of DER adoption. Figure 14 converts the data to years to positive cash flow by dividing the simple payback time in half. A simple spreadsheet analysis was used to determine the relationship between simple payback and years to positive cash flow, assuming the NEMS-GPRA financing assumptions. This analysis determined that, with NEMS-GPRA financing assumptions in place, the number of years to positive cash flow of a project is approximately half of the payback period. Ultimately, the decay above is represented by equation 2 below as a function of the *payback* variable as defined in NEMS-GPRA:

$$\max pen = \frac{1.1 penparm}{e^{0.24\, payback}} \quad (2)$$

One additional NEMS-GPRA fix has been implemented in the base and program cases to ensure that the changes to the adoption logic described above do not result in an exaggerated number of DG adoptions. An internal check is included to ensure that the percentage of existing buildings that have DER systems installed does not exceed the cap imposed on new buildings. This will prevent a case where the installations in new buildings are not allowed to reach the rate of existing buildings.

The NEMS-GPRA fixes, along with additional minor changes, are summarized in **Table 4**.

[7] The NEMS *payback* (or *simple payback)* variable is defined as the first year in the cash-flow stream for which an investment has a positive cumulative net cash flow. *(EIA, NEMS Commercial Module Documentation Report 2004, EIA/DOE-MO66(2004))*

Market Uptake

For industrial gas turbines, a modification in the customer acceptance payback distribution was made to reflect a market transformation improvement from the DESAI program. This change alters the payback distribution, allowing more customers to accept a shorter payback period. As well, a change is made to relax the yearly penetration rate for gas turbines from a maximum 5% to 10%. The rationale for these modifications was to reflect improvements in the technical barriers of CHP adoption.

No market potential or penetration analyses were done exogenously to NEMS-GPRA for this work. The market definition and penetration rates for DG are those that are endogenous to NEMS-GPRA, and these are described briefly here for the EMM and the Commercial Demand Module.

In the EMM, the market is driven by the growing electricity-demand forecast and the deferred cost of transmission and distribution (T&D) expansion. The two available DER generators (the peak and base-load units) compete against the cost of central-station generation and T&D upgrades to supply growing demand and replace retiring generating capacity. The total capacity of DG is constrained to correspond to a specific level of avoided T&D costs, indicating that there is a maximum economic value of T&D deferrals that DG can provide.[8]

In the NEMS commercial sector, the market is represented by 11 building types and is disaggregated into nine geographic census divisions or regions. Annual penetration into the new-building market is determined by the economic attractiveness of on-site generation with heat recovery relative to the purchase of electricity and other fuels. The retrofit market is not characterized distinctly, and the market adoption is simply proportional to the new-building adoption. Distributed generation adoption in the commercial sector is dominated by a few building types. The education, lodging, and mercantile/service sectors account for the large majority of DG capacity additions from the DE program. Regional DG adoption is distributed more evenly among census divisions, though the Pacific and Middle Atlantic regions account for a larger share of DG adoption, partly because of the higher electricity demand and prices forecasted for those regions.

Because DG market segments are broadly characterized in NEMS, an accurate representation of niche market adoption is difficult to include exogenously in NEMS-GPRA. Several niche market segments that contribute to the total market for DG (such as markets for reliability, security, or environmental benefits) are not represented in NEMS-GPRA.

[8] Energy Information Administration (2003). "The Electricity Market Module of the National Energy Modeling System: Model Documentation Report," U.S. Department of Energy, Washington, D.C. pg.91.

Table 3. Summary of DE Program and Baseline Representation in GPRA06

	DE Program	Program Goals	Representation in NEMS-GPRA	
			Baseline	Program
Technology Development	Industrial Gas Turbines	- 35% electric efficiency HHV - 0.5 g/kWh NOx by 2000, 0.4 g/kWh NOx by 2005, and 0.2 g/kWh NOx by 2008	- 10-year lag of Program case - EMM 1 MW baseload composite unit assumes forecast determined from Joe Iannucci report weightings	- Industrial module: electrical efficiency is 28%, 35%, and 38% for 1, 5, and 10 MW systems, respectively by 2006 and flat thereafter; combined efficiency values at 73%, 75%, and 77% respectively by 2008. - EMM baseload unit considered a composite plant without CHP capability with 20% gas turbine make-up. - Commercial module equivalent to 1 MW values.
	Advanced Microturbines	- 32% electric efficiency HHV by 2005, 33% electric efficiency HHV by 2008 - 0.4 g/kWh NOx by 2005, 0.2 g/kWh NOx by 2008	- 10-year lag of Program case	- 25% cost improvement from 2000 to 2008 and continuing trend through 2012- reaches 1,231$/kW by 2012 - electric efficiency is kept at AEO-4 value because it represents TeChars - 66% and 71% combined efficiency level by 2006 and 2008, respectively.
	Gas-Fired Reciprocating Engines	- 40% electric efficiency (HHV) by 2005, 42% electric efficiency (HHV) by 2008 - $380/kW by 2006, $360/kW by 2008 - 2.1 g/kWh NOx by 2006, 1.1 g/kWh NOx by 2008	- 10-year lag of Program case - EMM 1 MW peaker composite unit assumes forecast determined from Joe Iannucci report weightings	- 200 kW commercial module unit: 39% electric efficiency by 2008, $741/kW by 2012, 87% combined efficiency by 2008 - Industrial module 1 MW and 3 MW units: 42% and 44% electric efficiency by 2008, 25% cost improvement from 2000 to 2008 and continuing trend through 2012 or $601/kW and $597/kW, 75% and 73% combined efficiencies by 2008, respectively. - EMM 1 MW peaker unit is a composite plant without CHP capability with a 80% engine make-up.
	Technology Based-Advanced Materials and Sensors	Advanced material research to assist in other program goals	No additional changes	Included in acceleration cases represented by End-Use Integration programs

	DE Program	Program Goals	Representation in NEMS-GPRA	
			Baseline	Program
	Thermally Activated Technologies	Cost and efficiency improvements for direct-fired absorption chillers	- COP of 1.2 (2005) and 1.3 (2020), $79/kBtu-hr (2005) - $51/kBtu-hr (2020); allow installations in all building types	- COP of 1.3 (2005) and 1.4 (2020), $51/kBtu-hr by 2005 - allow installations in all building types
End-Use Integration	Distributed Energy Systems Applications Integration	Demonstration and integration projects in industrial sector, high-tech industry, hospitals, and other commercial sectors.[9]	- Percent of existing buildings that adopt DER set at 0.5% of new buildings (same as AEO-4)	- Percent of existing buildings that adopt DER increased to 10% of new buildings.
	Cooling Heating and Power Integration	Combined efficiency target of 70% by 2006 and 75% by 2008	- 10-year lag of Program case - Reduce the payback years for commercial gas engines and microturbines to account for enabled absorption chiller capability	- Apply CHP 2006 and 2008 CHP targets to commercial gas engine, gas turbine, and microturbine and industrial 1MW and 3MW gas engines and 1MW, 5MW, and 10MW gas turbines and scaling the CHP target to different size units using the TeChars - Reduce the payback years for commercial gas engines and microturbines to account for enabled absorption chiller capability

[9] The National Accounts Energy Alliance focuses on "Fortune 1000, national chain end-users, including the retail, supermarket, food service, hotel, and healthcare industries."

Table 4. Additional NEMS-GPRA Enhancements for both the Baseline and Program Cases

Change	Module	Program or Baseline	Implemented in NEMS-GPRA	Source/Rationale
Maximum Annual Penetration Caps for New Buildings	Commercial	Both	*Penparm* parameter currently set to 30%, change to 50%	Change made in GPRA05
Maximum Annual Penetration Caps for Existing Buildings	Commercial	Both	Remove penetration cap of 0.5% new building penetration	Additional methods are implemented to prevent oversaturation in existing buildings
Falloff of Maximum Annual Penetration Caps as a Function of Payback Years	Commercial	Both	Currently set as an inverse function: $\max pen = \frac{penparm}{simplepayback}$ Change to: $\max pen = \frac{1.1 penparm}{e^{0.24 simplepayback}}$	*Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project*. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.
Adjust commercial customer payback for gas engines and microturbines to include absorption cooling capability in these technologies	Commercial	Both	Modify *isimplepayback* for gas engines and microturbines by Census Division, building type, and year and corrected for change in energy consumption as a result of increased absorption cooling.	NEMS does not consider absorption cooling.
Adjust industrial customer acceptance payback distribution and relax the yearly penetration rate for gas turbines to reflect market transformation improvements with CHP	Industrial	Program	Modify the payback acceptance curve giving a greater acceptance rate for shorter paybacks. Also increased the yearly penetration rate from 5% to 10%.	Representing market transformation advancements of the CHP program.

Appendix E – GPRA06 Federal Energy Management Program Documentation

Introduction

The mission of the Federal Energy Management Program (FEMP) is to promote energy security, environmental stewardship and cost reduction through energy efficiency and water conservation, the use of distributed and renewable energy, and sound utility management decisions at Federal sites. [FY 2005 Congressional Budget Request, p. 475]

The Federal Energy Management Program goal is to provide technical and financial assistance to Federal agencies and thereby lead the Nation by example in use of energy efficiency and renewable energy. Through the Federal Government's own actions, FEMP's target is to increase Federal renewable energy use to 2.5% of total Federal electrical energy use by 2005, and reduce energy intensity in Federal buildings by 30% by 2005 (relative to the 1985 statutory baseline level of 138,610 Btu per gross square foot). By 2010, the target is to further reduce energy intensity in Federal buildings by 35% (relative to the 1985 statutory baseline level).[FY 2005 CBR, p. 476] Resource assumptions for FEMP are shown in **Table 1**.

Table 1. Resource Assumptions for FEMP, FY 2005 to FY 2010.
(in millions of nominal dollars)

FY05	FY06	FY07	FY08	FY09	FY10
18.4	17.1	17.1	17.1	17.1	17.1

Introduction to GPRA Metrics Approach

Pacific Northwest National Laboratory (PNNL) calculates the potential site energy impacts of FEMP's portfolio for DOE/EERE. The details of those mathematical calculations are available for review in an annotated Excel spreadsheet, which provides a transparent "A to Z" understanding of how the year 2010 impacts are estimated. Individuals interested in the specific details should refer to that file, available from PNNL by contacting Daryl Brown (daryl.brown@pnl.gov). FEMP's detailed spreadsheet model is not integrated into the larger FY 2006 GPRA models (NEMS-GPRA06 and MARKAL-GPRA06). However, to provide source energy savings, energy-expenditure savings, and carbon emission reductions attributed to FEMP, the outputs of the spreadsheet model are fed into the larger GPRA models exogenously and the larger models report these benefits.

A detailed narrative description of the approach, and a summary of the results, follows below in the section Energy Savings Calculation Mechanics. The purpose of this introductory section is to provide a general understanding of the approach and assumptions at a higher level.

There are four key principles governing PNNL's estimation of GPRA metrics for FEMP.

First, the principal goal examined for metrics development is the 2010 site energy-intensity goal for "standard" buildings and facilities described above. PNNL also estimates the impact of the Executive Order 13123 goal for energy-intensive operations, which is to reduce energy per square foot by 25% in 2010, relative to a 1990 baseline. Both of these goals are stated in terms of energy use, per year, per square foot of floor space. It is important to note that FEMP's mission is to assist the 31 Federal agencies in attaining these executive order goals for the Federal government. Strictly speaking, these are not goals for FEMP but goals for each individual agency, and their involvement is essential. As noted above, the Federal sector also has a renewables goal for FY05, but FEMP's role in helping Federal agencies meet this goal was not estimated by PNNL because any impact through FY05 would not be affected by the FY 2006 budget request.

Second, to estimate impacts in the Federal marketplace, PNNL treats the entire Federal Energy Management Program as one unified deployment program. That is, PNNL takes what is often called a "top-down" approach to calculate 2010 energy impacts. The impact of FEMP's broad portfolio of deployment activities – alternative financing, direct technical assistance, training and information, publication of the Annual Report to Congress, procurement recommendations – is estimated as one combined effect in the market, measured in terms of energy use per square foot per year. Put differently, separate impacts for each FEMP activity are *not* estimated and then summed; the approach is not "bottom-up".

Third, the target market is the Federal sector, the Nation's 3.0 billion square feet of federal buildings space – military bases, post offices, VA hospitals, Department of Energy (DOE) laboratories, courthouses – and the Nation's Federal energy intensive operations. (Energy-intensive operations include, for example, laboratories, check-processing facilities, and linear accelerators.) The Federal Government's actions – via leadership, awards, influence, and raw purchasing power – may well influence private-sector and state and local government decisions with respect to energy-related decisions, but any such "spillover" impact is not estimated in this GPRA process.

Finally, the question of attribution of impact must be addressed. The mission of FEMP is to assist the Department of Defense, GSA, and other Federal agencies in attaining legislative and executive order energy goals for those agencies. The analysis needs to determine how much of that goal achievement is attributable to FEMP. Very specifically, how much of the site energy-intensity reduction in Federal buildings and facilities, from FY 2006 to FY 2010, is attributable to the portfolio of FEMP activities funded between FY 2006 and FY 2010, assuming level funding? In the GPRA analysis, PNNL assumes that 50% of the progress is attributable to FEMP's leadership and to FEMP's diverse portfolio. The other 50% is attributable to conservation retrofit funding, awareness campaigns at other Federal agencies, as well as to the existence of appliance and equipment standards and general technological innovation.

The 50% estimate was originally derived from analysis performed in support of the Energy Savings Performance Contract alternative financing activity within FEMP.[1] An assessment of the likely agency markets for alternative-financing products from FEMP (both ESPC and Utility

[1] FEMP Fiscal Year 1999 ESPC Business Strategy Development Summary Report, K. McMordie-Stoughton and D. Hunt, Pacific Northwest National Laboratory, March 2000, PNNL-13204.

Programs) produced estimates of FEMP programmatic impact of 35% to 55%, with most of the remainder being attributed to the Army Corps' Huntsville ESPC operation. This estimate did *not* include the likely impacts of the rest of FEMP's portfolio – direct technical assistance, training, and information. Taking the lower-end estimate of 35% and including these other impacts, PNNL estimated that a reasonable impact was 50%.

Energy Savings Calculation Mechanics

Actual historical and estimated future energy consumption are characterized in terms of fuel consumption (MMBtu or million Btu), fuel mix (the fractions of total fuel consumption by fuel type), and building floor space (ksf or thousand square feet). A critical derived figure is building energy intensity (MMBtu/ksf). The development of these measures is described in the sections that follow.

Historical Federal Agency Energy Consumption and Cost

Estimates of future Federal agency energy consumption start from the latest data available for actual energy consumption. For the analysis of impacts resulting from the FY 2006 Budget Request, the latest actual data were for FY 2003. These data were provided by the individual Federal agencies to McNeil Technologies, which has the responsibility for collecting and managing these data for FEMP. In turn, PNNL receives these data from McNeil. These data are eventually documented in the *Annual Report to Congress on Federal Government Energy Management and Conservation Programs*[2] for each fiscal year. As of January 2005, the most recent published version of this report covered fiscal year 2001 and was published February 4, 2004.

The historical data available for analysis are energy consumption (MMBtu) by fuel type and building floor space (ksf). These data are reported by each agency. The fuel type categories are electricity, fuel oil, natural gas, liquefied petroleum gas (lpg), coal, purchased steam, and "other." Building energy intensities (MMBtu/ksf) are calculated from these raw data.

Future Federal Agency Energy Consumption

Future Federal energy consumption was estimated by combining estimates of future building energy intensity, fuel mix, and building floor space. Total energy consumption (MMBtu) is the product of building energy intensity (MMBtu/ksf) and building floor space (ksf), as defined by Equation 1. Energy consumption by fuel type (MMBtu) is the product of total energy consumption and fuel-mix fraction for each fuel type, as defined by Equation 2.

Total Energy = Building Energy Intensity * Building floor space   Eqn. 1.

Fuel Type "A" Energy = Total Energy * Fuel "A" Mix Fraction   Eqn. 2.

The Department of Defense (DOD), DOE, General Services Administration (GSA), United States Postal Service (USPS), and Veterans Affairs (VA) were selected for specific metric development because they are the five largest agencies measured by annual energy use, consuming nearly 90% of the Federal total in FY2003; DOD alone is nearly two-thirds of total

[2] Available on FEMP's Web site at http://www.eere.energy.gov/femp/about/annual_report.cfm

Federal energy use (see **Figure 1**). Reduction in MMBtu/ksf from FY2000 through FY2010 was estimated for each of these five agencies and all other agencies (24 total) grouped together for standard buildings. Metrics for energy-intensive operations were developed for the Federal government as a whole. The following subsections describe the development of building energy intensity, building floor space, and fuel-mix fraction assumptions. In addition, the resulting estimates of building energy intensity reductions are provided.

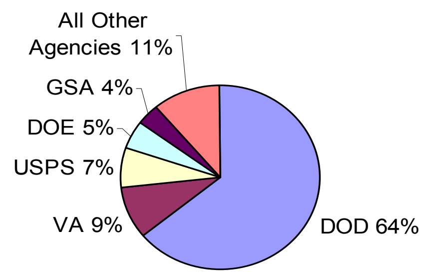

Figure 1. FY 2003 Federal Agency Standard Building Energy Consumption

Building Energy Intensity

Estimates for agency-specific reductions in MMBtu/ksf by FY2010 relative to FY2000 were aggregated from estimates due to a) cost-effective retrofits of building energy systems, b) replacement of equipment upon failure (with generally more efficient equipment), c) cost-effective retrofits of central energy plants and thermal distribution systems (DOD, DOE, and VA only), d) construction of new housing (DOD only), and e) improvements in O&M practices. These five categories have differing assumptions, and the assumptions for each agency can be different within a particular category. The assumptions are discussed in the text below, and are based on literature referenced in the text. **Table 2** presents the output estimates of energy intensity reductions derived from the spreadsheet model by category and agency.

Table 2. Energy-Intensity Reduction Estimates

Estimated Reduction in MMBtu/ksf by 2010 from 2000						
	Agency					
Reduction Source	**DOD**	**DOE**	**GSA**	**USPS**	**VA**	**Other**
Building Retrofit	7	11	9	8	8	9
Replace on Failure	4	4	4	4	4	4
CEP and Dist Retrofit	2.5	2.5			2.5	
Improved O&M	3	6	2	2	4	3
New Housing	0.5					
Total	17	23.5	15	14	18.5	16
FY2000 MMBtu/ksf	105	249	67	74	168	115

The reduction in MMBtu/ksf for Federal agencies was based primarily on data developed in two PNNL reports, *Economic Energy Savings Potential in Federal Buildings*[3], and *An Assessment of Prospective FORSCOM Energy Intensities*[4]. The former was prepared for FEMP by D. Brown, J. Dirks, and D. Hunt and is available from PNNL's Web site at http://www.pnl.gov/main/publications/; the latter was prepared for the U.S. Army's Forces Command (FORSCOM) by D. Brown and J. Dirks.

The report for FEMP specifically examined the retrofit potential based on government financing for all government agencies, while the report for FORSCOM examined the retrofit potential for their facilities based on either government or alternative-financing mechanisms[5]. The report for FORSCOM also looked at the impacts of the natural turnover of HVAC and service hot water (SHW) equipment (called "replace on failure" in **Table 2**), improvements to central energy plants (CEPs, i.e., boilers and/or chillers) and thermal distribution systems, and housing privatization plans (demolition, renovation, and new construction).

FORSCOM facilities represent about 10% of total DOD floor space and have a mix of buildings types generally representative of DOD as a whole. In addition, the retrofit-estimating methodology was more robust than that used for the DOD sector in the FEMP report. Therefore, the FORSCOM results were used as the basis for estimating retrofit potential for DOD, while the FEMP results were used as the basis for other agencies.

The estimated retrofit potential for non-DOD agencies from the FEMP report was reduced by one-third to reflect alternative financing rather than government financing (appropriations). This factor is driven by the higher interest rates and shorter financing periods typically seen for alternative financing and is based on work by J. Dirks, D. Brown, and J. Currie of PNNL[6]. Finally, 50% of the estimated potential via alternative financing was assumed captured by FY2010. This will approximately occur if the rate of annual alternative-financing investment from FY1998 through FY2000 continues through FY2010, with the same ratio of energy savings per dollar invested as seen in FY1998 through FY2000.

Replacement of HVAC and SHW equipment occurs continuously as equipment ages, fails, and must be replaced. In general, the efficiency of HVAC and SHW equipment has substantially improved because of technology advances, stimulated in part by stricter equipment and appliance standards at the national level. Other factors include building energy codes and the forces of technological innovation. As a result, replacement equipment will usually consume less energy than the equipment being replaced; and, in some cases, much less energy (refrigerators and chillers, for example). The estimated energy-intensity reduction from this mechanism was about 4 MMBtu/ksf in the FORSCOM study; the estimated impact for civilian agencies was judged by

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[3] D.R. Brown, J.A. Dirks, and D.M. Hunt. 2000. *Economic Energy Savings Potential in Federal Buildings*. PNNL-13332. Pacific Northwest National Laboratory. Richland, Washington.

[4] Distribution of the full report is limited by FORSCOM. The following paper, based on the full report, is publicly available. D.R. Brown and J.A. Dirks. 2002. "Prospective FORSCOM Energy Intensities." *Proceedings of the 25th World Energy Engineering Conference.* Association of Energy Engineers. Atlanta, Georgia.

[5] Alternative financing includes energy-saving performance contracts (ESPC) and utility energy service contracts (UESC).

[6] J.A. Dirks, D.R. Brown, and J.W. Currie. 1999. Sensitivity of ESPC Projects to Changes in Interest Rates and Energy Prices. Pacific Northwest National Laboratory. Richland, Washington. An informal letter report from PNNL to FEMP.

PNNL to be the same, since the phenomenon of improving energy efficiency in new equipment and appliances is economy-wide and not restricted to just DOD.

DOD sites often have large CEPs and accompanying thermal distribution systems. Results from the FORSCOM report indicated potential energy savings equivalent to a reduction in building energy intensity of 5 MMBtu/ksf. Again, it is unlikely that 100% of the potential will be captured. A 50% capture fraction was assumed to be consistent with the building retrofit capture fraction assumption. Among the four civilian agencies considered explicitly, only DOE and VA have a significant number of sites with CEPs, so this projected savings was only applied to these two agencies, in addition to DOD.

The estimated decrease in MMBtu/ksf from improved O&M practices was developed from data presented in *Using Targeted Energy Efficiency Programs to Reduce Peak Electrical Demand and Address Electric System Reliability Problems* by S. Nadel (et al) of American Council for an Energy Efficient Economy (ACEEE); and *Energy and Comfort Benefits of Continuous Commissioning in Buildings* by D. Claridge (et al) of Texas A&M University. Specifically, Nadel estimated cost-effective energy savings via improved O&M practices to be between 5% and 15% of existing energy consumption, with a maximum penetration rate of 50%. To be conservative, PNNL used a penetration rate of 25% for the FEMP GPRA analysis. Thus, starting from an average potential of 10%, the estimated savings from improved O&M practices was set equal to 2.5% of energy consumption in FY2000.

DOD is unique among the Federal agencies with respect to the housing stock it manages for military personnel and their families. About 90% of federal housing stock, or about 600 million square feet, resides in the military. All three branches of the military are currently privatizing a significant portion of their housing stock. Privatization plans, besides transferring ownership, call for significant demolition, new construction, and renovation. The impact of these housing-stock changes was estimated (in the FORSCOM report) to reduce FORSCOM's overall building energy intensity by about 3 MMBtu/ksf. This figure was reduced to 0.5 MMBtu/ksf for DOD, as a whole, because the energy impacts of housing privatization are concentrated within FORSCOM.

The FY2010 building energy-intensity calculations are defined by Equation 3 for standard buildings. To calculate energy intensity for FY2010, the estimated reductions in MMBtu/ksf shown in **Table 2** are subtracted from the actual energy intensities for each agency in FY2000. Although actual FY2003 energy consumption data are now available, the estimated energy intensities for FY2010 are based on FY2000 to be consistent with the references (reports for FEMP and FORSCOM described above) supporting the figures in **Table 2**. As described earlier, the FY2010 energy intensity for energy-intensive operations was set at the value that exactly meets the energy-intensity goal for these types of facilities.

Building Energy Intensity in FY2010 =
Building Energy Intensity in FY2000 –
Building Energy Intensity Reduction Estimate Eqn. 3

Energy intensities for years between FY2003 and FY2010 were geometrically interpolated between these two endpoints. Energy intensities beyond FY2010 were assumed to continue declining, with each year 1% less than the previous year. This is a conservative assumption compared to the average compounded rate of decline from 1985 through 2003, which was 1.5%.

Building Floor Space

Future building floor space was set equal to the FY2003 value, i.e. no change in floor space was assumed through FY2030. Note, however, that floor space has been increasing slowly since FY1997 at a rate of about 0.4% per year, after declining from FY1985 to FY1997. The decline through FY1997 was driven mostly by reductions in DOD, while the increase since FY1997 is mostly attributable to USPS. It is not clear whether an increase or decrease in floor space is more likely during the next 10 years, let alone the next 30 years; therefore, floor space was assumed to remain constant for the duration of the analysis period.

Fuel Mix

Since FY1985, total site use of coal and fuel oil has declined significantly, while the use of electricity has remained nearly constant and the use of natural gas has declined slightly. As a consequence of these changes, the fractions of fuel use associated with electricity (and to a lesser extent, natural gas) have increased over time (See **Figure 2**). EIA forecasts from the *Annual Energy Outlook 2004* suggest that this trend will continue, with site use of electricity increasing relative to other energy forms.

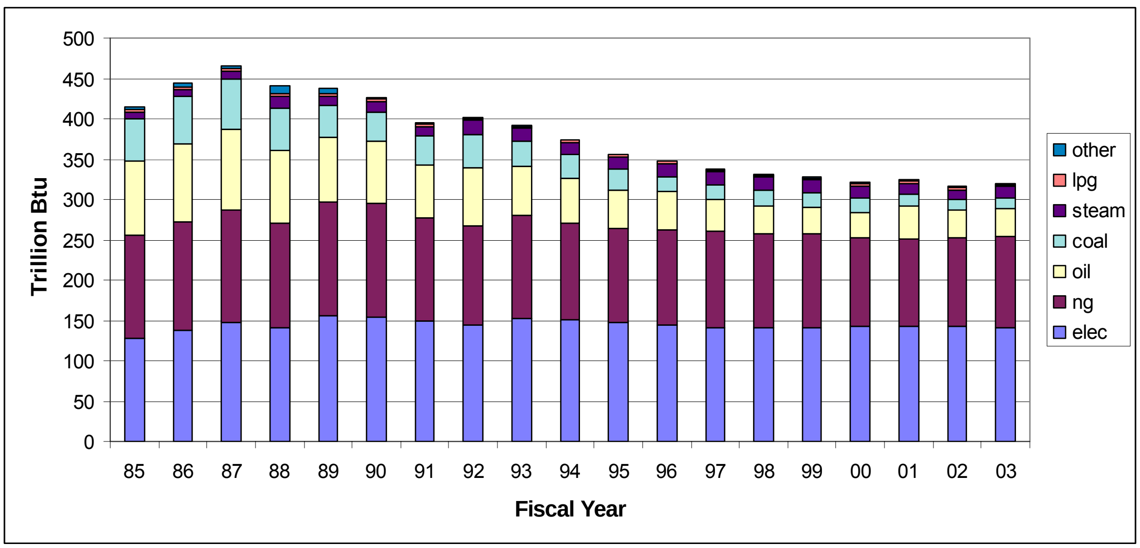

Figure 2. Historical Energy Use in Standard Federal Buildings

Changes in the forecast fuel mix for the commercial sector from EIA's *Annual Energy Outlook 2004* were applied to the actual Federal fuel mixes in FY2003 to estimate future federal fuel mixes. Projected changes for the commercial-sector fuel mix were first normalized relative to the existing commercial sector fuel mix in 2003. For example, the normalized electricity fraction in the commercial sector grew from 1.0 (by definition) in 2003 to 1.18 in 2030. In contrast, the normalized natural gas fraction in the commercial sector fell from 1.0 in 2003 to 0.86 in 2030. The normalized fuel fractions for each fuel and each year were multiplied by the actual Federal fuel fractions in 2003 for each agency or agency group to estimate future Federal fuel mixes.

This procedure was applied to standard buildings, but not to energy-intensive operations. There, it was not so clear what sector (commercial or industrial) would better represent energy-intensive operations or whether the year-to-year volatility in reported data for energy-intensive operations would invalidate the refined approach. Instead, future fuel mixes for energy-intensive operations were assumed to remain as they were in FY2003.

Federal Agency Energy Consumption Baseline

The baseline Federal agency energy consumption is the estimated Federal agency energy consumption in FY2005. FY2006 is the first possible year that could be affected by the FY2006 budget, so FY2005 is the logical baseline year. As previously described, the latest actual data are from FY2003. Energy consumption by fuel type is estimated for each year after FY2003, including the FY2005 baseline year, via the process described above in the section on Future Federal Agency Energy Consumption.

Future Federal Agency Energy Savings

Annual energy savings were calculated by subtracting the estimated energy consumption in FY2005 from the estimated energy consumption for FY2006 and each following year. These calculations were done for each fuel type. Implicitly, if not for activities conducted by FEMP and the Federal agencies, future energy consumption would remain as estimated for FY2005, and there would be no energy savings. Energy savings were summed across agencies and fuel types to determine total energy savings. Equations 4-6 define these calculations.

Fuel Type A Energy Savings for Agency B in FY20XX =
Fuel Type A Energy Consumption for Agency B in FY20XX –
Fuel Type A Energy Consumption for Agency B in FY2005 Eqn. 4.

Fuel Type A Federal Energy Savings in FY20XX=
Σ Fuel Type A Energy Savings across all Agencies in FY20XX Eqn. 5.

Federal Energy Savings in FY20XX =
Σ Fuel Type A Federal Energy Savings across all Fuel Types Eqn. 6.

Energy savings by fuel type, measured in MMBtu, were converted to alternative units for reporting requirements via the conversion factors listed in **Table 3**.

Table 3. Energy Conversion Factors[7]

Fuel Oil: 5.825 MMBtu/barrel
Natural Gas: 1.027 MMBtu/1000 cubic feet
Coal: 22.489 MMBtu/short ton
Electricity: 3.412 MMBtu/MWh
LPG: 3.603 MMBtu/barrel

[7] Source: Performance Planning Guidance (GPRA Data Call) FY2004-2008 Budget Cycle-Draft. April 1, 2002. U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy.

Energy Savings Results

Estimated annual and cumulative energy savings attributable to FEMP resulting from the FY 2006 Budget Request are summarized in **Table 4** and **Table 5**.

Table 4. Annual Energy Metrics for Federal Standard Buildings and Energy-Intensive Operations (FY 2006 Budget Request)

Year	Total Site Energy Displaced (TBtu)	Direct Electricity Displaced (billion kWh)	Direct Natural Gas Displaced (billion CF)	Direct Petroleum Displaced (million barrels)	Direct Coal Displaced (million short tons)	Direct Biomass Displaced (TBtu)	Direct Energy Displaced from Feedstocks (TBtu)	Direct Energy Displaced from Wastes (TBtu)	Other Direct Energy Displaced (TBtu)
2006	4.07	0.453	1.37	0.112	0.0218	0	0	0	0
2007	8.04	0.849	2.82	0.204	0.0479	0	0	0	0
2008	11.91	1.217	4.29	0.301	0.0711	0	0	0	0
2009	15.70	1.612	5.61	0.398	0.0939	0	0	0	0
2010	19.40	2.013	6.88	0.489	0.1154	0	0	0	0
2015	27.42	2.409	10.78	0.726	0.1705	0	0	0	0
2020	35.05	2.975	13.80	0.973	0.2204	0	0	0	0
2025	42.30	3.612	16.59	1.181	0.2636	0	0	0	0
2030	49.19	4.089	19.63	1.376	0.3067	0	0	0	0

Table 5. Cumulative Energy Metrics for Federal Standard Buildings and Energy-Intensive Operations (FY 2006 Budget Request)

Year	Total Site Energy Displaced (TBtu)	Direct Electricity Displaced (billion kWh)	Direct Natural Gas Displaced (billion CF)	Direct Petroleum Displaced (million barrels)	Direct Coal Displaced (million short tons)	Direct Biomass Displaced (TBtu)	Direct Energy Displaced from Feedstocks (TBtu)	Direct Energy Displaced from Wastes (TBtu)	Other Direct Energy Displaced (TBtu)
2006	4.07	0.45	1.4	0.11	0.022	0	0	0	0
2007	12.10	1.30	4.2	0.32	0.070	0	0	0	0
2008	24.02	2.52	8.5	0.62	0.141	0	0	0	0
2009	39.72	4.13	14.1	1.02	0.235	0	0	0	0
2010	59.12	6.14	21.0	1.50	0.350	0	0	0	0
2015	180.34	17.40	67.0	4.70	1.095	0	0	0	0
2020	340.47	31.12	130.2	9.05	2.097	0	0	0	0
2025	537.60	47.87	207.9	14.53	3.329	0	0	0	0
2030	769.91	67.35	300.1	21.03	4.778	0	0	0	0

Appendix F – GPRA06 Geothermal Technologies Program Documentation

1. Introduction

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal generation technologies, including both conventional and enhanced geothermal systems (EGS). EGS are defined as geothermal systems where the reservoir requires substantial engineering manipulation to make using the reservoir economically feasible.

Hydrothermal systems (flashed-steam power plants at the hotter reservoirs, and binary plants at moderate temperature reservoirs) are near-term commercial realities, based on known sites and indicated prospects largely discovered in the 1970s through 1990s. In flashed-steam power plants, steam from the reservoir passes directly through the power turbine. In binary plants, the geothermal fluid is used to heat a secondary working fluid, e.g., pentane; which, in turn, drives the power turbine.

EGS are expected to weigh in commercially in the longer term, based on resource assessments and exploration programs that are just beginning. While the program expects EGS to be applicable nationwide in the very long term, the first work on EGS will be concentrated west of the Rockies and it is modeled in that manner for GPRA.

Estimating the GPRA benefits involves projecting the market share for these technologies based on their economic and environmental characteristics. Separate estimates of geothermal energy physical resources and separate projections of technology improvements are used for hydrothermal (Flash and Binary) and EGS.

1.1 Target Markets

Geothermal power is expected to penetrate in three market segments: the least-cost power market, the state Renewable Portfolio Standards market, and the green power market. Only "centrally located" geothermal power plants were considered, although there is emerging industry interest in distributed applications. In fact, most geothermal known sites are located at some distance from the Western large urban markets, and the projects require substantial consideration of where the power will be sold and how it will be delivered. There is also an ongoing DOE program to measure the economics of small-scale modular geothermal plant technology development (<5 MW), but to date that has not been modeled in the GRPA processes.

- Least-Cost Power
  NEMS-GPRA06 and MARKAL-GPRA06 were run to estimate market penetration into the competitive bulk power marketplace for geothermal power technologies. The program goals for geothermal technology improvements are modeled directly by incorporating the capital and operation and maintenance (O&M) cost reductions. The models also take into account

site availability and maximum development per site per year for conventional and EGS geothermal capacity. The capital cost reductions for conventional geothermal were computed based on the program goals for surface systems and drilling cost improvements. The conventional geothermal O&M costs are from the EPRI/DOE *Renewable Energy Technology Characterizations* report [1]. The EGS characteristics were developed by Princeton Energy Resources International (PERI) in 2003 [2].

The DOE Geothermal Program has recently undertaken a large-scale restructuring of the means by which it sets its goals and bases them on detailed estimates of the specific R&D subprogram's (e.g., Exploration, Well Field Construction, Power Conversion, and Enhanced Geothermal Systems) likelihood of producing specific technology improvements at various levels of funding, and at various points in time. That restructuring will produce improved program goals for the FY-2007 GPRA work.

For the FY-2006 GPRA Baseline, the underlying estimates of cost reductions due to industry experience (a.k.a., "learning curve" effects) were modified from those in the AEO 2004 Reference Case. This was done because the DOE Energy Information Administration (EIA) appears to more or less have adopted the Geothermal Program estimates of technology improvements as its own estimates when they updated the learning functions for the AEO2004. The learning rate estimates in NEMS-GPRA-FY-2006 were set at one half the rates used in NEMS-AEO-2005. The resulting learning in the GPRA06 Baseline is very similar to that of the AEO2003 and the GPRA05 Baseline from last year.

- State Renewable Portfolio Standard (RPS) Markets
  While the Geothermal Program believes it has affected entry of geothermal power systems into the RPS markets, particularly in Nevada, the program gets no credit for this under GPRA assumptions. This is because announced plans for RPS projects are absorbed into the category of "Cumulative Planned Additions" in EIA's AEO tables, and not credited to the DOE Programs in the GPRA process. One effect of this is to systematically understate the impact of the DOE program's activities in very near term deployment of geothermal power projects.

- Green Power
  Flash, binary, and EGS technologies were all modeled as potential geothermal power plants that could be installed to meet the emerging green power market. Flash and binary technologies compete well within the green power market, with flash technology out-gaining binary due to its more attractive cost curve. EGS technologies have significant cost penalties that restrict capacity additions until after 2015, and even then only a very limited amount of EGS power is projected to be built to meet green power demand. Although geothermal plants were limited to the western portion of the United States, they were typically one of the least-expensive options, leading to significant penetration in those two regions. Projections for incremental green power geothermal installations were incorporated into the NEMS-GPRA06 and MARKAL-GPRA06 models as planned capacity additions.

1.2 Key Factors in Shaping Market Adoption of Geothermal Technologies

Most of the geothermal resources in the United States that are currently known lie in two western states, California and Nevada. Other potentially useful resources exist in Hawaii, Idaho, Oregon, and Utah. The other western states also have geothermal resources, but those are somewhat indeterminate with respect to near-term commercial quality. This means that relative few electric utilities and government regulators (federal, state, and local) are familiar with the promise and issues associated with geothermal energy as a source of electricity. This set of factors is being dealt with by the DOE Geothermal Program's "Geopowering the West" initiative [3], which has made substantial strides since 2001 in developing awareness and interest in twelve states. Some of the more significant issues are being addressed by the "Geothermal Collaborative"; for example, how geothermal power fits into the new state Renewable Portfolio Standards [4].

Note that commercial development of the Nation's primary scenic geothermal features, such as Yellowstone National Park, Wyoming, is simply off limits, under a number of Federal laws.

A second important factor is that, although a moderately large amount of geothermal hydrothermal resource capable of producing electricity appears to exist, much of that has either not been confirmed in detail or is too expensive to compete with conventional fuels. For example, costs are too high at some sites because the needed wells are too deep and expensive, or because the formation permeability is too low. The detailed estimates of site-specific costs are built into the NEMS Geothermal Electricity Submodule.

A third important factor is that the commercial work to discover and confirm a geothermal reservoir (a.k.a., "exploration") is risky and somewhat expensive. Because of that risk, the funding is entirely through equity capital, which is not always easy to procure. The Geothermal Program today works to ameliorate some of that risk through its Geothermal Resource Exploration and Definition Contracts, which encourage exploration by paying for the testing of new exploration methods and tools. That work is not explicitly modeled, but will eventually be, through the addition of new geothermal prospect sites to the NEMS-GRPA model, and perhaps to the EIA NEMS model. Other efforts to address the exploration issue lie in ongoing combined work of the Department of Energy and the Department of the Interior (e.g., Bureau of Land Management and the U.S. Geological Survey) to identify the most promising new sites for geothermal power development [5].

1.3 Methodology and Calculations

NEMS-GPRA06

The NEMS-GPRA06 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e. availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources in only three western regions, each with a set of capital and O&M costs. For the Program Case, three EGS sites in each of the three regions were substituted for the most expensive hydrothermal sites in those regions.

Conventional Geothermal (Hydrothermal) Systems

The capital and O&M cost reduction goals of the program are applied to each of the 51 sites. **Figure 1** illustrates the resulting supply curve of the hydrothermal sites in the Northwest United States in 2006 and 2020 that can be developed in each of those years in NEMS-GPRA06. These curves reflect the GPRA cost reductions, as well as the financing assumptions from the *Annual Energy Outlook 2004* (*AEO04*) Reference Case, and the limit of developing only 100 MW at a site each year. The limit of 100 MW development per site per year is an increase from the *AEO03* assumption of only 25 MW or 50 MW (depending on year). The limit change is made to reflect the program's efforts to reduce the risk associated with new geothermal development. The lowest part of the curve is not depicted for 2020, because it represents a portion of the capacity already developed.

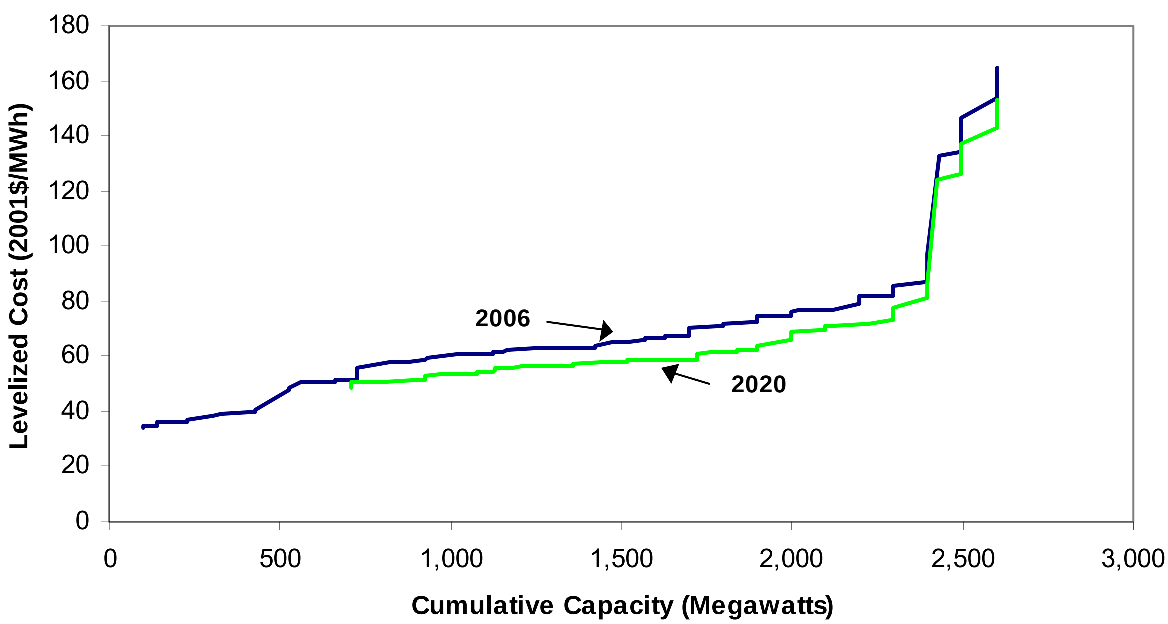

Figure 1. Geothermal Supply Curve – Northwest Region

Roughly 10 GW of hydrothermal resource in the Northwest and 23 GW in the lower 48 states is represented within NEMS-GPRA06. With the GPRA Base Case assumptions, much of this resource would be quite expensive to develop; today, an estimated 5 GW might be available at 6 cents per kWh.

Enhanced Geothermal Systems (EGS)

Characteristics for EGS systems were also provided. Nine new EGS sites, were substituted for the three most expensive hydrothermal sites in the western regions: Northwest Power Pool (NWP, Region 11), Rocky Mountain Power Area, Arizona, New Mexico, and Southern Nevada (RA, Region 12), and California (CA, Region 13). Each site represents a Type of EGS resource:

Type I. A site where EGS would be used to improve an existing commercial hydrothermal reservoir.

Type II. A site where EGS would work to develop economic power from identified sites with sub-commercial hydrothermal features.

Type III. A site where EGS would be used as a longer-term strategy to develop power systems in volumes of rock that have not been identified as hydrothermal prospects.

Similar to the conventional sites, each geothermal site is further specified in four stages of increasing costs (**Table 1**).

Table 1. EGS Site Characterization for NEMS-GPRA06

		Potential Capacity 1 (MW)	Potential Capacity 2 (MW)	Potential Capacity 3 (MW)	Potential Capacity 4 (MW)	Capacity Factor
Region 11	EGS Type I	550	550	550	550	0.9
	EGS Type II	2500	2500	2500	2500	0.9
	EGS Type III	5000	5000	5000	5000	0.9
Region 12	EGS Type I	0	0	0	0	0.9
	EGS Type II	1250	1250	1250	1250	0.9
	EGS Type III	5000	5000	5000	5000	0.9
Region 13	EGS Type I	300	300	300	300	0.9
	EGS Type II	2500	2500	2500	2500	0.9
	EGS Type III	5000	5000	5000	5000	0.9

Capital and O&M costs were provided for the initial development at each site and were the same for all regions. The EGS and conventional costs are shown below in 2001 dollars (**Table 2**). Hydrothermal flash and binary system costs are shown here for comparison. The relatively high O&M costs in **Table 2** for the EGS systems is occasioned in part by the need to substantially replace much of the reservoir at about the 15 year point of the 30 year project life. Note also that, in the long run, it is reasonable that technology improvements for EGS could drive the capital costs of new EGS projects (potentially plentiful) below the cost of newly discovered binary systems (which are estimated to become increasingly scarce in the out-years of the simulations).

Table 2. Geothermal Cost Characteristics for NEMS-GPRA06

	2005	2010	2015	2020	2025
Capital Cost (2001$/kW)					
Flash	1,882	1,784	1,728	1,703	1,681
Binary	2,807	2,661	2,577	2,539	2,507
EGS I	2,400	2,132	1,864	1,596	1,328
EGS II	2,760	2,452	2,144	1,835	1,527
EGS III	3,120	2,772	2,423	2,075	1,726
Total O&M Costs (2001$/kW-yr)					
Flash	80.3	71.2	66.6	62.5	60.7
Binary	84.3	71.7	63.9	56.3	55.3
EGS I	150.0	132.0	114.0	96.0	78.0
EGS II	172.5	151.8	131.1	110.4	89.7
EGS III	195.0	171.6	148.2	124.8	101.4

Note: Flash and binary costs vary by site. These costs shown here are based on the lowest cost-available site in 2005 with technology improvements applied over time.

While the estimated technology improvements in **Table 2** may appear to be somewhat aggressive, they are supported by recent detailed research into the historical costs of geothermal hydrothermal power systems, between 1980 and 2000 [6]. The 1980s saw extensive development of hydrothermal power systems in the United States, and the early 1990s saw that extended by American geothermal firms in the Philippines and Indonesia, so there was a useful test bed of historical deployment for analyzing costs. The research found that over the 20-year period, the real (inflation adjusted) total capital costs of both flash and binary hydrothermal systems had decreased by about 45%. The Geothermal Program believes that substantial opportunity for technology improvement remains.

MARKAL-GPRA06

The geothermal technologies represented in MARKAL-GPRA06 reflect the Geothermal Program goals (defined for FY-05, as described above) for both conventional systems and EGS. For conventional geothermal systems, the capital and operating and maintenance costs were changed to reflect program goals. However, EGS represents a new geothermal resource not previously represented in the MARKAL-GPRA06 model. The program identified three separate types of potential geothermal reservoirs, as discussed above.

Due to program activities, the capital and O&M costs of EGS systems are projected to decline over time. **Table 3** shows the estimated capital and O&M costs for the three types of EGS systems for 2000 and 2050.

Table 3: EGS Generation Assumptions for MARKAL-GPRA06

EGS Type	Projected Resource MWe	2000 Cost Capital Cost 01$/kW	2000 Cost O&M 01$/kW/yr	2050 Cost Capital Cost 01$/kW	2050 Cost O&M 01$/kW/yr
I	**3,400**	2,448	153	934	50
II	**25,000**	2,815	176	1,074	58
III	**60,000**	3,182	199	1,214	66

The EGS sites projected under the program are grouped into a set of supply steps and the discount rate of these technologies is set at 8% (instead of 10% for the industrial average) to reflect the accelerated depreciation schedule permitted by the IRS for renewable generation technologies. The EGS systems are modeled as centralized base-load generation.

Geothermal plants compete directly with fossil fuel-based plants for both electricity generation and meeting peak power requirements. In MARKAL-GPRA06, EGS becomes more competitive as its higher capital cost is offset by increased fossil fuel costs, which increase as demand increases.

GREEN POWER MARKET MODEL

PERI used the Green Power Market model to project regional green power additions [7]. These capacity additions are used by NEMS-GPRA06 and MARKAL-GPRA06 as planned new capacity or minimum capacity additions.

As shown elsewhere in this report, the only two technologies that penetrate the Green Power Market, as modeled in the EERE GPRA-2006 exercise, are photovoltaics and wind. The Geothermal Program analysts and management are surprised by this, since geothermal contributed substantially to the Green Power markets in California when they were first set up in the late 1990s [8]. However, the incremental green power projections used for GPRA only include additional capacity stimulated by cost reductions through R&D.

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7. Personal communication from J. McVeigh, PERI, to D. Entingh, January 20, 2005.

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Appendix G – GPRA06 Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) Program

1. Introduction

The target markets for the Office of Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) program include transportation (cars and light trucks) and stationary (particularly residential and commercial) applications. Each will be discussed separately below.

1.1 Target Market: Fuel Cell Vehicle Market

The market for fuel cell vehicles (FCVs) includes all cars and light trucks sold for both personal and business use. Today, the size of this market is approximately 17 million vehicle sales per year. Total car and light truck stock is about 220 million vehicles. EIA projects both sales and stock to grow to more than 20 million and 300 million respectively by 2025. Additional growth is expected post-2025.

1.2 Key Factors in Shaping the Market Adoption of FCVs

Key factors associated with the adoption of new vehicle technologies include how the new vehicle technologies compare with the baseline vehicle technologies in terms of the following vehicle attributes:

- Vehicle Price
- Fuel Economy
- Range
- Maintenance Cost
- Acceleration
- Top Speed
- Luggage Space

Of these, vehicle price and fuel economy are the most important.

Non-vehicle attributes that are important factors in a consumer's decision to purchase new vehicle technologies include the following:

- Fuel Price
- Fuel Availability

1.3 Methodology and Calculations

The factors listed above include the factors used in the modeling of new vehicle technology penetration by the NEMS and MARKAL models. FCV attributes and other factors are discussed below.

1.3.1 FCV Attributes

FCV attributes were developed based on the HFCIT program goals, discussions with HFCIT program managers, Powertrain Systems Analysis Toolkit (PSAT) modeling, and payback analysis (Refs. 1-3). The PSAT model is a simulation model used by DOE to evaluate the fuel economy and performance of light vehicles using various technologies. Payback analysis was used to estimate what the incremental price of FCVs would be when they become cost competitive with conventional vehicles, a goal of the program. (The incremental price equals the present value of the energy cost reduction achieved by FCVs over three years, assuming a hydrogen price of $1.50/gallon gasoline equivalent and 7.5% discount rate.) Other attributes were based on a review of past GPRA characterizations (e.g., Ref. 4).

Because the NEMS and MARKAL models require different levels of detail, two separate vehicle characterizations are provided. In both cases, most of the attributes are provided as ratios to the vehicle attributes of conventional vehicles. (For NEMS, the $ value of the price increments were provided.) The attributes are for new vehicles in the year listed. **Table 1** contains the vehicle attributes for FCVs provided for input to the NEMS model. Attributes are provided for two car size classes and five light-truck classes. NEMS uses six car size classes and six light-truck classes, but for the NEMS analysis of FCVs to 2025 fewer classes were deemed sufficient.

Table 2 contains vehicle attributes for FCVs provided as input to the MARKAL model. MARKAL uses only vehicle price and fuel economy attributes. MARKAL does not disaggregate cars and light trucks into various classes.

1.3.2 Hydrogen Price and Availability at Stations

Hydrogen price and availability assumptions are discussed in **Chapters 4 and 5** in the HFCIT Program sections.

1.3.3 FCV Market Penetration Methodology

Brief descriptions of how the NEMS and MARKAL models project new vehicle technology penetration using these vehicle attributes can be found in **Chapter 4** (NEMS) and **Chapter 5** (MARKAL).

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Table 1. FCV Attributes Input to NEMS

Fuel Cell Hydrogen	SMALL CARS 2022	SMALL CARS 2025	LARGE CARS 2018	LARGE CARS 2023	LARGE CARS 2025	Small-VAN and SUV 2020	Small-VAN and SUV 2025
Incremental Vehicle Price	2010	1605	2264	1582	1477	2462	1640
Range	0.90	0.96	1.00	1.00	1.00	0.90	1.0
Maintenance Cost	1.05	1.02	1.05	1.00	0.97	1.10	1.00
Acceleration	1.00	1.06	1.00	1.00	1.04	1.00	1.10
Top Speed	0.90	0.93	0.85	0.90	0.92	0.90	0.95
Luggage Space	0.80	0.86	0.90	1.00	1.00	0.90	0.95
Fuel Economy (a)	2.54	2.56	2.54	2.80	2.89	2.49	2.57

Fuel Cell Hydrogen	Large-VAN and SUV 2012	Large-VAN and SUV 2018	Large-VAN and SUV 2023	Large-VAN and SUV 2025	CARGO TRUCK 2024	CARGO TRUCK 2025
Incremental Vehicle Price	4500	3140	2086	1975	2886	2656
Range	0.90	1.00	1.00	1.00	0.90	0.93
Maintenance Cost	1.10	1.05	1.00	0.97	1.05	1.04
Acceleration	1.00	1.10	1.10	1.10	1.00	1.00
Top Speed	0.90	0.90	0.95	0.95	0.90	0.90
Luggage Space	0.90	0.95	1.00	1.00	0.90	0.91
Fuel Economy (a)	2.00	2.49	2.57	2.73	2.49	2.51

(a) Gasoline gallon equivalent

Table 2. FCV Attributes Input to MARKAL

Vehicle Type	Technology	Ratio	2010	2015	2020	2025	2030	2040	2050
Car	Fuel Cell	Cost		1.15	1.07	1.06	1.05	1.045	1.4
		MPG (a)		2	2.54	2.8	3.03	3.03	3.03
LT	Fuel Cell	Cost		1.15	1.07	1.06	1.05	1.045	1.04
		MPG (a)		2	2.49	2.57	2.96	2.96	2.96

(a) Gasoline gallon equivalent

2.1 Stationary Fuel Cell Market

Stationary fuel cells are one of a variety of distributed electricity-generation technologies. The particular market sectors in which stationary fuel cells are most applicable include residential and commercial applications.

2.2 Key Factors in Shaping the Market Adoption of Stationary Fuel Cells

Key factors associated with the market penetration of stationary fuel cells include the energy efficiency (electrical and combined heat and power), installed cost, and maintenance cost of the fuel cells relative to other distributed and traditional electricity-generation technologies.

2.3 Methodology and Calculations

2.3.1 Baseline Assumptions for Stationary Fuel Cells

The technology assumptions for distributed generation, including stationary fuel cells, were updated in AEO2004. A review of these assumptions revealed a few definitional differences in how the HFCIT Program goals are stated and how the technology characterizations are used within NEMS. There also appeared to be a difference in the view of current (or nearly current) technology that might reflect different trade-offs of efficiency and costs or may reflect differences in development. In either case, the same 2005 values should be used for the GPRA Baseline and Program cases so the Baseline was modified to reflect the Program view of 2005. As described below, the Program values were first adjusted to the same definitions as used in NEMS. By 2010, the Baseline returns to the AEO2004 values, with higher efficiencies and also higher costs than the values for 2005. Because of their relatively high costs, fuel cells are not cost-effective in the early years regardless of which source of data is used.

Residential 5kW PEMFC Baseline

AEO2004 Reference Case

Year	CHP System Efficiency	Electrical Efficiency	Installed Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.690	0.300	5500	264
2005	0.690	0.300	5500	264
2010	0.700	0.320	3800	184
2015	0.710	0.335	3000	168
2020	0.720	0.350	2200	152
2025	0.725	0.355	1750	140

GPRA06 Baseline

Year	CHP System Efficiency	Electrical Efficiency	Installed Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.630	0.270	3800	264
2005	0.675	0.288	2300	264
2010	0.700	0.320	3800	184
2015	0.710	0.335	3000	168
2020	0.720	0.350	2200	152
2025 to 2050	0.725	0.355	1750	140

Commercial 200kW Fuel Cell Baseline

AEO2004 Reference Case

Year	CHP System Efficiency	Electrical Efficiency	Installed Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.750	0.360	5200	232
2005	0.750	0.360	5200	232
2010	0.720	0.490	2500	128
2015	0.720	0.500	2150	124
2020	0.720	0.510	1800	120
2025	0.735	0.520	1450	112

GPRA06 Baseline

2003	0.630	0.270	3180	232
2005	0.675	0.288	1930	232
2010	0.720	0.490	2500	128
2015	0.720	0.500	2150	124
2020	0.720	0.510	1800	120
2025 to 2050	0.735	0.520	1450	112

2.3.2 Program Case Assumptions for Stationary Fuel Cells

Assumptions for distributed PEM fuel cells are based on the multiyear program plan (Ref.1). Capital costs and efficiencies were provided in the MYPP for the years 2003, 2005, and 2010. The costs are assumed to be in year 2003 dollars. No values were listed for maintenance costs, so the AEO2004 values are used. The costs and efficiencies assumed for NEMS by 2025 were held constant through 2050 in MARKAL.

The program goal capital costs were increased to account for the installation cost that is assumed in the Baseline fuel cells costs from the NREL report. In addition, the efficiencies in the multiyear plan are expressed in lower heating values and were converted to higher heating value efficiencies for use in NEMS.

Residential 5kW PEMFC Program Case

HFCIT Goals from Multiyear Plan

Year	CHP System Efficiency*	Electrical Efficiency*	Equip. Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.70	0.30	3000	n/a
2005	0.75	0.32	1500	n/a
2010	0.80	0.35	1000	n/a

* based on LHV on input fuel

Model Inputs for HFCIT Goals

Year	CHP System Efficiency	Electrical Efficiency	Installed Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.630	0.270	3800	264
2005	0.675	0.288	2300	264
2010	0.720	0.315	1800	184
2015	0.720	0.315	1800	168
2020	0.720	0.315	1800	168
2025 to 2050	0.720	0.315	1800	168

Commercial 200kW Fuel Cell Program Case

HFCIT Goals from Multiyear Plan

Year	CHP System Efficiency*	Electrical Efficiency*	Equip. Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.70	0.30	2500	n/a
2005	0.75	0.32	1250	n/a
2010	0.80	0.40	750	n/a

* based on LHV on input fuel

Model Inputs for HFCIT Goals

Year	CHP System Efficiency	Electrical Efficiency	Installed Cost (2003 $/kW)	Maint. Cost (2003$/kW-yr)
2003	0.630	0.270	3180	232
2005	0.675	0.288	1930	232
2010	0.720	0.360	1430	128
2015	0.720	0.360	1430	128
2020	0.720	0.360	1430	128
2025 to 2050	0.720	0.360	1430	128

There are no changes for large central-station fuel cells.

2.4 Sources

1. “Hydrogen, Fuel Cells & Infrastructure Technologies Program: Multi-Year Research, Development and Demonstration Plan” (Draft), U.S. Department of Energy, Energy Efficiency and Renewable Energy (June 3, 2003).

Appendix H – GPRA06 Industrial Technologies Program Documentation

1 Introduction

The information provided in this appendix is based on the Industrial Technologies Program (ITP) report of the GPRA06 process, "GPRA06 Quality Metrics – Methodology and Results," Energetics Inc., October 25, 2004. The report includes additional methodological details and the actual off-line energy savings results submitted to the Office of Energy Efficiency and Renewable Energy (EERE).

The GPRA06 calculation of future program impacts was performed separately for each planning unit and summed to produce the total ITP program impact. Within planning units, impacts were calculated differently for R&D planning units than for Technology Delivery planning units. Impacts for R&D planning units were calculated at the project level using a uniform methodology embodied in a spreadsheet-based computer tool called the Technology Impact Projections Model. Impacts for Industrial Assessment Center (IAC) and Best Practices planning units were calculated for subprogram element activities using historical data, estimates, and assumptions documented in tabular format; and summed to produce the planning unit impacts. ITP's subprogram structure includes:

R&D Planning Units

1. Aluminum Industry Vision
2. Chemicals Industry Vision
3. Forest Products Industry Vision
4. Glass Industry Vision
5. Metal-Casting Industry Vision
6. Steel Industry Vision
7. Mining Industry Vision
8. Supporting Industry Vision
9. Industrial Materials Crosscut
10. Sensors and Automation Crosscut
11. Combustion Crosscut

Technology Delivery Planning Units

1. Industrial Assessment Center (IAC) Program
2. Best Practices Program

1.1 Target Markets (The Baseline Case)

- **Target Market Description**

Advanced industrial energy efficiency technologies under development with program support will enter a variety of specialized markets for production equipment, plant energy conversion, distribution, heat recovery, and waste-reduction equipment. Underlying fuel prices, the electricity generation and distribution fuel mix and heat rates, and sector economic growth rates —which were used in the NEMS-GPRA06 runs that produced the ultimate results from ITP's energy-savings inputs—were consistent with the reference case in the Department of Energy's (DOE/EIA) *Annual Energy Outlook 2004*. ITP's off-line calculation of fuel and electricity savings for individual projects and program-element activities did not refer explicitly to macro-baseline quantities, except that a unique market growth rate was specified in each of the 163 Technology Impact Projections Model runs. This permitted the analysts to differentiate among highly varied market outlooks in the various industries. Except for several chemicals industry market targets with short-term growth rates of more than 3.0%, the range of these annual market growth rates was from -1.0% to 2.5%, with an average close to 1.5%.

Due to differences in the analytical framework of the NEMS-GPRA06 model and ITP's bottom-up energy-savings projection methodology, it was not possible to definitively match those models' base-case assumptions with the implicit base case in the GPRA study. NEMS-GPRA06 addresses the entire industry group in a top-down manner, assigning energy intensities to a comprehensive set of activities to project total industry energy use under alternative assumptions. The bottom-up ITP GPRA study specified the unit energy savings of a particular set of 163 advanced technologies, each in comparison to a best-available commercial technology alternative. ITP GPRA savings are only those savings attributable to these technologies in their primary intended markets.

The target market for each of 163 R&D technologies included in the ITP study was described qualitatively and quantitatively in a spreadsheet-based Technology Impact Projections Model run. The technologies were grouped based on common production activity Impact Targets. This was done to facilitate the identification of potentially overlapping markets; where potentially overlapping markets were found, either the market was split between the two competing technologies or only one spreadsheet model run was used to represent both technologies. Markets were defined in terms of the total number of technology units potentially in use at the year of introduction. This number was reduced to the fraction of those units considered technically and economically accessible, and further reduced to the likely achievable technology market share accessible to the technology as compared to other advanced technologies. And, finally, it was reduced to the savings potential attributable to the program. The market size was adjusted annually by the spreadsheet logic, based on the specified annual percentage growth rate.

- **Baseline Technology Improvements**

Continued baseline improvement in energy productivity was accounted for in the ITP methodology. ITP's method essentially subtracted a fixed "next best" baseline technology from a fixed advanced technology to obtain unit technology savings. However, the energy savings of a new technology were determined by the number of years the technology's market introduction is accelerated by the Federal program involvement. In particular, the energy savings associated with the program were explicitly projected to occur without the EERE R&D after a period of years known as the "acceleration period." Only the slice of energy savings attributable to the program's effort to accelerate technology development was counted as GPRA savings. In this way, the methodology incorporated an assumption that the energy intensity of industrial production will steadily improve, and that specific Federal interventions in cofunding R&D only temporarily accelerate the rate of improvement in the targeted production activities. Acceleration periods varying from two years to 42 years were found in the GPRA06 runs, with an average close to 10 years.

Likewise, in the ITP off-line study, the conventional technology with which each new technology was compared, was generally the best currently available technology—not a projected technology that might exist at the time of market introduction or future sales of the new technology, nor the average technology in use. While the industry-level rate of improvement in production energy intensity tends to follow fairly smooth curves of monotonic improvement, it is very difficult to predict the future energy performance of as-yet unidentified technologies to perform specific functions. In addition, the best currently available technology is often not yet widely adopted in the market, so that when the ITP technology enters the market, the current best-available technology may still represent the next-best decision alternative for many cases. Again, taking credit for only that slice of savings due to the presumed acceleration of the new technology's market introduction date was intended to minimize any overestimation of savings due to the underlying rate of technology improvement.

The commercial introduction of a technology normally occurs after a significant demonstration or using an operating prototype, and after an adequate test and evaluation period along with allowances for the beginnings of production, dissemination of information, initial marketing and sales, or other "start-up" factors. To capture this lengthy process, users of the Technology Impact Projections Model were asked to indicate the timeline for developing and introducing the technology into the market. This includes the years for when an initial prototype, refined prototype, and commercial prototype of the technology has or will be completed; and the year when the technology will be commercially introduced. An initial prototype is the first prototype of the technology. A refined prototype represents changes to the initial prototype but not a commercially scaled-up version. A commercial prototype is a commercial-scale version of the technology. Commercial introduction is when the first unit beyond the commercial prototype is operating. Prototype and commercial introduction years were to be consistent with the technology development program plans, and two values for a commercial introduction year were requested. One reflects when the technology is projected to be introduced, if the program proceeds as expected ("With ITP" case). The other reflects when the technology would have entered the market, if the program had not been involved ("Without ITP" case). The difference in commercial introduction years for the "With ITP" and "Without ITP" cases is referred to as the "acceleration period."

- **Baseline Market Acceptance**

The rate of market penetration of novel technologies in industrial production markets was captured explicitly in the methodology.

Based on historical data, new technologies normally penetrate a market following a familiar S-curve—the lower end representing the uncertainties overcome by "early adopters." The curve tails off at the far future, where some may never adopt the new technology. The steepest portion of the S-curve is where the new technology is most rapidly penetrating the market and producing new savings. The rate at which technologies penetrate their markets varies significantly. Penetrations of heavy industrial technologies generally occur over decades, while simple process or control changes can penetrate much more rapidly. The actual penetration rate varies due to economic, environmental, competitive, productivity, regulatory, and other factors.

In a 1998 study by Arthur D. Little Inc. ("Streamlining of OIT's GPRA Process (Draft)," Arthur D. Little Inc. Reference 33550-01, May 27, 1998), data was presented on a number of actual penetration rates of past and present technologies. These penetration rates were analyzed, normalized, and grouped into five classes based on a number of characteristics and criteria. Users of the ITP Technology Impact Projections Model were asked to complete **Table 1** for each project by adding the project title in the top row and either a, b, c, d, or e in the right-hand column for those characteristics for which they could make a judgment. Based on the strength of these characteristic scores, the overall technology market-penetration curve selection was entered in the first row at the right under "Score." The table was copied onto the spreadsheet model run at the "Background" tab. Note that the characteristics (rows) are relatively independent, and a given technology will likely fit best in different classes for different characteristics. By examining the pattern, however, it is possible (based on best judgment and experience) to select the most likely class (rate) at which the new technology may penetrate the market. This may be a "subjective average" of the characteristics, or it is possible that one or two characteristics are expected to dominate future adoption decisions that a particular class of penetration rate is justified. There also may be "windows of opportunity," where significant replacements of existing equipment may be expected to occur in the future for other reasons. The user was asked to insert into the spreadsheet the class of penetration rate believed most likely—all things considered—and provide a narrative of the rationale for selection if not obvious from **Table 1.**

For additional context, **Table 2** shows actual technologies and the class of their historical penetration rates. Comparison of the new technology, by analogy or similarity, with these examples provided additional insight into selecting the appropriate penetration rate that might be expected for the new technology. The actual technologies' historical market penetrations are shown graphically in **Figure 1,** falling within the market-penetration rate classes used by the model.

Table 1. Selecting the Market-Penetration Rate Class

Technology/project						**Score (a,b,c,d,e)**
Characteristic	**a**	**b**	**c**	**d**	**e**	
Time to saturation	5 yrs	10 yrs	20 yrs	40 yrs	>40 yrs	
Technology factors						
Payback discretionary	<<1 yrs	<1 yr	1-3 yrs	3-5 yrs	>5 yrs	
Payback non-discretionary	<<1 yr	<1 yr	1-2 yrs	2-3 yrs	>3 yrs	
Equipment life	<5 yrs	5-15 yrs	15-25 yrs	25-40 yrs	>40 yrs	
Equipment replacement	none	minor	unit operation	plant section	entire plant	
Impact on product quality	$$	$$	$$	$	0/-	
Impact on plant productivity	$$	$$	$$	$	0/-	
Technology experience	new to U.S. only	new to U.S. only	new to industry	new	new	
Industry factors						
Growth (% per annum)	>5%	>5%	2-5%	1-2%	<1%	
Attitude to risk	open	open	cautious	conserv-ative	averse	
External factors	forcing	forcing	driving	none	none	
Gov't regulation						
Other						

Table 2. Examples of Technologies

Class	A	B	C	D	E
Aluminum		Treatment of used cathode liners	Strip casting, VOC incinerators		
Chemicals	New series of dehydrogenation catalyst (incremental change)	CFCs -> HCFCs, incrementally improved catalysts, membrane-baed chlor-alkali	Polypropylene catalysts, solvent to water-based paints, PPE-based AN	Synthetic rubber and fibers	
Forest Products			Impulse drying, de-inking of waste newspaper	Kraft pulping, continuous paper machines	
Glass		Lubbers glass blowing, Pilkington float glass	Particulate control, regenerative melters, oxygenase in glass furnaces		
Metals Casting	New shop floor practice				
Petroleum	New series HDS catalysts	Alkylation gasoline	Thermal cracking, catalytic cracking	Residue gasification, flexicoking	
Steel	Improved EAF operating practice (e.g. modify electric/ burner heating cycle to minimize dust generation)	BOF steel making	Oxyfuel burners for steel, Level II reheat furnace controls, continuous casting, particulate control on EAF, high-top pressure blast furnace	Open-hearth technology, EAF technology	
Other		Advanced refrigerator compressors, oxygen flash copper smelting, solvent extraction with liquid ion exchange	Fluegas desulfurization (coal-fired utilities), low Nox industrial burners, industrial gas turbines, ore beneficiation		Dry-kiln cement, industrial ceramic recuperators Industrial heat pumps

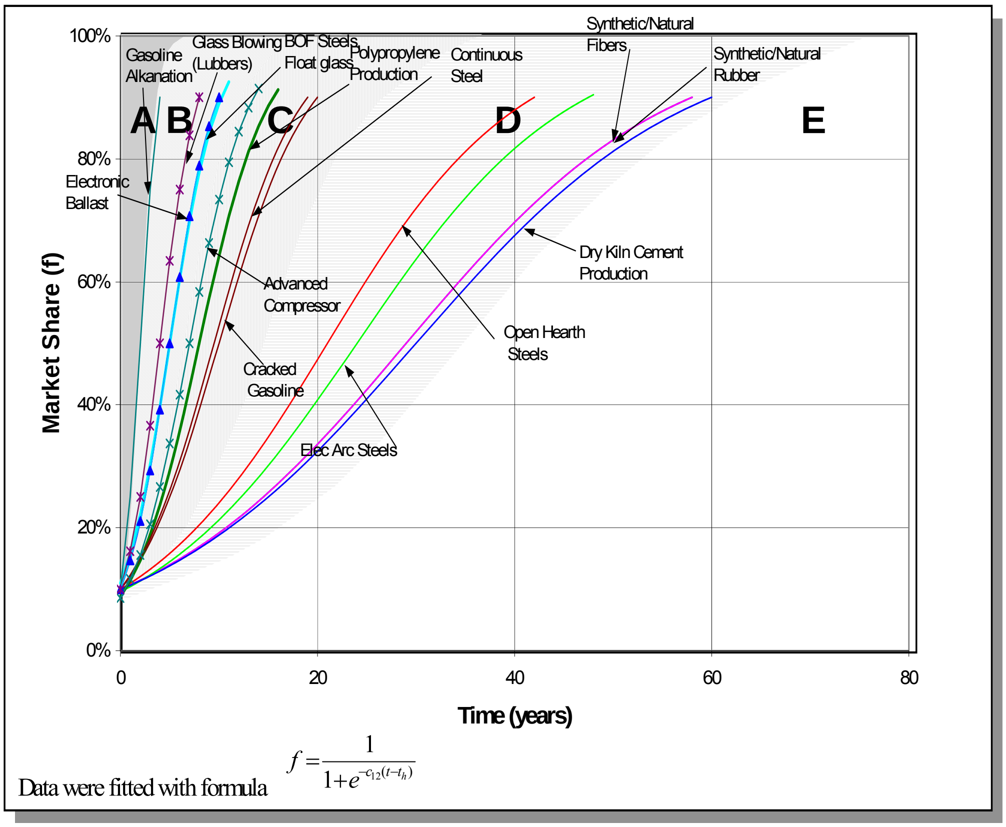

Figure 1. Market Penetration Rate Classes

1.2 Key Factors in Shaping Market Adoption of EERE Technologies

- **Price**

ITP methodology places little emphasis on cost-based estimation of market penetration, because useful cost information on industrial technologies in the R&D stage of development is, in nearly all cases, impossible to obtain. Instead, relative costs in the form of the expected payback period were one of numerous market-driving factors considered in selecting the market-penetration schedule best matching each innovative technology (see previous section). These market-penetration schedules are typical of historical industrial-sector technology innovations, whose characteristic payback period, scale, equipment lifetime, impact on product quality, relevant experience level, market growth rate, attitude to risk, and other factors were matched to each innovative technology to select the best market-penetration schedule.

- **Non-price Factors**

- Key Consumer Preferences/Values.

Several consumer preference/value issues were incorporated in the ITP market-penetration curve selection technique. These include factors such as technology scale, equipment lifetime, impact on product quality, etc. listed above.

- Manufacturing Factors.

The benefits-estimation approach requested the analyst to estimate the year in which the technology is expected to be successfully developed at the successive stages of (1) completion of initial R&D, (2) initial system prototype, (3) refined prototype, (4) commercial prototype, and finally (5) commercial introduction, given the push provided by the ITP program support. These estimates were documented as part of each spreadsheet model run.

- Policy Factors.

In the great majority of cases, no policy factors were considered significant to the market introduction and acceptance of ITP technologies. However, for cases where a regulation or other policy will drive the market to accept a new technology solution, the market-penetration curve selection procedure was set up to accept this information and allow it to play a role in the analysis. Any such influence was discussed in documentation provided in the spreadsheet model run.

1.3 Methodology and Calculations

- **Changes in Inputs to Base Case**

ITP did not provide inputs that changed the base case assumptions for the industrial markets.

- **Technical Characteristics of the Program Case**

ITP did not provide specific changes to the NEMS-GPRA06 industrial-sector characteristics.

ITP's estimates of the energy savings of its advanced technologies were based on information provided to the analysts through the proposal review and contracting process, which includes industry participation and review, followed by program review of these estimates. ITP analysis by sector has focused on assessing where energy is actually consumed and understanding current and best practices for each proposed technology. The participation of industry experts in this process has been critical to helping refine the estimates.

- **Expected Market Uptake**

- **R&D Planning Units**

GPRA06 energy savings in the ITP off-line study were projected for individual projects within planning units and summed to total results for planning units and for ITP as a whole. Active projects were selected by the ITP program managers for GPRA06; thus, the FY 2005 program portfolio was used as a surrogate for the (as-yet unknown) FY 2006 portfolio. The number of study projects in each planning unit was controlled to represent an aggregate nominal funding level not greater than 100% of the FY 2005 budget request.

This prospective assessment was carried out with the aid of an experience-based market-penetration model designed to estimate the national energy, economic, and environmental impacts of innovative industrial technologies. ITP's off-line calculations for GPRA06 did not utilize the model's capabilities to project environmental and cost impacts, so the results will focus only on energy savings. EERE guidance for GPRA06 was to project the energy impacts of the FY 2006 program, which subsequently were used by others to specify scenario projections by the NEMS-GPRA06. The resulting NEMS-GPRA06 runs (reported elsewhere) produce environmental and cost results using integrated demand and supply assumptions consistent across the demand sectors.

The Technology Impact Projections Model was used to estimate the potential energy savings resulting from research, development, and demonstration projects funded by the Industrial Technologies Program (ITP). Benefit estimates are critical for evaluating projects and presenting the merits of both individual projects and the overall RD&D portfolio.

Proposers responding to a Solicitation or Request for Proposals were asked to use the Technology Impact Projections Model to estimate program impacts. Where not provided in proposals, principal investigators were asked to provide inputs for their active projects. Use of the model across all projects allows ITP to estimate the impacts of its projects in a consistent manner.

Users were asked to provide their best estimate for each piece of information required for the spreadsheet model. A description of the advanced technology was required to provide an overview of the project/technology. This includes the project name, project number (once project is funded), estimates preparer, program manager, planning unit, lab and industry contacts, and data sources. A narrative summary of the technology on which benefit estimates are based was required. This described what constitutes a typical process unit for the technology, in terms of annual output (production capacity times duty factor). For simplicity, the analysis assumed that all units in the industry have the same capacity. An average, or typical, unit capacity was chosen, particularly for situations where the unit size may vary in different installations. By convention and to enable comparisons, units for the new technology and the current state-of-the-art were equal in output capacity; even if, in reality, the new technology might have a different unit capacity for various reasons.

The new technology also might not be a physical item of hardware. Rather, it could be a process change, a computer model or control system, operational change, or other nonphysical technique. In such cases, a unit was defined as the typical or average process or plant that would utilize the new technique. The annual energy inputs, based on the expected energy consumption of the process or plant with the new technique, were then compared with annual energy consumption required by existing techniques.

Key information was provided on the performance of single installed units or applications of the advanced technology. For comparison, information was required on the performance of the best-available technology for the application, not the average of all in-place technology units.

Users were required to provide energy use per year for the new and conventional units, by fuel:

Electricity - Includes direct electricity.

Natural Gas - Includes pipeline fuel natural gas and compressed natural gas.

Petroleum - Includes residual fuel, distillate fuel, and liquid petroleum gas.

Coal - Includes metallurgical coal, steam coal, and net coal coke imports.

Feedstock - Includes fossil fuels consumed in nonenergy uses such as process feedstocks.

Biomass - Includes the use of biomass (for energy or as feedstock).

Wastes - Includes the use of fuels that are generated as wastes or process byproducts. Examples of such fuels are refinery fuel gas, blast furnace gas, hog and bark fuel, and sewage sludge.

Other - Includes any fuels that may not be included in those listed above.

Total Primary Energy - Is calculated from individual energy inputs. The primary equivalent of direct electricity consumption includes losses in electricity generation and distribution. For GPRA06, fuel and electricity savings were used as inputs to specify NEMS-GPRA06 runs that themselves applied heat rates, etc. varying over time to produce primary energy savings.

Energy use was entered in physical units (e.g., billion cubic feet of natural gas) or primary units (trillion Btu). The exception was electricity use, which has to be entered as site energy consumption (either in billion kWh or trillion Btu).

To determine the potential impact of the new technology as it becomes adopted, it was necessary to estimate the total market for the technology, reduce that to the likely actual market, and estimate when—and the rate at which—the new technology will penetrate the market.

Users were required to estimate the number of installed units in the U.S. market in a specified year. That market was defined as narrowly as possible: The smallest group of applications that covers all potential applications for which the user may have some data. Users could apply their own data on energy use of the state-of-the-art technology. Other potential data sources include ITP's Energy and Environmental Profile for the relevant industry, EIA's MECS data, or industry sources.

The annual market growth rate was specified by the model user, based on an EIA or industry growth projection for the relevant industry and process. A source for the growth rate was called for in the comments section.

Market share was specified as a function of the potential accessible market share and the likely market share. The Potential Accessible Market Share was defined as the market that the new technology could reasonably access given technical, cost, and other limitations of the technology. For example, certain technologies may be applicable only to a certain scale of plant, certain temperature-range processes, certain types of existing equipment or subsystems, or only certain segments of the industry. A further delimiting fraction was called the Likely Market Share. In some instances, in addition to technical and cost factors, the technology may compete with other new technology approaches (or with other companies) for the market. The user was asked to use current market-share information or base their estimated market share on the number of competitors in the market, assuming they are using different technologies not resulting from this project. This is different than the possibility of "copycats," which should not be considered as competing. That is, if others adopt essentially the same (or slightly modified) technology due to this new technology, that adoption was triggered by the project being described and that project should be "credited" with causing that trend. This is potentially the case for techniques where the intellectual property cannot be, or is not, protected and becomes general knowledge throughout the industry.

In some instances, a program may be developing a technology in conjunction with another ITP, EERE, or DOE program. The analysts were asked in these cases to provide an estimate of the percentage of savings that is attributed to the program. The attribution percentage should be similar to the percentage of Federal funds provided to the project by the program. A default value of 100% was entered in the model.

To understand how rapidly the potential impact of the technology may be felt, the market penetration of the technology must be projected. This is based on two estimates: the technology development and commercialization timeline, and the market-penetration curve.

The technology development and commercialization timeline was first determined. The commercial introduction of a technology normally occurs after a significant demonstration or operating prototype and after an adequate test-and-evaluation period, along with allowances for the beginnings of production, dissemination of information, initial marketing and sales, or other "start-up" factors. To capture this lengthy process, the analyst indicated the timeline for developing and introducing the technology into the market. This includes the years for when an initial prototype, refined prototype, and commercial prototype of the technology has or will be completed, as well as the year when the technology will be commercially introduced. An initial prototype is the first prototype of the technology. A refined prototype represents changes to the initial prototype but not a commercially scaled-up version. A commercial prototype is a commercial-scale version of the technology. Commercial introduction is when the first unit beyond the commercial prototype is operating. Prototype and commercial-introduction years were to be consistent with the technology-development program plans. Two values for a commercial introduction year were requested. One reflected when the technology is projected to be introduced, if the program proceeds as expected ("With ITP" case). The other reflected when the technology would have entered the market if the program had not been involved ("Without ITP" case). If the technology would not have been commercially introduced without the program, then a year of 2050 for the "Without ITP" case was entered. The difference in commercial introduction years for the "With ITP" and "Without ITP" cases is referred to as the acceleration period. Only the slice of energy savings attributable to the program's effort to accelerate technology development was counted as GPRA savings.

New technologies normally penetrate a market following a familiar S-curve, the lower end representing the above uncertainties overcome by "early adopters." The curve tails off where some may never adopt the new technology. The major portion of the S-curve, where the new technology is penetrating the market and benefits are being reaped, is most important. The rate at which technologies penetrate their markets varies significantly. Penetrations of heavy industrial technologies generally take place over decades, while simple process or control changes can penetrate much more rapidly. The actual penetration rate varies due to economic, environmental, competitive, productivity, regulatory, and other factors.

Technology impact projections-model runs for individual R&D projects receiving R&D support were aggregated to obtain energy savings associated with each R&D planning unit. In aggregating the savings, market targets were examined explicitly to avoid double-counting the same potential savings in the infrequent instances when the same energy efficiency market is clearly addressed by multiple projects. Where possible market overlaps were found, the markets were either assigned to only one technology or divided among the competing technologies under development. This process increases confidence that any systemic double-counting within planning units has been minimized. Nevertheless, some double-counting across planning units within ITP or with other EERE programs is assumed to remain.

The approximate portion of the FY 2005 budget represented by the analysis for each planning unit was noted, but the results were not scaled to 100% of the FY 2005 budget. Typically, the projects analyzed represented 80% to 99% of the FY 2005 budget for the various planning units. Projected benefits for these planning units do not include the effects of R&D projects completed prior to the current year.

The justification for assuming that all of the projects analyzed will succeed is twofold. First, projects that fail will likely be replaced with new projects using different technical approaches to achieve similar goals. Using this theory, the basic goals will be met by the program in the long run and continuously funded. Second, the projects analyzed do not comprise 100% of the FY 2005 budget, which in itself discounts the aggregated results, equivalent to incorporating some risk of failure into the overall process. In addition, the knowledge benefits of ITP's R&D portfolio are not assessed here; this scientific and technical knowledge can help to underpin additional production technology innovations in the future, and spin-off applications in both the near and longer terms.

- Technology Delivery Planning Units

The Industrial Analysis Center program and the Best Practices program were assessed, based on retrospective analysis of performance data accumulated over a period of years. ITP's off-line Quality Metrics study for these planning units is based on the premise that continuation of the programs will result in beneficial impacts proportional to documented experience at historical budget levels. These analyses did not count as savings any continuing contributions from prior program expenditures, but only assumed that future expenditures will produce results proportionate to those reported for past expenditures.

The approaches for calculating the impacts of the IAC and best-practices planning units were similar. In each case, those program activities associated historically with documented energy savings were projected into the future based on assumed continuation at the FY 2006 budget level. The numbers of assessments, Web site visitors, trained individuals, etc. performed in each future year were used to logically arrive at the future energy savings attributable to the activity, given continued performance at historical levels of effectiveness. Each quantity and assumption was explicitly shown in a tabular format intended to show the contribution of each step of the calculation to the final result and to make the entire analytical process repeatable.

The IAC program benefits were supported by 25 years of actual assessment and implementation data. Among other assumptions, the effects of assessments were projected to last for seven years. The effects of student training were projected to persist for 11 years. The effects of the Web site information activity were projected to last for seven years.

Best Practices program benefits were based on findings of an Oak Ridge National Laboratory study of program effects, and on a FY 2004 peer review that focused on ORNL's outcome evaluation study. The basic methodology used in each of four best-practices activity areas was very similar. First, the activity reach was estimated by calculating the number of individuals touched by best-practices information. This number was then scaled back to calculate the number of plants taking action, due to this information dissemination. The scale-back factors included accounting for duplicate "touches" within the same company, the percentage of companies actually taking action, and a reduction factor to discount program credit due to it being but one of multiple sources of influence. To obtain the total program energy savings, reported rates of energy savings were applied to the number of plants estimated to be affected by best-practices activities in each future year.

Best Practices activity areas evaluated for GPRA06 were: Plant-wide Assessments, Training, Software Tools Distribution, and Qualified Specialists. Total annual energy savings attributed to Best Practices were the sum of the subtotals estimated for these four delivery channels.

1.4 Sources

"GPRA06 Quality Metrics – Methodology and Results," Energetics Inc., October 25, 2004.

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"Streamlining of OIT's GPRA Process (Draft),"Arthur D. Little Inc. Reference 33550-01, May 27, 1998.

Appendix I – GPRA06 Solar Energy Technologies Program Documentation

1. Introduction

This appendix provides detailed information on the assumptions and methods employed to estimate the benefits of EERE's Solar Energy Technologies Program. The benefits analysis for the Solar Program utilized both NEMS and MARKAL as the analytical tools for estimating the Program's benefits. As will be discussed below, a number of assumptions and structural modifications to the models were made in order to represent the suite of solar technologies funded by the program as accurately as possible (Photovoltaics, Concentrating Solar Power and Solar Water Heating). Many of the assumptions used in the FY06 analysis are the same as or similar to those employed in the FY05 analysis; however, two key changes are important to highlight up-front. First, the AEO2004 analysis used a new set of reference case assumptions with respect to photovoltaic technology cost reductions. The new sets of reference case assumptions are very similar to the Solar Program's targets for PV. This shift in assumptions necessitated developing a new approach for estimating the baseline (i.e., no program) input assumptions for PV. Second, the FY06 analysis included CSP technology benefits – CSP benefits were not included in the FY05 analysis.

The body of this appendix contains two sections. The first discusses the assumptions used to construct the GPRA06 Solar Program baseline scenario. The second discusses the modifications that were made to this baseline to construct the GPRA06 solar program scenario.

2. GPRA06 Solar Program Baseline Assumptions

Several changes from the AEO2004 Reference Case were incorporated into the GPRA06 Baseline. These changes include the following:

Revising projected PV cost. The AEO2004 reference case assumptions for PV technology costs were based on a recent report published by Navigant Consulting (2003). As shown in **Figure 1**, the cost projections in the new EIA reference case are very close to the Solar Program's targets. Because of this shift in EIA's reference case assumptions, a new set of baseline assumptions for PV technology needed to be developed. In constructing the GPRA06 baseline, the following approach was used. Between 2005 and 2015, the costs of PV are assumed to decline more slowly in the GPRA06 baseline, leading to a five-year lag between the GPRA06 baseline and the program's goals by 2015. Beyond 2015, the GPRA baseline and program numbers are assumed to continue to diverge. This approach incorporates a relatively conservative estimate of the Solar Program's impact on the cost of PV technology and captures the notion of technological lock-in (Cowan and Kline 1996).

Increasing the average commercial building system size from 10kW to 100kW. A sample of data from 14 PV systems installed by PowerLight Corporation, between July 1999 and March 2003, reveals that the average commercial system installed by PowerLight during this period was 381kW (**Table 1**).

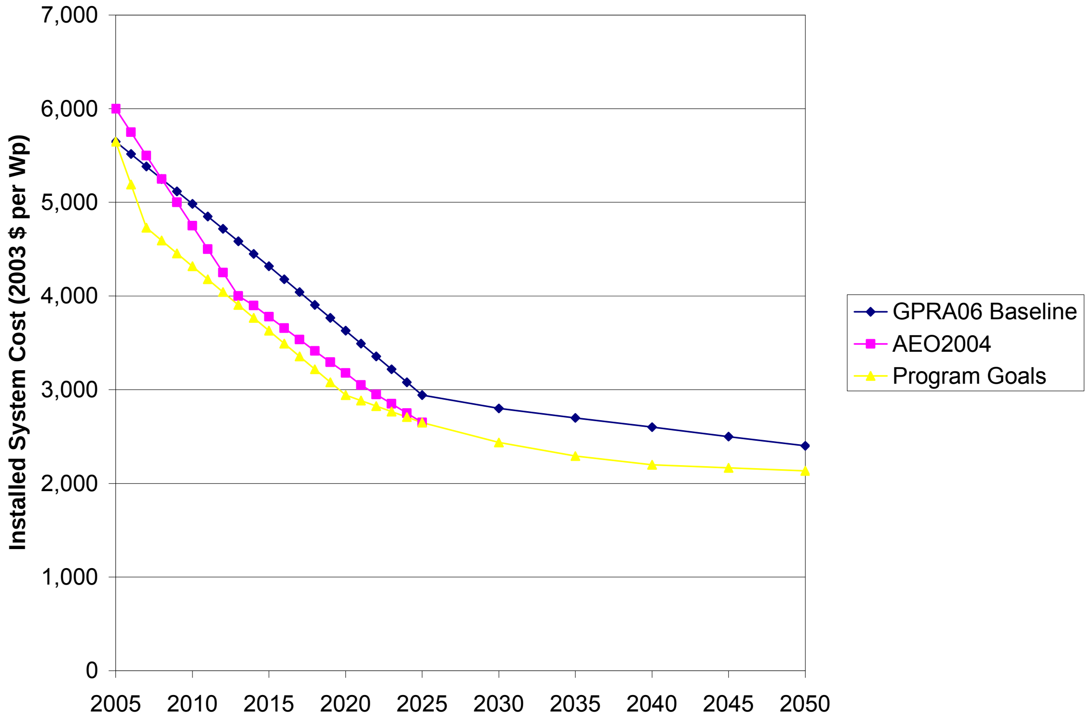

Figure 1. Projected PV Commercial System Costs

Table 1. Commercial System Size and Surface-Area Requirements

PowerLight System Installation Location	Date Completed	System Peak Capacity (kW)	PV Surface Area (sq. ft.)	W/sq.ft.
Santa Rita Jail - Alameda County, California	Apr-02	1,180	130,680	9.0
Cypress Semiconductor - San Jose, California	Jul-02	335	26,100	12.8
Fala Direct Marketing - Farmingdale, New York	Nov-02	1,010	102,700	9.8
Fetzer Vineyards, Hopland, California	Jul-99	41	3,750	10.9
Franchise Tax Board, Sacramento, California	Aug-02	470	50,000	9.4
Greenpoint Manufacturing - Brooklyn, New York	Mar-03	115	11,500	10.0
Mauna Lani Resort – Kohala Coast, Hawaii	Jan-02	528	43,330	12.2
Naval Base Coronado, California	Sep-02	924	81,470	11.3
Neutrogena Corporation - Los Angeles, California	Aug-01	229	30,154	7.6
Parker Ranch – Kameula, Hawaii	Jan-01	209	20,000	10.5
PSGA/Ortho-McNeil Facility - Pennsylvania	Apr-02	75	17,500	4.3
U.S. Coast Guard – Boston, Massachusetts	Sep-99	37	3,800	9.7
U.S. Postal Service - Marina del Rey, California	Nov-01	127	15,000	8.5
Yosemite National Park - Yosemite, California	Oct-01	47	4,500	10.4
Total		**5,327**	**540,484**	
Average		**381**	**38,606**	**10**

Source: PowerLight Case Study data sheets, Downloaded from www.powerlight.com, 5/21/03.
Note: Some of the locations shown in this table have multiple installations. In these cases, the total installed capacity is shown above and the most recent installation date is shown in the date-completed column.

The average space required for these systems was 0.1 sq. ft/W., based on a U.S. average commercial building size in 2000 of 14,500 square feet (AEO2003), and assuming a ratio of usable roof space to floor space of 0.7. This ratio of usable roof space to floor space was based on the "architecturally suitable area" in an International Energy Agency (IEA) report, Table 2, examining the potential for integrated photovoltaics in buildings (IEA 2001). Using this approximation, the average commercial building could easily accommodate a 100 kW PV system, i.e., a 0.7*14,500 sq. ft. = 10,100 sq. ft. PV array. Thus, setting the average system size at 100kW is a conservative assumption based on industry trends, as well as the available roof space on a large share (50+%) of the commercial building stock. This is a very conservative assumption based on the expectations that the efficiency of PV cells will increase; the space requirements for a PV system will decrease; and, as system costs decline, facades and other spaces (such as parking lots) also could be utilized for PV systems.

Increasing the maximum share of commercial buildings with solar access from 30% to 55%. Similar to the preceding ratio of usable roof space to floor space, the share of roof space suitable for PV installations was based on the recently published IEA report on integrated photovoltaics in buildings (IEA 2001). This report indicates that a reasonable estimate for the share of roof space suitable for PV installations is 55%. This estimate includes shading and other factors that would limit the use of roof space for PV systems (IEA 2001).

Increasing the average residential building system size from 2kW to 4kW. A couple of years ago, a typical residential rooftop PV system was a 2kW system—this is most likely the source for EIA's 2kW system size in the *AEO2004* reference case. However, residential rooftop systems being installed in Japan, Europe, and the United States have been growing larger. For example, the average Japanese rooftop system size in 2002 was 3.7 kW (Ikki 2003) and the average rooftop system size in California in 2004 was 3.6 kW[1]. The average home in the United States has 1,700 square feet of floor space (this is expected to increase in the future). Using data from EIA's residential energy-consumption survey (EIA 1999, Table HC1-2a) one can estimate a floor- to roof-space ratio of 0.7 (based on distribution of one-story, two-story, and three-story single-family homes). This is a conservative estimate—most homes have pitched roofs, which would increase the total available roof space (yet may make a significant portion of the roof oriented away from the sun). If a typical system requires 10 sq. ft./W (as above), then a 4kW system would require roughly 400 square feet of roof space, which is well below the average available space allowing for multiple floors and pitched roofs. Thus, roof space is not a constraint for installing residential rooftop PV systems in the 4kW range. Because the efficiency of PV cells is likely to improve, a trend toward larger systems on rooftops is likely to continue. Thus, based on available roof space and what is happening in the marketplace, setting the average system size at 4kW is a conservative assumption.

Increasing the maximum share of residential buildings with solar access from 30% to 60%. A maximum share of 60% for residential buildings with solar access was used. This estimate

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[1] This estimate was based on data from the California Energy Commission's Emerging Renewables Program, downloaded on 1/27/05 from www.energy.ca.gov/renewables/emerging_renewables.html. Data on small PV systems (i.e., with a system size under 10kW) were extracted from the full dataset, indicating that during 2004 a total of 15.9 MW of PV was installed in 4,372 small PV systems in California with an average system size of 3.6kW.

accounts for the fact that some homes will not be suitable for PV systems due to shading, building orientation, roof construction, or other factors. This value was calculated from a combination of single-family homes (70%) and multifamily homes (30%), using a 75%–25% split between single-family and multifamily homes (EIA 2003, Table A4). Thus, the average maximum share was set at 0.7*0.75 + 0.3*0.25 = 0.6.

Including a declining PV buy-down program in California. This assumed that the California renewable energy credit program that provided a PV credit of $4,000/kW in 2003 will continue to be available, but will decline by $400/kW per year. This credit was included for the entire Pacific region. Given that a number of other local credits were not included in the GPRA baseline, applying the California state-level credit to the whole Pacific region is likely to be a reasonable approximation.

Modifying the adoption rate of distributed generation technologies. The modification to the adoption rate was based on information provided by the DER program (**Figure 2**). This applies to PV as well as gas-fired CHP technologies.

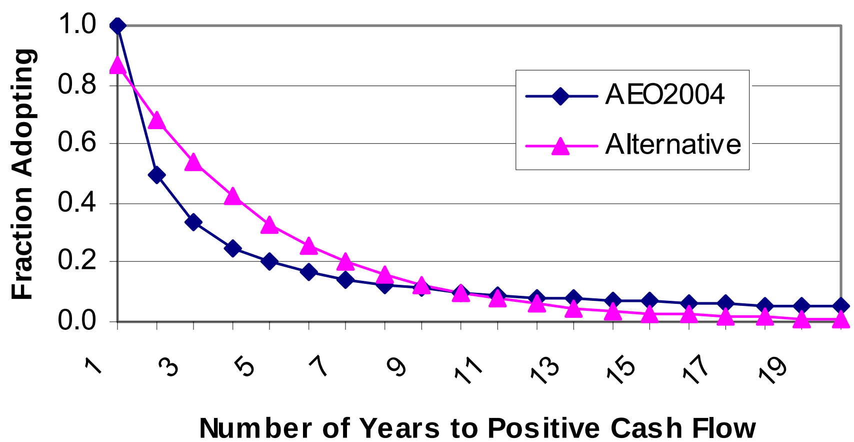

Figure 2. Commercial-Sector DG Adoption Rates

These changes lead to increased adoption of PV systems in the baseline. However, the *AEO2004* assumptions about PV installations through the Million Solar Roofs program were removed, so that there would not be double-counting when these were introduced in the GPRA Program Case.

One additional NEMS-GPRA06 model modification was made in the residential module. Solar water heaters were added as a technology option for new homes, and the algorithm governing water heater replacements was modified so that solar water heaters could compete in a larger market.

3. GPRA06 Solar Program Scenario Assumptions

Three key sets of assumptions were modified to generate the GPRA06 Solar Program scenario.

Green power additions. Green power additions by region, from Princeton Energy Resources International (PERI), were added back into the Solar Program scenario (**Table 2**). These projections take into account the Baseline assumptions of noneconomic capacity additions. This capacity is added in NEMS-GPRA06 as exogenous additions in residential and commercial buildings. Note that the CSP green power builds were very small (<70MW), so they were not include in the GPRA06 analysis.

Table 2. Incremental Green Power PV Capacity Additions (MW)

Incremental Green Power PV Capacity Additions (MW)					
	2006-2010	2011-2015	2016-2020	2021-2025	Total
ECAR	80	183	140	40	443
ERCT	73	167	127	36	404
MAAC	70	159	122	35	385
MAIN	21	47	36	10	113
MAPP	5	12	9	3	29
NY	15	35	27	8	84
NE	20	47	36	10	113
FL	94	214	164	47	518
STV	282	641	491	140	1,554
SPP	76	173	132	38	418
NWPP	13	31	23	7	74
RA	24	54	42	12	132
CNV	0	0	0	0	0
Total	773	1,761	1,348	385	4,267

Technology Characteristics. More aggressive technology targets were used for the range of solar technologies: concentrating solar power (CSP), central PV systems, distributed PV systems, and solar water heating systems. These technology characteristics were based on the Solar Program's most recent Multi-Year Technical Plan (EERE 2004), and the solar baseline scenario assumptions contained in Margolis and Wood (2004).

In order to define a consistent set of long-term targets going out to 2050, a multi-lab, multi-technology team was assembled in 2003. This team produced technology cost projections for use in NEMS that are consistent with the Solar Program's Multi-Year Technical Plan through 2025 and extended the Solar Program's targets to 2050 (for details, see Margolis and Woods 2004). Thus the targets shown in **Tables 3, 4 and 5** are consistent with the Multi-Year Technical Plan through the 2020-2025 timeframe. Beyond 2025, the targets are increasingly uncertain and are likely to be revised as the Solar Program continues to analyze the long-term prospects for PV technology cost reductions. Note that, on an annual basis, costs are assumed to decline linearly between the years shown in the tables below.

While the technology assumptions for commercial rooftop PV systems are shown above in **Figure 1**, detailed data for PV systems in the three markets modeled is provided in **Table 3**. Although the costs shown below are for specific years, the costs decline annually between the years shown. Note that in both the GPRA baseline and program scenarios, the AEO2004 Reference Case assumptions for solar insolation and capacity factors were used.

Table 3. PV Systems

	Central Generation		Residential Buildings		Commercial Buildings	
Year	Installed Price (2001$/kW)	O$M (2001$/kW)	Installed Price (2000$/kW)	O$M (2000$/kW)	Installed Price (2000$/kW)	O$M (2000$/kW)
2003	5,300	60	9,450	160	6,250	160
2007	3,600	40	6,250	40	4,500	40
2020	2,000	10	2,800	10	2,800	10
2025	1,800	9	2,520	9	2,520	9
2050	1,450	7	2,029	7	2,029	7

In NEMS, two solar water heaters are represented that have different efficiencies or electric backup requirements. In MARKAL, only one type of solar water heater is represented (shown in **Table 4** at the typical efficiency system).

Table 4. Residential Solar Water Heat

		Best (High efficiency)		Minimum (Typical efficiency)	
First Year	Last Year	Efficiency	Total Installed Cost($01)	Efficiency	Total Installed Cost($01)
1997	2004	2.5	3050	2.0	2800
2005	2009	2.6	2650	2.1	2500
2010	2019	2.7	1650	2.2	1500
2020	2025	3.0	1450	2.5	1300
2030	n.a	n.a	n.a	2.8	1162
2040	n.a.	n.a	n.a	3.0	1098

Notes: n.a. = not applicable. Change in data after 2030 reflects data structure in MARKAL.

The data for CSP technology shown in **Table 5** are for California. The CSP costs are up to 13% higher in other regions with less solar insolation to account for greater capacity and storage requirements. The annual capacity factors by 2020 range from 49% in MAPP (the Upper Midwest) to 74% in the Southwest. The capacity factors by time period were computed by Sandia analysts to optimize the timing of solar output for each region within the bounds of the storage potential. Note that the AEO2004 Reference Case assumptions include lower-cost CSP systems, but with significantly less storage and therefore lower electrical output.

The future cost assumptions for CSP technology in the Solar Program scenario are based on a funding level consistent with the FY06 budget request for FY06 and a funding level commensurate with those outlined in the Draft CSP Technology Transition Plan for years beyond FY06 (DOE 2004).

Table 5. Concentrating Solar Power

Year	Installed Price ($/kW)	O$M (mills/kWh)	Capacity Factor
2003	4,953	14.7	53%
2010	3,510	7.8	65%
2020	2,462	4.0	72%
2025	2,199	3.6	72%
2030	1,993	3.2	72%
2035	1,879	3.1	72%
2040	1,826	3.0	72%
2050	1,797	2.9	72%

4. Sources

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Appendix J - GPRA06 Vehicle Technologies Program

1. Introduction

The target markets for the Office of FreedomCAR and Vehicle Technologies (FCVT) program include light vehicles (cars and light trucks) and heavy vehicles (trucks more than 10,000 pounds Gross Vehicle Weight). Each will be discussed separately below.

1.1 Target Market: Alternate Technology Light Vehicle (ATV) Market

The alternate technology light vehicles (ATVs) included in the FCVT program are gasoline hybrid vehicles, diesel hybrid vehicles, and advanced diesel vehicles. The market for these technologies includes all cars and light trucks sold for both personal and business use. Today, the size of this market is approximately 17 million vehicle sales per year. Total car and light truck stock is about 220 million vehicles. EIA projects both sales and stock to grow to more than 20 million and 300 million respectively by 2025. Additional growth is expected post-2025.

1.2 Key Factors in Shaping the Market Adoption of ATVs

Key factors associated with the adoption of new vehicle technologies include how the new vehicle technologies compare with the baseline vehicle technologies in terms of the following vehicle attributes:

- Vehicle Price
- Fuel Economy
- Range
- Maintenance Cost
- Acceleration
- Top Speed
- Luggage Space

Of these, vehicle price and fuel economy are the most important.

Nonvehicle attributes that are important factors in a consumer's decision to purchase new vehicle technologies include the following:

- Fuel Price
- Fuel Availability

1.3 Methodology and Calculations

The factors listed above include the factors used in the modeling of new vehicle technology penetration by the NEMS and MARKAL models. ATV attributes and other factors are discussed below.

1.3.1 ATV Attributes

ATV attributes were developed based on the FCVT program goals, discussions with FCVT program managers, Powertrain Systems Analysis Toolkit (PSAT) modeling and payback analysis (Refs. 1-3). The PSAT model is a simulation model used by DOE to evaluate the fuel economy and performance of light vehicles using various technologies. Payback analysis was used to estimate what the incremental price of ATVs would be when they become cost competitive with conventional vehicles, a goal of the program. (The incremental price equals the present value of the energy cost reduction achieved by ATVs over three years, assuming a fuel price of $1.50/gallon gasoline equivalent and 7.5% discount rate.) Other attributes were based on a review of past GPRA characterizations (e.g., Ref. 4).

Because the NEMS and MARKAL models require different levels of detail, two separate vehicle characterizations are provided. In both cases, most of the attributes are provided as ratios to the vehicle attributes of conventional vehicles. (For NEMS, the $ value of the price increments were provided.) The attributes are for new vehicles in the year listed. **Table 1** contains the vehicle attributes for ATVs provided for input to the NEMS model. Attributes are provided for all six car size classes and six light truck classes that NEMS uses.

Table 2 contains vehicle attributes for ATVs provided as input to the MARKAL model. MARKAL uses only vehicle price and fuel economy attributes. MARKAL does not disaggregate cars and light trucks into various classes.

1.3.2 Fuel Price and Availability

Fuel price assumptions are discussed in **Chapters 4 and 5**. Gasoline and diesel fuel are assumed to be widely available.

1.3.3 ATV Market-Penetration Methodology

Brief descriptions of how the NEMS and MARKAL models each project new vehicle technology penetration using these vehicle attributes can be found in **Chapter 4** (NEMS) and **Chapter 5** (MARKAL).

1.4 Sources

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2. Phillip Sharer and Aymeric Rousseau, “Fuel Economy of Advanced Technology Vehicles” for Phil Patterson, DOE (June 17, 2004).

3. Payback model developed by Jim Moore, TA Engineering (2003).

4. “Program Analysis Methodology: Office of Transportation Technologies, Quality Metrics 2003 Final Report”, prepared by OTT Analytic Team, for Office of Transportation Technologies, U.S. Department of Energy (March 2002).

Table 1. ATV Attributes Input to NEMS

	2-SEATER				MINI-COMPACT				SUB-COMPACT				COMPACT			
Advanced Diesel	**2014**	**2019**	**2024**	**2025**	**2018**	**2023**	**2025**	**N/A**	**2012**	**2017**	**2022**	**2025**	**2011**	**2016**	**2021**	**2025**
Incremental Vehicle Price	1341	988	853	867	1278	946	900		1089	828	718	741	1160	841	728	766
Range	1.20	1.20	1.20	1.20	1.20	1.20	1.20		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Maintenance Cost	1.00	0.90	0.90	0.90	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Acceleration	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fuel Economy	1.50	1.60	1.70	1.72	1.50	1.60	1.64		1.50	1.60	1.70	1.76	1.50	1.60	1.70	1.78
Diesel Hybrid	**2016**	**2021**	**2025**	**N/A**	**2020**	**2025**	**N/A**	**N/A**	**2016**	**2021**	**2025**	**N/A**	**2014**	**2019**	**2024**	**2025**
Incremental Vehicle Price	1787	1380	1154		1999	1333			1413	1157	935		1433	1162	930	923
Range	1.25	1.25	1.25		1.25	1.25			1.25	1.25	1.25		1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05		1.05	1.05			1.05	1.05	1.05		1.05	1.05	1.05	1.05
Acceleration	1.00	1.00	1.00		0.90	0.90			0.90	0.90	0.90		0.90	0.90	0.90	0.90
Top Speed	1.00	1.00	1.00		0.90	0.90			0.90	0.90	0.90		0.90	0.90	0.90	0.90
Luggage Space	0.95	0.95	0.95		0.95	0.95			0.95	0.95	0.95		0.95	0.95	0.95	0.95
Fuel Economy	1.80	2.10	2.12		2.09	2.12			1.70	2.10	2.12		1.70	2.08	2.11	2.12
Gasoline Hybrid	**2012**	**2018**	**2023**	**2025**	**2011**	**2016**	**2021**	**2025**	**2010**	**2014**	**2019**	**2025**	**2007**	**2012**	**2017**	**2025**
Incremental Vehicle Price	1508	1248	1035	1046	1437	1195	1004	1019	1286	1047	858	867	1305	1062	861	882
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Acceleration	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Top Speed	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Fuel Economy	1.60	1.90	2.00	2.02	1.60	1.90	1.99	2.02	1.60	1.90	1.97	2.02	1.60	1.90	1.95	2.02

Table 1 (continued)

	MEDIUM CAR				LARGE CAR			
Advanced Diesel	**2010**	**2015**	**2020**	**2025**	**2009**	**2014**	**2019**	**2025**
Incremental Vehicle Price	1119	845	748	811	1208	898	794	860
Range	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Maintenance Cost	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Acceleration	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fuel Economy	1.40	1.50	1.60	1.70	1.40	1.50	1.60	1.70
Diesel Hybrid	**2014**	**2019**	**2024**	**2025**	**2014**	**2019**	**2024**	**2025**
Incremental Vehicle Price	1319	1267	1075	1078	1409	1154	1141	1144
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Fuel Economy	1.50	2.00	2.17	2.21	1.50	1.75	2.17	2.21
Gasoline Hybrid	**2006**	**2011**	**2016**	**2025**	**2009**	**2014**	**2019**	**2025**
Incremental Vehicle Price	1119	950	886	1014	1409	1010	941	1023
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Acceleration	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	0.90	0.90	0.90	0.90	1.00	0.90	0.90	0.90
Luggage Space	0.85	0.95	0.95	0.95	0.85	0.95	0.95	0.95
Fuel Economy	1.40	1.60	1.80	2.06	1.50	1.60	1.80	1.96

Table 1 (continued)

	MINIVAN				LARGE VAN			
Advanced Diesel	**2008**	**2013**	**2018**	**2025**	**2006**	**2011**	**2016**	**2025**
Incremental Vehicle Price	1226	931	822	883	1668	1204	1149	1080
Range	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Maintenance Cost	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Acceleration	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fuel Economy	1.40	1.50	1.60	1.70	1.40	1.50	1.70	1.70
Diesel Hybrid	**2013**	**2018**	**2023**	**2025**	**2012**	**2017**	**2022**	**2025**
Incremental Vehicle Price	1430	1241	1149	1138	1946	1605	1480	1391
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.09	1.05	1.05	1.05	1.09	1.05	1.05	1.05
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Fuel Economy	1.50	1.80	2.10	2.13	1.50	1.80	2.13	2.13
Gasoline Hybrid	**2009**	**2014**	**2019**	**2025**	**2010**	**2015**	**2020**	**2025**
Incremental Vehicle Price	1226	1150	1039	1072	1668	1487	1394	1311
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	0.75	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fuel Economy	1.40	1.70	1.90	2.00	1.40	1.70	2.00	2.00

Table 1 (continued)

	SMALL SUV				LARGE SUV				SMALL TRUCK				CARGO (Incl. 2b) TRUCK			
Advanced Diesel	**2008**	**2013**	**2018**	**2025**	**2007**	**2012**	**2017**	**2025**	**2008**	**2013**	**2018**	**2025**	**2006**	**2011**	**2016**	**2025**
Incremental Vehicle Price	1155	896	800	868	1563	1163	1019	1074	1112	859	764	830	1457	1089	962	1011
Range	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Maintenance Cost	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Acceleration	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fuel Economy	1.35	1.45	1.55	1.65	1.35	1.45	1.55	1.65	1.35	1.45	1.55	1.65	1.35	1.45	1.55	1.65
Diesel Hybrid	**2011**	**2016**	**2021**	**2025**	**2015**	**2020**	**2025**	**N/A**	**2012**	**2017**	**2022**	**2025**	**2016**	**2021**	**2025**	**N/A**
Incremental Vehicle Price	1485	1283	1098	1169	2024	1665	1399		1425	1239	1050	1118	1874	1558	1368	
Range	1.20	1.20	1.20	1.20	1.20	1.20	1.20		0.90	0.90	0.90	0.90	0.90	0.90	0.90	
Maintenance Cost	1.05	105	1.05	1.05	1.05	1.05	1.05		1.05	1.05	1.05	1.05	1.05	1.05	1.05	
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00		0.90	0.90	0.90	0.90	0.90	0.90	0.90	
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00		0.80	0.90	0.90	0.90	0.80	0.90	0.90	
Fuel Economy	1.50	1.80	1.95	2.13	1.50	1.80	1.95		1.50	1.80	1.95	2.13	1.50	1.80	1.92	
Gasoline Hybrid	**2007**	**2012**	**2017**	**2025**	**2008**	**2013**	**2018**	**2025**	**2010**	**2015**	**2020**	**2025**	**2010**	**2015**	**2020**	**2025**
Incremental Vehicle Price	1155	962	966	1102	1563	1249	1231	1363	1112	922	923	1054	1457	1169	1162	1283
Range	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Maintenance Cost	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.95	1.00	1.00	0.80	0.95	1.00	1.00
Fuel Economy	1.35	1.50	1.75	2.00	1.35	1.50	1.75	2.00	1.35	1.50	1.75	2.00	1.35	1.50	1.75	2.00

Table 2. ATV Attributes for Input to MARKAL

Ratios to Conventional Vehicles

		2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CARS											
Advanced Gasoline	MPG	1.0	1.0	1.01	1.02	1.03	1.025	1.02	1.015	1.01	1.01
	Incremental Price	1.0	1.01	1.05	1.09	1.24	1.25	1.25	1.25	1.25	1.25
Diesel	MPG	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.8	1.8	1.8
	Incremental Price	1.07	1.05	1.03	1.03	1.03	1.025	1.02	1.02	1.02	1.02
Gasoline HEV	MPG	1.3	1.5	1.7	1.96	2.06	2.22	2.22	2.22	2.22	2.22
	Incremental Price	1.1	1.07	1.05	1.045	1.04	1.03	1.02	1.02	1.02	1.02
Diesel HEV	MPG	NA	1.6	1.8	2.05	2.21	2.36	2.36	2.36	2.36	2.36
	Incremental Price	NA	1.1	1.08	1.075	1.07	1.055	1.04	1.035	1.03	1.03
LIGHT TRUCKS											
Advanced Gasoline	MPG	1.0	1.01	1.02	1.03	1.03	1.025	1.02	1.015	1.01	1.01
	Incremental Price	1.0	1.05	1.17	1.23	1.36	1.37	1.37	1.37	1.37	1.37
Diesel	MPG	1.3	1.35	1.4	1.5	1.65	1.7	1.8	1.8	1.8	1.8
	Incremental Price	1.06	1.04	1.035	1.03	1.025	1.02	1.02	1.02	1.02	1.02
Gasoline HEV	MPG	1.3	1.4	1.7	1.85	2	2	2	2	2	2
	Incremental Price	1.1	1.07	1.05	1.045	1.04	1.03	1.02	1.02	1.02	1.02
Diesel HEV	MPG	NA	1.5	1.8	1.9	2.13	2.13	2.13	2.13	2.13	2.13
	Incremental Price	NA	1.1	1.08	1.075	1.07	1.055	1.04	1.035	1.03	1.03

2.0 Heavy Vehicle Benefits Analysis Introduction

The following sections describe the approach to estimating benefits and analysis results for the Heavy Vehicle Technologies activities of the FreedomCAR and Vehicle Technologies Program of EERE. The scope of the effort includes:

- Characterizing baseline and advanced technology vehicles for Class 3–6 and Class 7 and 8 trucks,
- Identification of technology goals associated with the DOE EERE programs,
- Estimating the market potential of technologies that improve fuel efficiency and/or use alternative fuels,
- Determining the petroleum savings associated with the advanced heavy vehicle technologies.

In FY05, the Heavy Vehicles program activity expanded its technical involvement to more broadly address various sources of energy loss as compared to focusing more narrowly on engine efficiency and alternative fuels. This broadening of focus has continued in the activities planned for FY06. These changes are the result of a planning effort that occurred during FY04 and FY05 (Ref. 1).

This narrative describes characteristics of the heavy truck market as they relate to the analysis and provides a description of the analysis methodology—including a discussion of the models used to estimate market potential and benefits. The market penetration of advanced heavy vehicle technologies estimated here is then modeled as part of the EERE-wide integrated analysis (using NEMS and MARKAL) to provide final benefit estimates reported in the FY06 Budget Request.

2.1 Target Market: Heavy Vehicle Target Market

"Heavy Vehicles" are defined in this analysis as including Classes 3 through 6 (Medium Trucks) and Classes 7 and 8 (Heavy Trucks). The Heavy Truck classes are further subdivided by end-use types: i.e., Long-Haul, Intermediate, and Local Use. Vehicle Inventory and Use Survey (VIUS) data were examined for all vehicles in use and vehicles 2 years old or less (Ref. 2). The Heavy Truck vehicle market was then disaggregated into these three end-use types. The specific vehicle configurations grouped in each of the three types have similar usage and annual vehicle mile usage patterns. The vehicle type segments are made up of the vehicle configurations listed below:

- Local Use (Type 1) – multistop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, garbage collection, dump, and concrete delivery;
- Intermediate Use (Type 2) – platform, livestock, auto transport, oil-field, grain, and tank;
- Long-Haul (Type 3) – refrigerated van, drop frame van, open top van, and basic enclosed van.

The lower speed and "stop and start" duty characteristics of Type 1 trucks greatly reduce the potential efficiency benefits in that sector compared to Types 2 and 3. For similar reasons, fuel economy improvements due to other speed-dependent measures such as improved tires will have lower benefit here than in the other two types.

As compared to long distance, over the road travel, Type 2 vehicles tend to be used in a mix of local and regional delivery; and, as a result, will also realize greater fuel economy benefit from aerodynamic improvements than Type 1, but not as great as Type 3. Distances traveled by Type 2 vehicles are typically greater than Type 1, which infers that the typical speeds are higher. These characteristics make them a somewhat better market sector for measures that perform in relation to speed such as advanced tires. In general, Type 3 vehicles are the best candidates for technologies that reduce drivetrain or vehicle losses.

Refueling characteristics; i.e. central-source refueling or noncentral source also are considered in the market characteristics, as centrally refueled vehicles would find an alternative fuel source more practical than vehicles that always refuel at road-side facilities.

Eleven travel distance categories for medium trucks and 21 for heavy trucks are represented in the model. These categories were determined using travel distributions developed with the VIUS data by ORNL (Refs. 2, 3).

Exhibit 1 shows the distribution of annual travel for Class 3 through 6 and the three types of Class 7 and 8 vehicles. Type 3 vehicles display the greatest amount of annual travel of all heavy vehicle classes as is evidenced in part by the curve's peaking in the 120,000- to 139,000-mile segment.

Exhibit 2 shows the vehicle use pattern for Local or Type 1 Heavy trucks. The distribution based both on vehicles and vehicle-miles traveled are indicated.

The contrast in distribution by type is evident when Exhibits 2 and 3 are compared. **Exhibit 3** shows the same information as **Exhibit 2**—but for Type 3 trucks. For Type 1, the distribution peaks in the 20,000- to 39,000-mile segment. For Type 3, the peak distribution shows annual travel of 100,000 miles greater than Type 1—120,000 to 139,000 miles.

Centrally refueled and noncentrally fueled vehicle use characteristics also have been analyzed. Centrally refueled travel less per year than noncentrally refueled vehicles. In the noncentrally refueled vehicle segment, the majority of travel occurs from 100,000 to 140,000 miles per year. In the central refueling segment, the majority of travel occurs in a more even distribution between 20,000 and 140,000 miles per year.

Heavy vehicle market characteristics that are pertinent to the analysis are summarized in **Exhibit 4.** In the medium truck market segment (Classes 3 through 6), all vehicle types, with the exception of auto transport, on average travel about 20,000 miles per year. Heavy trucks, depending on type, travel an average of 40,000 miles to 92,000 miles per year. Based on discussions with program personnel, the baseline fuel economy for Type 3 heavy vehicles was changed to 7.5 MPG, a reduction from prior years. The fuel economy of this market sector remains significantly higher than that attributed to Type 1 heavy vehicles (7.5 vs. 4.55 MPG).

2.2 Key Factors Shaping Market Adoption of Technology

Based on a survey conducted by the American Trucking Associations in 1997, energy-conservation purchase decisions for this sector are significantly affected by economic viability—specifically the payback of the investment (Ref. 4). The survey of 224 motor carriers revealed that paybacks of one to four years were acceptable for energy-conserving technologies. Based on those findings, we model the market acceptance of the various technologies based on payback performance.

The Environmental Protection Agency has initiated regulation of emissions from Heavy Trucks. This is changing engine technology and diesel fuel refining. Some reduction in fuel economy with the new engines is also expected as the combustion process optimization is addressing reduction of emissions. These changes will impose both operating and capital costs on truck operators.

2.3 Methodology and Calculations

The analysis of the benefits expected from achieving the Heavy Vehicle technologies program goals was developed based on four primary reference sources:

- Technology energy efficiency and fuel-use characteristics—as provided by the managers of the technology programs;
- Vehicle characteristics and use information—as obtained from the 1997 VIUS. This provides information on both vehicle performance characteristics, such as fuel economy, and vehicle-use patterns such as miles traveled per year (Ref. 2);
- Truck operator investment requirements—as provided by a survey of Owner-Operators performed by the American Trucking Associations in 1995 (Ref. 4);
- Important "background" information such as energy prices and baseline technology fuel economies—as provided in the Annual Energy Outlook (Reference Case) prepared by the Energy Information Administration (Ref. 5).

The methodology involves the definition of the energy conservation or displacement and cost attributes of the advanced technologies being fostered by the program, the characterization of the markets affected, and the estimation of the benefits. Several models are used. Specifically, initial benefits estimates are generated through the linkage of four spreadsheet models:

- HTEB - Heavy Truck Energy Balance Model
- TRUCK 2.0 - Heavy Vehicle Market Penetration Model
- VISION 2.0, and
- Heavy Truck Summary (HVS) report generator.

The relationship of these four models is indicated in **Exhibit 5.**[1] Cost estimates are developed separately.

The **Heavy Truck Energy Balance Model** (HTEB) was developed to assess the overall fuel economy effect of several changes to the vehicle involving both the engine and other elements of the vehicle. It takes into account energy losses based on user selected inputs of vehicle use. It is a steady-state model. It was required as a result of the lack of existence of publicly available vehicle simulation tool. The fuel economies of new advanced heavy vehicle technologies estimated with the HTEB model are presented in **Exhibit 6.**

The cost estimates for these vehicles are also presented in **Exhibit 6.** The first cost of a technology is assumed to reduce to a two-year payback level as a program goal. As an example, the cost schedule for the **Exhibit 6** technologies in the Long Haul vehicle application is indicated in **Exhibit 7**. This process was replicated for Type 1 and Type 2 vehicles and Medium Trucks to develop similar cost estimates.

The values for fuel economy improvement from HTEB and cost are then input to **TRUCK 2.0.** This model was developed to estimate the potential market impacts of new technologies on the medium and heavy truck market. The results generated by this model are:

- Market penetrations, in units of percent of new vehicles sold for each type and class of vehicle, and
- Composite fuel economy rating (new mpg) of the vehicles sold, for each truck type.

As discussed, the TRUCK 2.0 model estimates market penetration based on cost effectiveness of the new technology. Cost effectiveness is measured as the incremental cost of the new technology less the expected energy savings of that technology over a specified time period in relation to specified payback periods**.**

Exhibit 8 shows the payback distribution assumed in the TRUCK model. This payback distribution was generated from the American Trucking Association's survey described above (Ref. 4). The survey found that, for example, 16.4% of the truck operators responding require a payback of one year on an investment. The TRUCK model market penetration calculation method for Class 7 and 8, Type 1 vehicles is described in **Exhibit 9.**

The market penetration results are supplied through a link to the **VISION 2.0** model (Ref. 6). The VISION model is used to estimate preliminary or first order oil/energy use and CO_2 emissions from highway vehicles through 2050. It contains a baseline estimate of heavy vehicle energy use to 2050. Through 2025 that baseline is the same as that of the AEO. By inputting the

[1] The HTEB was developed by William Shadis and James Moore of TA Engineering. The TRUCK (2.0) Model was developed as a collaborative effort, initially by John Maples of Oak Ridge National Laboratory (ORNL), with assistance from James Moore, of TA Engineering, Inc. Subsequent enhancements have been performed by Moore (TA Engineering). The Vision (2.0) model was developed by Margaret Singh and Anant Vyas of ANL. The Heavy Truck Summary Model is a report generating spreadsheet. It was initially developed by Maples, and has subsequently been modified by Analysts at the National Renewable Energy Laboratory, and TA Engineering.

market penetration and fuel economy of the advanced heavy vehicle technologies into the model, an alternative estimate of future heavy vehicle energy use is generated and benefits relative to the baseline can be estimated.

Since VISION does not disaggregate Types 1-3 Heavy Trucks or Hybrid-Non-hybrid Medium Trucks, the fuel economy multipliers generated by Truck 2.0 are aggregated on both a sales and VMT-weighted basis for input to VISION. These aggregated fuel economy multipliers are provided in **Exhibit 10**. They are also adjusted to take into account differences in baseline fuel economies provided in VIUS (used in TRUCK 2.0) and the AEO (used in VISION). These factors and the market penetration estimates also presented in Exhibit 10 are the factors ultimately used in the EERE-wide integrated analysis.

Finally, the **Heavy Truck Summary** report generator summarizes the first order benefits for the period covering 2000 through 2050. Benefits include the following:

- Heavy Truck Petroleum Use and Savings, by Class 3-6 and Class 7-8, Million BPD
- Heavy Truck Petroleum Savings - %
- Class 7&8 Truck Savings by Program Element (Technology), Million BPD
- Local Use Truck Savings by Program Element (Technology), Million BPD
- Intermediate Truck Savings by Program Element (Technology), Million BPD
- Long-Haul Truck Savings by Program Element (Technology), Million BPD.

These first order benefits have been generated and will be reported in a forthcoming report.

2.4 Sources

1. FreedomCAR and Vehicle Technologies R & D Plan (Draft), August 22, 2003.
2. "1997 Vehicle Inventory and Use Survey," EC97TV-US U.S. Bureau of the Census, Washington, D. C., 1999.
3. Personal Communication with Stacy Davis, ORNL, November 2001
4. "1997 Return on Investment Survey," American Trucking Association, Arlington Va., 1997.
5. "Annual Energy Outlook 2004, With Projections to 2030," Energy Information Agency, Department of Energy, Washington, D. C., (Web site address: http://www.eia.doe.gov/bookshelf.html *Library/Archives-Forecasting)*.
6. Singh, M.; A. Vyas, and E. Steiner, "VISION Model: Description of Model Used to Estimate the Impact of Highway Vehicle Technologies and Fuels on Energy Use and Carbon Emissions to 2050," ANL/ESD/04-1 (Dec. 2003).

Exhibit 1: Annual Miles Traveled for Four Truck Categories, 1997

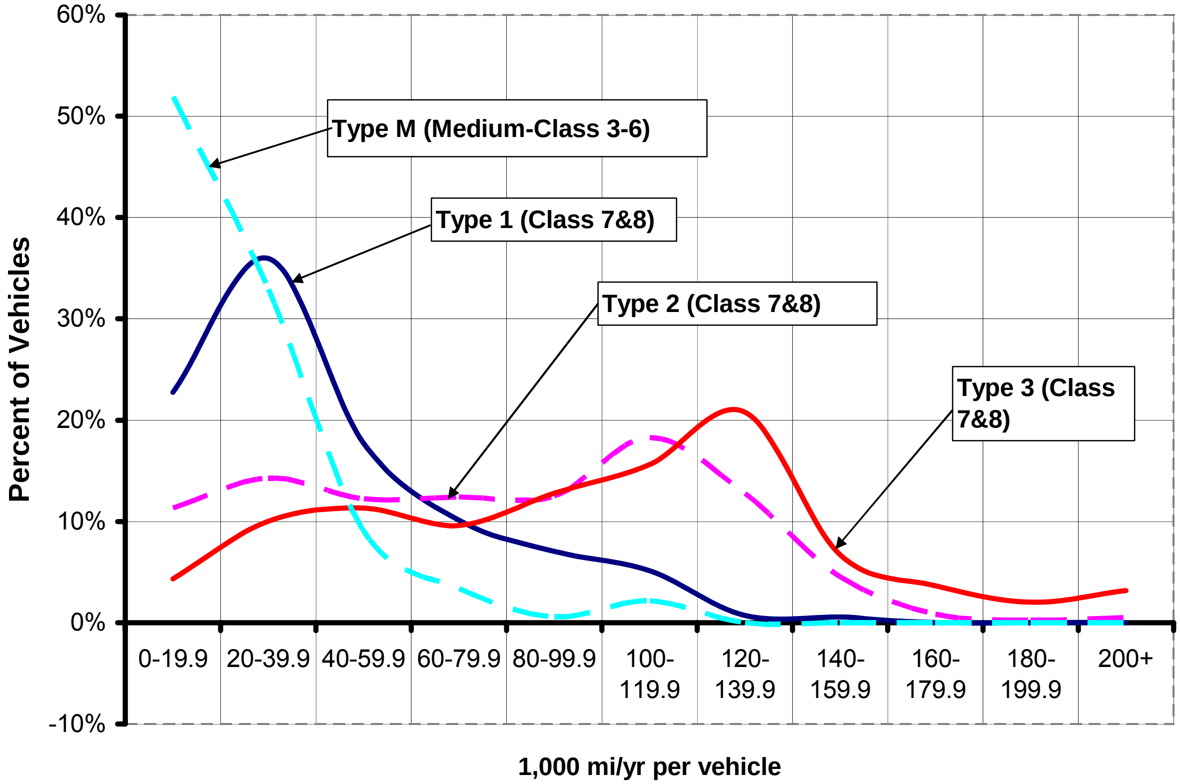

Exhibit 2: Type 1 Vehicle Use

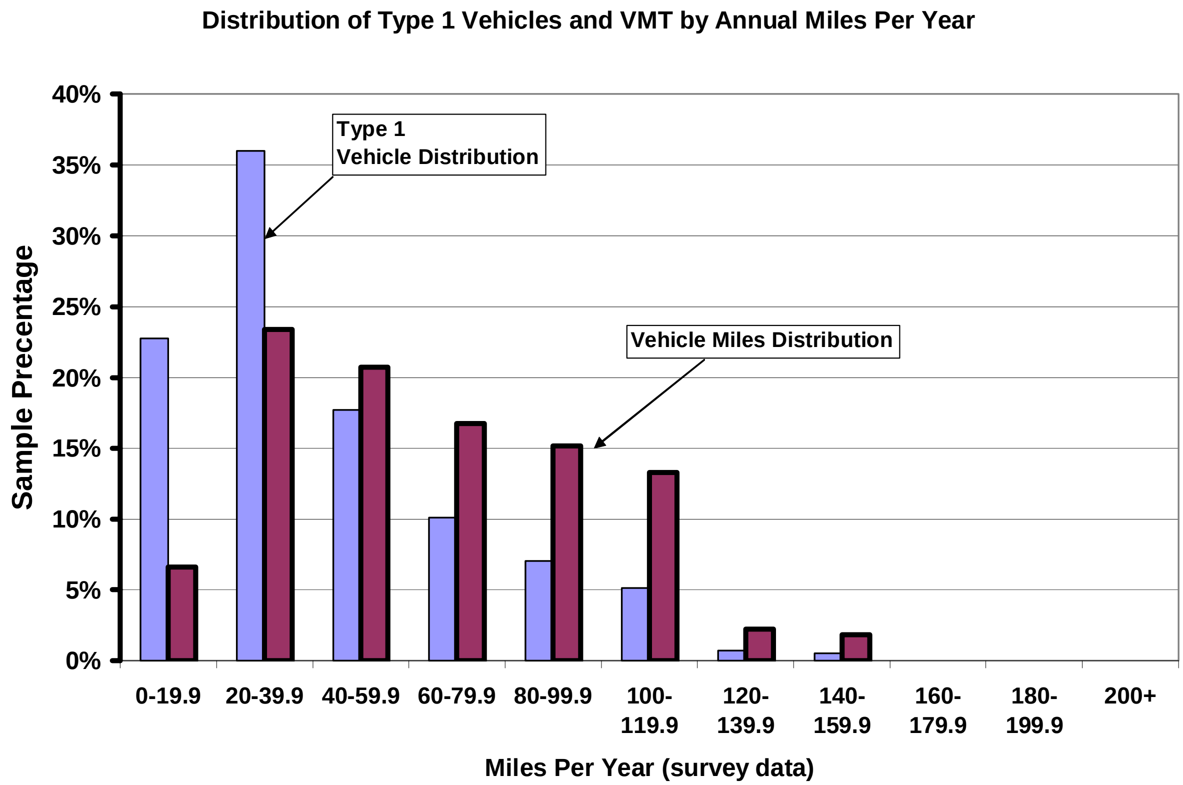

Exhibit 3: Type 3 Vehicle Use

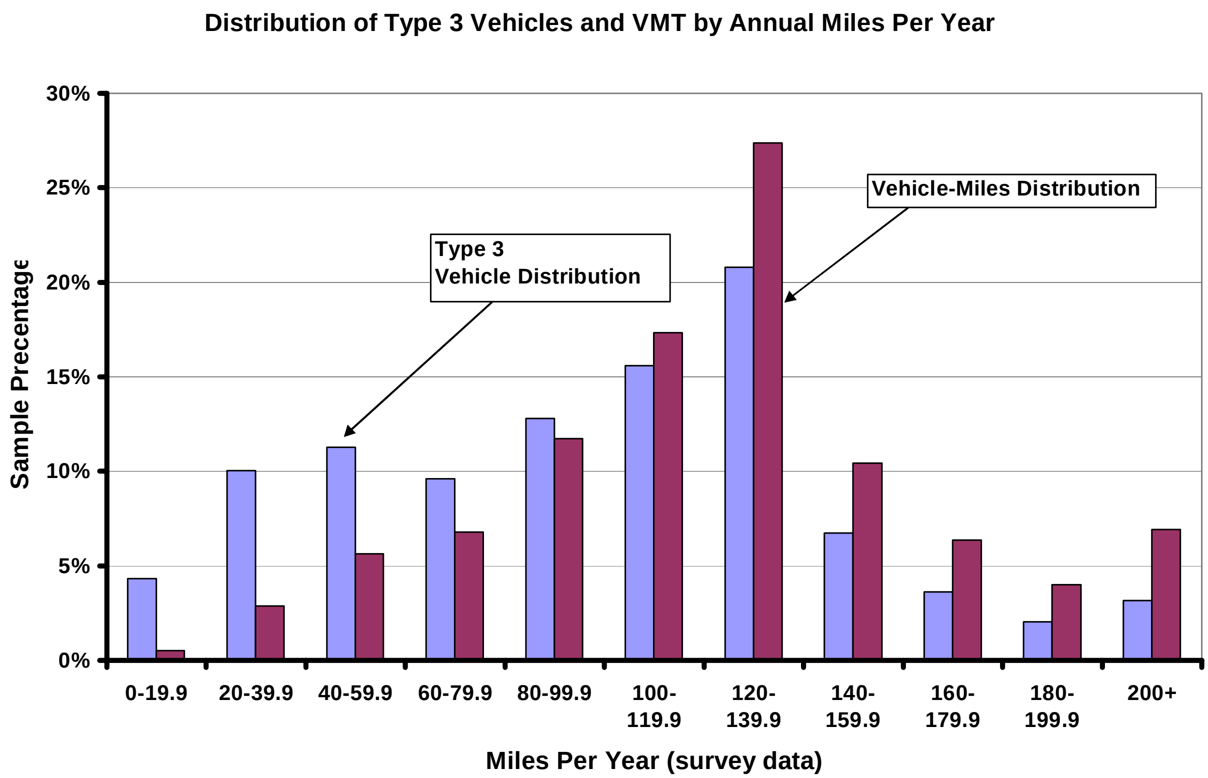

Exhibit 4: Heavy Vehicle Characteristics (1997)

Vehicle Type	Average Annual Miles	Fuel Economy, MPG	Percent Centrally Refueled
Class 3-6	20,126	8.90	40.1%
Class 7 & 8; Type 1	40,043	4.55	59.8%
Class 7 & 8; Type 2	74,066	6.16	41.0%
Class 7 & 8; Type 3	92,434	7.50	42.0%

Exhibit 5: Heavy Truck Benefits Analysis Models

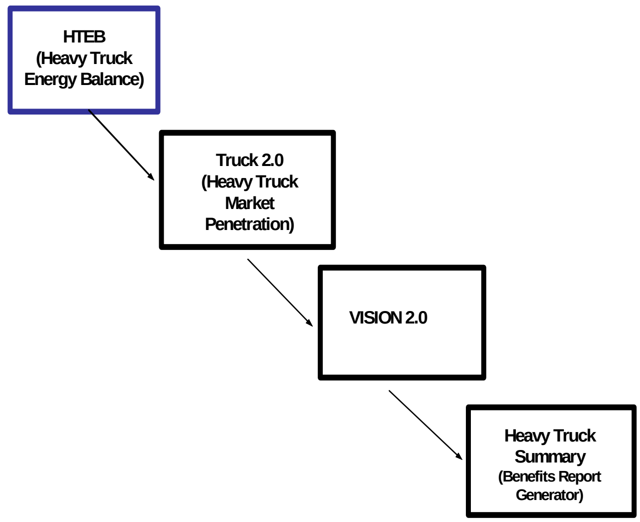

Exhibit 6: Advanced Heavy Vehicle Characterization (New Vehicles)

	Characteristic	2010	2020	2030	2040	2050
1	Fuel Economy Class 7-8, Local, mpg Multiplier	1.26	1.46	1.46	1.46	1.46
2	Fuel Economy Class 7-8, Intermediate, mpg Multiplier	1.35	1.64	1.64	1.64	1.64
3	Fuel Economy Class 7-8, Long-Haul, mpg Multiplier	1.47	1.79	1.79	1.79	1.79
4	Fuel Economy Class 3-6-Hybrid, mpg Multiplier	1.70	1.70	1.70	1.70	1.70
5	Fuel Economy Class 3-6-Non-hybrid, mpg Multiplier	1.20	1.37	1.37	1.37	1.37
6	Class 7-8, Iincremental Cost, $	$ 35,000	$ 15,000	$ 7,500	$ 7,500	$ 7,500
7	Class 3-6 Hybrid, Incremental Cost, $	$ 19,000	$ 5,400	$ 2,700	$ 2,700	$ 2,700
8	Class 3-6 Nonhybrid, Incremental Cost, $	$ 5,400	$ 1,700	$ 1,700	$ 1,700	$ 1,700

Exhibit 7: Example First Cost and Efficiency Schedule for Advanced Technologies

Year	Baseline Vehicle Cost ($)	*Enhancement: Program Portfolio*	
		Diesel Fuel (only)	
		Gross 1st Cost ($)	Efficiency Ratio
2000	150,000	0	1.000
2005	150,000	45,000	1.500
2010	150,000	35,000	1.500
2015	150,000	25,000	1.760
2020	150,000	15,000	1.760
2025	150,000	11,000	1.760
2030	150,000	7,500	1.760
2035	150,000	7,500	1.760
2040	150,000	7,000	1.760
2045	150,000	7,000	1.760
2050	150,000	7,000	1.760

Exhibit 8: ATA Survey Payback Preference Distribution

Number of Years	Percent of Motor Carriers
1	16.4%
2	61.7%
3	15.5%
4	6.4%

Exhibit 9: Truck Payback Algorithm—Type 1 Trucks

Spreadsheet Location	Description	Comments
Column A	**Year**	Identifies year for which values, calcuations and results are representative.
Columns B - F	**Fuel Economy by Technology**	Values are developed based on baseline technology mpg assumptions and efficiency ratios for advanced technologies.
Column G	**Cost of Alternative Fuel in $/GGE**	Links to Fuel Prices Page
Columns H - I	**Calculates annual savings for 2 alternative technologies**	For Advanced Diesel: (VMT(C10)x$/GGE/Baseline MPG - VMT x $/GGE/Adv. Diesel MPG)
Columns J - M	**Calculates Net Present Value of Savings for 'Advanced Diesel'**	Column J: 1 Year, K: 2 years, L: 3 years; M: 4 years
Columns N - Q	**Calculates Net Present Value of Savings for 'Alternative Fuel Technology'**	Column N: 1 Year, O: 2 years, P: 3 years; Q: 4 years
Columns R - U	**If-then Statement to determine 'Cost Effectiveness Factor' (CEF)**	If NPV of savings is > Cost of Technology, cell value is (cost - NPVSavings)/Cost; Otherwise cell value is 0. Columns are for paybacks of 1, 2, 3, and 4 years.
Column V	**Technology purchase cost 'Alternative Fuel Technology'**	Values are linked to Cost values on 'Inputs' page.
Column W - Z	**Repeats calcuations in Columns R through U for 'Alternative Fuel Technology'**	
Column AA	**If-then Statement to determine 'Technology Adoption Factor' (TAF) for 'Advanced Diesel'**	If 'Cost Effectiveness Factor' for Year 1 PB is 0, cell value = 100; Otherwise (100-((exp(1995 CE Factor-Current Yr. Factor) - 1)/10 x 100)
Column AB	**Continuation of TAF Calculation for Year 1 Payback market**	If AA<0, cell value is 1; Otherwise the Value is the same as AA.
Columns AC + AD	**Repeat AA and AB for 2 year payback market**	
Columns AE + AF	**Repeat AA and AB for 3 year payback market**	
Columns AG + AH	**Repeat AA and AB for 4 year payback market**	
Columns AI - AP	**Repeat Columns AA through AH methodology for 'Alt. Fuel Technology'**	
Column AQ	**If-then statement. Start of Market Penetration for 'Advanced Diesel'**	If AB = 100, then cell value is 0; Otherwise cell value is (1/(1+Abvalue/exp(-2 x Col. R CEF for 1 Year PB))
Column AR	**Same as AQ, but for 2 year PB market.**	
Column AS	**Same as AQ, but for 3 year PB market.**	
Column AT	**Same as AQ, but for 4 year PB market.**	
Column AU	**Final, Step 1; Weighted average market penetration for year 1 through year 4 markets weighting factors**	Weighting factors are based on ATA survey results and are listed at the top of Columns AQ-AT.
Column AV	**Final, Step 2: Reduces Market Penetration to account for market penetration of 'Atl. Fuel Technology' and stay below 100% share.**	=+(AU+(1-BA)*AU)/2
Columns AW - AZ	**Same as columns AQ - AT for 'Alterntive fuel technology'.**	
Column BA	**Final, Step 1; For 'Alt. Fuel Tech.', weighted average market penetration for year 1 through year 4 markets weighting factors**	
Column BB	**Final, Step 2: Reduces Market Penetration to account for market penetration of 'Atl. Fuel Technology' and stay below 100% share.**	
Columns BD - BN	**Macro Results Array-Centrally Refueled Advanced Diesels**	Central1 Macro results are printed in this part of spreadsheet
BO	**Final Step 3: 'Advanced Diesel' (Centrally Refueled) Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.**	Results are linked to Market Penetration Page
Columns BQ - CA	**Macro Results Array-Centrally Refueled Alternative Fuels**	Macro results are printed in this part of spreadsheet. Alt Fuel technology only competes in Centrally Refueled Segment
CB	**Final Step 3: 'Alt. Fuel' Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.**	Results are linked to Market Penetration Page
Columns CD - CN	**Macro Results Array-Non Centrally Refueled Advanced Diesels**	Macro results are printed in this part of spreadsheet
CO	**Final Step 3: 'Advanced Diesel' (Non-centrally refueled) Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.**	Results are linked to Market Penetration Page

Exhibit 10: Advanced Heavy Vehicle Market Penetration and Fuel Economy Results for NEMS Modeling

Year	Class 7 & 8				Class 3 - 6			
	Combined Market Penetration, % VMT	Base MPG (VISION) in gasoline equivalent gallons	Fuel Economy for All New Technology Sales, mpg	Fuel Economy Multiplier only for trucks with new techology which achieve the market penetration shown in Column 2	Combined Market Penetration, % VMT	Base MPG (VISION) in gasoline equivalent gallons	Fuel Economy for All New Technology Sales, mpg	Fuel Economy Multiplier only for trucks with new techology which achieve the market penetration shown in Column 6
1	2	3	4	5	6	7	8	9
2005	0%	5.70	10.00	1.75	0%	8.67	11.50	1.33
2006	0%	5.69	10.10	1.78	0%	8.64	11.56	1.34
2007	0%	5.67	10.21	1.80	0%	8.61	11.63	1.35
2008	0%	5.66	10.31	1.82	0%	8.57	11.69	1.36
2009	0%	5.64	10.42	1.85	1%	8.54	11.75	1.38
2010	1%	5.63	10.52	1.87	4%	8.51	11.82	1.39
2011	2%	5.69	10.59	1.86	12%	8.51	11.85	1.39
2012	3%	5.75	10.65	1.85	15%	8.51	11.88	1.40
2013	5%	5.81	10.72	1.84	24%	8.52	11.91	1.40
2014	10%	5.87	10.78	1.84	24%	8.52	11.94	1.40
2015	15%	5.94	10.85	1.83	33%	8.52	11.97	1.40
2016	19%	6.00	10.93	1.82	40%	8.52	12.01	1.41
2017	27%	6.06	11.00	1.82	43%	8.52	12.06	1.41
2018	28%	6.12	11.08	1.81	48%	8.53	12.10	1.42
2019	44%	6.18	11.15	1.81	48%	8.53	12.15	1.42
2020	53%	6.24	11.23	1.80	50%	8.53	12.19	1.43
2021	57%	6.24	11.24	1.80	52%	8.53	12.26	1.44
2022	58%	6.25	11.25	1.80	52%	8.53	12.33	1.45
2023	65%	6.25	11.26	1.80	52%	8.53	12.39	1.45
2024	68%	6.25	11.27	1.80	54%	8.53	12.46	1.46
2025	69%	6.26	11.28	1.80	56%	8.53	12.53	1.47
2026	70%	6.26	11.28	1.80	56%	8.53	12.65	1.48
2027	79%	6.26	11.29	1.80	56%	8.53	12.77	1.50
2028	80%	6.26	11.29	1.80	56%	8.53	12.89	1.51
2029	83%	6.27	11.30	1.80	67%	8.53	13.01	1.53
2030	84%	6.27	11.30	1.80	75%	8.53	13.13	1.54
2031	85%	6.27	11.30	1.80	78%	8.53	13.20	1.55
2032	86%	6.28	11.31	1.80	80%	8.53	13.26	1.55
2033	87%	6.28	11.31	1.80	83%	8.53	13.33	1.56
2034	88%	6.28	11.31	1.80	86%	8.53	13.40	1.57
2035	89%	6.29	11.32	1.80	89%	8.53	13.46	1.58
2036	89%	6.29	11.32	1.80	93%	8.53	13.53	1.59
2037	90%	6.29	11.32	1.80	93%	8.53	13.59	1.59
2038	90%	6.29	11.32	1.80	93%	8.53	13.66	1.60
2039	91%	6.30	11.33	1.80	93%	8.53	13.73	1.61
2040	91%	6.30	11.33	1.80	93%	8.53	13.79	1.62
2041	91%	6.30	11.33	1.80	93%	8.53	13.79	1.62
2042	92%	6.30	11.33	1.80	93%	8.53	13.79	1.62
2043	92%	6.31	11.34	1.80	93%	8.53	13.79	1.62
2044	92%	6.31	11.34	1.80	93%	8.53	13.79	1.62
2045	92%	6.31	11.34	1.80	93%	8.53	13.79	1.62
2046	92%	6.31	11.34	1.80	93%	8.53	13.79	1.62
2047	93%	6.31	11.34	1.80	93%	8.53	13.79	1.62
2048	93%	6.32	11.35	1.80	93%	8.53	13.79	1.62
2049	93%	6.32	11.35	1.80	93%	8.53	13.79	1.62
2050	93%	6.32	11.35	1.80	93%	8.53	13.79	1.62

Appendix K - GPRA06 Weatherization and Intergovernmental Program (WIP) Documentation

Introduction

Table 1 outlines the activities characterized for the GPRA06 Weatherization and Intergovernmental Program (WIP). 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.

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.

Table 1. WIP Subprograms, Projects, and Activities

Subprogram	Project	Activity
State Energy Program Grants and State Energy Activities	State Energy Program Grants	Codes and Standards Energy Audits Rating and Labeling Workshops/Training Incentives Retrofits Loans and Grants Technical Assistance
Weatherization Assistance Grants	Weatherization Assistance	Weatherization Assistance
Gateway Deployment	Rebuild America	Rebuild America Deployment
	Energy Efficiency Information Outreach	Outreach Activities
	Building Codes Training and Assistance	Building Codes Training and Assistance Deployment
	Energy Star Program	Clothes Washers Refrigerators Room Air Conditioners Compact Fluorescent Lamps Dishwashers Windows Home Performance
	Clean Cities	Clean Cities Deployment
	Inventions and Innovation	Inventions and Innovation
Intergovernmental Activities	Tribal Energy Activities	Tribal Energy Activities
	International Renewable Energy Program	International Renewable Energy Program
	Renewable Energy Production Incentive	Renewable Energy Production Incentive

1.0 State Energy Program Grants and State Energy Activities

1.1 State Energy Program Grants

1.1.1 Target Market

Project Description. The State Energy Program provides financial assistance to States, enabling State governments to target their own high priority energy needs and expand clean energy choices for their citizens and businesses. With these funds and the resources leveraged by them, the State and Territory Energy Offices develop and manage a variety of programs designed to increase energy efficiency, reduce energy use and costs, develop alternative energy and renewable energy sources, promote environmentally conscious economic development and reduce reliance on oil produced outside of the United States.

Market Description. The market includes all markets (including buildings, transportation, industry, and power technologies), except new construction and all categories of energy end use.

Baseline Technology Improvements. For this analysis, the Pacific Northwest National Laboratory (PNNL) did not suggest any changes in technology improvements apart from the Energy Information Administration (EIA) baseline.

1.1.2 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL'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). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[3].

Technical Characteristics. For the FY06 GPRA metrics, the State Energy Program (SEP) was characterized based on the budget request and leveraged funds. Based on the report, *Estimating Energy and Cost Savings and Emissions Reductions for the State Energy Program Based on Enumeration Indicators Data* (Schweitzer, et al. 2003)[1], eight activities (referred to in the report as program areas) supported by SEP were selected to represent the project. These activities—Codes and Standards, Energy Audits, Rating and Labeling, Workshops/Training, Incentives, Retrofits, Loans and Grants, and Technical Assistance—comprised approximately 98% of the total estimated savings reported. Because the Schweitzer et al. study only received responses from 20 states (representing about half of the SEP funding), PNNL assumed that the responses were representative of the whole program, so all indicators produced were multiplied by two to approximate a national total.

Because Schweitzer et al. did not differentiate between funds provided directly by SEP as part of the Formula Grants project and those that SEP administers on behalf of other EERE projects (e.g., Rebuild America, Training and Assistance for Codes) through the Special Projects grants, the methodology was modified in some cases to reduce the likelihood of double-counting the savings estimates. Therefore, outputs resulting from Special Project funding should be allocated to the originating project for purposes of this effort. As an example, outputs resulting from funding that originates in the Training and Assistance for Codes project, but is administered by SEP through Special Projects, should be allocated to Training and Assistance for Codes.

Codes and Standards. Based on the estimated savings contained in Schweitzer et al., PNNL determined that the greatest area of potential overlap between Formula Grants and Special Projects would come about through the Codes and Standards activities. The Schweitzer report provided funding data for each of the activities, with total SEP (Formula Grant and Special Project) funding of about $4 million allocated by the responding states to Codes and Standards activities. Based on information provided by the Building Energy Codes Project on Special Project funding, approximately $1.6 million of that amount would have originated within Training and Assistance for Codes. PNNL determined that codes activities are therefore also being funded out of the SEP Formula Grants, and that some level of savings should be allocated to SEP for codes activities.

For consistency, PNNL based the estimated savings of the Codes and Standards activities funded by the SEP on the savings estimates produced for the Training and Assistance for Codes project. The Schweitzer et al. section on Rating and Labeling cited a study (Feldman and Tannenbaum 2000) indicating that approximately 10% of Energy Star purchases are made as a result of state encouragement. PNNL applied this attribution percentage to the estimate developed for Training and Assistance for Codes, to allocate 10% to SEP and 90% to Training and Assistance for Codes.

Energy Audits. In Schweitzer et al., energy-audit calculations were based on three indicators: number of audits, square feet retrofit, and reported savings. For this effort, PNNL converted these three indicators to number of households and square footage of commercial floor space impacted.

Schweitzer et al provided a savings per audit of 6.8 MMBtu per household and 0.0167 MMBtu per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook*[2], approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 8% for residential space heating and cooling. Based on Tables 1.3.3 and 1.3.4 of the *Buildings Energy Databook*, approximately 126 kBtu/SF/yr are used by commercial space heating, space cooling, and lighting, yielding a load reduction of 13% for commercial space heating, space cooling, and lighting.

To convert the indicators into an estimated number of households, PNNL assumed that each residential audit represented one household, divided the total residential square feet retrofit by the report's assumed average square feet per household (1,600), and divided the estimated reported annual savings by the 6.8 MMBtu/HH figure. This yielded an estimate of approximately 5,500 households impacted by energy audits in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was then multiplied by two to provide a crude approximate of the national total in the absence of more data. This yielded a total annual estimate of 11,000 households impacted, or 0.014% of existing residential single-family buildings, in each year.

To convert the indicators into an estimated commercial square footage, PNNL assumed that each commercial audit represented one building multiplied by the average building size assumed in the report (14,500 square feet), used the square footage reported, and divided the estimated reported annual savings by the 0.0167 MMBtu/SF figure. This yielded an estimate of approximately 0.197 billion square feet impacted by energy audits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a crude national total, yielding a total annual estimate of 0.396 billion square feet impacted, or 1.576% of existing commercial office, education, and health-care floor space, in each year.

<u>Rating and Labeling.</u> Schweitzer et al provided a national per-device estimate for rating and labeling of approximately 895,400 MMBtu per year. While the report allocated these savings to states (based on population) to determine an estimate of savings for states reporting estimates, the device savings were allocated equally across all states, because no forecast is available for determining which states would fund rating and labeling projects in the future. The equivalent savings per state is about 17,900 MMBtu per device (the national estimate divided by 50).

Of the responding states, two states reported that they funded rating and labeling activities for a total of 82 devices. To convert to a national representation, PNNL assumed that four states would fund rating and labeling activities in any given year, and that each state would cover approximately 40 devices, yielding a total of 160 devices saving energy. PNNL assumed that the savings would be effective for 15 years, and that they were attributable to electricity.

<u>Workshops/Training.</u> An estimate of 13.1% HVAC and 8% lighting savings attributable to workshops and training was provided by Schweitzer et al. PNNL translated these inputs to a 13% load reduction for space heating and space cooling, and an 8% load reduction in lighting within commercial buildings. According to the report, 19 of 20 states funded workshop and training activities, with a total of 5,600 trainees attending and a weighted average of four buildings influenced per trainee. To convert this to a national representation, PNNL assumed that 40 states would fund workshop/training activities in any given year, yielding approximately 11,800 trainees impacting a total of 47,000 buildings. There are currently about 4.7 million existing commercial buildings in the United States.[(3)]. PNNL assumed that the relationship between the number of buildings influenced as a percentage of the total stock would be equivalent to the square footage influenced as a percentage of the total commercial square footage; therefore, workshops and training were assumed to impact approximately 1% of the commercial building stock per year.

<u>Incentives.</u> According to Schweitzer et al, approximately 0.145 MMBtu are saved per rebate dollar. During FY 2000, the ratio of incentive funding to rebate value was approximately 1:39, the percentage of SEP funds spent on incentives within the responding states was 0.31%, and the amount of leveraged funds received for incentives was $1.78 per dollar of funding. Based on the FY 2006 request, PNNL assumed that approximately $368,800 dollars would be spent on incentive activities, equating to about $14.3 million in rebates for an annual savings of about 2.0 TBtu. PNNL assumed that the savings would be in effect for 15 years.

Retrofits. Within Schweitzer et al, retrofit calculations were based on two indicators: number of retrofits and square feet retrofit. For this effort, PNNL converted these two indicators to number of households and square feet of commercial floor space impacted.

Schweitzer et al. provided a savings per audit of 14.51 MMBtu per household and 18.8% per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook,* approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 17% for residential space heating and cooling. PNNL applied the 18.8% savings to commercial space heating, space cooling, and lighting.

To convert the indicators into an estimated number of households, PNNL assumed that each residential retrofit represented one household and divided the total residential square feet retrofit by the report's assumed average square feet per household (1,600). This yielded an estimate of approximately 20,600 households impacted by retrofits in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was multiplied by two to approximate a national total. This yielded a total annual estimate of 41,000 households impacted, or 0.051% of existing residential single-family buildings, in each year.

To convert the indicators into an estimated commercial square footage, PNNL assumed that each commercial retrofit represented one building multiplied by the average building size assumed in the report (14,500 square feet) and used the square footage reported. This yielded an estimate of approximately 0.028 billion square feet impacted by retrofits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a national total, yielding a total annual estimate of 0.056 billion square feet impacted, or 0.222% of existing commercial office, education, and health-care floor space, in each year.

Loans and Grants. According to Schweitzer et al, loans average 0.0164 million source Btu per dollar, and grants average 0.0178 million source Btu per dollar. For the GPRA effort, the lower, more conservative value was used for this analysis. During FY 2000, the percentage of SEP funds spent on incentives within the responding states was 21.7%; and the amount of leveraged funds received for incentives was $3.77 per dollar of funding. Based on the FY 2006 request, PNNL assumed that approximately $44.0 million dollars would be spent on loans and grants activities for an annual savings of about 0.001 TBtu. PNNL assumed that the savings would be in effect for 15 years.

Technical Assistance. Within Schweitzer et al, technical assistance calculations were based on the number of recommendations. For this effort, PNNL converted these two indicators to number of households and square feet of commercial floor space impacted.

The report provided a savings per recommendation of 9.0 MMBtu per household and 9.4% per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook*, approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 11% for residential space heating and cooling. PNNL applied the 9.4% savings to commercial space heating, space cooling, and lighting.

To convert the recommendation indicator into an estimated number of households, PNNL assumed that each residential recommendation represented one household. This yielded an estimate of approximately 18,000 households impacted by technical assistance in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was multiplied by two to approximate a national total. This yielded a total annual estimate of 36,000 households impacted, or 0.045% of existing residential single-family buildings, in each year.

To convert the recommendation indicator into an estimated commercial square footage, PNNL assumed that each commercial recommendation represented one building, and multiplied by the average building size assumed in the report (14,500 square feet). This yielded an estimate of approximately 0.009 billion square feet impacted by retrofits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a national total, yielding a total annual estimate of 0.017 billion square feet impacted, or 0.069% of existing commercial office, education, and health-care floor space, in each year.

1.1.3 Sources

(1) Schweitzer, M., D.W. Jones, L.G. Berry, and B.E. Tonn. 2003. *Estimating Energy and Cost Savings and Emissions Reductions for the State Energy Program Based on Enumeration Indicators Data*. ORNL/CON-487, Oak Ridge National Laboratory, Oak Ridge, TN

(2) *2003 Buildings Energy Databook*. http://www.buildingsdatabook.eren.doe.gov.

(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.

2.0 Weatherization Assistance Grants

2.1 Weatherization Assistance

2.1.1 Target Market

Project Description. The Weatherization Assistance Project provides cost-effective energy-efficiency services to low-income households who otherwise could not afford the investment but who would benefit significantly from the cost savings of energy-efficiency technologies. The project focuses on households that spend a disproportionate amount of their income for energy, giving priority to households with elderly members, persons with disabilities, and children.

Weatherization Assistance provides technical assistance and formula grants to State and local weatherization agencies throughout the United States. A network of approximately 970 local agencies provide trained crews to perform weatherization services for eligible low-income households in single-family homes, multifamily dwellings, and mobile homes. Of the homes weatherized annually, 49 percent are occupied by an elderly person with special needs or a person with disabilities. All homes receive a comprehensive energy audit, which is a computerized assessment of a home's energy use and an analysis of which energy conservation measures are best for the home and a combination of those energy-saving measures are installed.

Market Description. The market includes households that are eligible for Federal assistance. Households are categorized as eligible for federal assistance if the household income is below the federal maximum standard of 150% of the poverty line or 60% of Statewide median income, whichever is higher. Individual States can also set the standard at a lower level than the federal maximum.[a] Target measures include air sealing; caulking and weather stripping; furnace and boiler tune-up, repair, and replacement; cooling system tune-up and repair; replacement of windows and doors; addition of storm windows and doors; insulation of building shells; and replacement of air conditioners, whole-house fans, evaporative coolers, screening, and window films.(2) Weatherization *Plus* expands this strategy to include water heating, refrigeration, lighting, and cooling.(1)

Size of Market. About 34 million eligible low-income homes are included in the market.

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

2.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL employed the average household weatherization cost of $1,830(6); this estimate does not include training, technical assistance, and administrative costs. Incremental investment beyond this amount for Weatherization *Plus* homes, estimated at an average of $1,400 by the Weatherization project(6), was assumed by the Weatherization Assistance Program to be provided by leveraging funds from other organizations. **Table 2** shows the estimated total costs by region for *Plus* homes.

Table 2. Estimated Regional Costs for Weatherization *Plus* Homes

Region	Cost per *Plus* Household
South	$2861
Northeast	$3674
West	$1814
Midwest	$3429

2.1.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL'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). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)(7).

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a Eligibility requirements for Weatherization Assistance can be found at http://www.eere.energy.gov/weatherization/apply.html

Technical Characteristics. For the GPRA metrics, this project was characterized based on an estimated level of savings per household, cost to weatherize each household, budget request, leveraged funds, and an assumed life expectancy of 15 years for weatherization measures. The basic assumptions were derived from a spreadsheet provided by the Weatherization project in September 2001[6].

Table 3 shows the savings per household used for each region for the FY 2006 metrics.

Table 3. Savings Per Household for the Weatherization Assistance Project

Region	Regular Household Savings (MMBtu/yr)	*Plus* Household Savings (MMBtu/yr)
South	22.25	24.23
Northeast	31.20	46.04
West	19.04	20.31
Midwest	31.20	49.21

The figures in the table were calculated based on the 1997 ORNL meta-evaluation report,[2] the ORNL *Meeting the Challenge* report,[3] and special tabulations from the 1997 "Residential Energy Consumption Survey."[4]

Of the units weatherized in FY 2006, nearly 50% were assumed by the Weatherization Project[3] to have the higher savings rates associated with Weatherization *Plus*. In the *Meeting The Challenge* report,[3] these savings rates were calculated on a regional basis and multiplied by the expected number of *Plus* households in each region.

To develop energy savings by building type, PNNL evaluated historical Weatherization project data in the 1997 ORNL report[2] concerning the types of households weatherized (see **Table 4**).

Table 4. Percent of Weatherized Households by Type

Household Type	% of Weatherized Households
Single Family	64.0%
Mobile Home	20.0%
Multi Family	16.0%

To develop energy savings by fuel type, PNNL also used the historical primary fuel Weatherization project data in the 1997 ORNL report[2]. Because the GPRA metrics are reported for electricity, natural gas, and fuel oil (but not for LPG and kerosene), other fuels were allocated within those types based on similarities of emissions. **Table 5** shows the allocation approaches used.

Table 5. Percent of Weatherized Households by Fuel Type

Primary Heating Fuel	% of Weatherized Households	Categorized As
Natural Gas	50.6	Natural Gas
Liquid Propane Gas	13.2	
Fuel Oil	16.0	Fuel Oil
Kerosene	3.2	
Other (includes wood and coal)	7.5	
Electricity	9.5	Electricity

The Department of Energy (DOE) budget and leveraged funding forecasts were used to determine the number of households weatherized in each category (regular or *Plus*) for each of the four regions (South, Northeast, West, and Midwest) based on the weatherization costs per household and assumptions regarding the use of leveraged funds. **Table 6** shows the projection for regular and *Plus* households to be weatherized. PNNL assumed that the number of households weatherized for each category would be constant from 2011 through 2030.

Table 6. Projected Regular and *Plus* Households to be Weatherized

	2006	2007	2008	2009	2010	2011
Total Households	189,650	188,286	186,942	185,618	184,267	182,983
Regular South	19,059	18,907	18,758	18,610	18,460	18,318
Regular Northeast	22,694	22,524	22,355	22,189	22,020	21,860
Regular West	24,855	24,758	24,661	24,567	24,470	24,378
Regular Midwest	28,217	27,955	27,697	27,442	27,183	26,936
Plus South	19,059	18,907	18,758	18,610	18,460	18,318
Plus Northeast	22,694	22,524	22,355	22,189	22,020	21,860
Plus West	24,855	24,758	24,661	24,567	24,470	24,378
Plus Midwest	28,217	27,955	27,697	27,442	27,183	26,936

The number of households in each category was multiplied by the estimated savings level for each category. The estimated savings level for each household category was further divided by household type and then by fuel type. PNNL assumed that savings from each household weatherized would be in effect for 15 years; i.e., savings from households weatherized in 2006 were included in the annual total savings estimates for the years 2006 through 2020.

2.1.4 Sources

(1) *Weatherization Plus: Opportunities for the 21st Century, April 1999, Millennium Committee Strategy Report* accessed at http://www.eere.energy.gov/weatherization/pdfs/mcsr.pdf

(2) Berry, L.G., M.A. Brown, and L.F. Kinney. 1997. *Progress Report of the National Weatherization Assistance Program*, ORNL/CON-450, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(3) Schweitzer, M. and J.F. Eisenberg. 2000. *Meeting The Challenge: The Prospect of Achieving 30 Percent Energy Savings Through the Weatherization Assistance Program*. ORNL/CON 479, Draft Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(4) Eisenberg, J.F., Oak Ridge National Laboratory. 2001. Special tabulations for the Weatherization Population derived from the 1997 Residential Energy Consumption Survey.

(5) Brown, M.A., L.G. Bery, R.A. Balzer, and E. Faby. 1993. *National Impacts of the Weatherization Assistance Program in Single-Family and Small Multifamily Dwellings*. ORNL/CON-326, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
(6) Eisenberg, J.F., Oak Ridge National Laboratory. 2001. Projections for the Weatherization Assistance Program, provided to PNNL in file "Projections02d230.xls."
(7) 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 Gateway Deployment

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.

3.1 Rebuild America

3.1.1 Target Market

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.

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.

Market Size.(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, PNNL did not suggest any changes in technology improvements apart from the EIA baseline.

3.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.

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

- Cost of WIP Technology:[7] \$103.00/ ft^2 for new commercial and multifamily; \$3/ ft^2 (2006 to 2009), increasing to \$4/ ft^2 (2010 to 2030) for existing buildings.
- Incremental Cost: 2% above base for new buildings; \$3/ft^2 (2006 to 2009), increasing to \$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.

3.1.3 Methodology and Calculations

Inputs to Base Case. PNNL 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 2006 [1] and 25%/ft^2 by 2010 [3].

Expected Market Uptake. PNNL 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 7** are based on project goals of committing 2.24 billion square feet by 2010.

Table 7. Penetration Goals for Rebuild America [2,6]

Building Type*	Penetration Rate %			
	2006	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 2006) and existing (2006 and prior construction).

3.1.4 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.

3.2 Energy Efficiency Information and Outreach

3.2.1 Target Market

Project Description. Energy Efficiency Information and Outreach activities will result in packaged information on appropriate EERE technologies for key market segments, e.g., consumers, homeowners, and school officials.

Market Description. The targeted market segments are primarily existing residential and commercial buildings in all climate zones, with the emphasis in FY 2006 on the residential sector, of which there are approximately 100 million existing household units.(1)

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

3.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL assumed that the cost of outreach activities (the average price per household) would be $1,000, based on discussions with the program manager. The outreach program provides information to the residential sector that causes consumers to undertake conservation measures that amount to $1,000 that they are assumed to not spend otherwise.

3.2.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL'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 2002 (AEO 2002). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[3].

Technical Characteristics. Outreach activities were based on funded projects such as the Home Energy Saver Web site, where consumers can compare their home's energy use with that of an average home in their area and receive information about possible retrofits for their homes. PNNL assumed that consumers visiting such sites and acting on the information were already planning to perform some energy-efficient retrofits to their household, so PNNL assumed that the average incremental space conditioning and water-heating load reduction would be about 5% (e.g., the homeowner was initially interested in replacing the HVAC system, but when provided additional information about other cost-effective energy-saving measures, decided also to add more insulation to the home). Outreach activities were modeled as an incremental load reduction, above what the homeowner would have done in the absence of the information.

Expected Market Uptake. The penetration rate for Information Outreach Activities was developed using a diffusion model based on Fisher and Pry (1971)[2]. 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 Outreach Activities, k=0.004%, t_m=17, and Δt=20. These values were developed through trial and error to achieve the expected annual household impact in 2006 and in "out" years, based on discussions with the program manager. **Table 8** displays the resulting estimated number of homes impacted based on the penetration curve developed.

Table 8. FY 2006 Market Penetration for Information Outreach Projects

Year	Annual No. Homes – Outreach Activities
2006	11,383
2007	13,998
2008	17,184
2009	21,039
2010	25,684
2011	31,240
2012	37,828
2013	45,574
2014	54,573
2015	64,891
2016	76,550
2017	89,478
2018	103,546

Year	Annual No. Homes – Outreach Activities
2019	118,549
2020	134,175
2021	150,060
2022	165,814
2023	181,051
2024	195,428
2025	208,671
2026	220,620
2027	231,149
2028	240,205
2029	247,896
2030	254,283

3.2.4 Sources

(1) Discussions with Kyle Andrews, Project Manager, August/September 2003.
(2) Fisher, J.C., and R.H. Pry, (1971) "A Simple Substitution Model of Technological Change." Technological Forecasting and Social Change, 3, 75-88.
(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.

3.3 Building Codes Training and Assistance

3.3.1 Target Market

Project Description. Building Codes Training and Assistance will provide technical and financial assistance to States to update and implement their energy codes and train approximately 2,000 code officials, designers, and builders to implement these codes. The program will work with three-five pilot States, builder organizations, and financial institutions to provide a package combining builder training, Energy Star promotion, and financing for new and existing homes.

Market Description. The market includes new residential low-rise buildings three stories or less in height, new commercial and multifamily high-rise buildings, and all additions and renovations to buildings requiring code permits.

Size of Market. About 2 billion ft^2 of new commercial floor space is added each year. The Federal sector represents nearly 2.3% overall of new commercial building construction. Additionally, each year about 1.4 million residential building permits are issued, of which 1 million are for single-family dwellings. Although not all jurisdictions currently have energy efficiency building codes in place, about half of all new residential construction is conservatively estimated to come under building energy code requirements, based on information gathered from state and regional offices by the Building Codes Assistance Program (BCAP). Also, consumers spend approximately 45 billion dollars a year on remodeling and renovating projects in private residences, about half of which could potentially be covered by an energy code.[8] One market not covered by codes is manufactured homes, which fall under Housing and Urban Development (HUD) jurisdiction and regulations.

Baseline Technology Improvements. PNNL assumed that initial compliance with new codes was lower in the base case, i.e., without building energy codes than with the building energy codes project. Compliance in this context is measured as the percentage of potential savings from the existing code to the updated code. For FY06, the percentage of potential savings, in the first year of the single future code, was assumed by PNNL to be approximately 20% for envelope measures and 30% for lighting measures without the building energy codes project. Ten years after adoption, compliance rates are assumed to increase to 50% for envelope and 60% for lighting. The impact of these compliance percentages vary by state. Some states are assumed to update from the ASHRAE 90.1-1989 standard; others from the ASHRAE 90.1-1999 standard.

3.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental investment costs were developed assuming a five-year payback period on investment (i.e., an annual energy cost savings of $1 implies an initial investment of $5). These estimates were based on a series of benefit-cost studies that examined the energy savings and first-cost impacts of code improvements on seven building prototypes[b].

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

- Improved environment and more comfortable buildings.
- Fewer 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.

3.3.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. With respect to codes, it is indeterminate as to whether potential future code improvements are incorporated into the NEMS-GPRA06 base case. The NEMS-GPRA06 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 codes requirements, improvements in materials) is not specified by EIA. Codes that have been issued—but that have not gone into effect—may be included in the NEMS-GPRA06 base case, but would not be included in the GPRA forecast of savings for that activity, because it would no longer be funded. Only an estimate of potential future codes is included in the GPRA estimates. For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[7].

[b] Further information on the series of reports can be found at the Building Energy Codes website: http://www.energycodes.gov/implement/tech_assist_reports.stm.

Technical Characteristics: Commercial Buildings. Energy savings from this project result from some basic improvements in the overall energy efficiency of commercial buildings. The present funding for conducting research activities to establish the cost-effective levels of energy codes for new commercial and multifamily high-rise buildings is through the Commercial Buildings Integration subprogram within the Building Technologies (BT) Program. The WIP Building Codes Training and Assistance project funds the development of core materials (such as compliance tools and training materials) and provision of training and financial and technical assistance for states to update and implement their building energy codes. Benefits cannot be clearly allocated to either project; thus, the benefits estimated are a function of both training and deployment as well as development of the commercial building energy codes and standards, and the resultant benefits are then allocated between WIP and BT.

Savings estimates for commercial codes are based on increased compliance and accelerated adoption from the ASHRAE 90.1-2004 code and the "next" code assumed to be published in 2007. For FY06, PNNL assumed future codes (up through 2010) would achieve a potential reduction of 18% in electricity and a 10% reduction in natural gas, compared to 90.1-1999. The WIP-funded activities are assumed by PNNL to increase the initial compliance with these codes to approximately 70% for envelope requirements and 80% for lighting requirements. Adoption is accelerated in the range of five to 10 years, depending on the historical experience with building codes on each state. Barring future guidance from DOE, PNNL assumed that benefits for FY 2006 would be allocated based on the ratio of actual funding levels.

The project's impact is primarily through two avenues: 1) developing and supporting code changes to improve the minimum energy efficiency requirements for commercial and multifamily high-rise buildings and 2) providing technical and financial assistance to states to update and implement their building energy codes. The latter includes developing tools that can ease the adoption of new codes and, through their use, can support improvements in compliance and enforcement of code provisions. Tools take the form of code-compliance software, computer-based training tools for building energy codes, and tools for implementing noncomputer-based codes.

Improvements to building codes are primarily supported by research efforts to review existing codes (conducted by the Building Technologies Program) and specific targeted areas of building energy use and the adoption of code modifications that promote cost-effective reductions in these energy-use areas. Support 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 2006 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2002 editions of ASHRAE 90.1-1999(4) standard (to comply with Section 304 of the Energy Conservation and Production Act), and 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 (e.g., IECC 2003) 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 principal differences among the ASHRAE 90.1-1989, 90.1-1999, and 90.1-2002(5) standards relate to requirements for better windows, reduced installed wattage for lighting, and more efficient heating and cooling equipment. The savings from improved equipment are not included in the project's savings estimates, because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Based on a series of simulations that include various U.S. locations, and that were developed specifically to evaluate the two ASHRAE standards (often referred to as the "determination" study[6]), the average reduction in site energy use was estimated to be about 3.5% or 2 MMBtu/sq ft. The GPRA estimates were partly based on states' accelerated adoption schedule of the ASHRAE 90.1-1999 and 90.1-2002 standards. Through the efforts of the Building Energy Codes project, 35 states were assumed by PNNL to have adopted the standard by the end of 2005. PNNL assumed that the project would accelerate the adoption of the standard by an average of four years nationwide.

The ongoing activities of the ASHRAE 90.1 committee were assumed by PNNL to lead to more stringent commercial-building standards in the future. PNNL assumed that DOE would 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, assumed by PNNL to become available in the latter part of the current decade. PNNL assumed that the overall result of these upgrades is to reduce electricity consumption by 10% and natural gas consumption by 2% in new commercial buildings. Successful state adoption of this standard by 2010 also depends on the project's continuing activities to assist states in the adoption (and compliance) process. Without these activities, PNNL assumed that the same standard would be adopted, on average, six years later.

PNNL assumed that the project activities would improve compliance rates for codes currently adopted by states and localities, as well as future building codes. Compliance is increased through increased familiarity with the codes over time, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for the existing code (a code based on ASHRAE 90.1-1999) and a future standard as discussed above. On a national average basis, compliance with existing codes was estimated at 60% in 2000, increasing to 66% without the project and 79% by 2010 with the project.

The compliance with several key provisions in ASHRAE 90.1-2001 (compared with 90.1-1999) was expected to be higher from the outset. On average, PNNL estimated the compliance to be 65% in the year of the adoption. Ten years later, compliance rates were assumed by PNNL to increase to 67% without the project and 72% with the project. For buildings that do not comply with the standard, only half of the incremental energy savings were assumed by PNNL to be achieved by adopting the ASHRAE 90.1-2001 standard.

PNNL assumed that the simplifications in the ASHRAE 90.1-1999 and 90.1-2001 standards will be extended to the new standard and will result in somewhat higher compliance when states first adopt them. PNNL assumed that initial compliance to be about 27% at the time of adoption, increasing to 31% without the project and 73% with the project after the first 10 years. The energy savings in buildings that do not comply with the new standards were assumed by PNNL to be 65% of that in buildings that comply fully with the code.

Expected Market Uptake: Commercial Buildings. As part of work for an internal analysis of the historical impacts of the Building Codes project in August 2003, the assumptions regarding the acceleration effect of the program were modified (e.g., program activities leading to states adopting codes more rapidly than they would have otherwise). In general, the states were classified into groups that: 1) immediately adopted the ASHRAE 90.1-1989 code, 2) would have adopted within five years without the project, or 3) would have adopted within 10 years without the project. These time periods were then reduced by one year for each successive code after the 1989 code. (Thus, for example, a five-year lag for 90.1-1989 is assumed to fall to three years for the forthcoming ASHRAE 90.1-2004 code). The overall impact of this change was to increase the average lag between the publication of a new standard and when it is adopted—without the Building Codes project. This modified set of assumptions increases the overall estimate of the future energy savings impact from the program.

Technical Characteristics: Residential Buildings. The FY 2006 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 2001 and 2003 editions of the International Energy Conservation Code (IECC) code (to comply with Section 304 of the Energy Conservation and Production Act), and 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 2003) with variations in climate by states and differences among states in their adoption and enforcement of building codes. This discussion uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology.

The principal difference between the 1995 Model Energy Code and the IECC 2001 involves the solar heat gain requirements for windows and increased thermal resistance requirements for ducts in unconditioned spaces. Based on a series of simulations for various U.S. locations, the percentage reduction in cooling load was estimated to be about 15%. This requirement increases the heating load by a small amount, about 2% nationally. (The requirement itself is restricted to the southern tier of states). The GPRA estimates were partly based on states' accelerated schedule of adoption of the IECC 2001 and 2003 codes. Through the efforts of the Building Energy Codes project, 31 states were assumed by PNNL to have adopted the standard by the end of 2005. PNNL assumed that the project would accelerate the adoption of the standard by an average of four years nationwide.

PNNL assumed that the IECC's ongoing activities would lead to more stringent residential standards in the future. PNNL assumed that DOE would 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, assumed to become available in the latter part of the current decade. Based on discussions with BT staff, PNNL assumed that the results of these upgrades were to reduce heating and cooling loads in new residential structures by 10%. Without these activities, PNNL assumed that the same standard would be adopted, on average, six years later.

Expected Market Uptake: Residential Buildings. PNNL also assumed the project's activities would improve compliance rates for codes currently adopted by states and localities as well as future building codes. Compliance increases through increased familiarity with the codes, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for various standards as discussed above. As a national average, compliance with existing codes was estimated at 45% in 2003, increasing to 49% without the project and 72% by 2010 with the project.

The compliance with several key provisions in the IECC 2000 and 2003 (compared with the 1995 Model Energy Code) was expected to be higher from the outset. On average, the compliance was estimated to be 68% in the year of the adoption. By 2010, PNNL assumed that compliance rates would increase to 69% without the project and 74% with the project. For homes that do not comply with the standard, only half of the incremental energy savings were assumed by PNNL to be achieved by adopting IECC 2001 or 2003.

PNNL assumed that when states first adopt the new standard, assumed to become available in the 2006-2007 time frame, the standard's greater stringency will result in somewhat lower compliance. PNNL assumed initial compliance to be about 30% at the time of adoption, increasing to 31% without the project and 73% with the project after the first 10 years. For IECC 2001 and 2003, the energy savings in units that do not comply were assumed to be 50% of that in units that comply fully with the code.

3.3.4 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.
(5) ASHRAE/IES Standard 90.1-2002, "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
(7) 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.
(8) U.S. Census Bureau (Census). 2000. "1997 Economic Census Construction Geographic Area Series." U.S. Department of Commerce, March 2000. Washington D.C. Located at the following website: http://www.census.gov/epcd/www/97EC23.HTM

3.4 Energy Star Program

3.4.1 General Target Market

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.

- **Market Description.** The market is determined by the project equipment. For FY 2006, the following residential equipment is characterized:Clothes washers
- Refrigerators
- Room air conditioners
- Dishwashers
- Compact Fluorescent Lamps (CFLs)
- Windows
- Home Performance

Baseline Technology Improvements. For this analysis, PNNL did not suggest any changes in technology improvements.

3.4.2 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.

3.4.3 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[c], 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.

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. PNNL 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.

3.4.4 Clothes Washers

3.4.4.1 Target Market

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

3.4.4.2 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.

[c] 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 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. In preliminary model runs, the values associated with clothes washers appeared to be too low compared with the information supplied by Lawrence Berkeley National Laboratory (LBNL) in support of an efficiency standard for clothes washers. Therefore, these factors were adjusted from 0.67 to 2.00 for vertical-axis machines. The coefficient for the horizontal-axis machine was increased from 0.24 to 0.40. The value for the vertical axis machine was estimated by making runs of the model with and without *any* hot water and observing the resulting energy consumption. The LBNL analysis (3) suggests that 80% to 90% of the energy consumption of clothes washers is attributable to water heating. **Table 9** shows the original and revised NEMS-PNNL inputs for clothes washers.

Table 9. Original NEMS and Revised NEMS-PNNL Inputs for Energy Star Clothes Washers

Technology	Start Yr	End Yr	Water Coeff.	Energy Factor	Installed Cost ($)	Type
Original NEMS Inputs						
1	1997	2020	0.67	2.71	90	V-Axis
2	1997	2004	0.67	3.88	645	V-Axis
3	2005	2020	0.67	3.88	590	V-Axis
4	1997	2020	0.24	4.45	800	H-Axis
5	2005	2020	0.24	5.27	800	H-Axis
6	2015	2020	0.24	5.44	800	H-Axis
NEMS-PNNL Inputs						
1	1997	2020	2.0	2.71	490	V-Axis
2	1997	2004	2.0	3.88	645	V-Axis
3	2005	2020	2.0	3.88	590	V-Axis
4	1997	2020	0.4	4.45	800	H-Axis
5	2005	2020	0.4	5.27	800	H-Axis
6	2015	2020	0.4	5.44	800	H-Axis

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. **Table 10** shows the market share results of the NEMS-PNNL model runs for clothes washers.

Table 10. Energy Star Clothes Washer Market Shares by Technology Estimated by NEMS-PNNL

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0000	0.0927	0.0000	0.0923
2	0.0000	0.0904	0.0000	0.0900
3	0.0000	0.0814	0.0000	0.0804
4	0.0000	0.0794	0.0000	0.0794
5	0.0000	0.0813	0.0000	0.0812

6	0.0000	0.0799	0.0000	0.0797
7	0.0000	0.0801	0.0000	0.0791
8	0.0000	0.0831	0.0000	0.0833
9	0.0000	0.0826	0.0000	0.0830
Note: Results shown are for new housing units; replacement shares are generally within 0.5 % of values shown here.				

3.4.5 Refrigerators

3.4.5.1 Target Market

Market Description. This project targets new refrigerator sales.

3.4.5.2 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. The market share of the through-the-door model is a constant 27% over the forecast horizon. A review of Arthur D. Little's[(4)] (ADL 1998) efficiency and cost forecasts, as well as a recent paper from Oak Ridge National Laboratory[(5)] (ORNL, Vineyard and Sand 1998), suggests some changes to EIA's assumptions used in the *Annual Energy Outlook 2001*[(2)] projection are warranted.

As part of the EIA forecast, the 2001 standard (Model 1) was assumed to yield no increase in cost. **Table 11** shows the EIA efficiency and cost assumptions, which appear to contradict some of the ADL findings.

Table 11. Refrigerator Efficiency and Costs: *Annual Energy Outlook 2001*

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)	Modified NEMS-PNNL Inputs	
						Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0	530.0	480.0
1	2002	2020	478	530.0	480.0	580.0	480.0
2	1997	2001	660	550.0	500.0	550.0	500.0
2	2002	2020	460	550.0	500.0	600.0	550.0
3	1993	2001	518	850.0	800.0	850.0	800.0
3	2002	2020	460	550.0	500.0	600.0	550.0
3	2005	2020	400	700.0	650.0	700.0	650.0
4	1993	2001	843	1313.8	1313.8	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8	1313.8	1313.8

The ADL performance/cost characteristics information suggests that a 460-kWh/yr unit would have an installed cost of $580 to $700. To be conservative, an installation cost of $600 could be assumed. Because a 478-kWh/yr unit is nearly as efficient as the 460-kWh/yr unit, one would expect it would be only negligibly less expensive. Using this logic, the cost of the 478-kWh/yr unit is assumed to be ~$580. These revised assumptions are included in the shaded columns in the table below.

The ADL report(4) suggests that a 460-kWh/yr model represents a typical model after 2002. A high-efficiency model is specified to consume 400 kWh per year. However, this specification is for a 20-cubic-foot model rather than 18 cubic feet. ADL suggests a cost differential of $100 to $120 between these two models.

Vineyard and Sand (1998)(5) add some support to this revision in the cost structure. They start with a "1996 model baseline unit" of 20 cubic feet, which uses 613 kWh/year. The baseline is already 16% more efficient than the 1993 standard (2.01 kWh/day) resulting from the National Appliance Energy Conservation Act.(6) From this baseline, they focus on two high-efficiency designs. The most aggressive design would reduce energy by 273 kWh/yr at a retail cost increase of nearly $270. A more cost-effective unit would consume 1.16 kWh/day (423 kWh/yr) at a projected cost increase of $106.

Based on this information, the resulting estimated cost increase of $100 between the 460- and 400-kWh/day units appears to be more reasonable (see Table B-8.4 of the ADL report) than EIA's incremental cost of $150. The ORNL baseline unit is less efficient than the 2001 standard and achieves a 30% energy reduction with a little more than a $100 cost increase. This suggests that the 13% efficiency improvement (460 kWh/day to 400 kWh/day) between models 2 and 3 could be achieved for $100 or less.

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

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

PNNL assumed the Energy Star project would increase the market share of the 400-kWh/yr refrigerator. With original EIA inputs for refrigerators, sales of the Energy Star unit are only about 3,000 per year. The baseline unit's efficiency was changed to 510 kWh/year. The most efficient model's cost and efficiency were changed as following discussions with EIA's John Cymbalsky about the new inputs to the NEMS model from Navigant. After baseline change, sales of the Energy Star unit were over 30,000 in the reference case with no change in parameters reflecting the discount rate.

In previous years, the beta2 parameter in rtekty was changed to -0.0055 to model this program. Given the choices described above, this value yielded the fraction of total sales that met Energy Star requirements in the range of 19%. For FY06, PNNL changed the parameter to -0040. This yields an Energy Star fraction in the range of 24 to 25%, which is somewhat lower than the estimated share of 28% in 2003. However, the Energy Star unit provided by Navigant is more efficient than the Energy Star criteria (more than 20% lower than the baseline, rather than the required 15%). As a result, the 25% share more accurately reflects the actual energy saving from the project. With the support of the Energy Star project, the parameters impacting market share were assumed by PNNL to change in the following manner, based on project goals:

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

3.4.6 Room Air Conditioners

3.4.6.1 Target Market

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

3.4.6.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. For 2005, EIA assumes 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. In the *Annual Energy Outlook 2001*(2) input file for the residential NEMS module, two models were at the low end of this range (COP = 2.83, COP = 2.93), while two models were at the high end of the range (COP = 3.22, COP = 3.43). To achieve a more realistic set of choices, a model with an intermediate efficiency of 3.11 was added and the unit at the 2.93 (COP) level was dropped. The increase in cost to go from a COP of 2.83 to 2.93 was assumed to be $30. **Table 12** shows both the original NEMS input data and the revised NEMS-PNNL data.

Table 12. NEMS-PNNL Input Parameters for Room Air Conditioners

Technology	Start Year	End Year	Seasonal COP	SEER*	Installed Cost
***Annual Energy Outlook 2001* and GPRA Baseline**					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	2.93	10.00	$500
4	2005	2020	2.93	10.00	$490
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.43	11.71	$760
7	2015	2020	3.22	10.99	$600
Revised NEMS-PNNL Inputs					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	3.11	10.61	$530
4	2005	2020	3.11	10.61	$520
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.52	12.01	$760
7	2015	2020	3.22	10.99	$600
*SEER – seasonal energy efficiency ratio.					

The high-efficiency units with a COP >3.4 were assumed by PNNL to fall under the Energy Star project. In the base case, the combined market share for the units with COPs of 3.43 and 3.52 were less than 1%. The split in market share between the lowest and intermediate efficiency unit (COP = 2.83 and 3.11, respectively) was generally about 75%/25% in favor of the lowest-efficiency model.

Expected Market Uptake. The *Annual Energy Outlook 2001*(2) 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:

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

Table 13 shows the specific NEMS-PNNL market share results for the high-efficiency model.

Table 13. NEMS-PNNL Results for Energy Star Room Air Conditioners (national market shares for new, single-family homes)

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0083	0.1301	0.0083	0.1299
2	0.0085	0.1323	0.0085	0.1321
3	0.0085	0.1319	0.0084	0.1314
4	0.0084	0.1314	0.0084	0.1312
5	0.0091	0.1396	0.0091	0.1395
6	0.0091	0.1402	0.0091	0.1398
7	0.0101	0.1522	0.0099	0.1501
8	0.0085	0.1327	0.0085	0.1327
9	0.0084	0.1314	0.0084	0.1317

3.4.7 Dishwashers

3.4.7.1 Target Market

Market Description. This project targets sales of new dishwashers.

3.4.7.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. The NEMS baseline (*Annual Energy Outlook 2001*)(2) data input for 2005 shows three dishwashers, with energy factors 0.46, 0.59, and 0.71. **Table 14** shows the associated costs of these units. Given the cost structure and logit choice parameters, the model suggests that consumers select slightly more than 6% of dishwashers with the 0.59 energy factor and virtually none of the very high=efficiency units.

Table 14. Key NEMS Data Inputs for Dishwashers

Census Division	Initial Yr	Ending Yr	Water Co-Efficiency	Energy Factor	Installed Cost ($)
1	1997	2020	0.80	0.46	350
2	1997	2004	0.80	0.59	500
3	2005	2020	0.80	0.59	450
4	1997	2004	0.78	0.71	700
5	2005	2014	0.78	0.71	600
6	2015	2020	0.78	0.71	500
7	2015	2020	0.80	0.60	400

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

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

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:

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

Table 15 shows the specific NEMS-PNNL market share results for the two high-efficiency models.

Table 15. NEMS-PNNL Results for Energy Star Project Dishwashers (estimated market shares for high-efficiency dishwashers)

Census Division	2005				2010			
	Baseline		Energy Star		Baseline		Energy Star	
	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71
1	0.0683	0.0012	0.2219	0.0322	0.0682	0.0012	0.2217	0.0321
2	0.0678	0.0012	0.2207	0.0318	0.0677	0.0012	0.2204	0.0317
3	0.0659	0.0011	0.2157	0.0305	0.0656	0.0011	0.2151	0.0304
4	0.0654	0.0011	0.2146	0.0302	0.0654	0.0011	0.2145	0.0304
5	0.0658	0.0011	0.2156	0.0305	0.0654	0.0011	0.2145	0.0304
6	0.0655	0.0011	0.2148	0.0303	0.0658	0.0011	0.2156	0.0305
7	0.0656	0.0011	0.2150	0.0303	0.0653	0.0011	0.2144	0.0302
8	0.0662	0.0011	0.2166	0.0308	0.0663	0.0012	0.2168	0.0308
9	0.0661	0.0011	0.2164	0.0307	0.0663	0.0012	0.2169	0.0308

EF – energy factor.

3.4.8 Energy Star CFLs

3.4.8.1 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). Analysis of Energy Star CFLs was based on the program's stated goal of converting 20% of the residential incandescent installed based to high-quality, high-efficiency, Energy Star CFLs.

3.4.8.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL assumed that the cost of the conventional incandescent technology is $0.75. The cost of the Energy Star CFL is assumed by PNNL to decrease over the study period from approximately $5 per CFL in 2004 to $3 per CFL in 2030.

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.

3.4.8.3 Methodology and Calculations

Technical Characteristics. Energy Star-qualified CFLs have the efficacies[7] shown in **Table 16.**

Table 16. Compact Fluorescent Lamp Efficacies

Lamp Power (Watts) & Configuration	Minimum Efficacy: Lumens/watt (Based upon initial lumen data)
Bare Lamp:	
Lamp power < 15	45
Lamp power >= 15	60
Covered lamp (no reflector):	
Lamp power <15	40
15 >= lamp power < 19	48
19 >= lamp power < 25	50
Lamp power <= 25	55
Reflector Lamp:	
Lamp power < 20	33
Lamp power >= 20	40

Modeling is based on the bare lamp, because reflector lamps represent only about 6% of the shipments of large incandescent lamps, and covered lamps are only a small fraction of the total CFL market. CFLs of 15W and greater can replace incandescent lamps at 75W and above, and were assumed by PNNL to have an efficacy of 60 lumens/watt. Less than 15W CFLs can replace incandescent of less than 75W and were assumed to have an efficacy of 45 lumens/watt. About 58% of incandescent lamps in homes have wattages less than 75W and 42% of incandescent lamps in homes have wattages 75W and greater[(8)]. The resultant weighted average lumens/watt for Energy Star CFLs is 51.3 lumens/watt.

Expected Market Uptake. PNNL assumed that by 2020, in the residential sector, Energy Star CFLs would capture 6.16% of non-can and non-R-lamp incandescent sales (i.e., sales for non-can and non-R-lamp Edison sockets that would not have otherwise converted to CFLs). The 6.16% is based on a market penetration goal of capturing 20% of the installed base. Energy Star CFLs were assumed by PNNL to penetrate both the high-use part of the market, where 76.4% of the residential lighting energy is consumed (e.g., rooms such as kitchens and living rooms), and the low-use part of the market. PNNL assumed that Energy Star CFLs would be put in high-use applications 70% of the time. The sockets in high-use areas (28.4% of the total sockets) will consume roughly the same number of the lamps as the low-use sockets. A sales fraction of 6.16% will yield a long-term installed base of 20% of all sockets with 70% of the Energy Star CFLs in high-use sockets and 30% in low-use sockets; the 20% of sockets that convert to Energy Star CFLs would be A-line incandescents without the Energy Star program. Penetration curves were developed based on market diffusion curves developed by PNNL and documented by PNNL[(10)] (see **Figure 1**)[d].

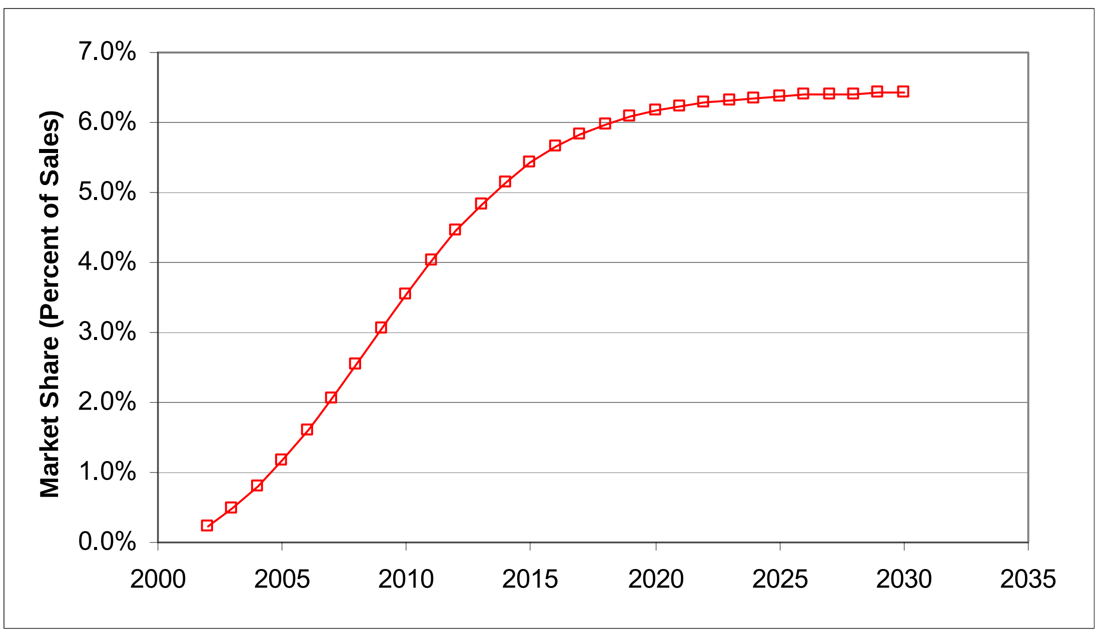

Figure 1. Actual Energy Star CFLs Market Penetration Curve – Percent of Sales to Non-Can, Non-R-Lamp, Incandescents

[d] The Energy Star CFLs are assumed to compete only against incandescents (not all Edison sockets). Hence, given that 4.0% of the Edison sockets are already CFLs by 2005 and that it is expected that by 2020 this will increase to 11% without Energy Star, the penetration against incandescents only is somewhat higher than the penetration against all Edison sockets. This curve compensates for the declining incandescent share of the Edison socket market such that the 20% (of all non-can and non-R-lamp Edison sockets that would not have otherwise converted to CFLs) installed base can be achieved.

3.4.9 Windows

3.4.9.1 Target Market

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

3.4.9.2 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 17**.

Table 17. 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 18**.

Table 18. 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 19**).

Table 19. 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 PNNL assumed that the DOE project would accelerate market acceptance by 10 years. The penetration rates are shown in **Figures 2 and 3**. For Low-e Market Acceptance/ Energy Star Windows, PNNL assumed that these projects would accelerate the acceptance of this technology in the marketplace by 10 years.

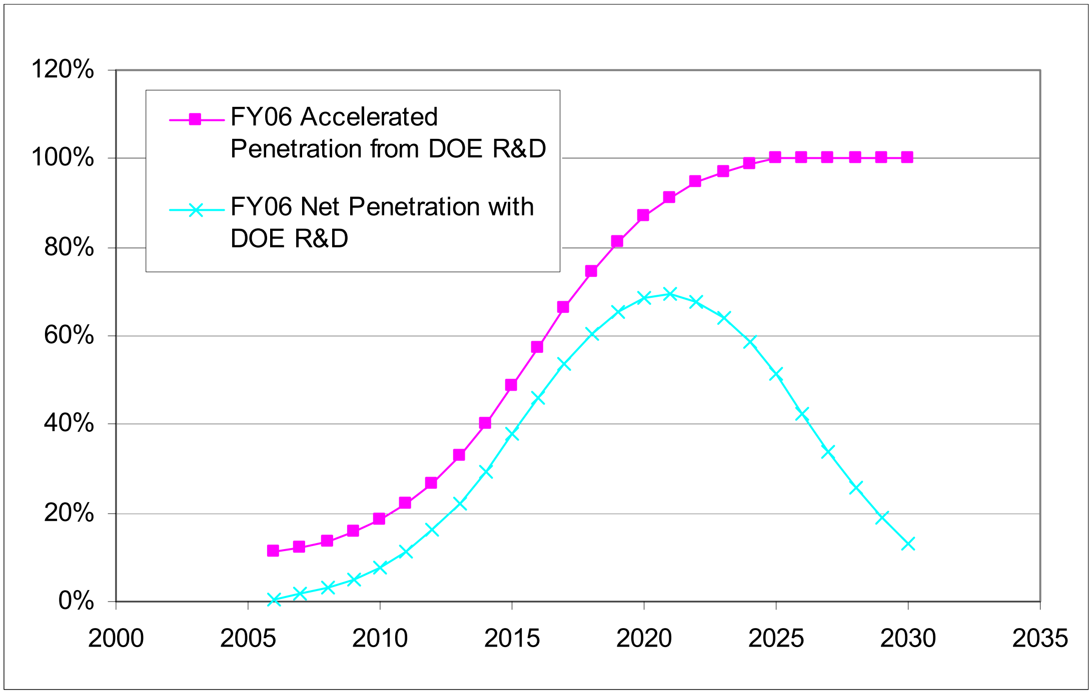

Figure 2. FY06 Low-e Windows – Commercial Buildings Percent of Sales

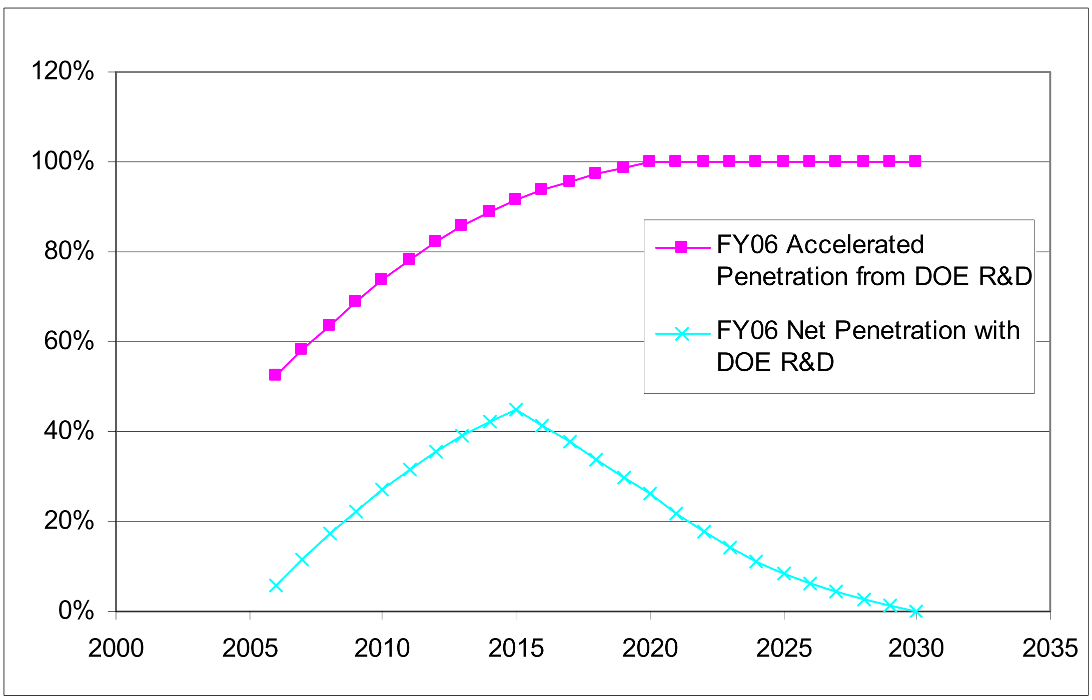

Figure 3. FY06 Low-e Windows – Residential Buildings Percent of Sales

3.4.10 Energy Star Home Performance

3.4.10.1 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.

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

3.4.10.2 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL'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). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[(10)].

Technical Characteristics. PNNL 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, PNNL 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 2006 and in "out" years, based on discussions with the program manager. **Table 20** displays the resulting estimated number of homes impacted based on the penetration curve developed.

Table 20. FY 2006 Market Penetration for Energy Star Home Performance

Year	Annual No. Homes
2006	569
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

PNNL assumed that the Energy Star Home Performance activity 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.

3.4.11 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.

3.5 Clean Cities

3.5.1 Target Market

Project Description. Clean Cities supports public-private partnerships that advance vehicle technologies and practices to reduce petroleum use in the transportation sector. Clean Cities works with local businesses and governments to guide them through the process, including goal setting, coalition building, and securing commitments.

Market Segment. Clean Cities seeks to reduce petroleum use in the transportation sector by:

1. Displacing current conventional gasoline and diesel vehicles and fuels with alternative-fuel vehicles, fuels, and infrastructure, as well as advanced vehicle technologies;
2. Increasing the use of fuel blends, such as ethanol and biodiesel;
3. Enhancing the acceptance of fuel-efficient vehicles and fuel economy practices;
4. Increasing market penetration of hybrid vehicles; and
5. Promoting the use of idle reduction technologies in heavy-duty vehicles.

Thus, Clean Cities targets on-road vehicles that use petroleum fuels, as well as off-road vehicles in select niches.

Market Size. The total conventional light-vehicle stock is 211 million[e]. Of the total stock, 15.7 million are fleet vehicles, including Commercial 2B trucks[f]. The Clean Cities Program works largely with fleet managers and buyers, rather than targeting all private consumers, because of the challenges of reaching out to the general public. The market for the Clean Cities Program also includes heavy-duty vehicles, such as trucks and buses.

Base Case Growth: For purposes of an estimate of the number of AFVs attributable to Clean Cities, exogenous to NEMS-GPRA06 modeling, this analysis assumed the activity in the alternative-fuel vehicle market to be very low - in the absence of the Clean Cities AFVs would grow at 1% per year. This assumption was developed in GPRA2005 based on expert judgment in consultation with Clean Cities DOE staff, Clean Cities lab analysts, and the Office of Planning,

[e] AEO 2004, Supplemental Table 46
[f] AEO 2004, Supplemental Table 52; includes only conventional vehicles; table is ambiguous as to whether commercial 2B trucks are included in the light truck section or should be added, as they are to calculate this number

Budget, and Analysis (PBA), and was not changed in GPRA2006. In the presence of the Clean Cities Program, Clean Cities DOE staff and Clean Cities lab analysts assumed that the number of AFVs would grow at 5% per year in Clean Cities and used in GPRA06 the same GPRA2005 assumption of 2.9% per year in non-Clean Cities, developed by Clean Cities DOE staff, Clean Cities lab analysts, and the Office of Planning, Budget, and Analysis (PBA). The resulting difference in AFV numbers was used as an input to NEMS-GPRA06. The NEMS-GPRA06 base case growth was not changed.

Consistency with EERE Baseline. The EERE baseline was used for Clean Cities NEMS-GPRA06 modeling. The exogenous calculations to determine a number of vehicles attributable to the Clean Cities program use a different baseline. For purposes of calculating the number of AFVs attributable to Clean Cities, an AFV growth rate of 1% was assumed to occur in the absence of a Clean Cities program. This assumption was developed in GPRA2005 based on expert judgment in consultation with Clean Cities DOE staff, Clean Cities lab analysts, and the Office of Planning, Budget, and Analysis (PBA), and was not changed in GPRA2006. This assumption may be compared with the regulatory requirement of EPAct, and with historical growth rates in areas that lack Clean Cities programs. DOE has estimated that the EPAct regulatory requirement results in purchases of approximately 30,000 AFVs per year[g], or about 0.2% of light-duty vehicle sales. However, AEO2004 shows a 10.7% growth in light-duty AFVs stock between 2002 and 2025. This high level of AFVs in AEO2003 is driven in part by EPAct regulatory targets that may be higher than expected market performance. Revising this baseline was considered for GPRA FY06, but was not performed because a proposed alternative baseline was not identified. According to the EIA data used for GPRA FY06, non-Clean Cities showed a 2.7% growth rate in numbers of AFVs between 1992 and 2001, so a baseline less than that value is a logical assumption.

Baseline Technology Improvements. No changes in technology improvements were attributed to Clean Cities for this analysis. Transportation technology changes were assumed by the PBA and the GPRA modeling team to occur outside of Clean Cities, as part of modeling of the Transportation Technologies R&D, so integrated modeling runs take into account both those technology changes and the deployment activities of Clean Cities.

Baseline Market Acceptance. The literature on consumer choice of vehicle technologies has not been reviewed for this project. DOE has developed a variety of detailed models of consumer choice of vehicles. These models include factors such as cost, performance, fuel availability, and other attributes of vehicles that are generally disadvantageous to AFVs. They are not useful for assessing market penetration of technologies whose advantages are primarily environmental, macroeconomic, and national security, such as AFVs. Data such as consumer discount rates have been reported in that literature with regard to vehicle technologies and fuel savings, although there is less specific research on AFVs. For purposes of the Clean Cities baseline market acceptance, no changes were recommended to the NEMS-GPRA06 baseline to reflect these market-acceptance issues. For purposes of calculating the number of AFV sales

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[g] U.S. Department of Energy (2001). "EPAct Fleet Information and Regulations Fact Sheet," DOE/GO-102001-1306, April 2001. Accessed at www.ott.doe.gov/ott/pdf/what_is_epact.pdf. DOE estimates that the EPAct regulatory requirement cause purchases of 20,000-25,000 AFVs per year, according to FR Vol 68, No 42, March 4, 2003, page 10326, "Office of Energy Efficiency and Renewable Energy; Alternative Fuel Transportation Program; Private and Local Government Fleet Determination: Notice of Proposed Rulemaking" Accessed online at www.afdc.doe.gov/pdfs/fr_notice_nopr.pdf.

attributable to Clean Cities, Clean Cities DOE staff, Clean Cities lab analysts, and the Office of Planning, Budget, and Analysis (PBA) assumed that the number of AFVs would increase by 1% per year in the absence of the program, as noted above.

3.5.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. AFVs are assumed in the baseline to cost more than equivalent conventional vehicles throughout the forecast period. Using AEO 2004 estimates, typical price increments for light-duty vehicles are typically $1,000 or less for E85 vehicles, $6,000 - $7,000 for dedicated CNG vehicles, and $6,000-$6,000 for dedicated LPG vehicles. Break-even points vary depending on vehicle, fuel, duty cycle, subsidies, and discount rate. Break-even timing is highly sensitive to fuel-input price. Incremental costs of heavy-duty vehicle technologies were not identified in AEO 2004 data tables. For buses, one source suggests typical incremental vehicle costs of about $20,000-$40,000[h]. Per-mile relative vehicle costs have also been estimated in some studies, and these are highly sensitive to fuel cost and other assumptions.

Key Consumer Preferences/Values. Vehicle-purchase decisions depend on a large number of preferences and values. Many of these are represented in the Transportation Sector Model of NEMS[i]. Some AFV features that may be especially important include:

1. Emissions performance.
2. Type or origin of fuel.
3. Vehicle performance and reliability.
4. Ease and safety of fueling.
5. Ease of maintenance.
6. Regulatory requirements on purchaser.

Of these, consumer preference for emissions performance and fuel origin do not appear to be included in the Transportation Sector Model as consumer values, but are included as regulatory effects on vehicle sales.

Clean Cities lab analysts and the OnLocation modeling team assumed that consumer preference for fuel type would change as a result of Clean Cities activities in NEMS-GPRA06. In the NEMS reference forecast, only a small fraction of E85 capable vehicles use E85 as the fuel (most use gasoline) in the flex-fuel vehicles. One Clean Cities activity is to promote the use of E85 use in the capable vehicles, and NEMS-GPRA06 reflects these activities by assuming that more vehicles use E85, and each vehicle using E85 uses more of it.

Manufacturing factors. Manufacturer decisions strongly influence availability of AFVs, and depend on factors such as:

1. Anticipated market size, influenced by extent of fueling infrastructure.
2. Expected vehicle price.
3. Estimated manufacturing costs.

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[h] General Accounting Office (1999). Mass Transit: Use of Alternative Fuels in Transit Buses. GAO/RCED-00-18. December 1999.

[i] U.S. DOE (2003). "The Transportation Sector Model of the National Energy Modeling System: Model Documentation Report." DOE/EIA-M070(2003). Accessed online at www.eia.doe.gov.

4. Maintenance and warranty issues for manufacturer.
5. Availability of competing investment opportunities.
6. Regulatory requirements on manufacturer.

Some manufacturing factors are included in NEMS, though not at this level of detail. None of these factors were explicitly considered in developing the estimates of vehicle sales attributable to Clean Cities. In addition to vehicle price, NEMS uses maintenance costs, fuel costs, luggage space, fuel economy, range, acceleration, etc. as vehicle attributes in which consumers are interested.

Policy factors. Policy factors are a significant consideration that influences AFV markets, including:

1. EPAct (1992) AFV purchase requirements.
2. EPA vehicle-emissions requirements.
3. Ethanol tax incentives.
4. AFV purchase incentives/rebates.

3.5.3 Methodology and Calculations

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

Technical Characteristics. The technical characteristics of alternative fuels and vehicles were not changed.

Expected Market Uptake. In the AEO base case, AFV market penetration is calculated based on the Transportation Sector Model. In the Clean Cities case for FY06 GPRA, Clean Cities lab analysts and the OnLocation modeling team assumed that additional AFVs attributable to Clean Cities would replace conventional vehicles, and this revised vehicle population was modeled. This method was unchanged compared to FY05, when it was developed in consultation with Clean Cities DOE staff and PBA. The calculation of additional AFVs attributed to Clean Cities is based on historical experience with the effect of Clean Cities on AFV markets, and also on a survey of Clean Cities coordinators to establish their expectations about future program effects.[j] The historical record shows that Clean Cities has been able to achieve growth in the population of AFVs in any given urban area of roughly 5%-18%, while areas not under the Clean Cities program achieved 2.9% growth. In a survey, Clean Cities coordinators estimated anticipated market growth at about 8%.

For GPRA FY06, the analytic team assumed, as described above, that a Clean Cities program would result in a 5% growth rate in AFVs in Clean Cities (starting in 2004) and a 2.9% growth rate (the historic growth rate for 1992-2001) in AFVs in non-Clean Cities (starting in 2003). Five percent for Clean Cities was selected because it is within the historical range and aligns with the reduced program funding assumptions for GPRA06. The non-Clean Cities growth rate extends the historical rate. NREL assumed that if the program had never existed, AFVs would

[j] Personal Communication, Elyse Steiner, formerly of NREL, January 29, 2004, describing survey by QSS.

have experienced a 1% growth rate starting from 1995. In effect, this assumes that the Clean Cities program began to have an influence on non-Clean Cities growth starting in 1996. This is based on the idea that some of the historical growth in non-Clean Cities may be attributed to Clean Cities, because of the program's impact on the broader market. The difference in number of vehicles between these two cases was used to calculate Clean Cities attributable vehicle stock and annual sales numbers, which provided the input to the NEMS-GPRA06 modeling run.[k] This difference was used starting in 2004, and a 15-year vehicle life was assumed by the On Location modeling team.

The resulting vehicle stocks and sales attributable to Clean Cities are shown in **Table 21**. Because the computation of annual sales from cumulative stock takes into account vehicle retirements, the sales values do not smoothly increase. The sales were allocated to vehicle types based on program information, and adjusted in the NEMS transportation model to reflect the fuel types in the model (they do not directly correspond in all cases). The largest shares of vehicles are CNG (44%), ethanol (34%), and LPG (17%). Electric and methanol vehicle shares are small. Half of the vehicles were assumed by the OnLocation modeling team to be flex vehicles and the other half to be single fuel dedicated vehicles. **Table 22** shows the flow of information, from program vehicle count to share used in NEMS.

Table 21. Vehicle Stocks and Sales Attributable to Clean Cities

Year	Cumulative Number of Vehicles	Annual Number of Vehicles (Sales)
2004	236,617	
2005	253,653	37,813
2006	271,438	39,705
2007	290,004	41,678
2008	309,383	43,734
2009	329,611	45,879
2010	350,723	48,115
2011	372,758	34,493
2012	395,756	54,789
2013	419,757	54,945
2014	444,805	44,794
2015	470,945	14,081
2016	498,224	100,612
2017	526,692	49,967
2018	556,400	72,889
2019	587,402	73,224
2020	602,718	75,684
2021	635,730	78,144
2022	670,181	81,768
2023	706,133	85,547
2024	743,652	89,491
2025	782,806	93,605

[k] Please see spreadsheet, CleanCityInput. This spreadsheet was obtained from John Holte, OnLocation, January 13, 2005.

Table 22. Information Flow from Program Vehicle Count to Share Used in NEMS-GPRA06

Original Mix of Vehicles (in 2002)		Allocated to Broader Categories		Allocated to NEMS Vehicle Types		
Vehicle Type	**Vehicles**	**Vehicle Type**	**Vehicles**	**Vehicle Type**	**Vehicles**	**Share**
Methanol	592	Methanol	592	Methanol Flex	0	0.0000
				Methanol	592	0.0034
Ethanol	37,890	Ethanol	58,868	Ethanol Flex	29,434	0.1708
Biodiesel	20,978			Ethanol	29,434	0.1708
CNG	73,927	NG	76,178	CNG	38,089	0.2211
LNG	2,251			CNG BiFuel	38,089	0.2211
Propane	29,258	LPG	29,258	LPG	14,629	0.0849
				LPG BiFuel	14,629	0.0849
Electric	4,132	Electric	7,387	Electric	7,387	0.0429
N Elec	3,255					
				Diesel Hybrid	0	0.0000
				FC Methanol	0	0.0000
				FC Hydrogen	0	0.0000
				FC Gasoline	0	0.0000
				Gasoline Hybrid	0	0.0000
				Adv Diesel	0	0.0000
				Gasoline	0	0.0000
		Total	172,283	**Total**	172,283	1.0000

In addition to the assumed increase in number of AFVs, NEMS-GPRA06 incorporates increased use of E85 due to Clean Cities activities, based on two projections: 1) an increasing number of vehicles using E85 (out of the increasing base of E85 capable vehicles), and; 2) an increasing share of E85 use in those vehicles using E85. The projections for these are shown in **Table 23**.

Table 23. Projections of E85 Vehicles

	2005	**2010**	**2015**	**2020**	**2025**
E85 Capable Vehicles (millions)	4.120	8.440	12.690	16.220	18.950
Vehicles Using E85 (millions)	0.152	0.180	0.208	0.236	0.264
Fraction of Vehicles using E85	0.037	0.021	0.016	0.015	0.014
Fraction of E85 Use per Vehicle	0.250	0.300	0.350	0.400	0.400

3.6 Inventions and Innovation

The Inventions and Innovation Program (I&I) is a Congressional mandated program to help inventors and very small businesses develop energy-saving technologies. Historically, I&I accepts proposals in two categories. Category 1 proposals are for concept development and have a $40K maximum grant. Category 2 proposals are for prototype testing and further technical development and have a $200K maximum grant.

The I&I program provides an orderly approach to identifying qualified proposals to fund using the steps below:

- Solicitation development
- Proposal evaluation
- Program-relevancy review
- Energy-savings analysis
- Monitoring and tracking
- Commercialization assistance
- Evaluation

Solicitation Development
Generally, changes to the solicitation are minor; but some major changes in emphasis have occurred over the lifetime of the I&I Program. There is more emphasis on the commercialization strategy of the applicant, and each applicant is required to articulate that strategy. Another major change has been the increased documentation of energy-savings methodologies and the definition of the "commercially available unit of production." The applicants are now required to make comparisons to existing commercially available technologies.

Proposal Evaluation
The changes in the solicitation have been designed to make it easier for the reviewer to adequately and fairly judge the invention's energy savings, compared to the savings of existing and commercially available technologies. The technical coefficients (fuel use per year) are approved by the reviewers.

These relatively small grants ($40K-$200K) do not call for the same rigorous market analysis that would occur on much larger grants or continuing programs. However, all grants do undergo a thorough technical and market evaluation.

Program-Relevancy Review
As part of the lengthy selection process, the I&I Program requires the designated EERE program manager to review every proposal within the office's technical scope. This review enables the I&I DOE project manager to eliminate grant proposals that are outside the scope of EERE. It also familiarizes the EERE program managers with potential I&I grants that could potentially segue with their ongoing portfolios.

Energy Savings Analysis
As I&I conducts a solicitation each year, and the selection of technologies is only bounded by EERE program scope, it is impossible to predict the FY06 program at the time of budget formulation. As a result, the FY04 program is used to estimate the FY06 savings potential (due to the solicitation schedule, results from the FY05 program were not available in time to be incorporated).

For the I&I Program, PNNL analyzes the impact of each selected technology using a model developed for DOE-OIT (Technology Impact Projections Model, Energetics Inc.) to be applied to industrial technologies considered in the GPRA process. The NEMS-GPRA06 model, used for most of the analysis in this report, does not have a sufficiently detailed technology- based industrial sector. This generally precludes NEMS-GPRA06 from being used to model I&I sponsored technologies.

The DOE-OIT model only considers the market segment appropriate for a given I&I technology. However, fuel prices, electrical plant heat rates, and environmental emissions rates are taken from EIA forecasts and applied to all technologies. All proposals to I&I contain estimates of current technology performance, the expected performance of the proposed technology, and the suggested market segment. Markets can be defined in terms of annual sales or manufacturing capacity.

Performance estimates are reviewed with the inventor and adjusted for items such as heat rates and fuel mix that differ from the EIA base data. Performance coefficients are prepared for a "Technology Unit" in terms of fuel use per year of operation. For example, a technology unit for the ethanol industry is a production capability of 10,000,000 gallons per year. Multiplying the fuel coefficients by the number of units derives total annual fuel use.

The market segment size is defined in terms of a number of technical units. Initial segment size is based on data from sources such as EIA, trade associations, and DOE industry profiles. Most of the inventors have studied the markets for their technology and offer additional sources and insights. The sector growth rate is derived from similar sources. The inventor proposes a year when the technology would first enter the market, however, when questioned by PNNL, most inventors delay the date from the original proposal.

Maximum market-share limitations are placed on each technology. Factors that limit the share are technology issues, such as the technology will only work on motors more than a certain size; and market issues, such as the technology will be effective only in certain climates. Commercialization plans that use exclusive licensing can limit market share. In a case where two inventors are addressing the same market, the maximum market is cut in half. As I&I technologies either already have intellectual property protection or are in the process of establishing protection, the technology life cycle is set at 15 years. However, to simulate continued program funding at current rates, the life cycle is extended to 2030.

The DOE-OIT model offers four market penetration "S curves." Each is defined in terms of the number of years required to reach 50% of the maximum market share within the defined segment. The choice of "S curve" is based on the new technology performance advantage, the inventor's commercialization plan, the market segment characteristics, and experience of the I&I tracking program for the same segment or type of technology. An inventor that has a development partner who represents a major share of the market segment would be assigned an "S curve" implying a shorter time to reach a 50% of maximum share than an inventor with no partner. Technologies that require large capital investment are given slower "S curves." General instructions supplied to model users are included in **Appendix A**.

Annual estimates of "technology unit" sales and total units installed are made for each technology, based on the above inputs. Energy, economic, and environmental consequences are derived based on the installed unit forecast. The model results are discussed with each inventor and a signed agreement obtained. Generally, model results show fewer units sold than the inventors suggested in their proposals to I&I. A summary of the model results for each technology is part of the I&I Fact Sheets available on the I&I Web site.[1]

Calculations Walk-through:

1) Annual market size is calculated from initial market size in "technical units," multiplied by market limitation fractions, and adjusted for market growth.
2) Annual market is multiplied by the market share from the selected "S curve" to derive annual sales.
3) Annual installed capacity is the total sales (to date) in technical units.
4) Energy savings are calculated by fuel type from the difference in performance coefficients between the new and current technology's technical units.
5) Other impacts are calculated from EIA prices and environmental coefficients multiplied by changes in annual fuel use.

Note: The market share is equal to the "S curve" fraction, multiplied by the market share limit fractions. Specific calculation inputs and associated estimates of program benefits are provided in **Appendix B.**

3.6.2 Target Market

Project Description. Descriptions of the activities on which outputs are based are included in **Appendix B**.

Market Description. Market segments are determined using public sources appropriate to each I&I technology. OIT's industry profiles are frequently used. Market limitations are introduced to better represent the true target of the technology. EIA forecasts of energy prices and electric power fuel mix are used for all cases.

Baseline Market Acceptance. The tracking of I&I technology acceptance provides an important input to the selection of the market penetration "S curve" and limitation of ultimate market share.

3.6.3 Methodology and Calculations

Inputs to Base Case. Because I&I cannot use NEMS-PNNL, each technology has its own base case. The same EIA fuel prices, electric plant fuel mix, and heat rate are used for all cases.

Technical Characteristics. Technical coefficients of technology performance (i.e. fuel use per operating unit per year) are provided by the inventor and approved by the proposal reviewers.

Expected Market Uptake. The market penetration rate and limits consider many factors. The DOE-OIT model assumes that a technology with equal technical coefficients appears in the

[1] http://www.eere.energy.gov/inventions/

market at some time after the technology being evaluated is introduced. Depending on the strength of intellectual property protection, the time lag is usually 10 to 15 years.

Calculation Results:
The FY04 grantees' energy savings are used to estimate FY06 results. FY04 had included 13 technologies (grants). Results for six technologies, representing about 85% of program savings, are shown in **Appendix B** to illustrate I&I's energy-saving impacts. Calculations were made using the above-described OIT model. Sources are noted for market size and growth rates. Comments on the main factors considered in the "S curve" selection appear after the market-penetration percentages.

4.0 Intergovernmental Activities

4.1 Tribal Energy Activities

The program potentially could lead to renewables development projects on Tribal land that could be significant generation sources for sale to off-reservation markets; however, the current level of funding is leading to projects more oriented toward electrification of tribal households on reservations. The vast majority of these households are located on the Navajo Reservation in Arizona. EIA has identified a maximum electrification potential of at least 13,000 housing units using the 1990 Census (EIA Report SR/CNEAF/2000-01).

Electrification, while an important outcome, in fact increases energy consumption. While new renewable supplies may be brought on line, there is no evidence that these resources would lead to displacement of existing fossil generation resources. In our assessment this program fills an important niche mission for the DOE, but energy savings is not the appropriate metric upon which to measure.

Based on these observations, analysis effort has been focused elsewhere.

4.2 International Renewable Energy Program

The program states the goal of developing 1000 MW of new renewables capacity worldwide by 2010. Even if all of this new generation displaced fossil generation, the savings are insignificant – especially on a world scale. In many instances, the new generation that would be created would serve to electrify currently unelectrified regions of the world – adding to world energy consumption. About 1,000 MW each five years would be equivalent to replacing one moderate-sized coal or oil-fired power plant each five years.

The activities of the program are more consistent with information programs and other outreach activities. The difference being that these activities occur with foreign governments. These activities could have the effect of placing U.S. technologies in foreign countries for demonstration or deployment, which may lead to potential adoption in the United States as a result, but this linkage is tenuous at best.

Based on these observations, analysis effort has been focused elsewhere.

Appendix A – I&I Market Factor in Technology Impact Projections

The Technology Impact Projections model is used to estimate the potential security, economic, and environmental benefits resulting from research, development, and demonstration projects funded by the Inventions & Innovation Program (I&I). Benefit estimates are critical for evaluating projects and presenting the merits of both individual projects and the overall RD&D portfolio.

Market Inputs

To determine the potential impact of the new technology as it becomes adopted, it is necessary to estimate the total market for the technology, reduce that estimate to the likely actual market, and estimate when (and the rate at which) the new technology will penetrate the market.

Total Market

Total market: the number of units that perform the same task as the proposed technology. Only the domestic U.S. market should be included.

Number of Installed Units in U.S. Market
Please define that market as narrowly as possible: i.e. the smallest group of applications that covers all potential applications for which you may have some data. You may base your estimate on the energy use of the state-of-the-art technology and the energy-use data provided in this package. Other potential data sources include OIT's Energy and Environmental Profile for the relevant industry, EIA's MECS data, or industry sources.

Annual Market Growth Rate
This should be based on an EIA or industry growth projection for the relevant industry.

Market Share

Market share is a function of the potential accessible market share and the likely market share.

Potential Accessible Market Share
The accessible market: The market that the new technology could reasonably access given technical, cost, and other limitations of the technology. For example, certain technologies may be applicable only to a certain scale of plant, certain temperature-range processes, certain types of existing equipment or subsystems, or only certain segments of the industry.

Likely Market Share
In some instances, in addition to technical and cost factors, the technology may compete with other new technology approaches, or with other companies, for the market. Please estimate the likely market share. Use current market-share information, or base estimated market share on the basis of the number of competitors in the market, assuming they are

using different technologies not resulting from this project. This is different than the possibility of "copycats," which should not be considered as competing. That is, if others adopt essentially the same, or slightly modified, technology due to this new technology, that adoption was triggered by the project being described and that project should be "credited" with causing that trend. This is potentially the case for techniques where the intellectual property cannot be, or is not, protected and becomes general knowledge throughout the industry.

Market Penetration

To understand how rapidly the potential impact of the technology will occur, the market penetration of the technology must be projected. This is based on two estimates, the technology development and commercialization timeline, and the market penetration curve.

Technology Development & Commercialization Timeline
The commercial introduction of a technology normally occurs after a significant demonstration or operating prototype and after an adequate test-and-evaluation period, along with allowances for the beginnings of production, dissemination of information, initial marketing and sales, or other "start-up" factors. To capture this lengthy process, please indicate the timeline for developing and introducing the technology into the market. This includes the years for when an initial prototype, refined prototype, and commercial prototype of the technology has or will be completed and the year when the technology will be commercially introduced. An initial prototype is the first prototype of the technology. A refined prototype represents changes to the initial prototype but not a commercially scaled-up version. A commercial prototype is commercial-scale version of the technology. Commercial introduction is when the first unit beyond the commercial prototype is operating. Prototype and commercial introduction years should be consistent with your technology-development program plans.

Market Penetration Curve (Technology Class)
New technologies normally penetrate a market following a familiar "S curve", the lower end representing the above uncertainties overcome by "early adopters." The curve tails off at the far future, where some may never adopt the new technology. The major portion of the "S curve," here the new technology is penetrating the market and benefits are being reaped, is the most important. The rate at which technologies penetrate their markets varies significantly: Penetration of heavy industrial technologies generally takes place over decades, while simple process or control changes can penetrate much more rapidly. The actual penetration rate varies due to many factors including economic, environmental, competitive position, productivity, regulatory, and others.

To assist in "S curve" selection, a large volume of actual penetration rates of past and present technologies were analyzed, normalized, and grouped into five classes, based on a number of characteristics and criteria. Those criteria have been distilled to the five choices in **Table A1.** Analysts and/or applicants can choose either a, b, c, d, or e as the rate class that best fits a given technology. Note that the characteristics (rows) are relatively independent, and a given technology will likely fit best in different classes for different characteristics. Selection of the most likely "rate class" at which the new technology may penetrate the market is based on best judgment and experience. This may be a "subjective average" of the characteristics, or it may be that one or two characteristics are believed to so dominate future adoption decisions that a particular class of penetration rate is justified. There also may be "windows of opportunity" where significant replacements of existing equipment may be expected to occur at some point for other reasons.

For additional assistance, **Table A2** shows actual technologies and the class of their historical penetration rates. Comparison of the new technology (by analogy or similarity) with these examples provides additional insight into selecting the appropriate penetration rate that might be expected for the new technology.

Table A1. Selecting the Market-Penetration Rate Class

Technology/project						**Score (a,b,c,d,e)**
Characteristic	**a**	**b**	**c**	**d**	**e**	
Time to saturation	5 yrs	10 yrs	20 yrs	40 yrs	>40 yrs	na
Technology factors						
Payback discretionary	<<1 yrs	<1 yr	1-3 yrs	3-5 yrs	>5 yrs	
Payback non-discretionary	<<1 yr	<1 yr	1-2 yrs	2-3 yrs	>3 yrs	
Equipment life	<5 yrs	5-15 yrs	15-25 yrs	25-40 yrs	>40 yrs	
Equipment replacement	none	minor	unit operation	plant section	entire plant	
Impact on product quality	$$	$$	$$	$	0/-	
Impact on plant productivity	$$	$$	$$	$	0/-	
Technology experience	new to U.S. only	new to U.S. only	new to industry	new	new	
Industry factors						
Growth (%per annum)	>5%	>5%	2-5%	1-2%	<1%	
Attitude to risk	open	open	Cautious	conservative	averse	
External factors	forcing	forcing	Driving	none	none	na
Gov't regulation						
Other						

Table A2. Penetration Rate of Technologies.

Class	A	B	C	D	E
Aluminum		Treatment of used cathode liners	Strip casting, VOC incinerators		
Chemicals	New series of dehydrogenation catalyst (incremental change)	CFCs -> HCFCs, incrementally improved catalysts, membrane-baed chlor-alkali	Polypropylene catalysts, solvent to water-based paints, PPE-based AN	Synthetic rubber & fibers	
Forest Products			Impulse drying, de-inking of waste newspaper	Kraft pulping, continuous paper machines	
Glass		Lubbers glass blowing, Pilkington float glass	Particulate control, regenerative melters, oxygenase in glass furnaces		
Metals Casting	New shop floor practice				
Petroleum	New series HDS catalysts	Alkylation gasoline	Thermal cracking, catalytic cracking	Residue gasification, flexicoking	

Appendix B – I&I Energy Savings Results

I&I Technology			**Pulse paper drying**			
Technology Description - Virtually all paper manufacturing equipment worldwide is limited by the evaporative drying stage. The most common air drying process improves efficiency of this process by 59% and speeds overall paper production 21%.						
Market segment is the paper manufacturing industry - technology unit is a plant producing 44,000 tons/yr						
Current technology units in operation - 2002			290	Source - DOE - OIT technology profile		
Sector annual growth rate			1%	Source - DOE - OIT technology profile		
New technology Introduction year			2006			
Savings per new install unit			235 Billion Btu (Natural gas)/year			
Year	2008	2010	2015	2020	2025	2030
Units in service	5	13	78	178	215	227
Annual unit sales	2	4	20	15	4	0
Primary energy savings	1.2	2.9	18.2	41.6	50.3	53.1
(trillion Btu/year)						
Market Penetration	2%	4%	24%	51%	59%	60%
Note: Industry is aware of this technology, but waits for the early adapter. Most plants in the industry are owned by a few companies, success will move quickly although the units are expensive. (10yr curve)						

I&I Technology	**High Speed/ Low Effluent process for Wet and Dry Mill Corn to Ethanol**					
Technology Description - A high speed/low effluent fermentation process based on the BPSC-15 yeast that has the property of forming stable high strength 'pellets'. Very high cell densities are easily attained with this yeast which leads to quick and complete fermentations Energy use reduced by 42% and requires fewer fermenters for the same production rate.						
Market segment is the ethanol manufacturing industry - technology unit is a plant producing 10,000,000 gal/yr						
Current technology units in operation - 2001			177	Source - EIA's Annual Energy Outlook 2001		
Sector annual growth rate			10%	Source - Energy Bill (5 Billion Gal by 2012)		
New technology Introduction year			2006			
Savings per new install unit			228,000 Million Btu (Coal)/year			
Year	2008	2010	2015	2020	2025	2030
Units in service	6	32	171	284	458	728
Units starting operation	4	17	22	26	42	58
Primary energy savings	1.4	7.3	39.1	64.8	104	166
(trillion Btu/year)						
Market Penetration	2%	8%	25%	26%	26%	26%
Note: Technology can be retrofitted or used with new plants. Retrofit cost are about 5% of original cost, but new plant would see a cost reduction (few fermenting units) in addition to energy savings. (5 yr curve)						

I&I Technology	**Electrochromic Windows - Advanced Processing Technology**					
The project is focused on developing advanced fabrication capabilities for energy-saving electrochromic (EC) smart windows. SAGE EC devices consist of an alt-ceramic stack of thin film coatings on a glass substrate. The window tint can be changed electrically by the application of low voltage DC power. SAGE has developed the basic materials and device technologies and moved operations from laboratory to pilot line.						
Market segment is residential and commercial windows - technology unit is 1 million Sq-meters of glazing						
Current technology units in operation - 2001			3000	Source - Implied from annual sales		
Sector annual growth rate			3%	Source - "Smart Windows" an SRI study		
New technology Introduction year			2005			
Savings per new install unit			304 billion Btu(gas, oil and Elect) /year			
Year	2005	2010	2015	2020	2025	2030
Units in service	11	106	617	1287	1638	1896
Units sold	11	37	147	103	58	34
Primary energy savings	3.6	32.4	182.5	375.3	477.5	552.8
(trillion Btu/year)						
Market Penetration	0%	3%	14%	25%	28%	28%
Note: Early years sales based on SRI markets study with later years keyed to LBNL saturation estimates referenced by the inventor.(10yr curve)						

I&I Technology	**Multi-rotor Micro Particle Generator**					
This mechanical generator incorporates a novel approach to continuous emulsification processing of any type of fine particle homogeneous suspensions. Through exceptionally efficient and effective particle size reduction or, in the case of organic materials, cell disruption, thus greater starch exposure. This process eliminates the current Jet Cooking process used to reach the "liquefaction stage" in the production of corn ethanol, saving up to 46% of the related energy costs.						
Market segment is the ethanol manufacturing industry - technology unit is a plant producing 10,000,000 gal/yr						
Current technology units in operation - 2001			177	Source - EIA's Annual Energy Outlook 2001		
Sector annual growth rate			10%	Source - Energy Bill (5 Billion Gal by 2012)		
New technology Introduction year			2004			
Savings per new install unit			37,400 Million Btu (Coal)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	2	77	176	284	458	728
Units sold	1	28	17	26	42	58
Primary energy savings	0.1	2.9	6.7	10.9	17.6	28.0
(trillion Btu/year)						
Market Penetration	1%	19%	26%	26%	26%	26%
Note: Basic technology exists, but has not been applied to corn. After testing and any necessary modifications units can be sold to new or retrofitted to existing plants. (5yr curve)						

I&I Technology	**High Efficiency Variable Dehumidification for Air Conditioners**					
The project goal is to produce a production prototype that will lead industry to a highly marketable improvement in energy efficiency, dehumidification, and maintenance of like-new performance for unitary air-conditioning and dehumidification.						
Market segment is Commercial and Residential AC - technology unit delivers 20,000 ton-hr/year						
Current technology units sales - 2002			5.42 million	Source - ADL report for OBT		
Sector annual growth rate			2%	Source - ADL report for OBT		
New technology Introduction year			2006			
Savings per new install unit			142 Million Btu (Electricity)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	0	108,198	700,628	1,683,669	2,138,463	2,371,813
Units sold	0	38,179	186,332	156,923	63,456	20,493
Primary energy savings	0.0	11.6	68.9	158.1	201	223
(trillion Btu/year)						
Market penetration		2%	10%	22%	25%	25%
Note: Technology requires major AC unit design changes, but with result little or no cost increase. Market is limited to regions with high humidity- Southeast and portions of South and Midwest. (10yr curve)						

I&I Technology	**Medium Voltage Energy Saving Motor Controller**					
Concept for a medium voltage electric motor controller that cost-effectively reduces energy consumption by up to 35% for underloaded medium voltage (2300-4600V) electric motors. While large electric motors comprise only 0.3% of the number of motors used in US manufacturing, they consume 19% of the total motor energy. When a motor is loaded less than 40% of its full load, its efficiency declines quickly.						
Market segment is Electric motors - technology unit a 1000 HP motor running at part load						
Current technology units sales - 1997			89,500	Source - DOE Motor Challenge data		
Sector annual growth rate			3%	Source - DOE Motor Challenge data		
New technology Introduction year			2006			
Savings per new install unit			4,466 Million Btu (Electricity)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	0	1123	3747	11363	26365	46524
Units sold	0	245	787	2149	3775	3825
Primary energy savings	0	5.0	15.3	44.4	103.0	181.7
(trillion Btu/year)						
Market Penetration	0%	1%	2%	6%	13%	20%
Note: Market is limited to motors over 200HP that operate at less the 40% of full load. The inventor already supplies controllers for smaller motors. Research will develop capability for larger motors. The inventor company knows the industry and provided market forecasts based on his own experience.(20yr curve)						

Appendix L – GPRA06 Wind Technologies Program Documentation

1 Introduction

The Wind Technologies Program seeks to reduce the cost and improve the performance of wind technology, and to reduce barriers to its use. The GPRA benefits are estimated primarily from model projections of the market share for wind technologies, based on their economic characteristics. Several models are utilized for this purpose. This document describes the inputs and assumptions that are used by the models to calculate those benefits. The most significant change from the GPRA05 benefits methodology in assumed program direction and activities for the current GPRA06 estimates is the inclusion of offshore wind energy technology development.

1.1 Target Markets (the Baseline Case)

Large-scale wind energy is expected to penetrate in two market segments: the least cost (competitive bulk power) power market and the green power market.

In the competitive power markets, wind technology is projected to improve significantly during the next decade, in part because of program-sponsored research. This improvement is represented in the GPRA06 modeling effort by a declining capital cost trajectory, lower O&M costs, and increased performance. The values used for the wind technology cost and performance projections are consistent with the program's 2012 cost of energy goals for low wind-speed technology, both onshore and offshore.

In addition to competing on an economic basis with other electricity-generation technologies, wind capacity may be partially valued for its environmental attributes. Princeton Energy Resources International (PERI)—using its Green Power Market Model—provided an estimate of wind capacity additions in response to the expanding green power markets in many places throughout the country. The projections for green power wind installations were incorporated exogenously into the OnLocation-modified NEMS (NEMS-GPRA06), and Brookhaven National Laboratory-modified MARKAL (MARKAL-GPRA06) models as planned capacity additions.

Description of Key Elements of the NEMS Approach to Modeling Wind

The electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e., capacity factor, which reflects energy conversion efficiency, and both resource and plant availability), the regional load requirements, and existing capacity resources. NEMS-GPRA06 characterizes wind by three wind classes, each with its own capital costs and resource cost multipliers. The regional resource cost multipliers increase capital costs as increasing portions of a wind class is developed in a given region to reflect 1) declining natural resource quality, 2) required transmission network upgrades, 3) competition with other market uses, including aesthetic or environmental concerns. As the cost in a particular region increases with greater development, at some point it may become more cost-effective to consider installing wind turbines in areas of lesser wind resource, but with lower ancillary costs and less costly access to the grid, as reflected in the model by the capital cost multipliers. These multiplier assumptions are viewed as very conservative, and may overestimate the effects of actual market dynamics.

Other key assumptions that can affect projections include a limit on the share of generation in each region that can be met with intermittent technologies. NEMS-GPRA06, as in the *AEO2004*, also assumes that the capacity value of wind diminishes with increasing levels of installed wind capacity in a region. Finally, another constraint on the growth of wind resource development is how quickly the wind industry can expand before costs increase due to manufacturing bottlenecks. The *AEO2004* assumption that a cost premium is imposed when new orders in a year are 20% higher than in the highest of the previous 10 years was maintained in the Program Case (the same as applied to all electricity generation technologies)

Further detail on the representation of wind power in NEMS may be found in **Chapter 4** and **Appendix A.**

Description of Key Elements of the MARKAL Approach to Modeling Wind

Wind generators are modeled as centralized plants to compete with fossil fuel-based plants. As in NEMS, resource cost multipliers were applied to the capital cost of wind generators as additional capacity is developed. The resource cost multipliers are based on the assumptions used in the AEO2004. However, since MARKAL-GPRA06 is a single region model, these multipliers were applied on a national basis.

To account for the intermittent nature of wind resources, the potential contribution of wind systems to meeting peak power demand is limited to a fraction of total wind capacity. This factor ranges between 30% and 40% depending on wind class, year, and maximum assumed capacity factor. This disadvantages wind generators, compared to fossil fuel generators, as additional reserve capacity is required to meet peak power requirements. However, this disadvantage is offset by fossil fuel cost savings, as well as the reduction in capital cost and performance improvements projected for wind technologies by the program. As a result, wind generators near the central grid can be competitive with fossil fuel-based power plants. The green power capacity additions are added as a lower bound in the MARKAL-GPRA06 model.

Developing the GPRA06 Baseline for Wind

The Baseline, which is used as the benchmark against which to measure the Wind Program's benefits, is developed using NEMS-GPRA06 and some of the technology assumptions in the Energy Information Administration's (EIA) *Annual Energy Outlook 2004 (AEO2004)* Reference Case. The AEO2004 baseline treats wind as a mature technology that experiences, in the future, only a limited amount of cost reduction through learning (only 1% reduction in costs is assumed for every doubling of capacity). As a result, in the EIA projections, the projected capital costs decline only slightly over time.

Three changes from the AEO2004 Reference Case were made regarding wind. The AEO2004 uses short-term (national growth) and longer-term (regional resource) multipliers. These factors account for various resource and market phenomena that are intended to reflect increases in the cost of deploying technology as cumulative installed capacity increases). In NEMS-GPRA06, the resource multipliers are applied by wind class rather than across the entire wind resource in each region. This is a more restrictive assumption in that it tends to increase the assumed cost of wind technology, and, therefore, to lower projections of installed capacity.

A second modification is to the capital cost and capacity factor assumptions for current (2005) wind technology. The EIA and program assumptions about the expected performance (capacity factor) of new wind capacity additions are significantly different. They needed to be reconciled, so that the same assumptions would be used for the year 2005 in both the Baseline and Program cases. For example, EIA assumes that the capacity factor of wind turbines in Class 6 winds, in 2005, is 38%, while the program believes it is 49%. A compromise between the two was made such that the capacity factor assumptions for 2005 are midway between the two views (e.g., 44% for Class 6). The Baseline wind capacity factors then improve over time at the same rate as assumed in the AEO2004. The capital costs estimates for 2005 were more similar, and the program's view for 2005 was adopted for the 2005 Baseline, followed by a small decline in cost over time at the same rate as in the AEO2004.

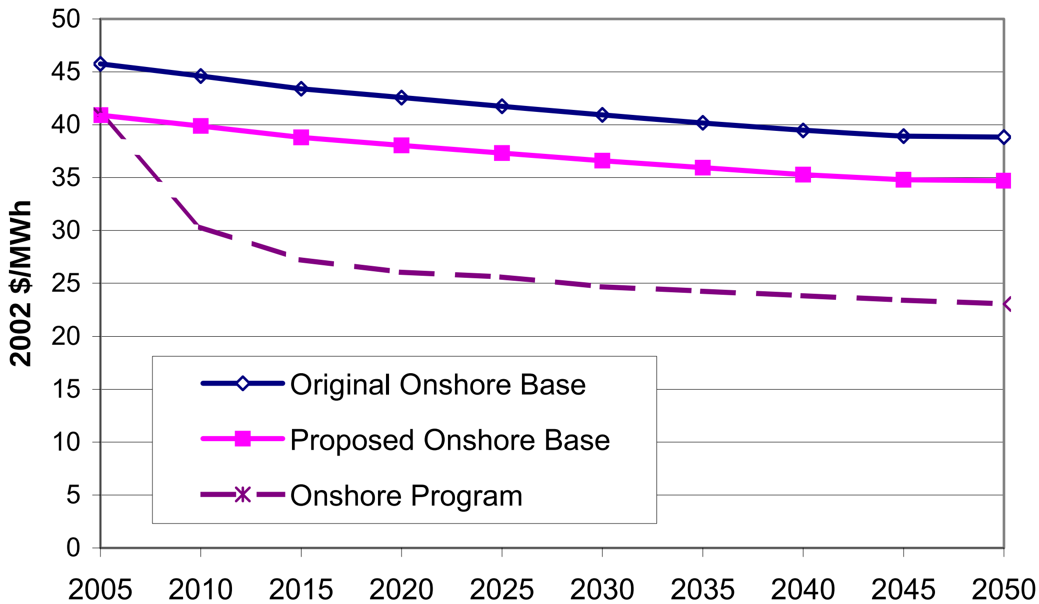

Figure 1. Onshore Wind Class 6 COE

The third change from the AEO2004 to the Baseline is the addition of offshore wind as a separate technology. The offshore wind is represented as a distinct technology that competes with all other generation technologies. It is characterized in a similar manner as onshore wind, with three wind classes, but also has a distinction between shallow and deep water sites. The constraints on intermittent generation and rapid growth apply similarly to offshore as to onshore wind development. The offshore wind does not have the regional resource cost multipliers because there is insufficient data on how they might apply.

Table 1 provides the complete set of technology assumptions used in developing the Baseline estimate for GPRA06.

Table 1. Baseline Projections for Capital Costs, Capacity Factors, and O&M Costs for Onshore and Offshore Wind Systems

		2005	2010	2015	2020	2025	2030	2040	2050
Capital Costs									
Onshore	Class 5 & 6	1050	1048	1045	1042	1039	1036	1031	1025
	Class 4	1103	1087	1084	1076	1053	1050	1045	1039
Offshore	Shallow Water	1243	1241	1234	1225	1212	1196	1155	1102
	Deep Water	1787	1767	1743	1707	1636	1604	1497	1383
O&M Costs									
Onshore	All Classes	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Offshore	Shallow Water	55.0	49.3	45.0	41.0	40.0	39.0	37.0	35.0
	Deep Water	55.0	51.3	47.0	43.0	42.0	41.0	39.0	37.0
Capacity Factors									
Onshore	Class 6	0.436	0.446	0.458	0.466	0.474	0.482	0.498	0.504
	Class 5	0.398	0.407	0.417	0.426	0.433	0.440	0.453	0.459
	Class 4	0.338	0.345	0.354	0.361	0.366	0.374	0.390	0.395
Offshore	Class 7	0.532	0.537	0.563	0.569	0.569	0.569	0.569	0.569
	Class 6	0.442	0.446	0.468	0.474	0.474	0.474	0.474	0.474
	Class 4	0.351	0.356	0.373	0.380	0.380	0.380	0.380	0.380

*Includes 1.05 contingency factor for onshore systems and 1.07 for offshore systems.
Sources: [1] [2]

1.2 Key factors in shaping market adoption of EERE technologies

Electricity produced from offshore locations is expected to be of higher value than many onshore locations in many cases, because proximity of several major load centers to the coasts could reduce transmission constraints and costs facing large-scale onshore power generation. The United States has an estimated 60 gigawatts (GW) of shallow water resource and 141 GW of deep water resources within 5-20 nautical miles (nm) of the coast, and a further 38 GW of shallow water resources and 668 GW of deep water resources located 20-50 nm out. Early offshore wind development in Europe, at shallow depths of 5-12m, has relied on the marinisation of land-based turbines anchored to the seabed. It is expected, however, that the growth of offshore wind technology in the United States will also require new technologies that allow deep water development (e.g., floating platforms and power distribution and transmission systems). [2]

1.3 Methodology and calculations

Technical Characteristics of the Program Case for Wind

The assumptions about capital costs, capacity factors, and O&M costs, which are used as inputs into the Program Case, are provided in **Table 2.** These projections match the program's performance goals, as described in the *Wind Energy Multi Year Program Plan For 2005-2010*, November 2004, available for downloading in PDF format at: http://www.nrel.gov/wind_meetings/2003_imp_meeting/pdfs/wind_prog_mypp_15Nov2004.pdf

So far, the program has only completed preliminary analyses of the costs and performance of deep water wind turbines. For this reason, their estimated cost and performance should be regarded as tentative, reflecting the best program judgment available at the time of this analysis, but being almost certain to change as more knowledge is gained and more comprehensive studies are completed. A more detailed examination of cost-reduction potential is being undertaken in 2005, and will be structured using the wind program's Technology Improvement Opportunity (TIO) pathways framework.

Table 2. Program Projections for Capital Costs, Capacity Factors, and O&M Costs for Onshore and Offshore Wind Systems

		2005	2010	2015	2020	2025	2030	2040	2050
Capital Costs									
Onshore	Class 5 & 6	1050	893	840	819	814	788	767	746
	Class 4	1103	982	919	893	866	866	856	840
Offshore	Shallow Water	1243	1129	1070	1070	1050	1016	989	962
	Deep Water	1787	1723	1370	1177	1050	1024	977	945
O&M Costs									
Onshore	All Classes	25.0	20.0	16.0	15.0	14.2	13.8	13.2	12.8
Offshore	Shallow Water	55.0	47.0	41.0	38.0	37.3	36.0	34.0	32.0
	Deep Water	55.0	49.3	44.0	41.0	40.0	39.0	37.0	36.0
Capacity Factors									
Onshore	Class 6	0.436	0.495	0.507	0.514	0.517	0.519	0.522	0.525
	Class 5	0.398	0.442	0.453	0.457	0.460	0.460	0.462	0.462
	Class 4	0.338	0.404	0.463	0.469	0.472	0.480	0.482	0.483
Offshore	Class 7	0.535	0.546	0.604	0.604	0.604	0.604	0.604	0.604
	Class 6	0.442	0.450	0.501	0.501	0.501	0.501	0.501	0.501
	Class 4	0.352	0.359	0.401	0.401	0.401	0.401	0.401	0.401

*Includes 1.05 contingency factor for onshore systems and 1.07 for offshore systems..
Sources: [2] [3]

Green Power Market Penetration Projections

Green power additions (estimated by the PERI Green Power Market Model) were provided by region and are included as planned capacity additions. (For more details on the Green Power Market Model, see **Appendix M**). Estimates of the Green Power additions were provided to

2035. After 2035, they remain flat as most of the renewable capacity will likely be introduced competitively by then. The same general technology assumptions were made for the green power additions as for the economic builds predicted by NEMS or MARKAL. However, none of the Green Power additions was modeled as coming from offshore installations, due to their generally higher cost in the near term when green power markets are assumed to be most important. **Table 3** summarizes the green power capacity additions. The green power additions do not necessarily lead to greater total wind capacity than those projected for pure economic reasons, because development costs are assumed to increase as wind resources are developed.

Table 3. Green Power Wind-Capacity Additions (MW) for Program Case

Wind	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1. ECAR	160	164	69	39	27	28	487
2. ERCT	142	179	91	46	36	38	532
3. MAAC	316	204	16	18	19	20	592
4. MAIN	99	101	43	24	16	17	300
5. MAPP	13	27	21	11	4	4	79
6. NY	210	136	11	12	13	13	395
7. NE	231	139	22	20	19	19	450
8. FL	0	0	0	0	0	0	0
9. STV	0	0	0	0	0	0	0
10. SPP	146	192	104	52	38	41	573
11. NWPP	18	33	23	14	9	10	107
12. RA	28	47	32	20	14	15	156
13. CNV	7	18	17	8	3	3	57
Total	1,372	1,239	448	262	198	210	3,729

1.4 Sources

1. Cohen, Joseph M., "Assessment Of Potential Improvements In Large-Scale Low Wind Speed Technology," proceedings of Global Windpower 2004, March 29, 2004, American Wind Energy Association, Washington, DC.

2. Musial, W., and Butterfield, S., *Future For Offshore Wind Energy in the United States*, June 2004, NREL.CP-500-46413 http://www.nrel.gov/docs/fy04osti/36313.pdf

3. Milborrow, D., Offshore Wind Rises to the Challenge, *Windpower Monthly*, April 2003.

Appendix M – GPRA06 Estimate of Penetration of Generating Technologies into Green Power Markets

1. Introduction

The Green Power Market Model (GPMM or the model) identifies and analyzes the potential electric-generating capacity additions that will result from "green power" programs, which are not captured in the "least-cost" analyses performed by the National Energy Modeling System (NEMS) and the Market Allocation (MARKAL) model. The term "green power" is used to define power generated from renewable energy sources, such as wind, solar, geothermal, and various forms of biomass. The Green Power market is an increasingly important element of the national renewable energy contribution, with changes in the regulatory and legislative environment and the recent dramatic changes in natural gas prices slowly altering the size of this opportunity.

1.1 Target Markets

The GPMM attempts to quantify the size of the green power market opportunity for the GPRA Benefits Analysis process. The model projects green power-capacity additions resulting from both green power marketing programs available in deregulated markets, and utility green pricing programs offered in regulated markets. Electricity markets are now restructured and openly competitive in 17 states and the District of Columbia: Arizona, Connecticut, Delaware, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Oregon, Rhode Island, Pennsylvania, Texas, Virginia, and Washington D.C. Electric-market restructuring has been delayed or repealed in seven states: Arkansas, California, Montana, Oklahoma, Nevada, New Mexico, and West Virginia.[1]

Of the states with competitive electricity markets, green power marketing products are currently being offered in nine states and the District of Columbia: Maine, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, Texas, Virginia, and Washington DC.[2] Green power pricing programs are being offered by utilities in 34 states: Alabama, Arizona, California, Colorado, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kentucky, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Washington, Wisconsin, and Wyoming.[3]

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[1] The Green Power Network, 2004, *Green Power Markets- Green Marketing*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, available on the Internet at: http://www.eere.energy.gov/greenpower/markets/marketing.shtml.
[2] The Green Power Network, 2004, *Green Power Markets- Green Marketing*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, available on the Internet at: http://www.eere.energy.gov/greenpower/markets/marketing.shtml.
[3] The Green Power Network, 2004, *Green Power Markets- Green Pricing*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, available on the Internet at: http://www.eere.energy.gov/greenpower/markets/pricing.shtml.

The GPMM estimates are provided to the National Renewable Energy Laboratory (NREL) and the Department of Energy (DOE), in terms of installed capacity (MW) and energy generation (kWh) for each renewable power technology, in a format compatible with NEMS.

The model was first developed in 2000, and many of the assumptions have been revised on an annual basis. Additionally, this year a systematic review and revision of the data inputs and methodology of the model was undertaken, including: a review of the recent literature on green power market developments and status of new and existing programs; an update of current state legislation on electricity market restructuring and access to green power programs either through regulated green pricing or competitive green marketing programs; an update of input data, from EIA and NREL, on demographic and demand data, and renewable energy technology characterizations; and conversion of all dollar values from 2000$ to 2004$, including data inputs on energy prices and technology costs.

Baseline Technology Improvements and Market Acceptance
A "base case" run of the GPMM was established this year for the first time. This version of the model uses the technology characterization from the FY2006 GPRA-Base Case run, and serves as the baseline reference for how green power marketing and green pricing programs would develop in the absence of efforts by the renewable energy programs. After this baseline was set, the "program case" was run, using the NREL and DOE projections for technology characterizations for renewable technologies that are used in the FY2006 GPRA- Program Case run. Additionally, the solar photovoltaic (PV) capacity additions from the Million Solar Roofs (MSR) program are included in the program case results of the GPMM. Instead of the entire capacity additions and energy generation from the program case run, only the difference between the base and program runs is credited to the renewable energy programs for the benefits calculations. These incremental results are then used by OnLocation Inc. and added to the FY2006 GPRA- Program Case run, to produce the renewable energy program benefits calculations.

1.2 Key Factors in Shaping Market Adoption

Price is the main factor in most electricity purchases where the customer has a choice in products offered. Aside from some reliability issues for a number of industrial and commercial customers, price is the one characteristic that is distinguishable between competing electric service programs. The electricity provided to the customer is the same regardless of which electric provider and package is selected (i.e., the lights come on when the switch is flipped). However, green power is one product that offers more than just the electricity to power a home or business. Green power is really the combination of the electricity produced by green technologies and the attributes associated with that generation (e.g., reduction in pollution and emissions, fuel diversity, and price stability). While green power is generally more expensive than conventional electricity packages, the additional nonprice factors provide an increased value of the product to the customer. Many residential customers choose green power to reduce their impacts on the environment and to help support the development of these emerging clean technologies. Additionally, a number of reasons exist for businesses to commit to purchasing green power, such as fostering good relations with their customers by enhancing their public image, offsetting emissions from manufacturing or other business processes, enhancing the reliability of their power supply, and limiting exposure to fossil fuel price fluctuations.

However, the development of green power markets still faces a number of obstacles. Many renewable technologies are capital intensive, requiring high up-front costs, which hinder or reduce the potential financing mechanisms for development. Also, issues with reliability and predictability, as well as potential impacts on transmission system operations present further barriers to market adoption. To counter these obstacles, a number of government programs and incentives, from the federal down to the local level, have been initiated to stimulate the market. Additionally, aggregation of a number of customers, on the residential, commercial, industrial, and governmental levels, have allowed these groups to commit to significant purchases of green power at favorable rates, which has spurred further development of green power.

1.3 Methodology and Calculations

Time frame

The model projects increased capacity and electricity generated from green technologies for five-year periods from 2006 to 2035.

Technologies

Thirteen individual technologies, comprising five technology types, were selected as both green and commercially viable for this analysis. These are:

1) Biomass:	- Direct-Fired Biomass
	- Biomass Gasification
	- Landfill Gas
2) Geothermal:	- Flash Geothermal
	- Binary Geothermal
	- Hot Dry Rock
3) Concentrated Solar Power:	- Solar Thermal Trough
	- Solar Thermal Dish-Hybrid
	- Solar Central Receiver
4) Photovoltaics:	- Residential PV (Neighborhood)
	- Central Station PV (Thin Film)
	- Concentrator PV
5) Wind:	- Onshore Wind Turbines

Offshore wind technology characterizations are currently being added to the modeling capabilities of NEMS and MARKAL. However, the specifications of offshore wind turbines for the base case and program case runs were not available for inclusion in this year's GPMM. It is expected that this technology will be included in the FY2007 GPMM base and program runs.

Although the model was initially designed to distinguish between dispatchable and intermittent technologies, more recent versions of the model exclude this distinction. The original distinction was accomplished by adding an extra cost to intermittent technologies associated with "firming up" the technologies' ability to provide a constant power supply. However, since green power programs only guarantee that a certain number or percentage of total kilowatt-hours generated will come from green sources over the course of a year, the developers of new green power do not have the incentive to include backup generation to provide a continuous source of power. Developers are therefore assumed to build the sites in least-cost fashion (i.e., without backup) and take the "green" electrons when and from where they are able.

Regions

The model is composed of regional segments, used to capture differences in the costs of competing technologies, resource availability, levels of participation in voluntary green marketing programs, and electricity demand by sector. U.S. Census regions are used in this model, as the availability of regional data often takes this format. Eight regions (the South Atlantic and East South Central regions are combined) are modeled independently, and then summed to produce national results (see Appendix A). The regions for this analysis are 1) New England, 2) Middle Atlantic, 3) East North Central, 4) West North Central, 5) South Atlantic and East South Central, 6) West South Central, 7) Mountain, and 8) Pacific.

This regional breakdown is different from the regional divisions of NEMS, however. In order to be hardwired into NEMS, the eight regional capacity projections must be converted to the 13 divisions used in NEMS. The NEMS divisions are based on the North American Electric Reliability Council's (NERC) regions. The names of these regions, and the conversion formulas from the census region breakdown, are documented in the model. Detailed results of the model are shown by NEMS Region in **Appendix B.**

Assumptions

The technology cost and performance characterizations for both the base and program cases were taken from FY2006 GPRA Base Case and Program Case input data, as provided by Frances Wood of OnLocation Inc., and the Assumptions to the AEO2004 document. All technology cost figures were converted to 2004$, using GPD price deflators.[4]

The fraction of each region assumed to have competitively set electricity rates, and therefore green marketing program access, is consistent with those used in the Annual Energy Outlook 2004 (AEO2004), as provided by Frances Wood of OnLocation Inc. The state-by-state access to utility green pricing programs, and customer participation rates, for both green marketing and green pricing programs, are taken from a 2001 NREL report, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*.[5] Access to green power programs in regulated markets, is assumed to start at 10% and increases by 5% each year to 55%. Meanwhile, in competitive markets, 100% of customers are assumed to have access to green market programs. Customer participation in regulated markets is assumed to start at 0.75% for residential customers in first year, increasing by 0.75% annually to 7.5% in the 10th year; while

[4] Office of Management and Budget, Budget of the United States Government: Fiscal Year 2005, Table 10.1—GROSS DOMESTIC PRODUCT AND DEFLATORS USED IN THE HISTORICAL TABLES: 1940–2009, available on the Internet at: http://www.gpoaccess.gov/usbudget/fy05/sheets/hist10z1.xls.

[5] Swezey, Blair, R. Wiser, M. Bolinger, and E. Holt, 2001, Growing *the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*, National Renewable Energy Laboratory, US Department of Energy, NREL/TP-620-30101 LBNL-48611.

in competitive markets, customers participation is assumed to start at 1% and increase to 15% in the 15th year of open access. Nonresidential (i.e., commercial and industrial) customers are assumed to be a constant 25% of residential participation in both regulated and competitive markets. Commercial and industrial customers' participation rates are set at 16.7% and 8.3%, respectively, of their residential customers counterparts. A key assumption of the model is that all customers continue in the programs, once they have joined.

These access and participation rates are summed across the regions, and are prorated based on the electricity demand in each state compared to the region as a whole. Regional assumptions for restructuring, green power access, and customer participation rates are shown in Appendix C. Figure 1 shows the combined regional customer participation rates in both green power marketing and green pricing programs.

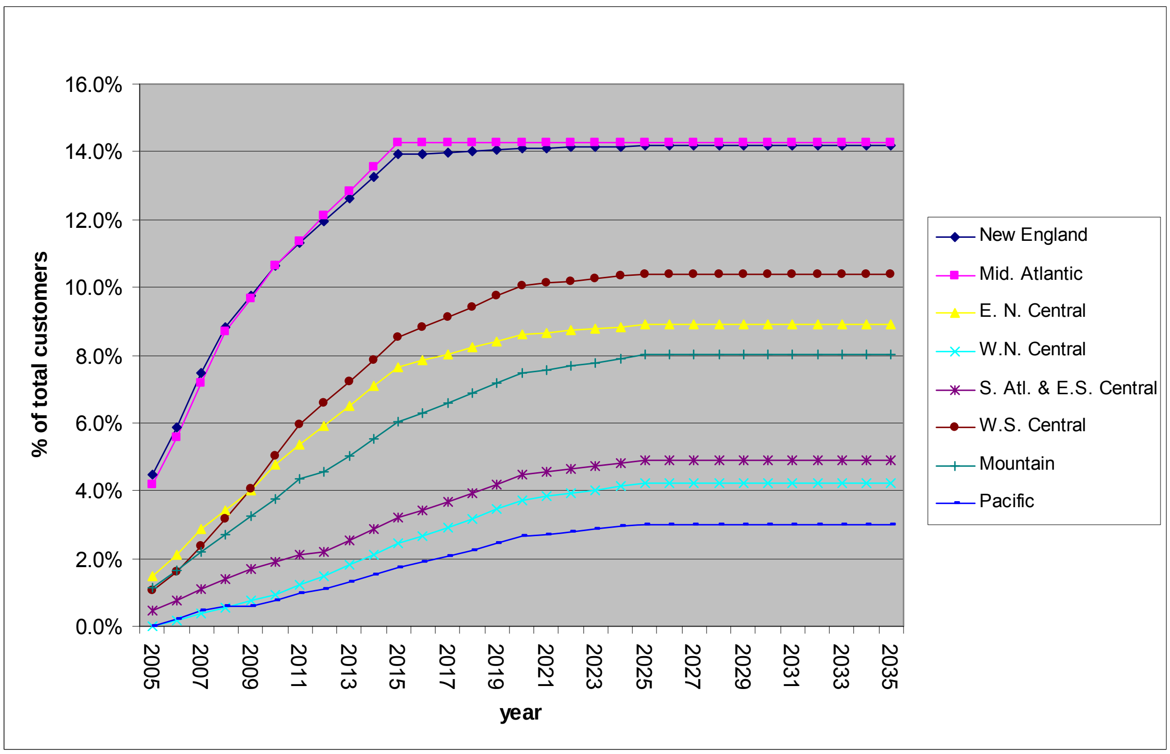

Figure 1. Total Regional Customer Participation Rates in Green Power Marketing and Green Pricing Programs

The choice of how to model the pricing premium for participation in green power programs is another important modeling assumption. The electricity purchased in a green power program is functionally equivalent to any other option offered by a utility or electric service provider. The nonelectric attributes of green power (i.e., from renewable energy sources with no or lower emissions than conventional fuel types) are the reason that customers are willing to pay a premium for this power. A range of payment methods exist for current green programs, with some programs charging an additional amount per kilowatt-hour, a fixed amount each month, or a percentage of the total bill. PERI has chosen to use the percentage of the total bill, assumed to be 10%, to more accurately show the regional energy price variation. The model uses only the dollars from new customers joining green programs each year to build the new capacity. Money from customers who have joined in prior years is assumed to continue to finance projects built in those years. Further, it is assumed that all of the money collected from these programs will go toward building additional capacity.

A very important modeling construct allows the model to build multiple competing technologies in a region, not only the least-cost alternative. This approach avoids so-called knife-edge choices, and recognizes that single-point estimates of data actually represent a range of values. The percentage of funds apportioned to each technology is inversely related to its first-year cost of energy (FY COE) through a sharing algorithm (i.e., a logit function), consistent with NEMS modeling procedures. The spread of the distribution depends on a scaling factor, lambda, which often ranges from 0 to 15. As this factor increases, the lower-cost technologies receive a higher percentage of the total distribution. PERI has chosen to set this factor at 3.2. A small sensitivity analysis was conducted ranging lambda from 2 to 8 with minor impacts (less than 10%) on the resulting totals.

Another set of assumptions deals with creating regional distinctions in the model by varying the resource potential of the technologies. This was done both throughout the entire nation and in subsets of the regions, depending on the specific technology characterizations. Landfill gas, for example, is limited nationwide by the availability of an economically viable resource base. To account for this, a 70 MW capacity limit was instituted in each region for each five-year time period. For other technologies, such as CSP and geothermal, resource-based regional distinctions were introduced via adjustment factors (AF). For each technology, the capacity factors (CF) used in each run are multiplied by the AFs, in order to create the regional distinctions. An AF greater than one implies that the resource is more prevalent in a region; and, therefore, the cost of producing electricity from that technology is lower. The AFs are based on available resource levels as determined from resource maps in the Renewable Energy Technology Characterizations report.[6] The AFs for each region, and the subsequent regional CFs, are noted in **Appendix D**.

Additionally, certain technologies are excluded from regions, due to prohibitively high costs or the absence of a resource base, by setting their respective AFs to zero. **Table 1** documents these exclusions.

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[6] U.S. Department of Energy/Electric Power Research Institute, 1997, *Renewable Energy Technology Characterizations*, Office of Utility Technologies, Energy Efficiency and Renewable Energy, U.S. Department of Energy, EPRI- TR109496.

Table 1. Regional Exclusions of Green Technologies in the FY06 GPMM

Technology	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Direct-Fired Biomass								
Biomass Gasification								
Landfill Gas								
Flash Geothermal	X	X	X	X	X	X		
Binary Geothermal	X	X	X	X	X	X		
Hot Dry Rock	X	X	X	X	X	X		
Solar Thermal Trough								
Solar Thermal Dish Hybrid								
Solar Central Receiver	X	X	X		X			
Residential PV								
Central Station PV								
Concentrator PV								
Onshore Wind Turbines								

X- Indicates regions where technology is assumed to be unavailable.

Geothermal technologies are restricted to penetrate only in the Pacific and Mountain regions. Central receivers are restricted to regions west of the Mississippi, consistent with NEMS modeling procedures. Despite the fact that the central receiver technology is the only type of CSP technology modeled in NEMS, other CSP technologies (i.e., troughs and dishes) are allowed to compete more widely in the GPMM model. Although these CSP technologies are available in all regions, they are given substantial penalties in regions with lower solar insolation via the AFs. For example, the trough technology has a national average of 33% for its CF; however, due to the reductions introduced by the AFs for the New England and Middle Atlantic regions, the CF in these regions is about 23%. The reduction in CF also has the effect of increasing the COE, making this technology less competitive in these regions.

Annual Energy Outlook Inputs

The number of customers by economic sector for each region is determined by the number of residential housing units for the residential sector, the amount of commercial floor space for the commercial sector, and the industrial gross output for the industrial sector. This data is taken from the most recent Energy Information Administration's (EIA) assumptions for the *Annual Energy Outlook 2004, DOE/EIA-0383(2004)*.[7] The residential housing-units data was updated using data provided by EIA.[8] The commercial floor space and industrial gross output were updated from the AEO2004 supplemental data tables, Tables 22 and 23, respectively. The number of commercial establishments is calculated assuming 13,000 square feet per establishment; and the number of industrial establishments is calculated assuming $10 million of gross output per establishment. The regional energy consumption and prices were taken from Tables 1-20 of AEO2004 Supplemental Data Tables.

[7] Energy Information Administration, 2004, *Annual Energy Outlook 2004: With Projections to 2025*, Office of Integrated Analysis and Forecasting, US Department of Energy, DOE/EIA-0383(2004).

[8] Personal contact with EIA, June 25, 2004, John Cymbalsky sent housing data in Excel file "AEO 2004 households data- from J Cymbalsky- 6-25-04.xls".

Other Inputs

For the program case run, PERI includes additions to the green capacity and generation estimates to account for the Million Solar Roofs (MSR) program, as shown in **Table 2.** However, these additions are not included in the base case run, as they are expected to result from program actions and would not be expected to occur in the absence of the program. A primary means of deployment for PV is expected to be in distributed systems, which are customer-sited and customer-owned. This market for distributed systems will be easier for PV to compete in, because it allows PV to compete with retail electricity prices, not the very low competitive grid prices. The MSR initiative targets this application. The realization of MSR goals for PV (i.e., 600,000 systems installed by 2010) has formed the basis for the distributed power-penetration projections since the FY2001 GPRA benefits reporting. Projections beyond 2010 assume declining annual growth rates, as would be expected to occur after the end of a major initiative.

Table 2. Million Solar Roofs – Incremental Capacity Additions in the GPMM05

Year Period	FY2006 MSR Capacity Additions (above 2005 Baseline)
2006-2010	773
2011-2015	1,761
2016-2020	1,348
2021-2025	385
2026-2030	0
2031-2035	0
Total for 2006-2035	4,267

For both the base case and program case runs, the EIA "floors" builds are subtracted from the results of the model. EIA describes the inclusion of "Floors" capacity in the Renewable Fuels Module section of the *Assumptions to the Annual Energy Outlook 2004*, page 137, and in the *Model Documentation- Renewable Fuels Module of the National Energy Modeling System* report, page 81. "Recognizing that some new solar generating capacity is installed for reasons other than represented in the EMM, such as for market testing or unique economic requirements, EIA includes estimates of minimal new grid-connected generating capacity using solar resources."[9] An additional 332.5 MW of central station PV and 75.5 MW of central station solar thermal capacity are "assumed by EIA to be installed for reasons in addition to least-cost electricity supply," during the period 2001 to 2025.[10] **Table 3** shows the "floors" capacity additions, which are prorated for 2006 to 2025 and regionally divided among the regions that have capacity additions in these technologies.

[9] Energy Information Administration, 2004, *Model Documentation- Renewable Fuels Module of the National Energy Modeling System*, U.S. Department of Energy, DOE/EIA-M069(2004).

[10] Energy Information Administration, 2004, *Assumptions to the Annual Energy Outlook 2004- Renewable Fuels Module*, U.S. Department of Energy, DOE/EIA-0554(2004).

Table 3. EIA "Floors" Incremental Capacity Additions for PV and Solar Thermal in NEMS

Year Period	EIA PV "Floors" Capacity Additions (above 2005 Baseline)	EIA Solar Thermal "Floors" Capacity Additions (above 2005 Baseline)
2006-2010	69.3	15.7
2011-2015	69.3	15.7
2016-2020	69.3	15.7
2021-2025	69.3	15.7
2026-2030	0.0	0.0
2031-2035	0.0	0.0
Total for 2006-2035	277.1	62.9

These amounts are then subtracted from the residential PV and solar central receiver green power builds, respectively, for each region. However, if the prorated regional portion of the "Floors" additions was greater than the regional builds in the GPMM, only the amount predicted to be built by the GPMM was subtracted (i.e., value reported as zero, no negative numbers reported), as shown in **Tables 4 and 5**, for the base case and reference case, respectively.

Table 4. EIA "Floors" Incremental Capacity Subtracted from FY2006 GPMM - Base Case

Year Period	EIA PV "Floors" Capacity Additions Subtracted from the FY2006 GPMM (above 2005 Baseline)	EIA Solar Thermal "Floors" Capacity Additions Subtracted from the FY2006 GPMM (above 2005 Baseline)
2006-2010	0.0	7.4
2011-2015	0.0	10.9
2016-2020	0.0	7.9
2021-2025	0.0	4.8
2026-2030	0.0	0.0
2031-2035	0.0	0.0
Total for 2006-2035	0.0	31.0

Table 5. EIA "Floors" Incremental Capacity Subtracted from FY2006 GPMM - Reference Case

Year Period	EIA PV "Floors" Capacity Additions Subtracted from the FY2006 GPMM (above 2005 Baseline)	EIA Solar Thermal "Floors" Capacity Additions Subtracted from the FY2006 GPMM (above 2005 Baseline)
2006-2010	0.0	1.6
2011-2015	0.0	4.4
2016-2020	4.3	5.6
2021-2025	3.8	3.5
2026-2030	0.0	0.0
2031-2035	0.0	0.0
Total for 2006-2035	8.0	15.0

As can be seen in **Tables 4 and 5**, not all of the PV or solar thermal "floors" additions in **Table 3** were subtracted from the FY2006 GPMM model results. No Residential PV capacity is built by the model in the base case run, and very little capacity is built in the program case run, resulting in almost no PV subtractions in **Tables 4 and 5**. The solar central receiver technology competes better in the base case run, as its COE is more competitive relative to other renewable technologies in the base case. In both cases, the subtractions due to the "floors" capacity effectively eliminates the solar central receiver builds of the model, until after 2025, when no "floors" capacity is accounted for in NEMS.

Results

The results of the base case and program case runs of the model, and the incremental capacity between these two runs are shown in **Tables 6, 7 and 8**, respectively. The electricity generated from this capacity for the base case, program case runs, and the incremental difference is shown in **Tables 9, 10 and 11**, respectively. It should be noted that technologies with negative results in the incremental difference between the program and base cases are treated as zeros for inclusion in NEMS (i.e., no capacity additions for the technology due to penetration in the green power markets). A detailed accounting of the results for the base case and program cases is given by NEMS region, in **Appendix B**.

Table 6. Green Power Capacity Constructed in the GPMM- Base Case (MW)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	28	31	16	10	6	7	98	Total Biomass
Biomass Gasification	327	316	144	69	41	44	941	1,341
Landfill Gas	54	66	63	50	33	35	302	
Flash Geothermal	12	17	12	4	2	2	49	Total Geothermal
Binary Geothermal	12	17	12	4	2	2	49	183
Enhanced Geothermal Systems	5	14	17	22	13	14	85	
Solar Thermal Trough	9	14	9	5	3	3	44	Total Solar Thermal
Solar Thermal Dish Hybrid	7	10	7	4	2	3	34	83
Solar Central Receiver	0	0	0	0	2	3	5	
Residential PV	0	0	0	0	0	0	0	Total PV
Central Station PV	0	0	0	0	0	0	0	2
Concentrator PV	0	0	0	1	0	1	2	
Wind	762	632	256	119	72	77	1,920	Total Wind 1,920
GPMM Total	1,217	1,116	537	288	178	192	3,529	

Table 7. Green Power Capacity Constructed in the GPMM- Program Case (MW)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	27	35	26	11	6	6	111	Total Biomass
Biomass Gasification	182	175	90	35	18	19	519	918
Landfill Gas	60	64	60	47	27	29	287	
Flash Geothermal	7	10	6	5	3	3	34	Total Geothermal
Binary Geothermal	7	10	6	5	3	3	34	109
Enhanced Geothermal Systems	4	8	9	10	5	6	41.3	
Solar Thermal Trough	4	24	30	19	10	11	97	Total Solar Thermal
Solar Thermal Dish Hybrid	3	19	23	15	8	8	76	177
Solar Central Receiver	0	0	0	0	2	2	4	
Residential PV	773	1,761	1,348	385	0	0	4,267	Total PV
Central Station PV	0	0	0	0	1	1	2	4,280
Concentrator PV	0	0	4	4	1	1	11	
Wind	1,372	1,239	448	262	198	210	3,729	Total Wind 3,729
GPMM Total	2,440	3,344	2,051	796	282	300	9,212	

Table 8. Green Power Capacity Constructed in the GPMM- Incremental between Program Case and Base Case (MW)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	-1	4	10	1	0	-1	13	Total Biomass
Biomass Gasification	-145	-141	-54	-34	-23	-25	-422	-423
Landfill Gas	6	-2	-3	-3	-6	-6	-15	
Flash Geothermal	-5	-7	-6	1	1	1	-15	Total Geothermal
Binary Geothermal	-5	-7	-6	1	1	1	-15	-74
Enhanced Geothermal Systems	-1	-6	-8	-12	-8	-8	-43.7	
Solar Thermal Trough	-5	10	21	14	7	8	53	Total Solar Thermal
Solar Thermal Dish Hybrid	-4	9	16	11	6	5	42	94
Solar Central Receiver	0	0	0	0	0	-1	-1	
Residential PV	773	1,761	1,348	385	0	0	4,267	Total PV
Central Station PV	0	0	0	0	1	1	2	4,278
Concentrator PV	0	0	4	3	1	0	9	
Wind	610	607	192	143	126	133	1,809	Total Wind 1,809
GPMM Total	1,224	2,227	1,515	508	106	109	5,683	

Table 9. Green Power Generation from Capacity Constructed in the GPMM- Base Case (MWh)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	203,345	226,184	118,849	79,465	47,821	51,252	726,918	Total Biomass
Biomass Gasification	2,382,657	2,311,085	1,063,801	517,959	311,251	333,200	6,919,952	10,084,016
Landfill Gas	430,441	520,977	505,734	413,013	274,315	292,667	2,437,147	
Flash Geothermal	103,733	156,729	117,709	49,216	27,331	30,134	484,853	Total Geothermal
Binary Geothermal	103,733	156,729	117,709	49,216	27,331	30,134	484,853	969,705
Enhanced Geothermal Systems	0	0	0	0	0	0	0.0	
Solar Thermal Trough	11,655	17,187	12,269	7,502	4,379	4,779	57,771	Total Solar Thermal
Solar Thermal Dish Hybrid	11,655	17,187	12,269	7,502	4,379	4,779	57,771	132,629
Solar Central Receiver	1,945	2,803	1,949	1,233	4,379	4,779	17,088	
Residential PV	0	0	0	0	0	0	0	Total PV
Central Station PV	0	0	0	0	0	0	0	4,321
Concentrator PV	0	0	0	1,845	1,187	1,290	4,321	
Wind	2,613,395	2,218,216	927,525	452,599	272,147	292,004	6,775,886	Total Wind 6,775,886
GPMM Total	5,862,560	5,627,097	2,877,814	1,579,549	974,519	1,045,019	17,966,558	

Table 10. Green Power Generation from Capacity Constructed in the GPMM- Program Case (MWh)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	187,902	247,839	180,982	78,120	40,784	44,090	779,718	Total Biomass
Biomass Gasification	1,275,579	1,226,983	631,830	242,111	125,630	135,760	3,637,894	6,683,001
Landfill Gas	476,017	502,570	470,259	373,657	212,817	230,067	2,265,388	
Flash Geothermal	60,450	79,644	54,513	41,294	22,225	24,622	282,747	Total Geothermal
Binary Geothermal	60,450	79,644	54,513	41,294	22,225	24,622	282,747	872,025
Enhanced Geothermal Systems	26,650	58,742	66,084	71,331	39,702	44,022	306,531	
Solar Thermal Trough	16,109	84,255	107,385	67,047	36,097	39,192	350,084	Total Solar Thermal
Solar Thermal Dish Hybrid	16,109	84,255	107,385	67,047	36,097	39,192	350,084	784,998
Solar Central Receiver	3,774	12,958	19,760	12,695	16,983	18,659	84,831	
Residential PV	1,625,155	3,702,326	2,834,035	809,424	0	0	8,970,941	Total PV
Central Station PV	0	0	16	326	2,510	2,736	5,587	8,999,004
Concentrator PV	0	0	8,986	8,245	2,510	2,736	22,476	
Wind	5,622,554	5,265,935	1,928,285	1,164,033	887,251	934,466	15,802,523	Total Wind 15,802,523
GPMM Total	9,370,750	11,345,152	6,464,031	2,976,624	1,444,830	1,540,163	33,141,550	33,141,550

Table 11. Green Power Generation from Capacity Constructed in the GPMM- Incremental between Program Case and Base Case (MWh)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Specific Technology Totals	Cumulative RET Totals
Direct-Fired Biomass	-15,443	21,654	62,133	-1,345	-7,037	-7,162	52,801	Total Biomass
Biomass Gasification	-1,107,078	-1,084,101	-431,971	-275,847	-185,620	-197,440	-3,282,058	-3,401,016
Landfill Gas	45,576	-18,407	-35,475	-39,355	-61,498	-62,600	-171,758	
Flash Geothermal	-43,283	-77,085	-63,197	-7,922	-5,107	-5,512	-202,105	Total Geothermal
Binary Geothermal	-43,283	-77,085	-63,197	-7,922	-5,107	-5,512	-202,105	-97,680
Enhanced Geothermal Systems	26,650	58,742	66,084	71,331	39,702	44,022	306,531	
Solar Thermal Trough	4,454	67,068	95,116	59,544	31,718	34,413	292,313	Total Solar Thermal
Solar Thermal Dish Hybrid	4,454	67,068	95,116	59,544	31,718	34,413	292,313	652,369
Solar Central Receiver	1,829	10,155	17,812	11,463	12,605	13,880	67,743	
Residential PV	1,625,155	3,702,326	2,834,035	809,424	0	0	8,970,941	Total PV
Central Station PV	0	0	16	326	2,510	2,736	5,587	8,994,682
Concentrator PV	0	0	8,986	6,400	1,323	1,446	18,155	
Wind	3,009,158	3,047,719	1,000,759	711,434	615,104	642,462	9,026,636	Total Wind 9,026,636
GPMM Total	3,508,191	5,718,055	3,586,217	1,397,074	470,311	495,144	15,174,992	

1.4 Sources

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Appendices

Appendix A: National Results of the GPMM

Base Case

Cumulative Capacity Additions from 2003 Baseline (MW)

	2010	2015	2020	2025	2030	2035
Biomass (incl. LFG)	409	821	1,045	1,174	1,255	1,341
Geothermal	29	77	118	147	165	184
CSP	17	41	57	67	74	83
PV	0	0	0	1	1	2
Wind	762	1,395	1,651	1,770	1,842	1,920
Total	1,217	2,334	2,871	3,159	3,337	3,529

* Includes MSR additions for PV Residential and EIA "Floors" subtractions for PV Central Station and CSP Troughs

Green Revenues ($millions/period)

	2010	2015	2020	2025	2030	2035
Residential	265	259	132	72	42	45
Commercial	43	40	20	14	10	11
Industrial	14	13	7	5	4	4
Total ($millions/year)	322	312	160	91	56	60

Appendix A: National Results of the GPMM (Continued)

<u>Program Case</u>
Cumulative Capacity Additions from 2003 Baseline (MW)

	2010	2015	2020	2025	2030	2035
Biomass (incl. LFG)	269	543	719	812	863	918
Geothermal	18	45	67	86	97	109
CSP	7	50	103	136	156	177
PV	773	2,534	3,886	4,275	4,277	4,280
Wind	1,372	2,612	3,059	3,321	3,519	3,729
Total	2,440	5,784	7,835	8,631	8,912	9,212

* Includes MSR additions for PV Residential and EIA "Floors" subtractions for PV Central Station and CSP Troughs

Green Revenues ($millions/period)

	2010	2015	2020	2025	2030	2035
Residential	265	259	132	72	42	45
Commercial	43	40	20	14	10	11
Industrial	14	13	7	5	4	4
Total ($millions/year)	322	312	160	91	56	60

Appendix B: Capacity Installed by NEMS region

Capacity Installed by NEMS region- GPMM FY06- Base Case

Direct Fired Biomass	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	3.2	3.9	2.2	1.3	0.8	0.8	12.3
2	2.7	3.8	2.4	1.4	0.9	1.0	12.3
3	6.8	5.2	0.9	0.8	0.6	0.7	15.1
4	1.8	2.1	1.1	0.6	0.4	0.4	6.5
5	0.2	0.5	0.5	0.3	0.1	0.1	1.8
6	4.4	3.2	0.3	0.3	0.3	0.3	8.9
7	4.0	2.8	0.5	0.6	0.5	0.6	9.0
8	0.3	0.9	1.1	0.6	0.3	0.3	3.6
9	1.0	2.8	3.2	1.9	0.8	0.9	10.7
10	2.8	4.1	2.7	1.6	1.0	1.0	13.2
11	0.2	0.4	0.4	0.3	0.2	0.2	1.6
12	0.4	0.6	0.5	0.4	0.2	0.3	2.4
13	0.1	0.2	0.3	0.2	0.1	0.1	0.9
Total	28	31	16	10	6	7	98

Biomass Gasification	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	41.5	44.0	22.2	10.0	6.0	6.3	130.0
2	30.6	37.6	21.1	9.1	5.9	6.4	110.7
3	90.8	61.0	8.9	6.1	4.9	5.1	176.8
4	24.3	23.9	10.5	4.8	3.1	3.3	69.8
5	2.9	5.5	4.3	1.9	0.7	0.8	16.2
6	59.1	37.2	2.5	2.6	2.6	2.7	106.6
7	23.0	13.5	2.1	2.1	1.8	1.9	44.4
8	4.3	10.6	10.2	4.4	1.9	2.1	33.6
9	12.9	31.8	30.6	13.3	5.8	6.4	100.8
10	31.3	40.3	23.7	10.2	6.2	6.8	118.6
11	2.1	3.4	2.5	1.4	0.8	0.9	11.1
12	3.3	4.9	3.3	2.0	1.3	1.4	16.0
13	0.9	2.0	1.9	0.8	0.3	0.3	6.1
Total	327	316	144	69	41	44	941

Landfill Gas	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	7.8	8.4	8.4	7.2	4.3	4.5	40.5
2	5.2	5.2	5.2	5.2	4.9	5.2	31.1
3	5.5	6.1	5.0	4.4	3.5	3.6	28.2
4	3.7	3.7	3.7	3.4	2.2	2.3	18.9
5	1.2	3.2	3.1	1.6	0.6	0.6	10.4
6	2.5	2.5	1.8	1.8	1.8	1.8	12.2
7	2.4	2.4	2.4	2.4	2.4	2.4	14.5
8	3.6	4.8	4.8	3.4	1.5	1.6	19.7
9	10.7	14.3	14.3	10.2	4.5	4.9	59.0
10	5.9	7.4	7.4	6.3	5.2	5.6	37.8
11	2.0	2.4	2.3	1.5	0.8	0.9	9.9
12	3.0	3.0	3.0	2.1	1.3	1.5	13.9
13	1.0	2.0	1.9	0.9	0.3	0.3	6.4
Total	54	66	63	50	33	35	302

Capacity Installed by NEMS region- GPMM FY06- Base Case (Continued)

Binary Geothermal	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	4.1	5.7	3.9	1.3	0.8	0.8	16.5
12	6.4	8.5	5.3	1.8	1.2	1.3	24.6
13	1.4	2.8	2.5	0.8	0.3	0.3	8.2
Total	12	17	12	4	2	2	49

Flash Geothermal	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	4.1	5.7	3.9	1.3	0.8	0.8	16.5
12	6.4	8.5	5.3	1.8	1.2	1.3	24.6
13	1.4	2.8	2.5	0.8	0.3	0.3	8.2
Total	12	17	12	4	2	2	49

Enhanced Geothermal Systems	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1.8	4.6	5.5	7.3	4.4	4.8	28.5
12	2.8	6.7	7.4	10.5	6.9	7.7	41.9
13	0.7	2.6	4.1	4.3	1.5	1.6	14.8
Total	5	14	17	22	13	14	85

Capacity Installed by NEMS region- GPMM FY06- Base Case (Continued)

Solar Thermal Dish-Hybrid	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.9	3.8	2.4	1.2	0.8	0.9	12.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.1	0.3	0.3	0.2	0.0	0.0	0.8
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	3.0	4.0	2.6	1.3	0.8	0.9	12.6
11	0.4	0.8	0.6	0.4	0.2	0.2	2.7
12	0.6	1.0	0.7	0.5	0.3	0.4	3.5
13	0.2	0.6	0.7	0.3	0.1	0.1	2.1
Total	7	10	7	4	2	3	34

Solar Central Receiver	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.8	0.9	1.6
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.8	0.9	1.7
11	0.0	0.0	0.0	0.0	0.2	0.2	0.5
12	0.0	0.0	0.0	0.0	0.3	0.4	0.7
13	0	0	0	0	0	0	0
Total	0	0	0	0	2	3	5

Solar Thermal Trough	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.8	5.0	3.1	1.6	1.0	1.1	15.7
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.1	0.3	0.4	0.2	0.1	0.1	1.1
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	3.9	5.3	3.4	1.7	1.1	1.2	16.5
11	0.5	1.0	0.8	0.5	0.3	0.3	3.5
12	0.8	1.3	1.0	0.7	0.4	0.5	4.6
13	0.3	0.8	0.9	0.5	0.2	0.2	2.8
Total	9	14	9	5	3	3	44

* Includes Subtractions of NEMS "Floor" Capacity Additions

Capacity Installed by NEMS region- GPMM FY06- Base Case (Continued)

PV Residential	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.00	0.00

Central Station PV	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.00	0.00

* Includes Subtractions of NEMS "Floor" Capacity Additions

Concentrator PV	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.4	0.2	0.3	0.9
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.4	0.2	0.3	0.9
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0	0	0	1	0	1	2

Capacity Installed by NEMS region- GPMM FY06- Base Case (Continued)							
Wind	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	89.3	83.3	36.8	16.0	9.6	10.2	245.2
2	73.2	81.3	39.8	17.0	11.0	12.0	234.3
3	134.3	81.3	12.3	7.8	5.9	6.1	247.7
4	50.9	45.9	17.9	7.8	5.0	5.3	132.7
5	6.1	9.5	6.5	2.9	1.1	1.2	27.3
6	85.0	48.3	3.0	2.9	2.9	3.0	145.1
7	175.9	96.9	13.9	8.5	7.2	7.5	309.9
8	13.6	17.8	15.6	6.8	3.0	3.3	60.1
9	40.7	53.3	46.9	20.5	9.1	9.9	180.4
10	74.7	85.6	43.6	18.7	11.6	12.6	246.8
11	6.3	9.6	6.4	3.4	1.9	2.2	29.8
12	9.6	13.3	8.1	4.7	3.0	3.3	42.0
13	2.8	6.3	5.5	2.3	0.8	0.8	18.5
Total	762	632	256	119	72	77	1,920

Appendix B: Capacity Installed by NEMS region (Continued)

Capacity Installed by NEMS region- GPMM FY06- Program Case

Direct Fired Biomass	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	3	4	3	1	1	1	13
2	2	3	2	1	1	1	9
3	5	5	2	1	1	1	14
4	2	2	1	0	0	0	5
5	0	0	0	0	0	0	1
6	3	2	0	0	0	0	7
7	4	2	0	0	0	0	8
8	1	3	3	1	1	1	9
9	3	9	9	4	2	2	28
10	2	3	2	1	1	1	10
11	0	1	1	0	0	0	2
12	0	1	1	0	0	0	3
13	0	0	0	0	0	0	1
Total	27	35	26	11	6	6	111

Biomass Gasification	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	23	22	12	5	2	3	67
2	15	14	7	3	2	2	42
3	42	27	7	3	2	2	83
4	12	9	4	2	1	1	28
5	1	2	2	1	0	0	6
6	26	13	1	1	1	1	42
7	12	5	1	1	0	1	20
8	8	15	11	4	2	2	42
9	23	46	34	12	5	5	125
10	15	15	8	3	2	2	45
11	2	2	1	1	0	0	6
12	2	3	2	1	1	1	9
13	1	1	1	0	0	0	3
Total	182	175	90	35	18	19	519

Landfill Gas	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	8	8	8	6	3	3	38
2	5	5	5	4	3	3	26
3	6	6	4	4	3	3	26
4	4	4	4	2	1	1	16
5	1	2	2	1	0	0	7
6	3	3	1	1	1	1	9
7	2	2	2	2	1	2	12
8	5	5	5	5	2	3	24
9	14	14	14	14	7	8	72
10	6	7	7	5	3	3	30
11	2	2	2	1	1	1	9
12	3	3	3	2	1	1	13
13	1	2	2	1	0	0	6
Total	60	64	60	47	27	29	287

Capacity Installed by NEMS region- GPMM FY06- Program Case (Cont.)

Binary Geothermal	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	2	3	2	2	1	1	11
12	4	5	3	2	1	2	16
13	1	2	2	1	0	0	6
Total	7	10	6	5	3	3	34

Flash Geothermal	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	2	3	2	2	1	1	11
12	4	5	3	2	1	2	16
13	1	2	2	1	0	0	6
Total	7	10	6	5	3	3	34

Enhanced Geothermal Systems	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	1	3	3	3	2	2	14
12	2	4	4	5	3	3	20
13	0	1	2	2	1	1	7
Total	4	8	9	10	5	6	41

Capacity Installed by NEMS region- GPMM FY06- Program Case (Cont.)

Solar Thermal Dish-Hybrid	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	2	2	2	1	1	8
2	1	2	2	1	1	1	9
3	0	2	1	1	1	1	6
4	0	1	1	1	0	0	3
5	0	0	0	0	0	0	1
6	0	1	0	0	0	0	2
7	0	1	0	0	0	0	3
8	0	1	2	1	1	1	6
9	1	4	7	4	2	2	19
10	1	2	3	2	1	1	9
11	0	1	1	1	0	0	3
12	0	1	1	1	1	1	5
13	0	0	1	1	0	0	2
Total	3	19	23	15	8	8	76

Solar Central Receiver	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	0
2	0	0	0	0	1	1	1
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	1	1	1
11	0	0	0	0	0	0	1
12	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0
Total	0	0	0	0	2	2	4

Solar Thermal Trough	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	2	3	2	1	1	10
2	1	3	3	2	1	1	11
3	0	3	2	1	1	1	8
4	0	1	1	1	0	0	3
5	0	0	0	0	0	0	1
6	0	1	0	0	0	0	3
7	0	1	1	1	0	0	3
8	0	2	3	2	1	1	8
9	1	5	9	5	2	2	24
10	1	3	3	2	1	1	12
11	0	1	1	1	1	1	4
12	0	1	2	1	1	1	6
13	0	1	1	1	0	0	3
Total	4	24	30	19	10	11	97

* Includes Subtractions of NEMS "Floor" Capacity Additions

Capacity Installed by NEMS region- GPMM FY06- Program Case (Cont.)

PV Residential	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	80	183	140	40	0	0	443
2	73	167	127	36	0	0	404
3	70	159	122	35	0	0	385
4	21	47	36	10	0	0	113
5	5	12	9	3	0	0	29
6	15	35	27	8	0	0	84
7	20	47	36	10	0	0	113
8	94	214	164	47	0	0	518
9	282	641	491	140	0	0	1,554
10	76	173	132	38	0	0	418
11	13	31	23	7	0	0	74
12	24	54	42	12	0	0	132
13	0	0	0	0	0	0	0
Total	773	1,761	1,348	385	0	0	4,267

* Includes Additions of MSR Capacity Additions

Central Station PV	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	1	1	1
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
Total	0	0	0	0	1	1	2

* Includes Subtractions of NEMS "Floor" Capacity Additions

Concentrator PV	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	0	0	0	0	0	0	1
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	1
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	1	1	0	0	2
9	0	0	3	2	1	1	6
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
Total	0	0	4	4	1	1	11

Capacity Installed by NEMS region- GPMM FY06- Program Case (Cont.)							
Wind	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
1	160	164	69	39	27	28	487
2	142	179	91	46	36	38	532
3	316	204	16	18	19	20	592
4	99	101	43	24	16	17	300
5	13	27	21	11	4	4	79
6	210	136	11	12	13	13	395
7	231	139	22	20	19	19	450
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	146	192	104	52	38	41	573
11	18	33	23	14	9	10	107
12	28	47	32	20	14	15	156
13	7	18	17	8	3	3	57
Total	1,372	1,239	448	262	198	210	3,729

Appendix C: Regional Green Power Access and Market Penetration Parameters

Fraction of each region assumed to have competitively set electricity rates in the AEO2004

	NEMS Regions	2005	2010	2015	2020	2025	2030	2035
1	ECAR	32%	63%	63%	63%	63%	63%	63%
2	ERCOT	40%	90%	100%	100%	100%	100%	100%
3	Mid Atlantic	70%	100%	100%	100%	100%	100%	100%
4	MAIN	33%	55%	55%	55%	55%	55%	55%
5	MAPP	0%	0%	0%	0%	0%	0%	0%
6	New York	70%	100%	100%	100%	100%	100%	100%
7	New England	70%	100%	100%	100%	100%	100%	100%
8	Florida	0%	0%	0%	0%	0%	0%	0%
9	SERC	7%	13%	13%	13%	13%	13%	13%
10	SPP	12%	33%	41%	41%	41%	41%	41%
11	NWP	10%	22%	25%	25%	25%	25%	25%
12	RA	26%	59%	65%	65%	65%	65%	65%
13	California	5%	5%	5%	5%	5%	5%	5%

Fraction of each region assumed to have competitively set electricity rates in the AEO2004

	Census Regions	2005	2010	2015	2020	2025	2030	2035
1	New England	70%	100%	100%	100%	100%	100%	100%
2	Mid. Atlantic	70%	100%	100%	100%	100%	100%	100%
3	E. N. Central	31%	58%	58%	58%	58%	58%	58%
4	W.N. Central	5%	14%	18%	18%	18%	18%	18%
5	S. Atl. & E.S. Central	14%	24%	24%	24%	24%	24%	24%
6	W.S. Central	26%	62%	71%	71%	71%	71%	71%
7	Mountain	20%	46%	51%	51%	51%	51%	51%
8	Pacific	6%	9%	10%	10%	10%	10%	10%

Percent of All Customers Participating in Green Programs (both marketing and pricing)

	2005	2010	2015	2020	2025	2030	2035
New England	4.2%	10.7%	13.9%	14.1%	14.2%	14.2%	14.2%
Mid. Atlantic	4.0%	10.6%	14.3%	14.3%	14.3%	14.3%	14.3%
E. N. Central	1.1%	4.2%	6.8%	7.7%	7.9%	7.9%	7.9%
W.N. Central	0.0%	0.3%	1.1%	1.8%	2.0%	2.0%	2.0%
S. Atl. & E.S. Central	0.2%	0.8%	1.8%	2.6%	2.9%	2.9%	2.9%
W.S. Central	0.7%	3.9%	7.2%	8.5%	8.8%	8.8%	8.8%
Mountain	0.6%	2.6%	5.1%	6.3%	6.8%	6.8%	6.8%
Pacific	0.0%	0.2%	0.7%	1.1%	1.2%	1.2%	1.2%

Appendix C: Regional Green Power Access and Market Penetration Parameters (Cont.)

Customer Penetration Yearly Addition- Incremental Penetration

	2005	2010	2015	2020	2025	2030	2035
New England	1.3%	0.9%	0.7%	0.0%	0.0%	0.0%	0.0%
Mid. Atlantic	1.4%	1.0%	0.7%	0.0%	0.0%	0.0%	0.0%
E. N. Central	0.5%	0.7%	0.5%	0.2%	0.0%	0.0%	0.0%
W.N. Central	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%
S. Atl. & E.S. Central	0.1%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%
W.S. Central	0.4%	0.8%	0.6%	0.3%	0.1%	0.0%	0.0%
Mountain	0.3%	0.5%	0.4%	0.3%	0.1%	0.0%	0.0%
Pacific	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%

Appendix D: Regional Adjustment Factors and Capacity Factors

Direct-Fired Biomass		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
New England	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Mid. Atlantic	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
E. N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
W.N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
S. Atl. & E.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
W.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%

Biomass Gasification		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
New England	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Mid. Atlantic	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
E. N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
W.N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
S. Atl. & E.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
W.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%	80.00%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

Landfill Gas		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
New England	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
Mid. Atlantic	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
E. N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
W.N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
S. Atl. & E.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
W.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%

Flash Geothermal		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
New England	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid. Atlantic	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E. N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
S. Atl. & E.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	93.00%	95.00%	95.50%	96.00%	96.00%	96.00%	96.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	93.00%	95.00%	95.50%	96.00%	96.00%	96.00%	96.00%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

Binary Geothermal		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	93.00%	95.00%	95.50%	96.00%	96.00%	96.00%	96.00%
New England	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid. Atlantic	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E. N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
S. Atl. & E.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	93.00%	95.00%	95.50%	96.00%	96.00%	96.00%	96.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	93.00%	95.00%	95.50%	96.00%	96.00%	96.00%	96.00%

Enhanced Geothermal Systems		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	82.00%	83.00%	84.00%	85.00%	85.00%	85.00%	85.00%
New England	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid. Atlantic	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E. N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
S. Atl. & E.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	82.00%	83.00%	84.00%	85.00%	85.00%	85.00%	85.00%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	82.00%	83.00%	84.00%	85.00%	85.00%	85.00%	85.00%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

CSP Trough		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	41.70%	51.20%	51.20%	51.20%	51.20%	51.20%	51.20%
New England	Adjustment	0.69	0.69	0.69	0.69	0.69	0.69	0.69
	Cap Factor	28.84%	35.41%	35.41%	35.41%	35.41%	35.41%	35.41%
Mid. Atlantic	Adjustment	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Cap Factor	29.32%	36.00%	36.00%	36.00%	36.00%	36.00%	36.00%
E. N. Central	Adjustment	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	Cap Factor	29.99%	36.82%	36.82%	36.82%	36.82%	36.82%	36.82%
W.N. Central	Adjustment	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	Cap Factor	33.90%	41.62%	41.62%	41.62%	41.62%	41.62%	41.62%
S. Atl. & E.S. Central	Adjustment	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Cap Factor	31.37%	38.52%	38.52%	38.52%	38.52%	38.52%	38.52%
W.S. Central	Adjustment	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	Cap Factor	38.09%	46.77%	46.77%	46.77%	46.77%	46.77%	46.77%
Mountain	Adjustment	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	Cap Factor	40.96%	50.29%	50.29%	50.29%	50.29%	50.29%	50.29%
Pacific	Adjustment	0.84	0.84	0.84	0.84	0.84	0.84	0.84
	Cap Factor	34.82%	42.76%	42.76%	42.76%	42.76%	42.76%	42.76%

Solar Thermal Dish- Hybrid		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%
New England	Adjustment	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	Cap Factor	45.28%	45.28%	45.28%	45.28%	45.28%	45.28%	45.28%
Mid. Atlantic	Adjustment	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	Cap Factor	45.95%	45.95%	45.95%	45.95%	45.95%	45.95%	45.95%
E. N. Central	Adjustment	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	Cap Factor	46.94%	46.94%	46.94%	46.94%	46.94%	46.94%	46.94%
W.N. Central	Adjustment	1.06	1.06	1.06	1.06	1.06	1.06	1.06
	Cap Factor	53.23%	53.23%	53.23%	53.23%	53.23%	53.23%	53.23%
S. Atl. & E.S. Central	Adjustment	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	Cap Factor	49.08%	49.08%	49.08%	49.08%	49.08%	49.08%	49.08%
W.S. Central	Adjustment	1.19	1.19	1.19	1.19	1.19	1.19	1.19
	Cap Factor	59.71%	59.71%	59.71%	59.71%	59.71%	59.71%	59.71%
Mountain	Adjustment	1.29	1.29	1.29	1.29	1.29	1.29	1.29
	Cap Factor	64.28%	64.28%	64.28%	64.28%	64.28%	64.28%	64.28%
Pacific	Adjustment	1.09	1.09	1.09	1.09	1.09	1.09	1.09
	Cap Factor	54.46%	54.46%	54.46%	54.46%	54.46%	54.46%	54.46%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

Solar Central Receiver		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	44.00%	65.00%	71.00%	77.00%	77.00%	77.00%	77.00%
New England	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid. Atlantic	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E. N. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.N. Central	Adjustment	1.06	1.06	1.06	1.06	1.06	1.06	1.06
	Cap Factor	46.84%	69.20%	75.59%	81.97%	81.97%	81.97%	81.97%
S. Atl. & E.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.S. Central	Adjustment	1.19	1.19	1.19	1.19	1.19	1.19	1.19
	Cap Factor	52.54%	77.62%	84.78%	91.95%	91.95%	91.95%	91.95%
Mountain	Adjustment	1.29	1.29	1.29	1.29	1.29	1.29	1.29
	Cap Factor	56.57%	83.57%	91.28%	99.00%	99.00%	99.00%	99.00%
Pacific	Adjustment	1.09	1.09	1.09	1.09	1.09	1.09	1.09
	Cap Factor	47.92%	70.80%	77.33%	83.87%	83.87%	83.87%	83.87%

Residential PV		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	24.00%	24.00%	24.00%	24.00%	24.00%	24.00%	24.00%
New England	Adjustment	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	Cap Factor	22.10%	22.10%	22.10%	22.10%	22.10%	22.10%	22.10%
Mid. Atlantic	Adjustment	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	Cap Factor	22.35%	22.35%	22.35%	22.35%	22.35%	22.35%	22.35%
E. N. Central	Adjustment	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Cap Factor	22.68%	22.68%	22.68%	22.68%	22.68%	22.68%	22.68%
W.N. Central	Adjustment	1.05	1.05	1.05	1.05	1.05	1.05	1.05
	Cap Factor	25.12%	25.12%	25.12%	25.12%	25.12%	25.12%	25.12%
S. Atl. & E.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	24.04%	24.04%	24.04%	24.04%	24.04%	24.04%	24.04%
W.S. Central	Adjustment	1.17	1.17	1.17	1.17	1.17	1.17	1.17
	Cap Factor	28.05%	28.05%	28.05%	28.05%	28.05%	28.05%	28.05%
Mountain	Adjustment	1.22	1.22	1.22	1.22	1.22	1.22	1.22
	Cap Factor	29.21%	29.21%	29.21%	29.21%	29.21%	29.21%	29.21%
Pacific	Adjustment	1.07	1.07	1.07	1.07	1.07	1.07	1.07
	Cap Factor	25.79%	25.79%	25.79%	25.79%	25.79%	25.79%	25.79%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

Central Station PV		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	24.00%	24.00%	24.00%	24.00%	24.00%	24.00%	24.00%
New England	Adjustment	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	Cap Factor	22.10%	22.10%	22.10%	22.10%	22.10%	22.10%	22.10%
Mid. Atlantic	Adjustment	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	Cap Factor	22.35%	22.35%	22.35%	22.35%	22.35%	22.35%	22.35%
E. N. Central	Adjustment	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Cap Factor	22.68%	22.68%	22.68%	22.68%	22.68%	22.68%	22.68%
W.N. Central	Adjustment	1.05	1.05	1.05	1.05	1.05	1.05	1.05
	Cap Factor	25.12%	25.12%	25.12%	25.12%	25.12%	25.12%	25.12%
S. Atl. & E.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	24.04%	24.04%	24.04%	24.04%	24.04%	24.04%	24.04%
W.S. Central	Adjustment	1.17	1.17	1.17	1.17	1.17	1.17	1.17
	Cap Factor	28.05%	28.05%	28.05%	28.05%	28.05%	28.05%	28.05%
Mountain	Adjustment	1.22	1.22	1.22	1.22	1.22	1.22	1.22
	Cap Factor	29.21%	29.21%	29.21%	29.21%	29.21%	29.21%	29.21%
Pacific	Adjustment	1.07	1.07	1.07	1.07	1.07	1.07	1.07
	Cap Factor	25.79%	25.79%	25.79%	25.79%	25.79%	25.79%	25.79%

Concentrator PV		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	24.20%	24.20%	24.20%	24.20%	24.20%	24.20%	24.20%
New England	Adjustment	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Cap Factor	21.86%	21.86%	21.86%	21.86%	21.86%	21.86%	21.86%
Mid. Atlantic	Adjustment	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	Cap Factor	22.23%	22.23%	22.23%	22.23%	22.23%	22.23%	22.23%
E. N. Central	Adjustment	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	Cap Factor	22.74%	22.74%	22.74%	22.74%	22.74%	22.74%	22.74%
W.N. Central	Adjustment	1.06	1.06	1.06	1.06	1.06	1.06	1.06
	Cap Factor	25.70%	25.70%	25.70%	25.70%	25.70%	25.70%	25.70%
S. Atl. & E.S. Central	Adjustment	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	Cap Factor	23.78%	23.78%	23.78%	23.78%	23.78%	23.78%	23.78%
W.S. Central	Adjustment	1.19	1.19	1.19	1.19	1.19	1.19	1.19
	Cap Factor	28.88%	28.88%	28.88%	28.88%	28.88%	28.88%	28.88%
Mountain	Adjustment	1.28	1.28	1.28	1.28	1.28	1.28	1.28
	Cap Factor	31.05%	31.05%	31.05%	31.05%	31.05%	31.05%	31.05%
Pacific	Adjustment	1.09	1.09	1.09	1.09	1.09	1.09	1.09
	Cap Factor	26.40%	26.40%	26.40%	26.40%	26.40%	26.40%	26.40%

Appendix D: Regional Adjustment Factors and Capacity Factors (Continued)

Wind		2005	2010	2015	2020	2025	2030	2035
National	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
New England	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
Mid. Atlantic	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
E. N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
W.N. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
S. Atl. & E.S. Central	Adjustment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cap Factor	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
W.S. Central	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
Mountain	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%
Pacific	Adjustment	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cap Factor	46.68%	46.77%	48.50%	49.14%	50.76%	51.14%	50.90%

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14. ABSTRACT *(Maximum 200 Words)*
The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its 11 research, development, demonstration, and deployment (RDD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. EERE designs its RDD&D activities to improve the Nation's readiness for addressing current and future energy needs.This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2006 Budget Request. EERE has adopted a benefits framework developed by the National Research Council (NRC) to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development supported by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security.

15. SUBJECT TERMS
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