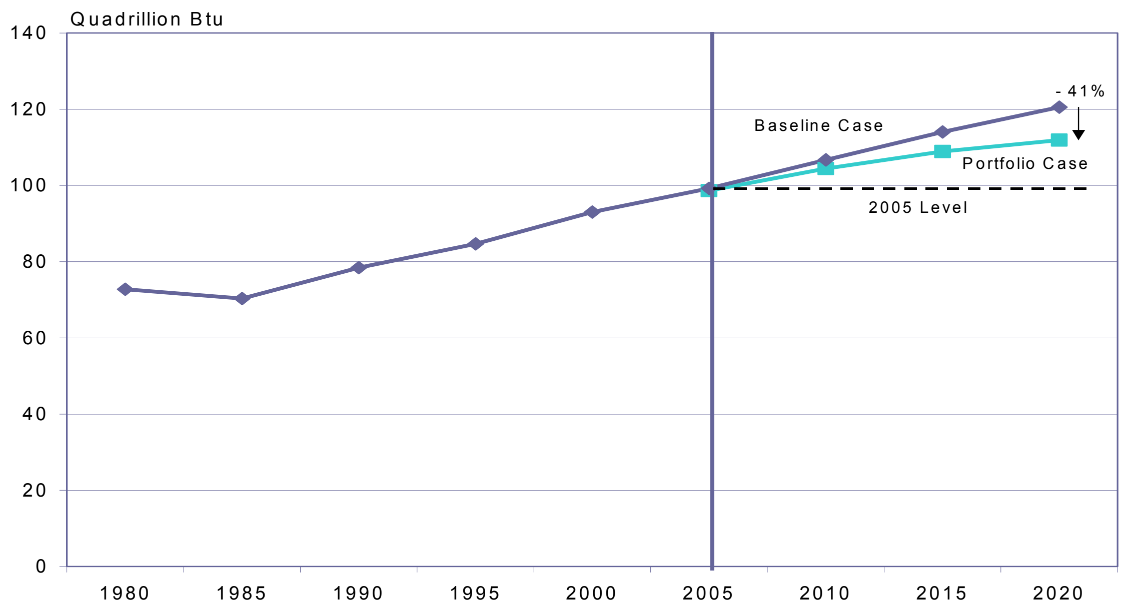
Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 – FY 2020



Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Prepared for the

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy Programs

Prepared by the

National Renewable Energy Laboratory

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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 research, development, and deployment (RD&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. The RD&D activities of EERE are designed to improve the nation's readiness to address future energy needs.

This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2004 Budget Request. EERE is adopting 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 prompted 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 indicators of these benefits estimated for FY 2004 are identified in **Table ES.1**. These measures 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 will be implementing additional portions of the NRC Framework as these elements are developed.

Table ES.1: EERE FY 2004 Benefits Metrics

Primary Outcome	
Energy displaced	• Reductions in nonrenewable energy consumption
Resulting Benefits	
Economic	• Reductions in consumer energy expenditures
Environmental	• Reductions in carbon dioxide emissions
Security	• Reductions in oil consumption • Reductions in natural gas consumption • Increases in renewable energy-generating capacity

Table ES.2 shows the estimated energy displaced and resulting benefits to the Nation of realizing the EERE program goals associated with the FY 2004 budget request. These impacts are the benefits expected in the reported year—that is, the benefits are annual, not cumulative. Between 2005 and 2020, under a business-as-usual energy future, realization of these goals would:

- Reduce the expected increase in U.S. energy demand by 41%. (**Figure ES.1**)
- Reduce the expected increase in U.S. consumer energy expenditures by 49%. (**Figure ES.2**)

[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 science and engineering communities.

- Reduce the expected increase in annual U.S. carbon dioxide emissions by 39%. (**Figure ES.3**)
- Reduce the expected increase in U.S. oil consumption, most of which is expected to derive from outside the United States, by 31%. (**Figure ES.4**)
- Reduce the expected increase in U.S. natural gas consumption, much of which is expected to originate outside the United States, by 45%. (**Figure ES.5**)
- Increase the expected additions to U.S. renewable electric-generating capacity by 553% (**Figure ES.6**) and renewable electric generation by 517%. (**Figure ES.7**)

Table ES.2. Summary of EERE Integrated Portfolio Benefits for FY 2004 Budget Request

EERE Benefits (Annual)	**2005**	**2010**	**2020**
Energy Displaced (quads)	0.6	2.3	8.7
Economic Benefits			
• Energy-expenditure savings (billion 2000 dollars)	8.5	31.2	101.8
Environment			
• Carbon dioxide emission reductions (mmtce equivalent)	10.6	38.9	151.0
Security			
• Oil savings (quadrillion Btu)	0.2	0.7	3.3
• Natural gas savings (quadrillion Btu)	0.4	1.2	3.8
• Renewable electric-generating capacity (gigawatts)	1.5	7.2	39.4

These overall EERE benefits are measured from a Baseline Case, which accounts for the energy efficiency and renewable energy improvements that would be expected to occur even in the absence of EERE programs. The Baseline Case also includes improvements resulting from EERE program efforts in the past. As such, the reported benefits reflect only the net annual improvement from 2005 to 2020 of program activities included in EERE's FY 2004 Budget Request (including subsequent-year funding) and do not include the benefits from past work. Benefits estimates assume the funding will remain constant in inflation-adjusted dollars over the analysis period (or until the completion of the activity) and that the programs will achieve their technology goals and market targets by following multiple technology paths in parallel or sequentially until a successful avenue is found. Because funding continues over time, these technology and market improvements tend to be larger over time (e.g., more can be accomplished with a 10-year effort than a one-year effort).

EERE annually develops these benefits projections pursuant to the Government Performance and Results Act (GPRA) of 1993. The analysis summarized in this report is based on the technological and deployment progress expected by EERE programs, and generally assumes that programs continue to receive their requested funding levels through the completion of each activity. As such, the analysis addresses the performance-budget integration goal of the President's Management Agenda (PMA). This analysis also addresses the benefits criterion in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) as part of the PMA.

In order to help improve the consistency of estimates across EERE programs, EERE specifies a common methodology and set of assumptions to be used in developing benefits estimates.

The FY 2004 benefits estimates were developed following the guidance in place before the EERE reorganization occurred.[2] Baseline Case assumptions are updated annually to reflect new energy forecasts developed by the Energy Information Administration (EIA) (see **Appendix A**).

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

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

In Step 1, EERE uses an energy-economy model (NEMS-GPRA04), both to develop the Baseline Case and to estimate the impacts of EERE programs. This model is a modified version of the National Energy Modeling System (NEMS), the principal energy model used by the EIA. EERE modifies EIA's *Annual Energy Outlook 2002* Reference Case (AEO2002) forecast to remove any identifiable effects of EERE programs already included in the forecast. The Baseline Case, therefore, provides a consistent representation of business-as-usual future energy markets without the benefits of EERE programs, and ensures consistent assumptions about future energy prices, conversion factors, economic growth, and other external factors, which might affect the analysis results. A summary of the Baseline Case results is included in **Appendix A.**

In Step 2, once the Baseline Case is established, the EERE program's technology goals (or outputs) are assessed with regard to their likely market impacts. Although many of the program outputs can be characterized by improvements in the costs and performances of the technologies, some of the programs (particularly deployment assistance programs that include activities such as information dissemination, market assessments, and codes and standards) characterize their outputs as market-penetration levels. Because the success or failure of energy technologies can depend heavily on the external-to-DOE market and policy conditions found in each energy market, such conditions must often be taken into account on a case-by-case basis in estimating individual program benefits. **Appendices B through E** describe the market-specific analyses undertaken in this step.

In Step 3, the program- and market-specific information from Step 2 is incorporated into NEMS-GPRA04, which enables accounting for market feedbacks and interactions that can change the ultimate level of energy savings associated with realizing each program's goals. Where program activities cannot be directly modeled in NEMS-GPRA04, initial energy impacts are estimated "off-line" (e.g., without the use of a full, program-wide model). For the FY 2004 benefits analysis, EERE undertook a new approach of adjusting these off-line estimates to account for areas of overlapping program impacts. This (usually) downward revision was made based on judgment of the Integrated Modeling Team of analysts. The resulting benefits estimates of these individual program analyses are listed by program—along with FY 2004 program budgets, in **Table ES.3** below.

[2] Prior to the reorganization, estimates of benefits were made based on guidances developed by EERE's then Office of Planning, Budget, and Outreach. The FY 2004 analysis was begun using the pre-existing guidance for FY 2003 (see http://www.eere.energy.gov/office_eere/ba/gpra_estimates_fy03.html).

NEMS-GPRA04 is also run with all programs simultaneously represented in order to derive estimates of the benefits of the EERE portfolio overall. This portfolio analysis accounts for interactions among EERE's programs and tends to report slightly reduced benefits compared to the sum of the individual programs.[3] These fully integrated results are listed in **Table ES.2,** above, and displayed in the graphs in this **Executive Summary**. Specific details of the representation of the program outputs in NEMS-GPRA04 and the underlying program analysis and documentation are provided in **Chapter 3** of this report.

The budget-planning year for the FY 2004 budget request was a year of transition within EERE. A major reorganization resulted in the consolidation and realignment of 31 programs (analyzed as 46 "GPRA units") across five sectors to just 11 programs (analyzed as 12 "GPRA units" for better correspondence with the budget). The FY 2004 benefits analysis began under the old organization, but concluded with the new organization. As a result, the documentation for Step 2—individual program and market analysis—does not reflect the new program structure nor the more-integrated approach to benefits estimates made possible by the reorganization. Nonetheless, it provides the reader with a sense of the ways in which the inputs to the NEMS-GPRA04 Benefits Estimates described here were calculated.

EERE is pursuing a number of improvements to its benefits analysis. Important changes planned for analysis of the benefits of the FY 2005 budget request include:

- Extension of the benefits projection time frame to 2050 to better capture the longer-term benefits of programs such as the Solar Energy Technologies Program and the Hydrogen, Fuel Cells, and Infrastructure Technologies Program.
- 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—as well as developing methods for estimating the option value of preparing the Nation for possible future energy needs beyond business-as-usual. 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.

[3] In previous years, the difference between the sum of individual program results and the portfolio results were much larger; the small difference in this year's analysis is due in large part to the adjustments made to the off-line estimates in Step 2, described above, as well as the use of NEMS-GPRA04 for program-level results.

Table ES.3. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy: FY 2004 Funding Summary and Selected 2020 Benefits by Program[4]

	FY 2004 Request ($ thousands)	Energy Displaced (quads)	Energy Expenditure Savings (billions 2000$)	Carbon Dioxide Emissions Reductions (million MTce)	Oil-Use Reductions (quads)
Hydrogen, Fuel Cells, and Infrastructure Technologies	165,482	0.2	3.9	4.6	0.2
FreedomCAR and Vehicle Technologies	157,623	1.6	25.5	29.8	1.5
Weatherization and Intergovernmental	369,460	1.4	14.7	26.3	0.6
Solar Energy Technologies	79,693	0.1	1.4	2.4	0.0
Wind and Hydropower	49,089	1.2	5.4	20.9	0.1
Geothermal Technologies	25,500	0.4	1.8	7.5	0.0
Distributed Energy and Electric Reliability	128,650	0.5	9.0	8.5	0.0
Building Technologies	56,563	1.3	16.3	22.7	0.1
Industrial Technologies	64,429	2.1	20.2	36.3	0.5
Biomass	78,558	0.4	1.9	3.6	0.3
Federal Energy Management	22,262	0.1	0.8	1.3	0.0
National Climate Change Technology Initiative	24,500	N/A	N/A	N/A	N/A
Facilities and Infrastructure	4,950	N/A	N/A	N/A	N/A
Program Direction	93,241	N/A	N/A	N/A	N/A
Sum of programs *	**1,320,000**	**9.3**	**100.9**	**163.9**	**3.4**

* 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.

[4] Budget request from *FY 2004 Budget-in-Brief*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy04_budget_in_brief.pdf.

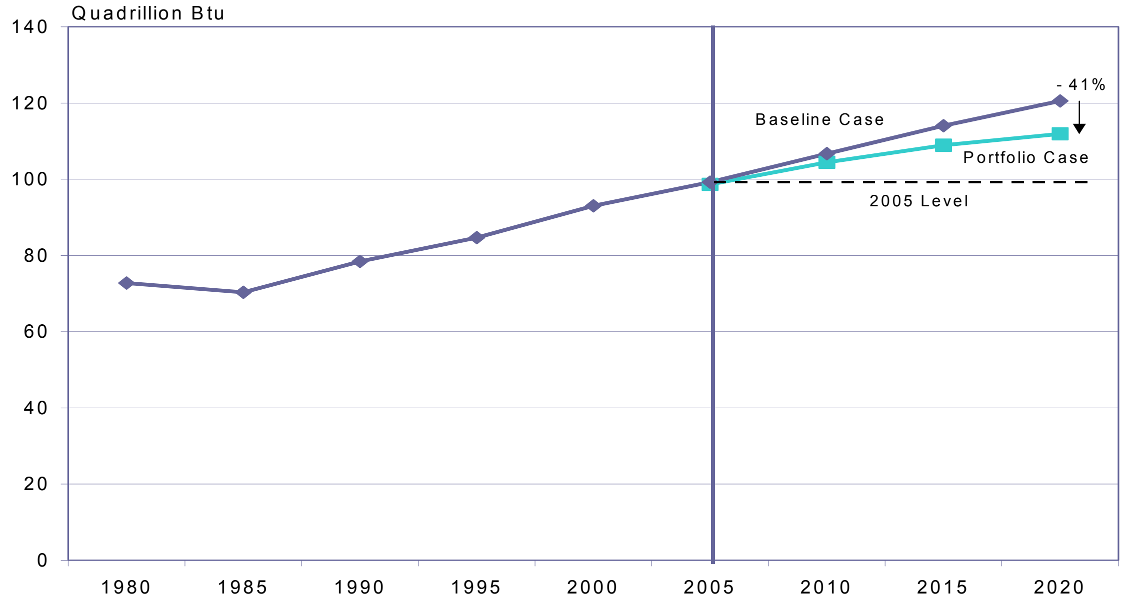

Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for year 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

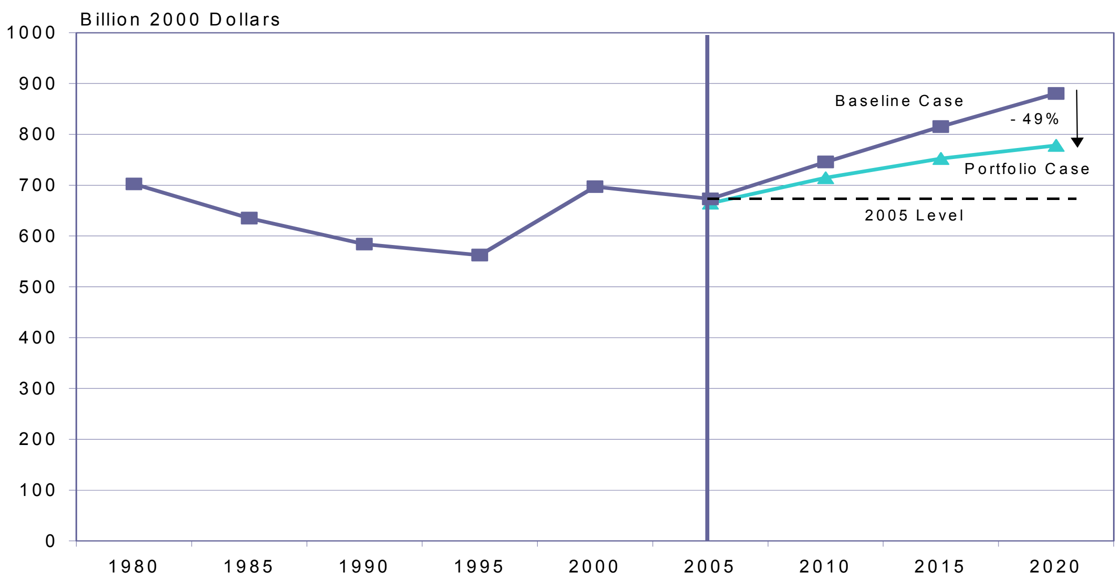

Figure ES.2. U.S. Total Energy Expenditures, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Sources: 1980-1995: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 3.4 and Table E1, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2000: Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), Supplemental Table 20.

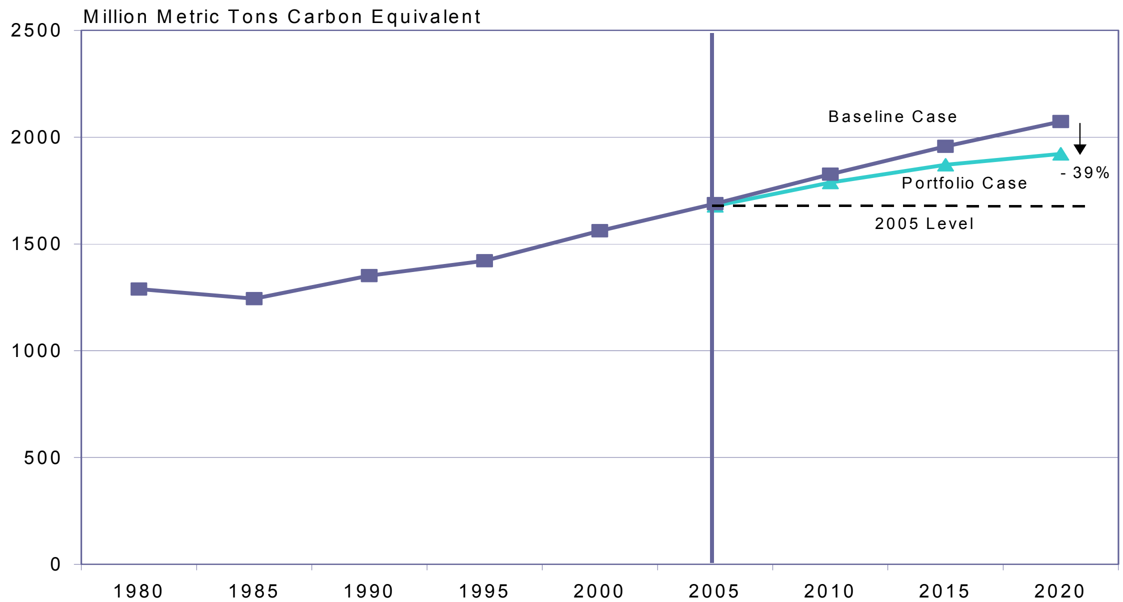

Figure ES.3. U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

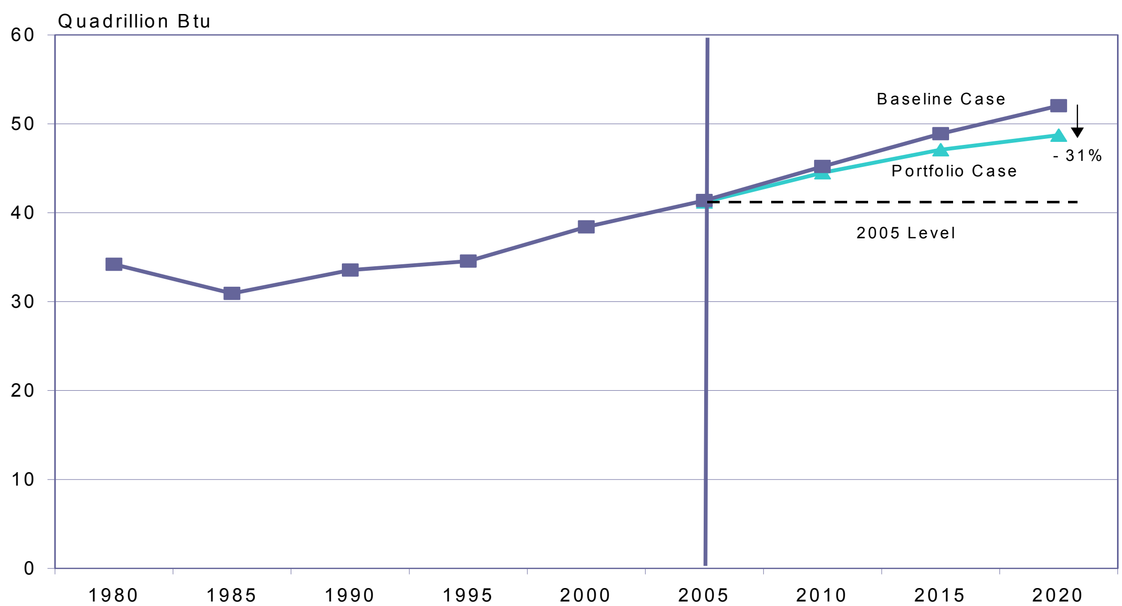

Figure ES.4. U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

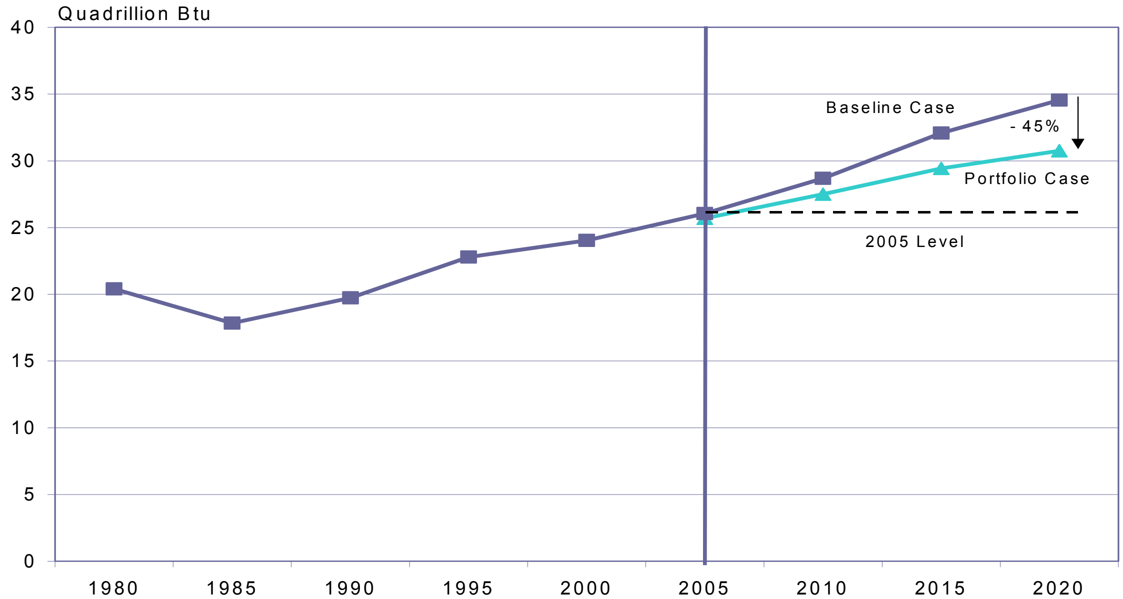

Figure ES.5. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005. Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

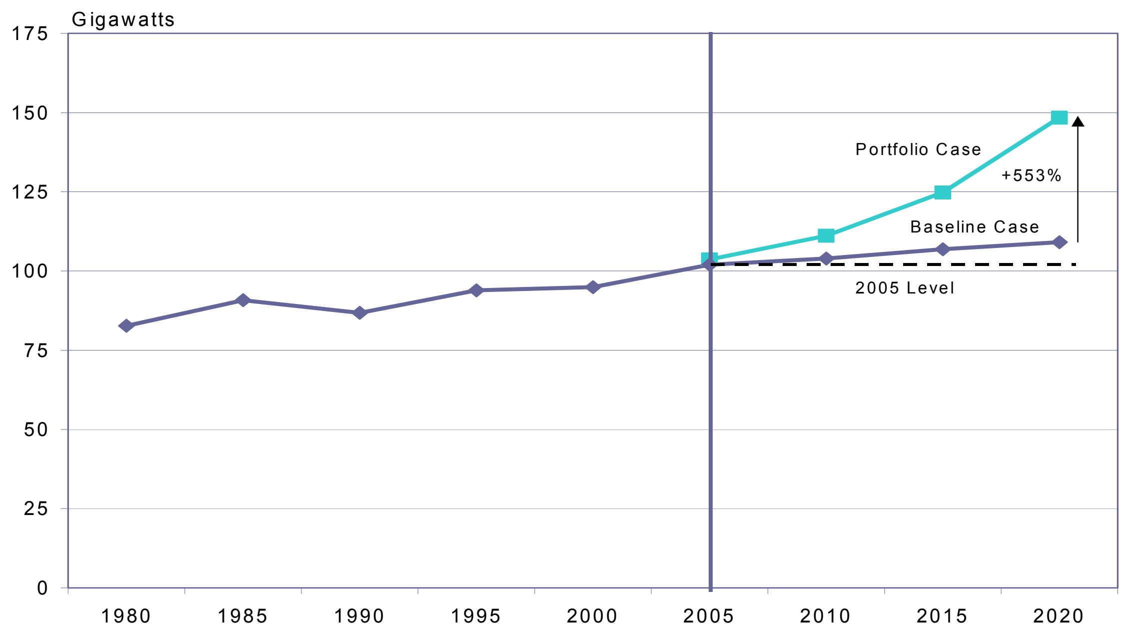

Figure ES.6. U.S. Renewable Electricity Capacity, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005. Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 8.7a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

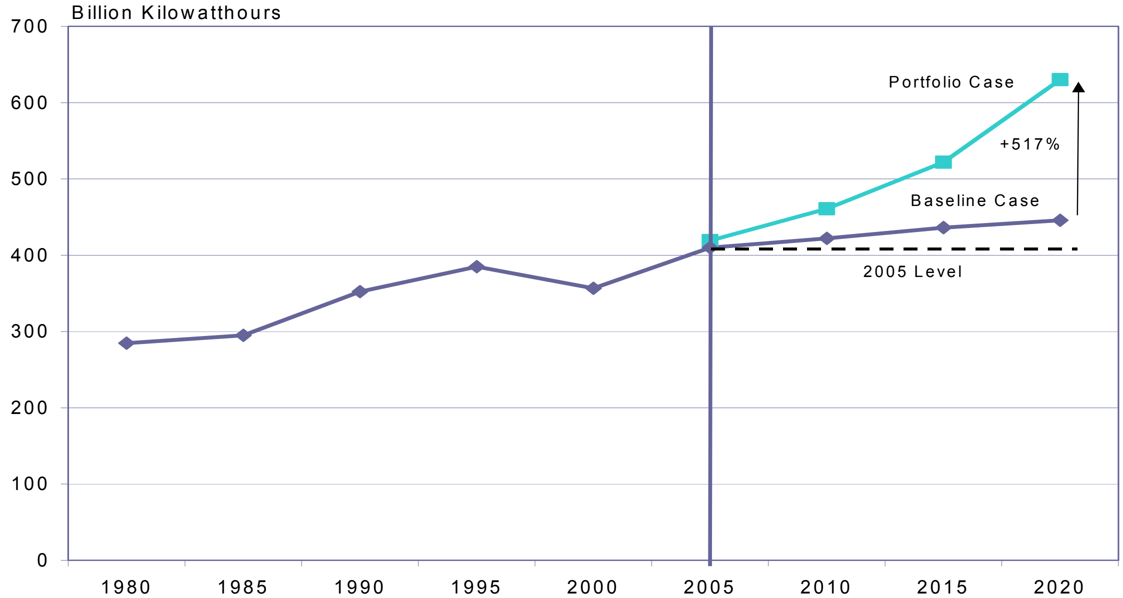

Figure ES.7. U.S. Renewable Electricity Generation, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 8.2a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

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 FY 2004 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

The Government Performance and Results Act (GPRA) of 1993 requires Federal Government agencies to prepare strategic plans, annual performance plans, and annual performance reports. 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 of EERE's programs are realized. The consumer energy-cost savings,[2] carbon emission savings, and reduced reliance on fossil fuels estimated 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.

EERE initiated its benefits analysis in 1994. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions, and an annual external review of the methodologies and assumptions employed was initiated in 1997 and continued through 2001 when EE was reorganized. Although the benefits analysis has changed since it was initiated 10 years ago, the energy saved or displaced continues to be the key measure of the EERE program impact.

With its reorganization in 2002, EERE centralized the benefits-analysis effort within the Office of Planning, Budget Formulation, and Analysis (PBFA) and integrated it into the broader planning and analytical needs of EERE. While technology information (such as cost and performance) is still provided by the EERE programs, market analysis is now conducted by PBFA.

The analysis summarized in this report is based on the technological and deployment impacts of the EERE program activities, with the following key assumptions:

- Programs will be funded at the levels requested in DOE's fiscal year (FY) 2004 Budget Request;
- Funding levels will remain constant in inflation-adjusted dollars or rise to accommodate key initiatives in particular cases, as indicated;

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

[2] These consumer cost savings are the gross savings from avoiding purchased energy. They are not net of the investments that would have to be undertaken to achieve these savings. The NEMS model does not currently address net costs, and these are considered separately.

- Programs will achieve their technology and market targets and goals based on the assumption that one of the many technical paths pursued will succeed. It is important to note that this assumption of technical success, although uncertain, is generally not dependent on a single technical pathway and instead encompasses a number of alternative approaches, of which many may fall short without jeopardizing realization of the final goal. For most programs, the basic technical capability for achieving the overall goal is already demonstrated. For example, the efficiency of thin-film photovoltaic cells needed to achieve the overall PV program goal already has been demonstrated in the laboratory, and no additional breakthroughs are needed. Further, there are several completely different PV materials and manufacturing processes by which the goal could be realized. For some technologies, significant technical advances are still needed.

The analysis is budget-based. As such, it addresses the performance-budget integration goal of the President's Management Agenda (PMA). It also addresses the benefits criterion in the R&D Investment Criteria developed by the Office of Management and Budget (OMB) as part of the PMA.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model as the foundation for managing its portfolio of efficiency and renewable investments[3] and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, this logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities (**Figure 1.1**). The logic model 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 are specified in GPRA and are included in the annual budget request.

Multiyear Program Plans (MYPPs),[4] 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.[5] 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

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[3] 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, CA, 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 J. B. Jordan (1999). "Logic models: a tool for telling your program's performance story." *Evaluation and Program Planning* 22(1): 65-72.

[4] These program plans are being formalized as part of the EERE reorganization. Final plans will be available during 2004. For this transitional year, benefit analysts worked with any updated program goals available and utilized existing goal statements where necessary.

[5] 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

outputs. Outputs, often referred to as "program goals" or "program performance goals,"[6] 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[7] evolve over time as the program pursues increasing levels of technology performance or market penetration.

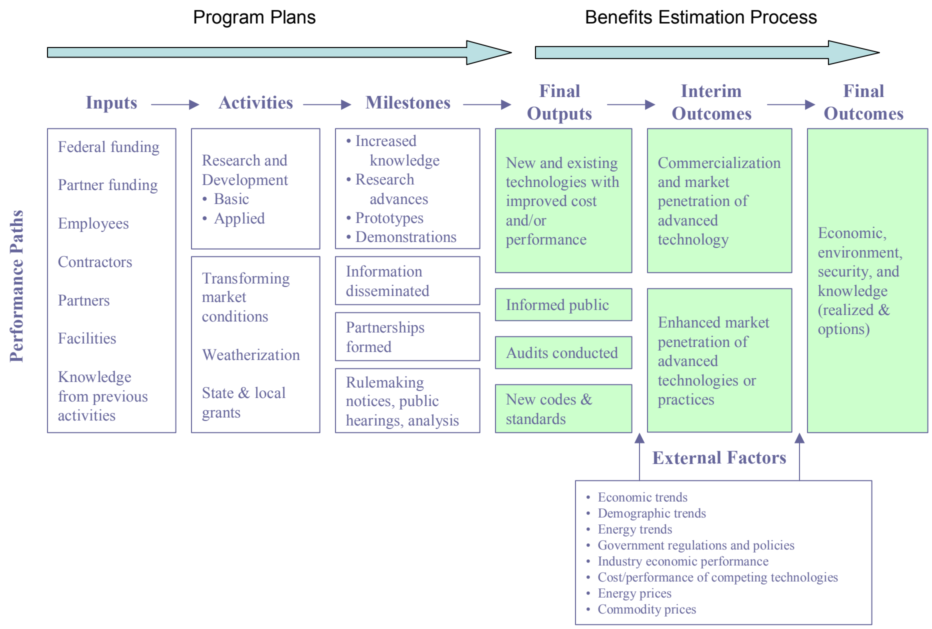

Figure 1.1. Generalized EERE Logic Model

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 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.

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.

[6] 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-GPRA04 and the underlying program analysis and documentation are found in Chapter 4 of this report and Appendices B through E.
[7] 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.

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, and on 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.

EERE, along with the Office of Fossil Energy (FE), 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 (see **Box 1.1, National Research Council Review**). 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. EERE and FE 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.[8] Similarly, EERE is in the process of extending the NRC analysis of realized benefits to include its full portfolio (**Figure 1.2**).

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

Figure 1.2. FY 2004 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 methodology.** EERE uses the Energy Information Administration's (EIA) reference case as a consistent starting point for analysis of all of its programs. A standard methodology is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE

[8] 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. A more general definition for prospective analysis—expressed in the Real Options literature—defines a real option as an asset, such as a technological innovation that creates future choices (i.e., options) and establishes an analytic decision-making framework on how to enhance asset value at future points in time. See Dixit, Avinash K., and Robert S. Pindyck, *Investment under Uncertainty*, Princeton University Press, Princeton, New Jersey (1994).

program goals. This methodology addresses approaches and assumptions that are applicable to all of EERE's program activities and markets.

- **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 short- (5–10 years) and mid-term (10–20 years) time frames. EERE is developing tools to address the long term (20–50 years) for the FY 2005 budget cycle.

- **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 products 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 an integrated energy-economic model to produce final benefit estimates that consider these feedbacks and interactions at the program and portfolio levels.

EERE's 2002 Reorganization

EERE reorganized in June 2002. The previous organization, consisting of five sectors (buildings, federal, industry, power, and transportation) and 31 programs was replaced by a set of 11 programs. This reorganization facilitated use of the logic model, with clear program responsibilities for linking inputs to outputs. A new analysis group—Planning, Budget Formulation, and Analysis (PBFA)—assumed responsibility for assessment of outcomes and benefits related to these program outputs.

Under the prior organization, benefit analyses were undertaken by each of the five sectors for the programs within their sector, with guidance provided by EERE management. These analyses provided program-level estimates of benefits, but did not account for feedbacks from other markets—or, in some cases, even within target markets. The annual guidance provided a consistent basis for estimating benefits across programs, but the disaggregated nature of the analysis often made it difficult to implement this guidance in a consistent way. The energy savings from these individual program estimates were then assessed, using an energy-economic model to estimate the savings across EERE's entire portfolio.

The new organization brings together a team of analysts, which includes experts in both individual energy markets and energy-economic modeling. This new team enables EERE to take market feedbacks into account at the program level, as well as at the portfolio level. It also enables analysts to improve coordination in implementing EERE's benefits methodology.

The FY 2004 benefits analysis was initiated under the old organization. As a result, the program-level analyses were undertaken based on the prior sector structure. As in past years, each sector report (**Appendices B through E**) includes program-level energy savings estimates, which do not include feedback effects. With the creation of the integrated analysis team midway through this analysis effort, it was possible to produce a final set of 11 program benefit estimates that account for market feedbacks. It is these final integrated estimates that are included in this report and that appear in the EERE FY 2004 Budget Request.

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.

Management and Overall Responsibility

- EERE
  - Integrated: MaryBeth Zimmerman, Susan Holte, Phil Tseng
  - Buildings: Jerry Dion
  - Industry: Ken Friedman, Peggy Podolak
  - Transport: Phil Patterson
  - Power: Tina Kaarsberg, Susan Holte
  - Bioenergy: Tien Nguyen
- Contractors
  - Project Managers: Bill Babiuch, Doug Norland (NREL)
  - Guidance: Patrick Quinlan (NREL), John Mortensen (Independent Consultant), Jim Wolf (Independent Consultant)
  - Energy-Economic Integration: Frances Wood, John Holte, Aliza Seelig (OnLocation, Inc.); Chip Friley, John Lee (BNL)

R&D and Deployment Programs

- Biomass: Jerry Hadder (ORNL); Michael Wang (ANL); Roger LeGassie, Steve Zukor (TMS); David Andress (D. Andress & Associates); Margaret Singh (ANL); David Andress, Tracy Carole (Energetics); Larry Goldstein (NREL); Tom Schweizer (PERI)
- Buildings: Dave Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Sean McDonald (PNNL)
- Distributed Energy and Electric Reliability (DEER): Larry Goldstein (NREL), Tom Schweizer (PERI)
- Federal Energy Management Program (FEMP): Daryl Brown, Andrew Nicholls (PNNL)

- FreedomCAR and Vehicle Technologies: Margaret Singh (ANL), Elyse Steiner (NREL), Jim Moore (TA Engineering, Inc.)
- Hydrogen and Fuel Cells: Margaret Singh, Steven Plotkin (ANL); Elyse Steiner (NREL)
- Geothermal: Larry Goldstein (NREL); Tom Schweizer, Dan Entingh (PERI)
- Green Power: Jim McVeigh (PERI)
- Industry: Jim Reed (Independent Consultant); Joan Pellegrino, Nancy Margolis, Shawna Mcqueen, Diane McBea (Energetics); Ken Greene, Bill Choate, Roy Tiley (BCS); John Mortensen (Independent Consultant); Douglas Norland (NREL); Peter Angelini (ORNL); Elmer Fleischman (INEL)
- Inventions and Innovations: Nancy Moore (PNNL)
- Renewables (all): Chris Marnay, Kristina Hamachi LaCommare (LBNL)
- Solar: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Wind and Hydropower: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Weatherization and Intergovernmental Programs (WIP): David Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Duane Deonigi, Nancy Moore (PNNL)

In all cases, these lead analysts drew on 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 three 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 results of each program area.

Five appendices are included. **Appendix A** provides the Baseline and Portfolio Cases. **Appendices B through E**, respectively, provide sector-analysis team inputs for buildings, industry, renewables, and vehicles.

Box 1.1—National Research Council Review

Energy Research at DOE: Was It Worth It?

In 1999, at the request of the U.S. Congress, the National Research Council (NRC) of the National Academy of Sciences began a retrospective study of the benefits of EERE energy efficiency RD&D programs, examining activities from 1978 to 2000. The activities examined accounted for about one-fifth of the cumulative EERE funding for energy efficiency projects, excluding renewable technology programs. Using a conservative methodology to evaluate about $1.6 billion of the EERE energy efficiency programs, the NRC found a net realized economic benefit of approximately $30 billion, or a return of about $20 for each $1 of EERE investment in the programs considered.* Also included in the study were the R&D programs of DOE's Office of Fossil Energy.

The methodological framework developed by the NRC was designed to reflect the public policy purpose of the R&D and the state of commercialization of the R&D activity. A matrix was developed to represent these features, as shown in the table below. The rows of the matrix represent the net benefits to be achieved by the R&D (accounting for any extra costs as well as benefits associated with the new technology). After reviewing energy policy documents, the committee concluded that the benefits of energy R&D can be grouped into three primary categories: economic benefits, environmental benefits, and security benefits (including reliability).

The columns of the matrix represent the state of the R&D activity and related technologies at the time of the evaluation. Realized benefits are those achieved by technologies that have been successfully developed or are in final development and demonstration, for which current economic and policy conditions are favorable for deployment in the marketplace. Options benefits are for technologies that are under development or are technologically successful, for which economic or policy conditions are not yet favorable to their deployment but could become favorable under reasonable future scenarios. Knowledge benefits are for those technologies for which R&D is not yet completed, for technologies that would not be commercialized, and for technologies for which development was unsuccessful but nevertheless yielded knowledge that is potentially applicable elsewhere. The NRC study did not evaluate knowledge benefits for successful technologies.

	Realized Benefits and Costs	Options Benefits and Costs	Knowledge Benefits and Costs
Economic Benefits and Costs			
Environmental Benefits and Costs			
Security Benefits and Costs			

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"** (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 estimated benefits were based on analyses of 17 case studies. The estimated benefits also assumed that without the EERE program, the technology would have been developed and introduced in the market five years later by the private sector. In addition, the NRC stopped counting benefits for technology units entering the market after 2005.
** See www.esd.ornl.gov/benefits_conference.

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**). **Step 1** provides a consistent baseline for the analysis, which reflects an energy future without EERE's contributions, along with a standard methodology (guidance) to help ensure consistency in estimates across programs. **Step 2** provides the specific technology and market information, which is necessary to understanding the potential roles of each program in its target markets. In **Step 3**, this program and market information is used to assess the impacts of each EERE program, as well as the overall EERE portfolio, on energy markets in the United States using an integrated energy-economic model.[1]

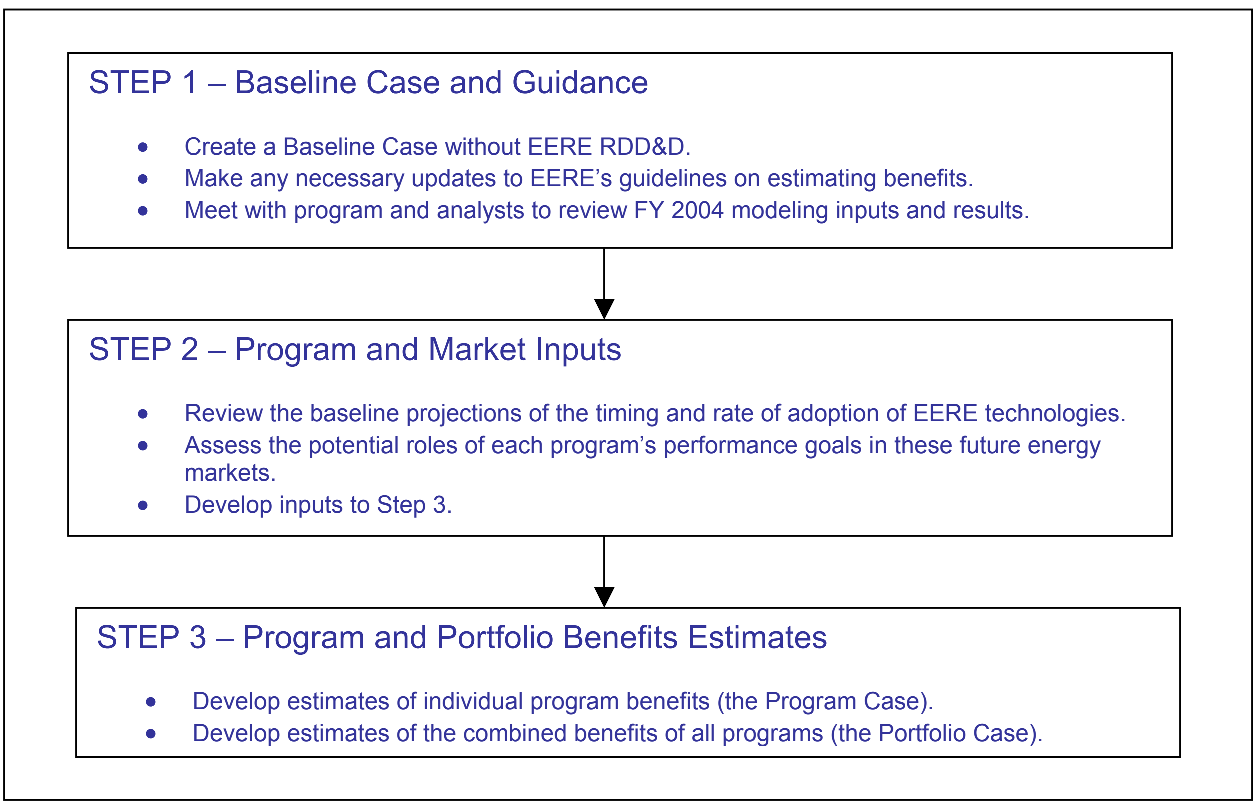

Figure 2.1. EERE Program and Portfolio Benefits-Analysis Process

[1] The FY 2004 benefits assessment was already well underway at the time of EERE's reorganization in June 2002. As a result, the analysis described here and in the appendices is something of a hybrid between the pre-reorganization process and the new process described here.

Step 1: Baseline Case and Guidance

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 is intended to serve four purposes: First, it 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. Second, it assures that each program's benefits are estimated based on the same initial forecasts for economic growth, energy prices, and levels of energy demand. Third, 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 ensure that underlying improvements in efficiency and renewable energy are not counted as part of the benefits of the EERE programs.[2]

EERE utilized the most recent Annual Energy Outlook (AEO) Reference Case as the starting point for developing this base case.[3] The Energy Information Administration (EIA) AEO Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy, technology improvements that might improve the efficiency of energy use, and changes in energy-resource production costs, including renewable energy. Current energy policies, such as state renewable portfolio standards (RPS), 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.

In establishing its Baseline Case, EERE makes a number of modifications to the EIA Reference Case in order to remove discernable representations of EERE programs and to update policy and market factors where additional information is available. These modifications are made using the same model, the National Energy Modeling System (NEMS), used by EIA in developing the AEO. To distinguish it from EIA's version, the model is referred to as NEMS-GPRA04.

EIA includes some of the impacts of EERE's programs in its Reference Case. These representations are removed from the EERE Baseline Case so that they can be analyzed in the Program Case. Those impacts that are *explicitly* represented in the EIA Reference Case are removed from the EERE Baseline Case. For example, scheduled but not yet completed appliance standards are in the AEO. They are removed for this Baseline Case so that their benefits can be assessed as part of the Building Technologies Program. Beyond the specific program representations, removing the impacts of future program results from the EIA reference case is very difficult. The AEO2002 forecast includes technology improvements in virtually all areas of energy demand and supply; and no clear means of identifying what portion is due to future

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[2] EERE is codeveloping, with the Office of Fossil Energy, scenarios to reflect several potential energy futures, pursuant to a recommendation by the National Research Council to reflect market uncertainties (referred to as "option value") and suggestions made in a follow-up conference on ways to represent market uncertainties in benefits analysis. Scenarios will include differences in policy as well as potential differences in energy markets.

[3] *The Annual Energy Outlook 2002 with Projections to 2020*, December 2001, DOE/EIA-0338 (2002). See http://www.eia.doe.gov/oiaf/archive/aeo02/pdf/0383(2002).pdf.

EERE program efforts is currently available. In the absence of a clear-cut approach to removing program-induced technology improvement from the Baseline Case, no modifications are made to the technology assumptions of the AEO2002. This approach underestimates EERE program benefits.

The EERE Baseline Case also is updated to reflect new policy or market information. The production tax credit (PTC) for wind and closed-loop biomass, for example, is extended to 2003 in the FY 2004 EERE Baseline Case. The extension was not included in the AEO2002 Reference Case, because the PTC extension occurred after the AEO2002 was completed. Market factors are similarly updated. Residential lighting demand, for example, is substantially increased in the EERE Baseline Case, based on a recent lighting-markets report performed for EERE.[4] This change also was adopted by EIA for the AEO2003 but is not reflected in the AEO2002, on which this analysis was based. Similarly, the limit on the share of generation in each region that can be met with intermittent technologies is raised from a limit of 12 percent to 30 percent, based on experience with the introduction of intermittent power in other countries. Building this updated policy and market information into the Baseline Case, as well as the Program Case, helps ensure that the analysis does not ascribe credit for these external developments to EERE program activities.

The adjustments to the AEO2002 Reference Case result in an insignificant difference in energy consumption. For example, in 2020, conventional energy demand in the AEO2002 Reference Case is 121.9 quads. The EERE Baseline Case value is 120.5 quads, a 0.6 quad difference. If graphed in **Figure 2.2**, the AEO2002 Reference Case data for conventional energy demand would virtually overlay EERE's Baseline Case.

Nonrenewable energy demand in the Baseline Case increases by 21 percent from 2005 to 2020. Underlying energy efficiency and renewable energy improvements, however, contribute toward a 23 percent reduction in conventional energy intensity (conventional energy used per dollar of GDP produced), due to private-sector R&D advances and investments, as well as structural changes in the economy during the same period (**Figure 2.2**).[5] Between 2005 and 2020, renewable energy technology improvements result in increases in electric generation (in billions of kWh) of 17.2 for geothermal, 15.3 for biomass, 6.5 for wind, 5.7 for municipal solid waste, 0.6 for photovoltaics, and 0.2 for solar-thermal. More detail from EERE Baseline Case projections is in **Appendix A**. EERE benefit estimates do not include any of these Baseline Case improvements. Rather, the R&D improvements represented in this case provide the "next best technologies" to which additional EERE improvements are compared.

[4] Navigant Consulting, *U.S. Lighting Market Characterization, Volume I*, September 2002.

[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).

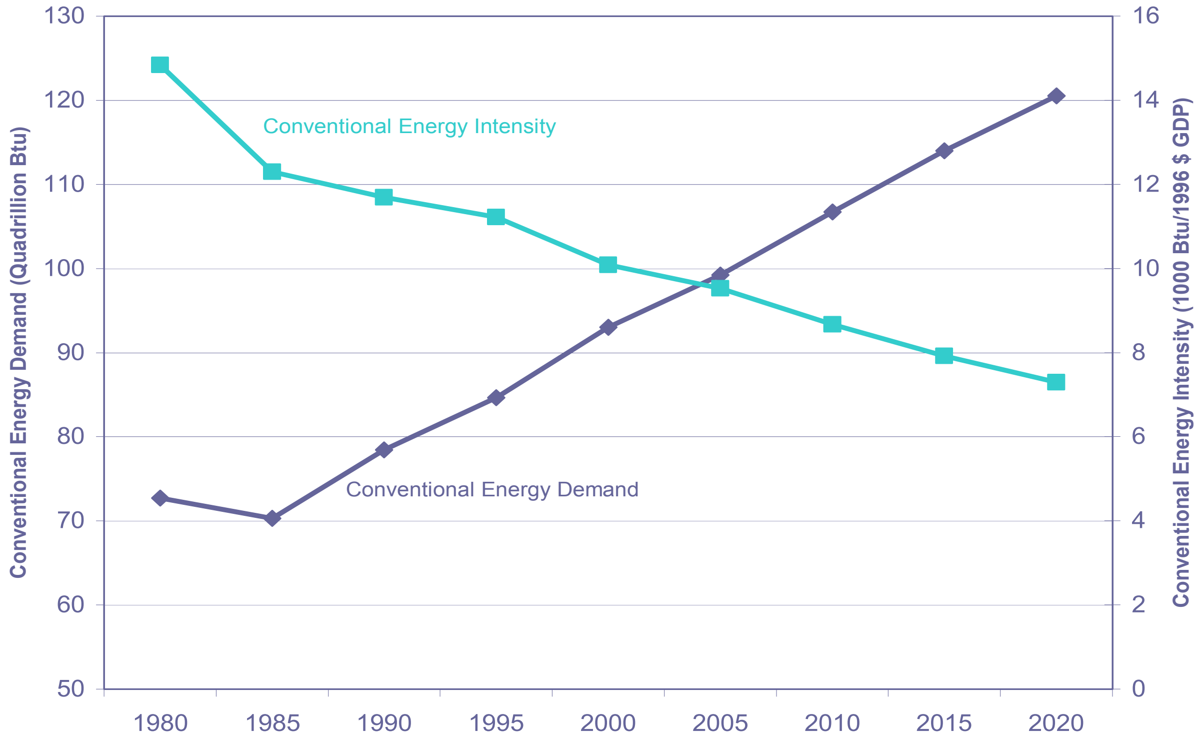

Figure 2.2. U.S. Conventional Energy Demand and Energy Intensity, 1980-2000, and Baseline Projections to 2020

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Tables 1.3, E1 Web site http://www.eia.doe.gov/emeu/aer/contents.html.

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, these common elements were provided in the form of an annual "GPRA Data Call"[6] to the five EERE Sectors, which undertook separate analyses based on these common guidelines. With the reorganization, the benefits-analysis team utilizes this methodology directly, including:

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

Converting nominal dollars to real dollars. EERE's benefits analysis is done in constant or real dollars (i.e., without inflation). In cases where future expenditures or costs are provided by the program or other sources in nominal dollars, these are converted to constant dollars based on a forecasted GDP deflator.

[6] The guidance used for FY 2004 benefits estimates followed the guidance for FY 2003 (see http://www.eere.energy.gov/office_eere/ba/gpra_estimates_fy03.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 otherwise available to the market, not simply 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 model does not have explicit technology representation, the "next best technology" is reflected in the Baseline Case rates of technology and market improvements. EERE assumes that its R&D efforts work principally to 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.[7] 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 fully saturate their target markets, 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 energy savings over time, as well as other attributes in selected cases. Where technologies are not explicitly represented, adoption rates are embedded in efficiency trends. 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 are assumed to remain the same for the Program Case and the Baseline Case, unless there is a basis for assuming that 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 (TCs) 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.

[7] 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 sector-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 2.3a**).[1] 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 2.3b**). 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.

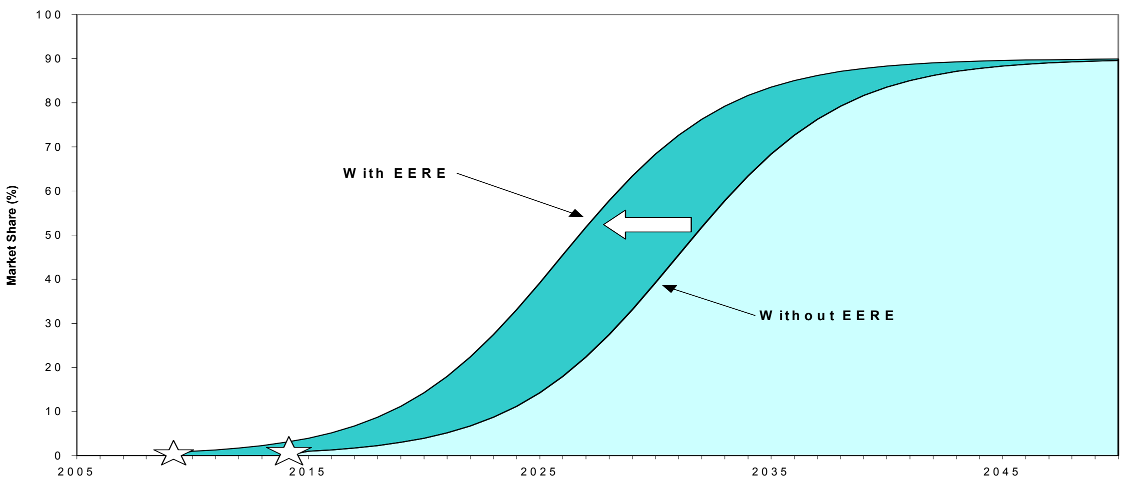

Figure 2.3a. Potential Impacts of EERE R&D Programs on Technology Introduction

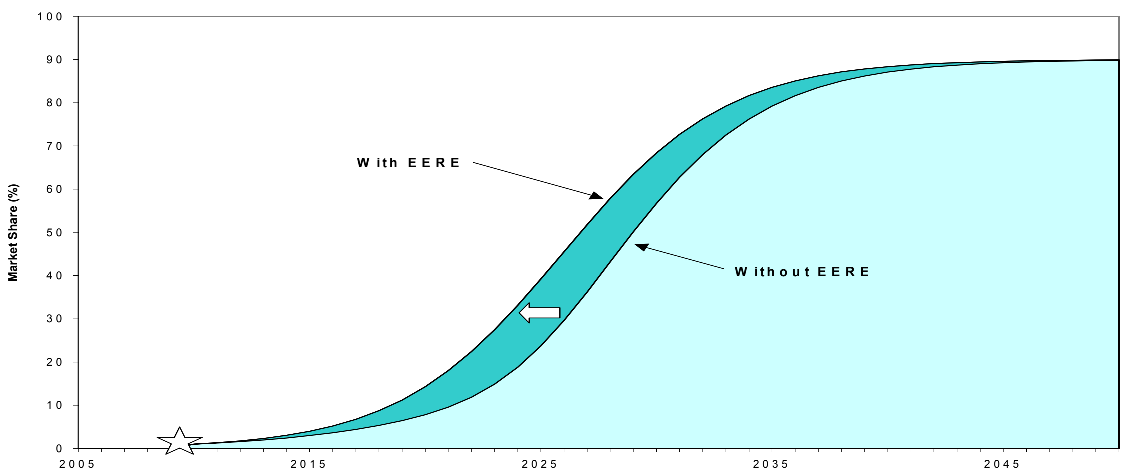

Figure 2.3b. Potential Impacts of EERE Deployment Programs on Market Penetration

*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 TCs are of interest: Baseline Case and Program Case. The EERE Baseline Case already includes expected private-sector advances in efficiency and renewable technologies (see **Figure 2.4**). In many cases, the specific technology characteristics are included directly in the NEMS-GPRA04; 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 are generally reflected in the program output goals.

For example, the Wind Program aims to reduce the cost of wind generation by reducing the capital costs and improving the performance of wind turbines (**Figure 2.4**). These cost and performance improvements reduce the cost of wind energy faster than occurs in the Baseline Case. For deployment activities, the individual technologies targeted are identified in program plans and related materials. For these programs, the TCs remain at their baseline levels. In both the Baseline Case and Program Case, technologies typically improve incrementally over time as research progresses. The additional R&D dollars provided by the program increases the rate of technology improvements.

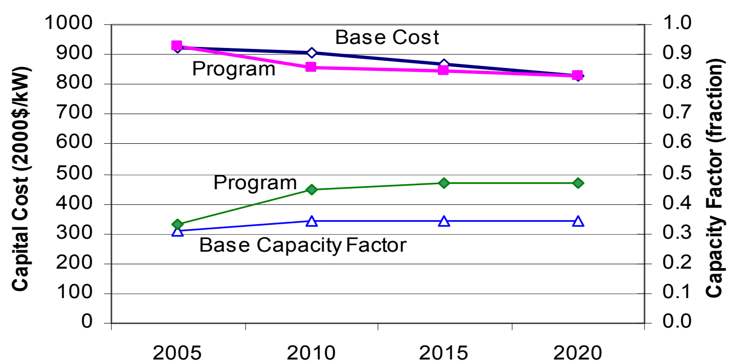

Figure 2.4. Class 4 Wind Capital Cost and Capacity Factor

Calculating direct energy and primary energy displaced. For any given technology, the "wedge" between technology sales under the Program and Baseline cases—which includes all the projected business-as-usual improvements, coupled with relative efficiencies—produce the energy savings (or displacement) attributable to the program. NEMS-GPRA04 provides 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 marginal efficiency of power production will change over time as the mix of displaced plants shifts from existing plants to avoidance of new capacity construction. When the principal market analysis is performed outside of NEMS-GPRA04, and resultant energy savings are used as an input to the model, they are expressed in direct energy terms. The model then computes primary energy savings. (See **Box 2.2 – Energy-Economic Modeling**).

The GPRA04 analysis began under the previous EERE organization, and the programs were requested to compute the full GPRA metrics including primary energy. The guidance provided at the beginning of the analysis included a conversion factor for direct to primary energy that reflected the anticipated shift over time in the marginal sources of energy for power production. Therefore, the supporting documentation (**Appendices B though E**) includes estimates of primary energy savings, even though the final values used in the FY 2004 budget are those from NEMS-GPRA04.

Box 2.2—Energy-Economic Modeling

Markets are fundamentally interactive. Relatively small changes in one energy market are unlikely to generate noticeable changes in other markets. In these cases, a simple "back of the envelope" estimate will suffice in estimating resulting energy savings. However, larger changes in energy markets–or a large number of small changes—can have impacts on the level of energy saved or displaced well beyond the immediate technology. A reduction in home heating and cooling costs, for instance, may result in some "take back" in the form of increased demand for heating and cooling. It also may change the mix of fuels used to produce electricity, over the time frame being analyzed here, especially if peak demand for electricity drops and fewer new power stations are needed. This will reduce the role of conventional power plants, but will also limit the development of wind and other emerging electricity sources. Similarly, a 10 percent improvement in energy efficiency in each residential energy-using device could have a noticeable impact on electricity prices and fuels.

EERE's portfolio generates significant enough changes in energy markets that it is necessary to account for these various feedbacks, up-stream impacts, and cross-market changes in order to develop better estimates of resulting benefits at the Program and EERE Portfolio levels. Mathematical models are useful to provide an internally consistent framework and baseline for the analysis. In models of this type, EERE technologies can compete with each other and with other energy technologies in these respective markets. In addition, the models can represent the extensive interactions among energy markets, such as price changes in response to changes in demand or supply levels, demand response to changes in the prices of technologies, and the potential for fuel switching. Such models also can account for a number of external factors, including fossil fuel prices, economic and demographic growth, and stock turnover.

NEMS-GPRA04 is an energy-economic model that reflects the ways in which energy is currently produced and consumed in the United States, the energy choices consumers make, and the ways in which different parts of our energy markets interact. It contains a detailed slate of energy-using technologies, including their capital costs, operating costs, efficiencies, and other technology characteristics—such as likely improvements in the technologies in the future. From those characteristics, the adoption and penetration of technologies are projected, based on algorithms that represent consumer response based on the capital, O&M, and fuel costs of competing technologies, technology efficiencies, discount rates, equipment replacement rates, and a variety of other consumer preference factors, where applicable. It is also designed to keep track of scores of possible energy paths for supplying energy to consumers. For example, the model helps discern the mix of coal, natural gas, and other energy sources likely to supply the mix of future peak and off-peak electricity loads expected.

While this model compares the costs of different paths for providing electricity and other types of energy to consumers, it also tries to reflect observed market factors beyond price. The model has assumed discount rates used by consumers in making energy investments, which vary substantially by market segment and technology. It also builds in "typical" lag times for market for supplies of new technologies or energy resources and many of the other "market frictions" that can dampen market acceptance of a new technology.

Integrating models differ enormously in terms of the amount of market information included, depending on both the purpose of the model and the data actually available. In general, longer-term modeling must be based on simpler representations of individual energy markets. Some aspects of energy, such as regional variations in energy supplies or prices, can be incorporated into many models—if the information is available at a regional level. The breadth of EERE's portfolio—in terms of markets addressed, geographic regions, and time frame—limit the extent to which any one model, including NEMS-GPRA04, can be relied on in estimating program benefits. Indeed, for much of EERE's portfolio, however, NEMS-GPRA04 does not reflect the level of detail needed here to provide a good understanding of how a particular EERE technology might fare. In these cases, some of the analysis must be undertaken off-line, or outside of the model. In practice, a significant amount of market-specific information must be developed outside or "off-line" from the model. Benefit estimates developed outside of these energy-economic models are reduced by judgment to account for market feedbacks.

Calculating carbon equivalent emissions reductions. Similar to primary energy, carbon emissions are computed using NEMS-GPRA04, based on energy savings that result either from an internal estimation of program impacts on energy markets or from an external analysis of direct energy savings that is used as an input to the model. Much of the growth in electricity generation is expected to be produced from relatively low-carbon natural gas, rather than higher-carbon coal. The resulting carbon emission factors for electricity reflect this lower and changing carbon content for marginal electricity sources. The GPRA 2004 documentation of program analyses also includes estimates of carbon emissions in addition to estimates for primary energy. These are based on direct energy savings and carbon emission factors (the amount of carbon contained in the fuel) that are provided for each fossil energy source and for electricity.

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 current capabilities to reflect specific market conditions in energy models available to EERE.

Other factors have been considered to augment EERE's current analysis. Some of these have been deemed to not have a significant impact on the resulting estimates of benefits and, therefore, have been excluded from the analysis.[8] In some cases, however, empirical evidence or energy-model assessments, or improved data or methodologies, would produce more accurate or robust (i.e., less sensitive to assumptions) benefit estimates. EERE is currently identifying important areas of improvement and prioritizing those improvements with respect to their ability to improve the consistency of EERE's benefit estimates.

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 NEMS-GPRA04 utilizes 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-GPRA04 contains a detailed technology representation of electricity markets, most residential and commercial end uses, and vehicle choice—but uses trends for the representation of industrial efficiency improvements and existing residential shell retrofits. In those first cases where the NEMS-GPRA04 includes both explicit representation of the program technology and target-market characteristics, this step simply requires (1) confirming representation of the target market in the Baseline Case and (2) providing the program goals in a format consistent with the

[8] For example, when market analysis indicated that there is no substantial difference between future average and marginal electricity prices, EERE chose to not include this additional market consideration in its guidance and benefits analysis. By comparison, it turned out that there is a significant difference between average and marginal carbon emissions from electricity production, and ignoring this difference would overstate the climate benefits of EERE technologies. Being able to ignore some market details helps reduce the complexity and cost of benefits analysis, but requires an up-front investment to assess which details can be safely ignored.

model. Any updated market characteristic information is used to adjust NEMS-GPRA04 for both the Baseline Case and the Program Case. The program goal information is used 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-GPRA04.

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, the most detailed off-line analyses are performed for the Industrial Technologies Program, Weatherization and Intergovernmental Program (WIP), Federal Energy Management Program (FEMP), and portions of the Building Technologies Program, along with the heavy-truck portion of the FreedomCAR and Vehicle Technologies Program. These off-line analytical approaches are tailored to the characteristics of the program and target market being analyzed; but, in any case, are conducted within the overall guidance provided through the GPRA benefits estimation process.

Where NEMS-GPRA04 does 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 model. 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.

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.

Off-line analysis also can be required for targeted submarkets that are simply not included in NEMS-GPRA04—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 home efficiency improvements are directly purchased by the Federal Government.

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-GPRA04; and, therefore, another model specifically designed to analyze this market is used. 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, the following features are explored in these external analyses:

Target Markets. New technologies will not necessarily be well suited to all applications served by existing markets. Especially in early years, technologies may occupy niche markets. In some cases, initial markets may be geographically limited as well. Where NEMS does 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. 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 benefits, in particular, may differ from those expected. Modeling stock turnover is crucial to estimating benefits accurately for both new technologies and deployment programs.

Next Best Technology. Where this 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. This set of baseline technologies is then used to assess the specific markets in which the EERE technology might be competitive in different timeframes.

Market Penetration. Over time, new technologies typically make their way into markets—and, therefore, affect energy use—gaining in share of new sales as consumers learn about the availability of the product, manufacturing capacity grows, and product prices fall with economies of scale and learning.[9] While price helps determine whether a product is cost-effective on average, energy prices vary by type of customer and region, so that new products may be cost-effective for some customers before they are generally cost-effective (a niche market). Price, or cost-effectiveness, is often not the only aspect of the new technology or deployment program that shapes its market acceptance. Many nonprice or cost factors affect consumer behavior. Analysts may adjust models and analyses for such factors using judgments based on better information on expected consumer behavior.

[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).

Only for R&D programs does EERE assume the impact of the program is to accelerate the commercial introduction of a technology—assuming that 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) that could improve the reliability of the electricity grid. This is because the markets do not provide the price signals that would generate profits from these public benefits. In some cases, that may be the only effect.

As an example, the off-line analysis for the Industrial Technologies Program uses a spreadsheet model that provides several possible market penetration curves. A curve is chosen by the analyst, 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, or through the use of NEMS, program analysts produce estimates of market penetration and direct energy savings. However, these "off-line" estimates are not the final/official benefits estimates. These off-line estimates are integrated within the NEMS-GPRA04 model as the final part (Step 3) of the process.

Through the use of a specialized spreadsheet or other models, or through the use of NEMS, the market analysts produce estimates of market penetration and direct energy savings. For GPRA04, they also produced benefits estimates.[10] These, however, are not the final/official benefits estimates. The resulting technology and market data and assumptions are integrated within the NEMS-GPRA04 model, as in the final step of the process.

Step 3: Program and Portfolio Benefits Estimates

The final step for estimating the impacts of EERE's FY 2004 Budget Request begins by each EERE program being modeled separately within NEMS-GPRA04 to the extent possible. In each program NEMS-GPRA04 run, 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. Each program is modeled separately

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[10] As EERE's benefits analyses are streamlined under the new organization, the step of producing initial benefits estimates for each program will be eliminated, and information about key market factors will be incorporated directly into the integrated benefits analysis. Key market information will be updated as market conditions change or new market information becomes available. In addition, benefits out to 2050 will be modeled using MARKAL. For programs that cannot be modeled using NEMS or MARKAL, additional tools and judgment will again be used regarding how to integrate such program benefits into the overall analysis.

to derive estimated energy savings without the interaction of the other programs. The results from the program NEMS-GPRA04 runs are then compared to the Baseline Case to measure the individual benefits of the EERE program being analyzed.

A few of the programs were modeled in groups, and then the joint benefits were allocated to the individual programs. This was primarily due to the legacy of the previous EERE organization. The renewable electricity-generation technologies (solar, wind, hydropower, geothermal, and biomass gasification) were one such group. In addition, fuel cell vehicles (from the HFCIT Program) were modeled along with hybrid vehicles and diesel vehicles (from the FCVT Program) and with natural gas vehicles (from WIP). The grouping likely reduces somewhat the benefits of each program, because they compete in the same markets. The detailed representation of how each of the programs was modeled in the EERE Benefits Case is described in **Chapter 4**.

For programs modeled using NEMS-GPRA04 directly, the Benefits Case is computed 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-GPRA04 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.

Program impacts that cannot be easily modeled in detail using NEMS-GPRA04 are estimated using a variety of 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 that are then used as inputs to NEMS-GPRA04. In cases where the off-line analyses produce a direct estimate of site energy savings, this information is also incorporated, with adjustments, in NEMS-GPRA04 in order to calculate primary energy savings.

Another challenge in estimating benefits is the potential for program results—individually, or in combination—to be significant enough that market responses and interactions need to be considered. Past EERE experience indicates that failure to reflect market responses tends to overestimate some program benefit levels, even if the overall impact on the EERE portfolio is small. NEMS-GPRA04 takes these feedbacks and interactions into account, which off-line tools generally do not.

As such, in many cases,[11] these off-line results are adjusted based on the judgment of the integrated modeling team before using these as inputs into NEMS-GPRA04. As a general rule, the program estimates were reduced in these cases, rather than implemented at the full savings level in the models.

[11] An example exception is the Weatherization Program, which involves direct field application of energy-savings improvement.

The integrated modeling team selected a discounting of 30 percent to be conservative about these programs that could not be economically evaluated.[12]

Once each of the programs (or group of programs) was represented individually within NEMS-GPRA04, the benefits of EERE's portfolio were estimated by combining all of the programs assumptions into one scenario. The purpose of this approach 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.

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

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[12] Program energy savings that were estimated outside the integrated model and then used as exogenous inputs to NEMS were discounted, primarily in an attempt to account for integration effects. In most cases, these estimates are derived for single program activities without consideration of other activities within the same program. The 30 percent reduction reflects the overall average decrease in individual program impacts for those programs that can be modeled in NEMS for the portfolio estimates. As such, 30 percent is used as a "rule of thumb" for the balance of the portfolio that cannot be modeled in NEMS-GPRA04 directly. The impact of an activity, such as the industrial Best Practices Program, is generally developed from a Baseline Case that does not include other activities; in this case, other industrial program impacts. In addition, the cost-effectiveness of a technology—and, therefore, its adoption rate—will be affected by the adoption of other technologies. As a result, estimated savings for a single activity is likely to be overestimated. In contrast, program activities that can be modeled in NEMS-GPRA04 based on technology characteristics, both types of interactions are captured internally. Therefore, for single-activity programs estimated outside NEMS-GPRA04, a discount factor is applied to the off-line estimates to make them more comparable. A secondary purpose in discounting the off-line savings is that, in many cases, an economic analysis was not conducted; and, therefore, the savings were not fully justified. Discounting such savings provides a rough but conservative way to account for the uncertainties inherent in the estimates.

CHAPTER 3

FY 2004 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 2004 budget request are estimated for 2005-2020. The year 2020 is the last date for which an independent reference forecast was available at the time of this analysis.

Benefits estimates are intended to reflect the value of program activities from 2005 forward. These estimates 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, as 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.

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 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 categories:

Primary Outcome:

Energy Displaced: Displaced energy (or energy savings) is calculated as the difference in nonrenewable energy consumption with and without the technologies and market improvements developed by EERE programs. Energy savings are measured 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.

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[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.

Primary Benefits:

Economic Benefits: Economic benefits are the potential for EERE technologies to make energy more affordable, increase economic productivity and GDP, reduce the impact of energy price volatility on the U.S. economy, and improve the balance of trade.

EERE currently utilizes one primary measure related to affordability:

Energy-expenditure savings: Energy-expenditure savings are calculated as the difference in total consumer energy bills, with and without the availability of technologies and market improvements developed by EERE technologies. This is a gross savings estimate, as it does not include the incremental cost to end users of acquiring the new technology. The EIA NEMS model does not currently have the capability to provide net costs.

Energy efficiency improvements and increased use of nonfuel renewable energy 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). Both elements are included in this metric.

Environmental Benefits: Environmental benefits include lower carbon, SOx, NOx, and other air emissions associated with renewable energy use and energy efficiency improvements, improvements in water quality, reductions in noise, a reduced "footprint" for energy exploration and development, and the health and ecological implications of each of these.

Of these, EERE currently estimates only the impacts of its programs on carbon emissions:

Carbon savings: Carbon savings (i.e., emission reductions) are calculated as the difference in the level of U.S. energy-related carbon emissions with and without the availability of EERE technologies and market improvements.

Carbon emission reductions result from the reductions in fossil fuel consumption when these new supply (renewables) and 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.

Security Benefits: Security benefits include improvements in the reliability of fuel and electricity deliveries, reduced likelihood of supply disruptions, and reduced impacts from an energy disruption.

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 imports and the reliability and diversity of electricity supplies:[2]

1. **Oil savings:** Oil savings are calculated as the difference in total U.S. oil consumption with and without EERE technologies and market improvements.
2. **Natural gas savings:** Natural gas savings are calculated as the difference in total U.S. natural gas consumption with and without EERE technologies and market improvements.
3. **Electricity generation capacity:** Electricity-generation capacity impacts are calculated variously as the difference in renewable power-generating capacity (capacity additions); the amount of electricity capacity displaced by efficiency improvements (displaced capacity); or the amount of distributed generation, with and without EERE technologies and market improvements.[3]

The natural gas and electricity capacity security metrics are new for EERE this year. A natural gas measure was added to reflect the growing importance in the U.S. energy mix of natural gas imports. The electricity-generation capacity metric reflects increasing concerns about the adequacy of traditional, centralized electricity systems to provide reliable electricity in the years and decades ahead.

In interpreting these results, 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, less the cost to the consumer of investing in the efficient or renewable technology; any negative, as well as positive, environmental impacts). EERE's current modeling tools lack the ability to back out some of these types of costs. Carbon emission reductions, as well as oil and natural gas savings are calculated on a net basis (e.g., accounting for cases in which EERE programs tend to increase rather than decrease use or emissions); while consumer-expenditure estimates do not reflect the costs to consumers of purchasing more efficient or cleaner technologies.[4]

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[2] The inclusion of reliability improvements within the security category was part of the NRC suggestions on how to structure the types of EERE benefits. The 2003 blackout in the Midwest and New England indicates the extent to which security and reliability are intertwined.

[3] 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).

[4] EERE is in the process of adopting an additional economic model, which is able to provide estimates of net economic costs. This model, MARKAL, will also estimate benefits out to 2050.

Portfolio Benefits

Table 3.1 presents the 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.

Table 3.1. Annual EERE Portfolio Benefits for FY 2004 Budget Request for Selected Years

EERE Portfolio Benefits	2005	2010	2020
Energy Displaced (quadrillion Btu)	0.6	2.3	8.7
Economic Benefits:			
▪ Energy-expenditure savings (billion 2000 dollars)	8.5	31.2	101.8
Environmental Benefits:			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	10.6	38.9	151.0
Security:			
▪ Oil savings (quadrillion Btu)	0.2	0.7	3.3
▪ Natural gas savings (quadrillion Btu)	0.4	1.2	3.8
▪ Renewable electric-generating capacity (gigawatts)	1.5	7.2	39.4

Energy Displaced: EERE's portfolio significantly dampens the expected growth in conventional energy consumption. Absent the results of EERE's programs,[5] energy use is expected to grow by nearly 21 quads from 2005 to 2020, to about 121 quadrillion Btus of energy. EERE's investment portfolio would reduce nonrenewable energy consumption by nearly 9 quadrillion Btu by 2020, or more than 40% of the expected incremental growth in energy demand over this time period (see **Figure 3.1**).

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, therefore, the market opportunity for renewable-generation technologies. The overall effect of these interactions is to reduce EERE benefits in 2020 by about one-half quad compared to the sum of the individual program benefits (i.e., Program Case, see **Figure 3.2**).

Economic Benefits: The energy savings resulting from these efficiency and renewable energy contributions are estimated to reduce annual consumer energy expenditures in 2020, expressed in real 2000 dollars, by $102 billion relative to the baseline projection of $880 billion (**Figure 3.3**), or about 12 percent of the nation's expected energy bill.

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

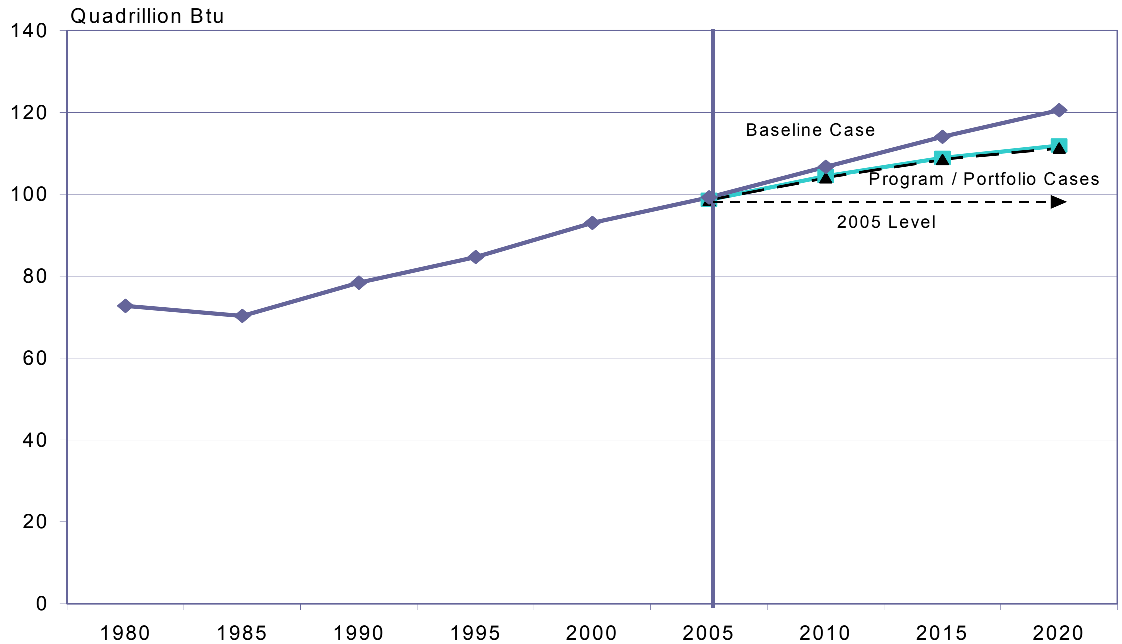

Figure 3.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

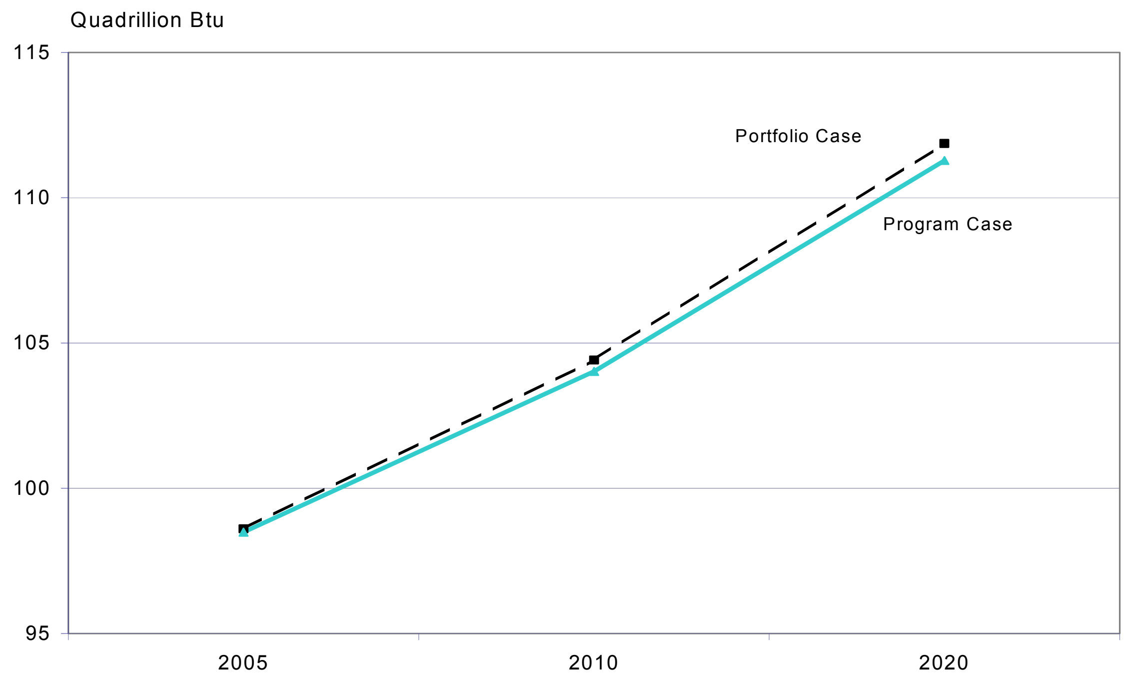

Figure 3.2. Comparison of Program and Portfolio Nonrenewable Energy Consumption Estimates, 2005, 2010, and 2020 (quadrillion Btu)

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site: http://www.eia.doe.gov/emeu/aer/contents.html.

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. 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.

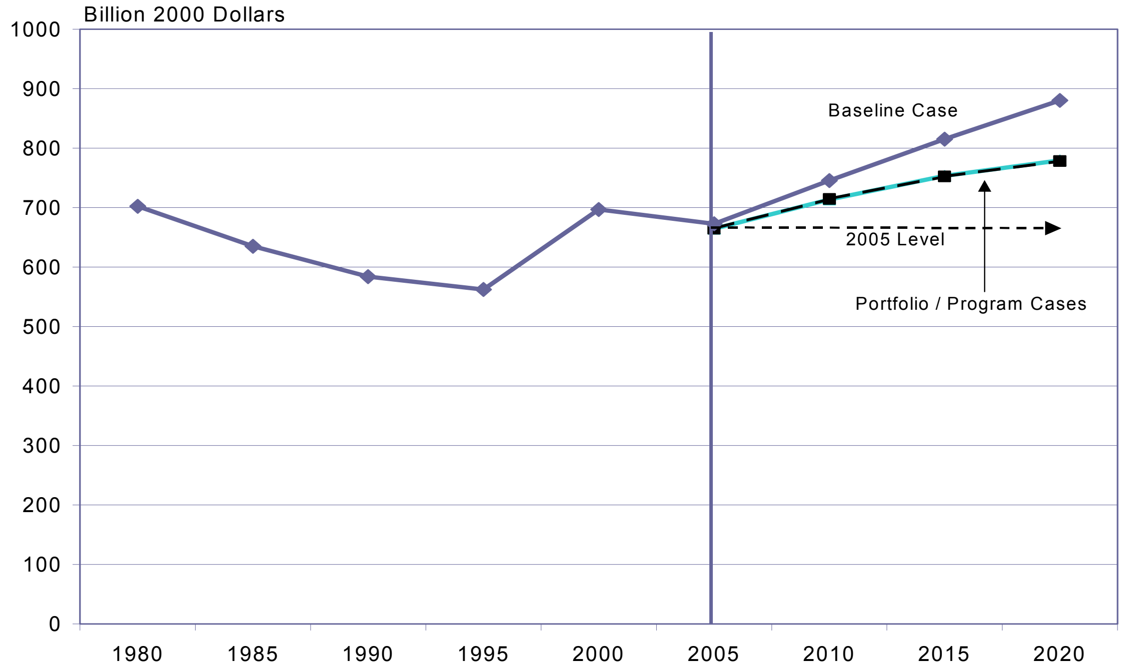

Figure 3.3. U.S. Total Energy Expenditure, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-1995: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 3.4 and Table E1, Web site http://www.eia.doe.gov/emeu/aer/contents.html. Data Source, 2000: Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Supplemental Table 20.

EERE's Weatherization Grant Program specifically targets energy savings and energy bill reductions for low-income families. At the FY 2004 request level, the program directly funds weatherization of nearly 230,000 low-income-family homes per year, including homes weatherized by additional governmental and utility funding. In FY 2004, these homes save each year an average ranging from $3,429 in the Midwest to $1,814 in the West. By 2020, this will translate into about $917 million in annual energy bill savings for low-income families.[6]

[6] U.S. Department of Energy, Energy Efficiency and Renewable Energy, *Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP*," PNNL 14231 (April 2003), pp. B-27–B-31. Because homes that are weatherized continue to save energy in the years following the weatherization, the total number of homes saving energy due to this program grows over time, even when program funding remains constant.

Environmental Benefits: Annual carbon dioxide emissions are projected to be 151 million metric tons (carbon equivalent) less than the 2020 baseline projection of 2,073 million metric tons, a reduction of about 7.5% (**Figure 3.4**) or 39% of the expected increase from 2005 to 2020. By 2010, the projected reduction will be about 39 million metric tons, which could provide about one-third of the targeted 2012 carbon reduction under President Bush's Climate Change Initiative.

Although not quantified here, EERE's portfolio also 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 in this sector). 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 WIP facilitates local purchases of alternative-fuel vehicles.

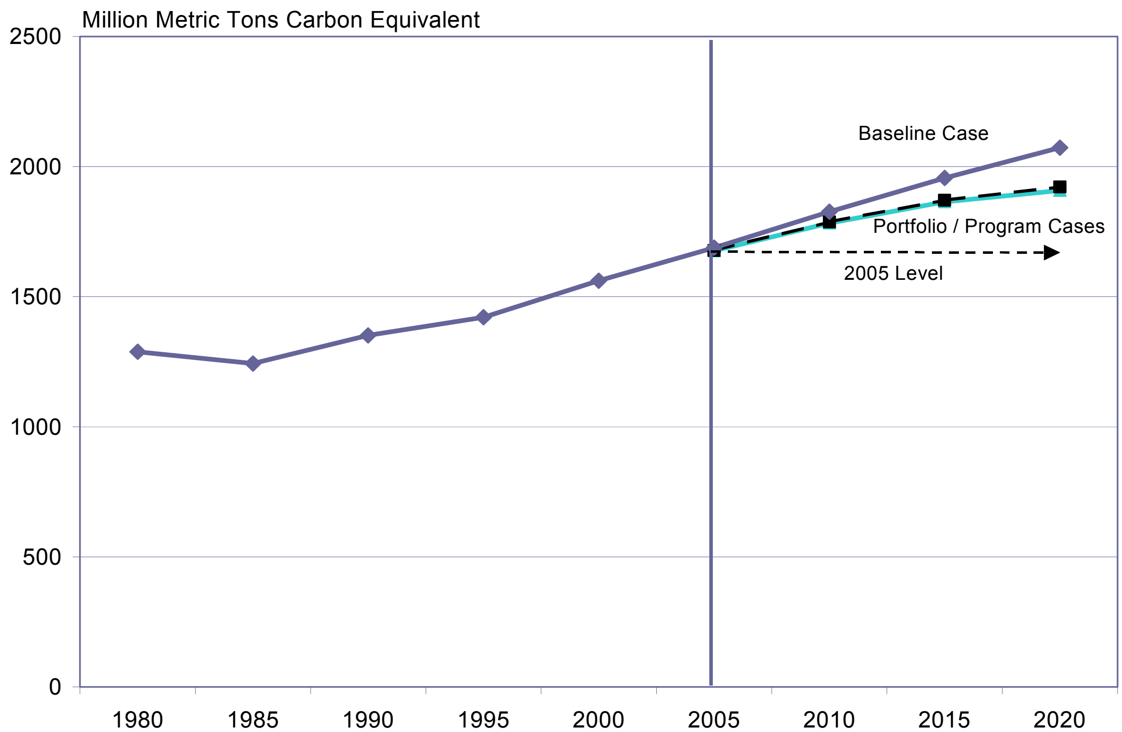

Figure 3.4. U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), 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 3 quadrillion Btu from the 2020 baseline of 52 quadrillion Btu (**Figure 3.5**), or about 1.6 million barrels of oil per day (about 31% of expected growth in oil demand between 2005 and 2020).

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

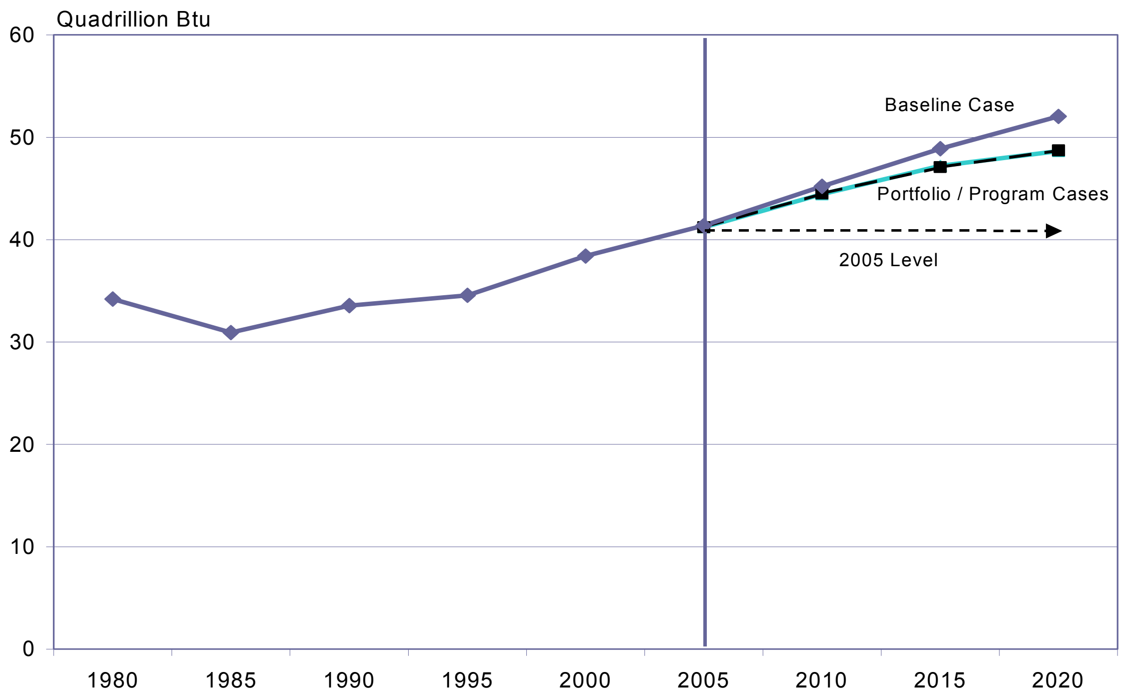

Figure 3.5. U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

consumption by 4 quadrillion Btu from the baseline of 35 quadrillion Btu (**Figure 3.6**) in this time frame.[7] 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.

Capacity Benefits: When evaluated as part of a portfolio, energy efficiency improvements developed by EERE reduce the market opportunity for the development of new renewable resources by reducing the demand for additional energy capacity. Even with these reductions, EERE projects that renewable energy technologies will provide significantly larger electricity capacity additions than in the Baseline Case by 2020. As shown in **Figure 3.7**, renewable energy capacity additions are projected to grow by an additional 40 GW compared with the Baseline Case by 2020. Moreover, if some of these efficiency improvements fail to materialize, it is likely that they would be partly "backfilled" by the development of additional renewable energy resources. In addition, EERE's technology programs contribute to security of the Nation's electricity supplies in another important way: through the combination of reduced peak demand for electricity (through improved efficiency or when coincident with renewable generation) and the development of on-site electricity generation sources (to mitigate bottlenecks in the electricity transmission grid).

[7] The remaining chapter of this report describes some of the limitations and omissions in the current benefits analysis, which limit EERE's ability to reflect the full benefits for each EERE program.

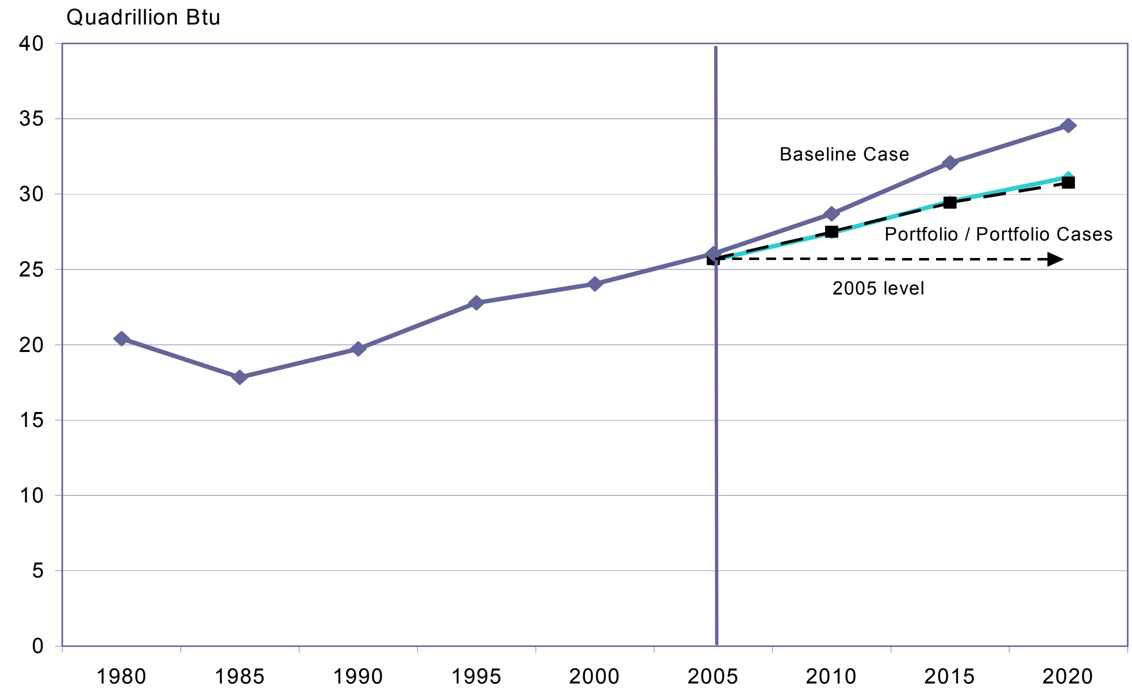

Figure 3.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

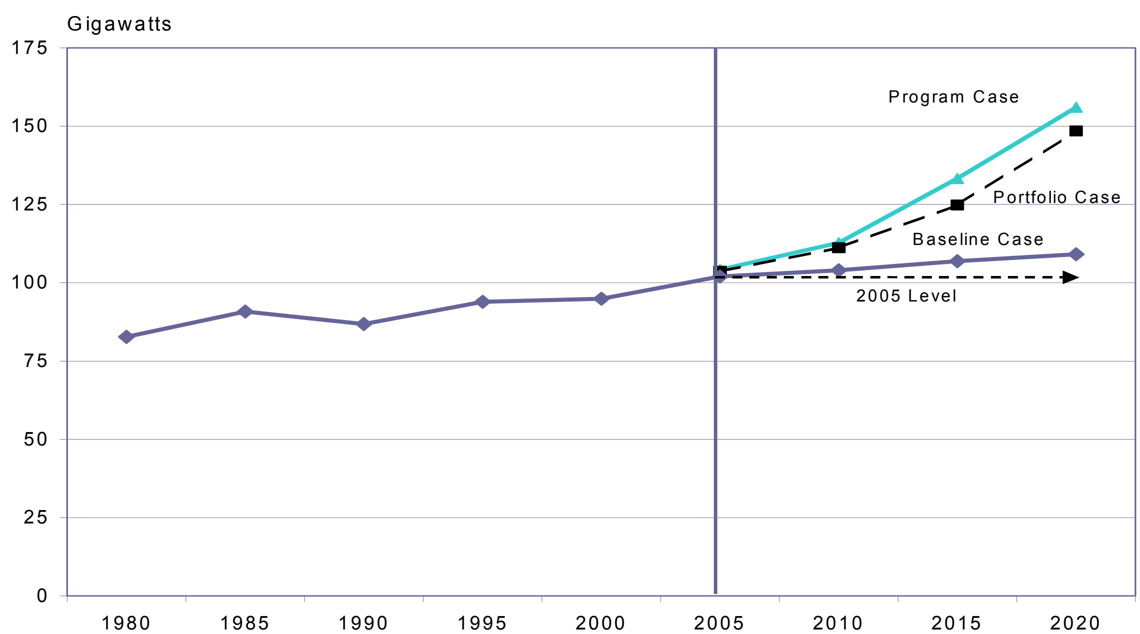

Figure 3.7. U.S. Renewable Energy Capacity, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 8.7a, 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 budgets and benefits. **Figure 3.8** displays the EERE program budgets for FY 2004. The largest program budget is $369 million for the WIP (Weatherization and Intergovernmental Program), which includes $284 for Low-Income Weatherization Assistance.

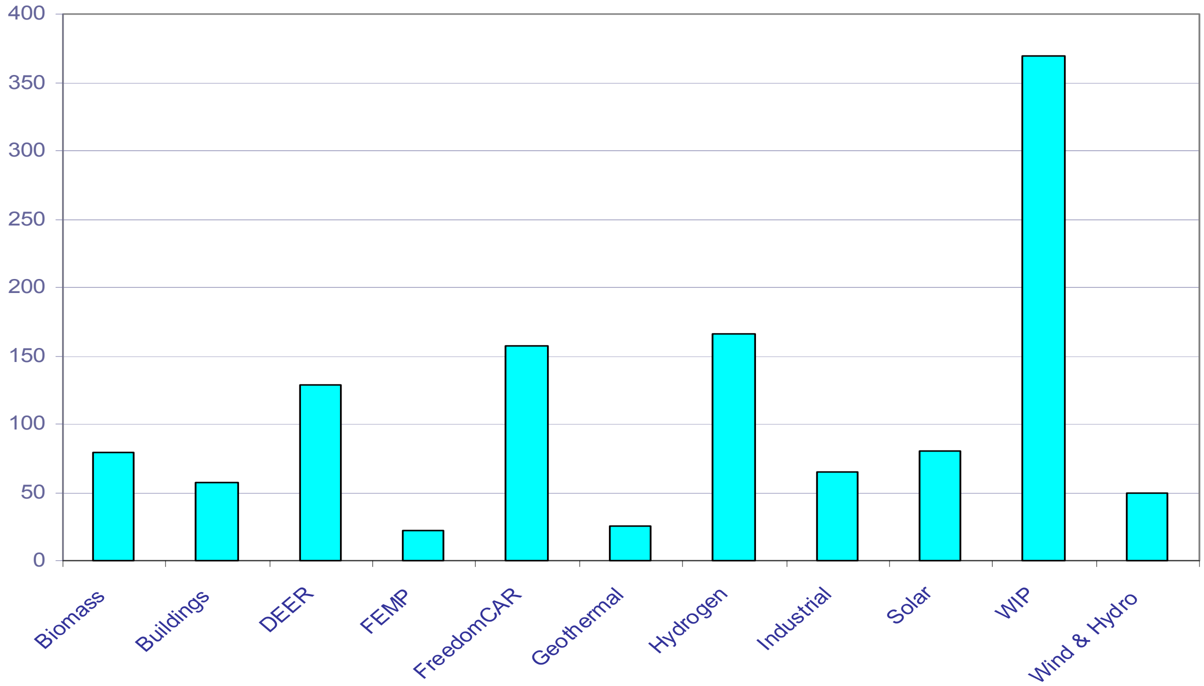

Figure 3.8. EERE Program FY 2004 Budget Requests (2000 dollars)

Source: Budget request from *FY 2004 Budget-in-Brief*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy04_budget_in_brief.pdf.

The FY 2004 estimates of benefits for the individual EERE programs are shown for 2020 in **Figures 3.9 through 3.14**. The benefits vary widely across EERE's programs, with each program providing a different level and mix of types of benefits. Nonrenewable energy savings in 2020, for example, range from 0.07 quadrillion British thermal units (Btu) for the Federal Energy Management Program (FEMP) to 2.13 quadrillion Btu for the Industrial Technologies Program (**Figure 3.9**). The differences in benefits result from a number of factors: (1) program size and target market; (2) time frames for program results; (3) primary types of benefits addressed by each program; and (4) technical potential achievable within each program and the amount of improvement already included in the baseline. Note that these estimates do not reflect the relative technical or market risk associated with these program activities. In addition, in this transition year for EERE, not all programs were able to generate new performance goals indicating the years in which they expected each technology to be ready for market in time for this analysis. As a result, portions of some program benefits are not reflected in the estimates reported here.

Once a technology enters the market, benefits increase for some period of time as (1) market shares or sales grow; (2) total market size grows to reflect increased population or GDP; and (3) the existing stock of energy-using buildings and equipment is replaced in comparison to the expected improvement in the business-as-usual case.

EERE programs differ greatly in anticipated dates of commercialization, with those programs likely to generate market results in the near term showing the largest benefits during the 15 years addressed by this analysis. In several cases, such as hydrogen-based vehicles, EERE technologies are not expected to be available until about 2020, so it was not possible to include meaningful estimates of even initial benefits levels. Those programs with a larger number of early technology introductions are likely to exhibit larger benefits.

Several EERE programs are targeted toward benefits not well reflected in any of EERE's quantified benefits metrics. For instance, the Distributed Energy Resources (DER) Program focuses on improving electricity reliability by developing electricity-generating capacity at or near the point of use (**Figure 3.14**). 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 **Chapter 4**.

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.

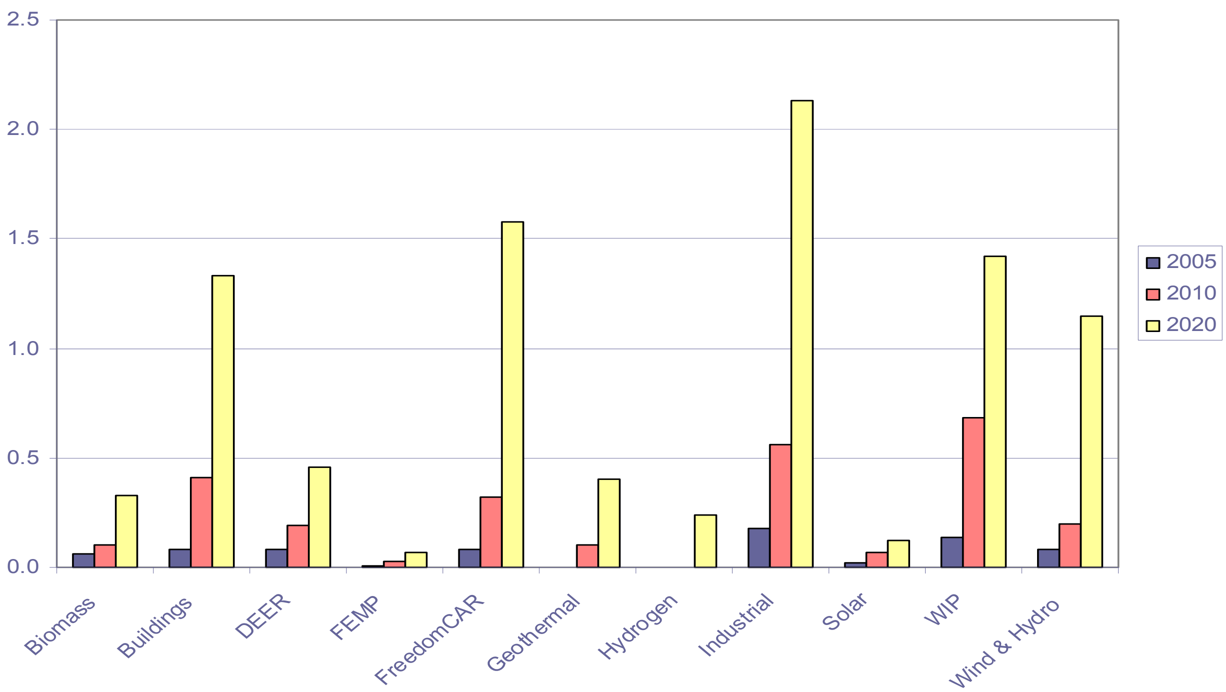

Figure 3.9. Annual Nonrenewable Energy Savings: 2005, 2010, 2020 (quadrillion Btu)

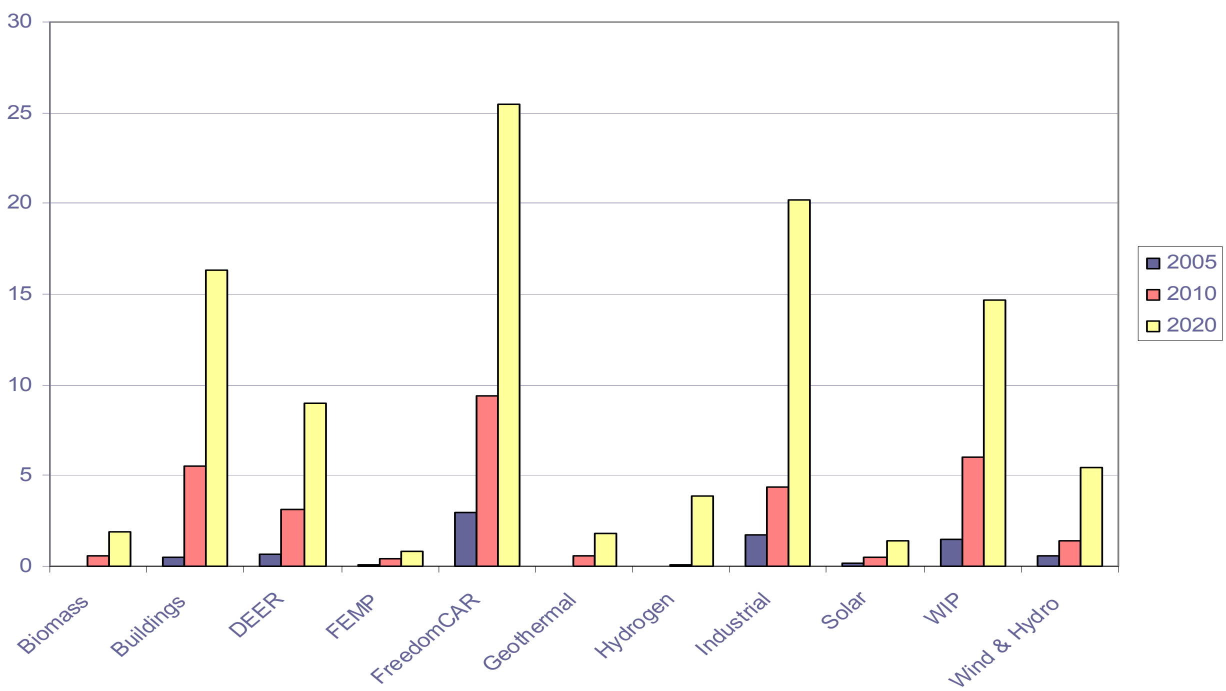

Figure 3.10. Annual Energy Expenditure Savings: 2005, 2010, 2020 (billion 2000 dollars)

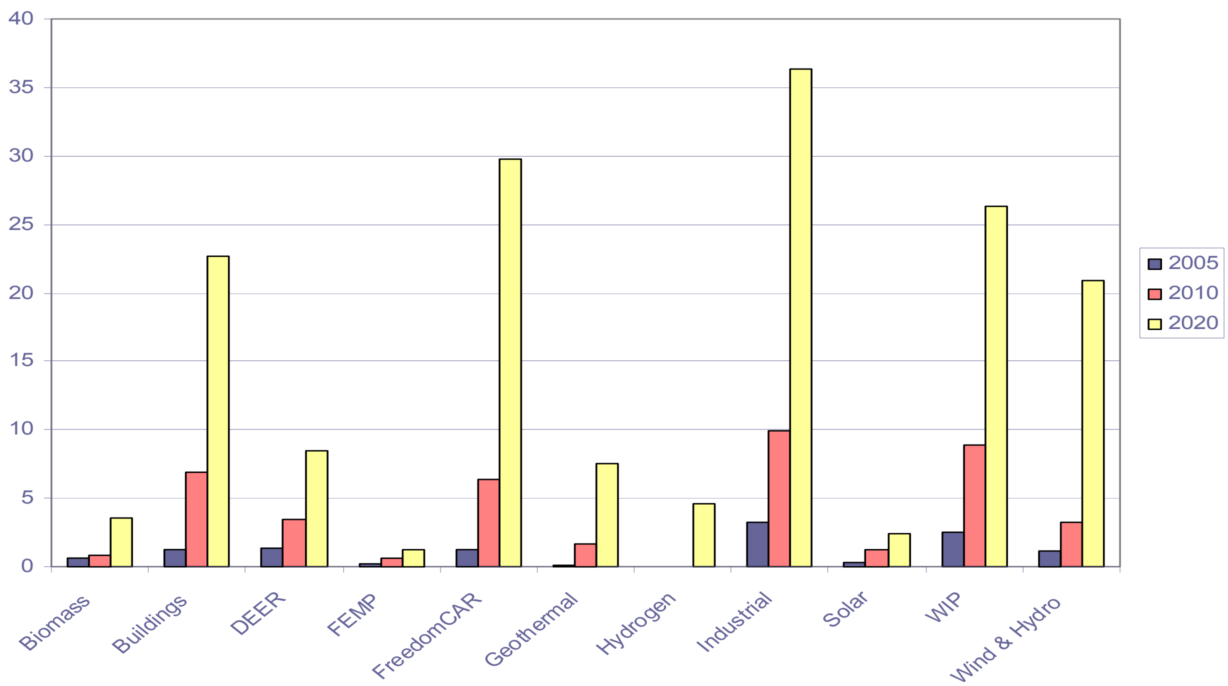

Figure 3.11. Annual Carbon Dioxide Savings: 2005, 2010, 2020 (mmt carbon equivalent)

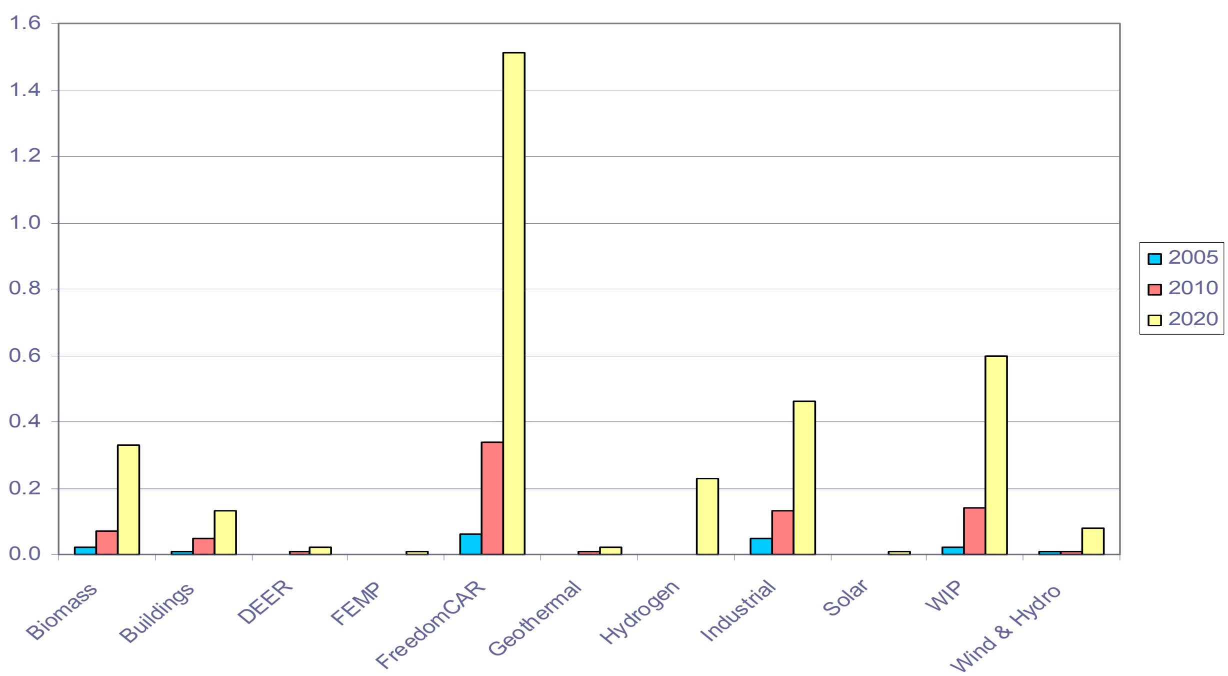

Figure 3.12. Annual Oil Savings: 2005, 2010, 2020 (quadrillion Btu)

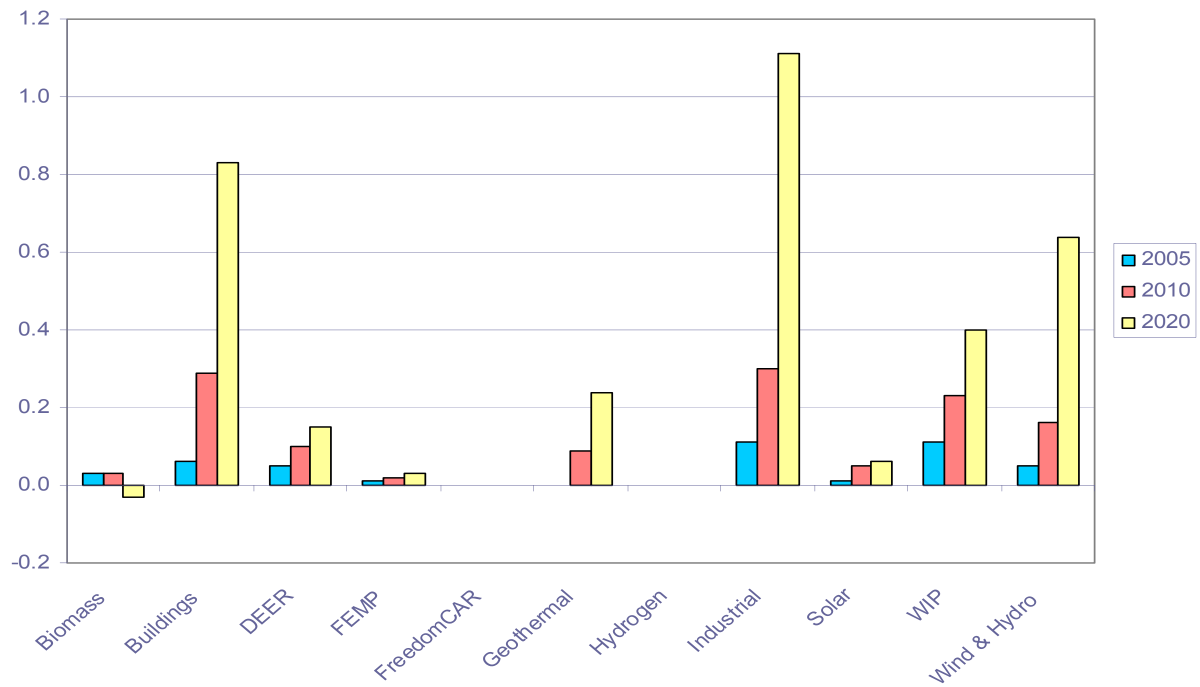

Figure 3.13. Annual Natural Gas Savings: 2005, 2010, 2020 (quadrillion Btu)

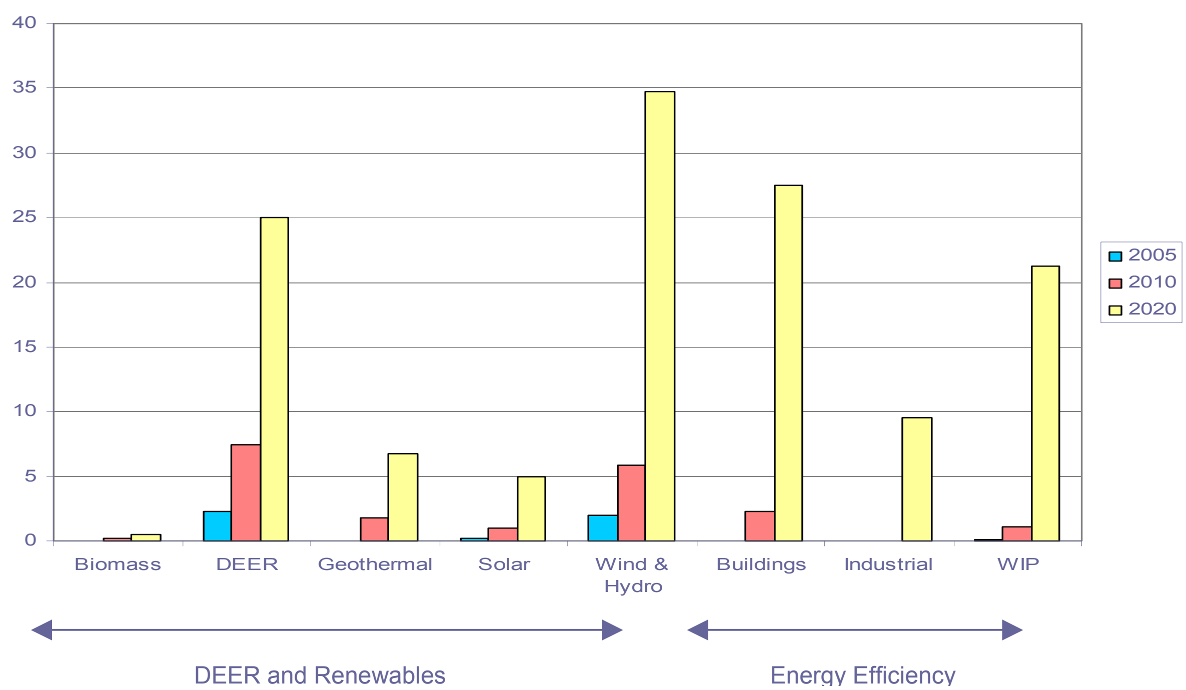

Figure 3.14. Annual Renewable Electric Capacity – Energy Efficiency, DEER, and Renewables: 2005, 2010, 2020 (gigawatts)

Note: The FEMP, Hydrogen, and FCTV programs either do not have renewable electric-capacity impacts or do not have measurable impacts in quads by 2020.

CHAPTER 4

BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

As outlined in the description of Step 2 of the EERE benefits-analysis process in **Chapter 2**, the inputs for estimating benefits for each of EERE's 11 programs are developed using a variety of analytical tools suitable for assessing specific target markets. The results of these analyses are then reflected in NEMS-GPRA04 to estimate the benefits for each program and for EERE's overall portfolio. In some cases, program performance goals (outputs) can be incorporated directly into NEMS-GPRA04. In other cases, adjustments to the program analyses have to be made when incorporating them in NEMS-GPRA04. This chapter describes the NEMS-GPRA04 analyses for each program. It is helpful to recognize the uses and limits of the NEMS-GPRA04 model—the final modeling step for EERE benefits analysis (see **Box 4.1 – Uses and Limitations: NEMS-GPRA04** at the end of the chapter).

To aid the reader, **Table 4.1** shows a breakdown by program of the two types of analytical tool—specialized "off-line" tools and NEMS-GPRA04—employed in its benefits analyses.

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

Program	Subprogram	Step 2 Off-Line Tools	NEMS-GPRA04
Biomass	Bio-products	√	
	Bio-power		√
	Cellulosic Ethanol	√	√
Building Technologies	Technology R&D	√	√
	Regulatory Actions		√
	Market Enhancement	√	
DEER	DER / CHP		√
FEMP		√	
FreedomCAR & Vehicle Technologies	Light-Vehicle Hybrid and Diesel		√
	Heavy Vehicles	√	
	Lightweight Materials	√	
Geothermal			√
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		√
	Production	√	
Industrial Technologies	R&D	√	
	Deployment	√	
Solar Energy Technologies	Solar Buildings		√
	Photovoltaics	√	√
Weatherization and Intergovernmental	Weatherization	√	
	Domestic Intergovernmental	√	
Wind and Hydropower Technologies	Wind		√
	Hydropower	√	

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-GPRA04. Specialized off-line tools are used to develop the inputs to NEMS-GPRA04 for each program case. The subprograms listed are groupings of activities within each program that share either technology or market features. They do not represent actual program management categories. As EERE completes its reorganization, some of this Step 2 off-line analysis can be incorporated directly into NEMS-GPRA04, streamlining the effort considerably.

Biomass Program

The Biomass Program focuses on three major areas: bio-products, bio-power, and cellulosic ethanol (**Table 4.2**). The methodology for computing the EERE FY 2004 benefits estimates varied, depending on the biomass area and the relevant components of the NEMS-GPRA04 framework.[1]

Bio-products: The bio-products activities seek to develop biomass-based chemical products through innovative biomass-conversion processes. The use of biomass would displace traditional reliance on petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, NEMS-GPRA04 does not have sufficient detail within its representation of this industry to explicitly model bio-products. Energy savings were estimated by the program that reflected an assumption of 15 percent per year growth from 2010. 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-GPRA04. The model was then used to compute the other benefits of primary energy savings, carbon emission reductions, and energy expenditure savings.

Bio-power: The main thrust of the bio-power activities are to develop and verify gasification technologies that enable the increased efficiency of bio-power generation from the current 20 percent efficiency to 30–35 percent efficiency. In estimating the benefits of EERE's FY 2004 budget request, the biomass generation capital and operating and maintenance (O&M) costs were modified to reflect the program's goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report.[2] These costs and the biomass heat rates are very similar to those already in the Baseline Case, although the projected increase in biomass capacity is quite small in the baseline. In addition to competing on an economic basis with other electricity-generation technologies, biomass capacity may be constructed for its environmental benefits. Projections for green power biomass installations, as developed by Princeton Energy Resources International (PERI) using their Green Power Market Model, were incorporated into NEMS-GPRA04 as the planned capacity additions. The majority of projected biomass-generating capacity in this forecast stems from the green power additions. The roughly 500 MW by 2020 is expected to generate 3.7 billion kilowatt-hours.

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[1] The Biomass Program was created from three activities located in three different offices under the old organization. Appendix D provides details of the off-line benefits analysis.
[2] This report can be found on the Web at http://www.eere.energy.gov/power/pdfs/techchar.pdf.

Cellulosic ethanol: Cellulosic ethanol research is aimed at reducing the cost of producing ethanol from cellulosic biomass (corn is currently the U.S. feedstock). The improvements in cellulosic ethanol production costs in the AEO2002 (and, therefore, the EERE Baseline Case) are similar to the program's goals—but the growth in projected production is assumed to be constrained. For the FY 2004 EERE benefits estimates, these constraints are relaxed, so that cellulosic ethanol production equals the program goals (assuming other baseline assumptions), which were developed using EERE's ethanol analytic model. NEMS-GPRA04 then adjusts the overall level of ethanol purchased by accounting for the price impacts of competing sources of demand for biomass (e.g., for electricity production). Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline through enhanced blending. In the FY 2004 EERE benefits projections, a large portion of the cellulosic ethanol displaces corn ethanol, which does not lead to fossil energy savings. The cellulosic ethanol research, however, does lead to additional carbon emission savings through its lower life-cycle carbon emissions. The NEMS-GPRA04 results are adjusted to reflect this differential in net carbon emission during the analysis period.

Table 4.2. FY 2004 Benefits Estimates for Biomass Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.06	0.10	0.33
▪ Cellulosic ethanol production (billion gallons)	0.00	0.11	0.82
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.6	1.9
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.6	0.8	3.6
Security			
▪ Oil savings (quadrillion Btu)	0.02	0.07	0.33
▪ Natural gas savings (quadrillion Btu)	0.03	0.03	-0.03
▪ Renewable electric-generating capacity* (gigawatts)	0.0	0.2	0.5

* Includes bio-power only.

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 lesser extent) market enhancement. With the reorganization of EERE, the majority of the market-enhancement activities in buildings markets are part of the Weatherization and Intergovernmental Program.[3]

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 that are available in the Baseline Case. Building technologies in NEMS-GPRA04 are represented by end use. For most end uses, there are conversion technologies (e.g. furnaces and water heaters)

[3] Appendix B provides the details of the off-line calculations.

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.

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

The residential and commercial sectors are each represented by several building types[4] within nine census divisions. End-use technology choice is computed 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.

Improved EERE technologies that have no incremental costs above the baseline technologies, such as Commercial Buildings Integration R&D, must be treated differently. If they were introduced into the modeling framework as technologies with zero incremental costs, there would be immediate adoption and unrealistic market shares. Thus, for these activities, off-line penetration estimates are used to compute a target savings. The target savings, however, are first reduced by 30 percent, as are other off-line estimates that cannot be modeled on an economic basis.[5] These savings were achieved in NEMS-GPRA04 by lowering the consumer hurdle rates for the appropriate end uses or by modifying the autonomous shell-efficiency indices.

Regulatory activities: Regulatory activities include the setting of new appliance standards, based on the legislatively mandated schedule; and encouraging State adoption of more stringent building codes. Representing appliance standards is straightforward. In the year that the new standard is assumed to be implemented (based on program goals), all technologies that are less efficient than the standard are 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. The baseline was adjusted to remove any future appliance standards in the AEO2002 that are part of the Building Technologies Program. As a result, the revised Baseline Case has higher space-heating consumption in the residential model and space-cooling consumption in the commercial model.

Market enhancement: Building-code development is a regulatory activity at the State level. The Building Technologies Program provides technical assistance in developing new codes and helps States to adopt updated standards. A spreadsheet computation of average savings is made using program estimates for the fraction of buildings within areas that adopt more stringent codes; and the heating, cooling, and lighting load reductions associated with the new levels of codes. The building shell packages are modified to produce the appropriate savings.

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[4] The residential sector is includes three building types and the commercial sector by 11 types (e.g., offices, schools, etc.).

[5] See Chapter 2, Footnote 12.

The Building Technologies Program benefits (**Table 4.3**) are estimated with the integrated NEMS-GPRA04, 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 4.3. FY 2004 Benefits Estimates for Building Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.08	0.41	1.33
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.5	5.5	16.3
Environmental			
▪ Carbon dioxide emission reductions (million metric tons carbon equivalent)	1.3	6.9	22.7
Security			
▪ Oil savings (quadrillion Btu)	0.01	0.05	0.13
▪ Natural gas savings (quadrillion Btu)	0.06	0.29	0.83
▪ Renewable electric-generating capacity (gigawatts)	0.0	2.3	27.5

Distributed Energy and Electric Reliability Program

The Distributed Energy and Electric Reliability (DEER) Program encompasses many technologies and markets. The benefits were estimated by focusing on a segment of the distributed energy market: gas-fired combined heat and power (CHP) systems within commercial building and industrial applications.[6] Distributed energy resource (DER) applications that are motivated by the need for electric reliability primarily will be systems that produce only electricity and are used in backup mode. EERE currently does not have analytical tools to assess this market. Its absence from the benefits estimates may result in an underestimation of DER capacity; although this is less significant in regard to energy or emissions savings, because these systems typically run for few hours per year and generally have similar or lower efficiencies than larger central station plants.[7] To the extent that the central grid relies on DER for emergency power, avoided central station capacity may be underestimated as well.

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 use 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,

[6] Appendix D provides the details of off-line analyses.
[7] The exception is building solar systems, which may be purchased for reliability purposes; but which, because they do not require fuel purchases, are operated during nonpeak or nonemergency periods as well.

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 NEMS-GPRA04 framework uses a cash-flow model to evaluate the DER technologies (CHP and photovoltaic systems) within the building sectors. For commercial buildings, debt and interest payments are computed over a loan period of 20 years, along with associated taxes and tax benefits and assuming a 20 percent down payment. Annual fixed maintenance costs are also included. For the gas-fired CHP technologies, fuel costs are computed based on the delivered cost of natural gas and the technology efficiency. Netted against the fuel cost is the value of the useful waste heat produced as computed, 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 power rate. The number of years until positive cash flow is reached determines the market share in new buildings. The market share (as shown below) drops off sharply as the number of years increases, which reflects the high rates of return generally expected for energy-related projects by commercial building owners. The market share for existing buildings is assumed to be a fraction of the share for new.

The analysis is performed for each of 11 commercial building types in nine regions. Even so, this is a fairly high level of aggregation; and, therefore, the model may not capture some of the niche markets that DER may fill. The DEER Program facilitates the development of the DER 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.

The FY 2004 Baseline Case includes some DER technological advancement.[8] It was beyond the scope and schedule for this year's analysis to separate how much of the baseline improvements might stem from government R&D efforts, and therefore should be removed. As a result, the FY 2004 benefits may be underestimated for the smaller commercial-sector systems. Although not in the AEO2002, the baseline also assumes that small combined heat and power systems receive favorable tax treatment in terms of accelerated depreciation.

The DEER Program's impact on consumer adoption rates was represented in several ways. The maximum market share that can be achieved in new buildings was increased from 30 percent in the Baseline Case to 50 percent in the Program Case. **Figure 4.1** shows how the ultimate market share for new buildings varies by payback year. In addition, there is an adoption-rate parameter that was accelerated to reflect faster market maturity in the Program Case (see **Figure 4.2**).

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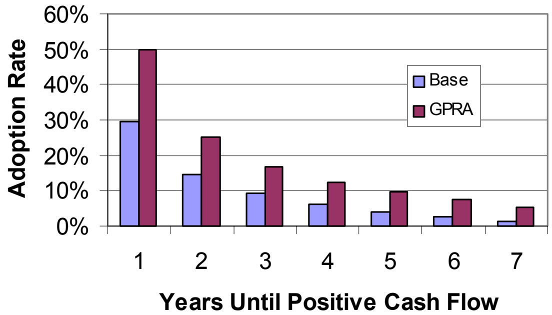
[8] The Annual Energy Outlook 2002 assumes improved CHP technologies in the commercial sector. The input files for the industrial sector CHP systems show improvements as well, but a coding error led to these being unused and the technology characteristics remain at their year 2000 values.



Source: NEMS-GPRA04 inputs

Figure 4.1. DER Market-Penetration Function in New Buildings for 2010

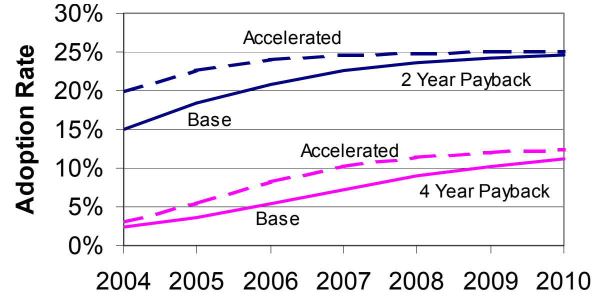
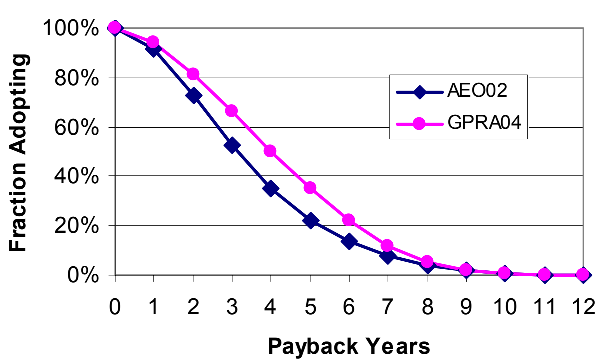


Figure 4.2. DER Market Share Over Time in New Commercial Buildings

The market share for the existing building stock is tied to the market share computed for new buildings. The Baseline Case assumes that the existing stock share is one-fiftieth of the new share, while the Program Case assumes that the existing share is increased gradually from one-fiftieth to one-thirtieth of the new share. The share for the existing stock of buildings is considerably smaller than the market share for new buildings, which reflects that the entire existing stock will not make investments in distributed technologies in a single year.

An economic competition for CHP systems is also performed in the industrial sector. All of the industrial CHP technologies improve over time in the Benefits Case compared to the Baseline Case. The technology characteristics for the smaller internal combustion systems were taken from the draft *EERE Gas-Fired Distributed Generation* and *Microturbine Technology Characteristics* reports, while the larger system improvements are the intended EIA assumptions.[9] For the industrial CHP systems, as well as the commercial sector, it was assumed that the DEER Program will enhance consumer acceptance (see **Figure 4.3**) and lower hurdles to adoption. This was reflected in the model by shifting the function determining the adoption rates as a function of payback years.



Source: NEMS-GPRA04 inputs

Figure 4.3. Industrial CHP Market Acceptance

[9] The assumptions in the AEO2002 input files as described in Footnote 8.

The incremental DER capacity and generation that results from this representation of the DEER Program activities is shown in **Table 4.4**, along with the projected total quantities. Of the 25 GW of incremental capacity, roughly half of the increase is expected from commercial building applications and half from generally larger industrial applications. The DER increase in the building sector is proportionally much larger, because there is currently relatively little DER in this sector.

In the Baseline Case, the commercial sector is projected to satisfy roughly 3 percent of its total electricity demand with distributed generation and 15 percent in the industrial sector. With the DEER Program, the share increases to 8 percent in the commercial sector and 20 percent in the industrial sector.

Table 4.4. Distributed Energy Resources: Capacity and Generation: 2005, 2010, and 2020

	Capacity (GW)			Generation (BkWh)		
	2005	2010	2020	2005	2010	2020
Baseline Case						
Buildings	1.3	2.3	7.4	9	16	53
Industry	29.0	33.0	41.2	173	202	259
Total*	30.3	35.2	48.5	183	218	312
Benefits Case						
Buildings	2.1	5.4	20.3	15	39	146
Industry	30.5	37.3	53.2	184	233	347
Total*	32.6	42.7	73.6	199	272	493
Incremental						
Buildings	0.8	3.2	13.0	6	22	93
Industry	1.5	4.3	12.1	11	31	88
Total*	2.3	7.4	25.0	17	54	180

* Excludes nontraditional large QF cogenerators.

The DEER Program benefits are projected within the integrated modeling framework, so that the impact of the program will be reflected in the remainder of the energy system. As a result of increased investments in DER, 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 2 GW of additional capacity retired by 2020 in the Program Case. Roughly 27 GW of central station investments are avoided by the additional DER. In the Baseline Case, about 90 percent of new central station capacity additions from 2005 to 2020 are projected to be natural gas fired, so about 90 percent of those avoided investments are natural gas fired.

Distributed generation makes up roughly 12 percent of new capacity additions from 2005 to 2020 in the Baseline Case. This share increases to 18 percent in the Program Case. For the later period of just 2015 to 2020, the distributed share increases from 16 percent in the Baseline Case to 26 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 DER. 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 gas combined-cycle and combustion turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour. For example, in 2010, the average nonrenewable energy avoided is at a rate of 9,500 Btu per kWh; and, by 2020, the value is reduced to 7,800 Btu per kWh.

The benefits estimates for the High Temperature Superconductivity (HTS) R&D, another component of the DEER Program, were based on an analysis performed by a contractor for the program. The estimates provided for kilowatt-hour reductions from HTS generators, transformers, cables, and motors were represented in NEMS-GPRA04 by reducing T&D losses. Total benefits for the DEER Program are shown in **Table 4.5.**

Table 4.5. FY 2004 Benefits Estimates for DEER* (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.08	0.19	0.46
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.7	3.1	9.0
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.4	3.4	8.5
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.01	0.02
▪ Natural gas savings (quadrillion Btu)	0.05	0.10	0.15
▪ Renewable electric-generating capacity (gigawatts)	2.3	7.4	25.0

* Includes increased market penetration for stationary fuel cells

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 roughly 1.5 percent of residential and commercial building energy consumption. FEMP leads to 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 targeting a specific market segment, FEMP is difficult to model in an integrated framework such as NEMS-GPRA04.[10] However, there is also less uncertainty associated with the program, because there is little or no technological risk.

[10] Publicly available documentation of FEMP Program GPRA benefits was not available at the time of this report; however, documentation will be available in the forthcoming GPRA FY2005 Benefits report. The off-line analysis methodology is the same for both years.

Delivered energy savings that have been estimated by FEMP are used as inputs for the integrated modeling. These projected savings are subtracted from the Baseline Case for commercial-building energy consumption. The model is used to compute other benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings (see **Table 4.6**).

Table 4.6. FY 2004 Benefits Estimates for FEMP (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Energy savings (quadrillion Btu)	0.01	0.03	0.07
Economic			
▪ Energy-expenditure savings (Billion 2000 dollars)	0.1	0.4	0.8
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.2	0.6	1.3
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.01
▪ Natural gas savings (quadrillion Btu)	0.01	0.02	0.03
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

FreedomCAR and Vehicle Technologies Program

The FreedomCAR and Vehicle Technologies (FCVT) Program consists of research on light-vehicle hybrid and diesel technologies, heavy vehicle and parasitic loss reduction technologies, and lightweight materials for engines and vehicles. In addition, the program includes research in advanced petroleum and renewable fuels.[11]

Light-vehicle hybrid and diesel technologies: This research aims to improve engine technologies in light-duty vehicles, which include passenger cars and light-duty trucks. Benefit estimates for these activities are computed by an analysis process, which 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. Fuel cell vehicles are included in the modeling with the other transportation vehicles, but their associated savings are attributed to the Hydrogen, Fuel Cells, and Infrastructure Technologies Program. **Appendix E** provides detailed data on light vehicles.[12]

Heavy vehicle 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). The benefits of this R&D activity are derived from penetration rates estimated by the Heavy Vehicle Model developed for the FCVT using efficiency and technology cost assumptions. This model, by TA Engineering, Inc., is described in **Appendix E**.

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[11] Details of the off-line analysis for light-duty and heavy vehicles are presented in Appendix E.

[12] Several updates were made to the actual values in the table compared to the previous year. Those values can be found in the 2003 GPRA methodology report on the EERE Web site (http://www.ott.doe.gov/facts/pdfs/appendix2003.pdf). No methodology report for 2004 has been written.

Lightweight materials for engines and vehicles: The lightweight materials developed under this program are used in both light and heavy vehicles. The benefit estimates for materials are proportional to the percent of the fuel economy gain in light vehicles that is due to weight reduction. The benefits from weight reduction for heavy vehicles will be estimated in the future, but they are not in the current estimates.

In the NEMS-GPRA04 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 (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-GPRA04 model also includes "calibration" coefficients to calibrate the model to historical data. The associated characteristics for all the "nonconventional" 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 acceptance in the marketplace, but each characteristic has a differing degree of influence. The vehicle cost is generally the most influential of the characteristics, certainly having a much stronger influence than luggage space, for example. All the technologies are competed against each other using a nested logit formulation. In a logit formulation, the sum of all the influences from the characteristics for each technology is the "utility" for that technology, and the relative sizes of the "utility" for each technology determines the relative penetration shares for that technology. Technologies that have higher "utilities" are given greater sales shares. The overall sales penetration results are the sum of the more disaggregated results.

In the FY 2004 benefits analysis, the Baseline Case for transportation programs is essentially the AEO2002 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-GPRA04 model. These include removing the "calibration" coefficients (used by the model for a tie to history) from the formulation and revising the coefficients for make and model availability. These later changes reflect the program's partnerships with manufacturers that make the alternative-fuel vehicles more widely available. The removal of the calibration coefficients that bias the choice to conventional gasoline vehicles represents that consumers become more comfortable with other vehicles types, due to improved attributes and greater adoption rates. In other words, there is a learning-by-doing effect, where the bias is eliminated due to more experience with the new vehicles.

In the FY 2004 benefits results, the overall sales share for gasoline vehicles decreases from 87 percent in 2020 in the Baseline Case to 43 percent in the Program Case. This decrease in share is due to the penetration of the alternative technologies. The overall share in 2020 for advanced combustion diesel increases from 3 percent to 9 percent, for gasoline hybrids from 3 percent to 33 percent, and for diesel hybrids from 1 percent to 3 percent. (See **Figures 4.4 and 4.5**, below**.**)

These large vehicle sales shares for advanced technology vehicles in 2020, however, translate into much smaller shares for overall vehicle stocks (**Figures 4.6 and 4.7**) and overall shares of vehicle miles traveled (VMT) (**Figures 4.8 and 4.9**) 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 3,218 billion miles in 2020 to 2,211 (about 61 percent of the VMT) between the two cases. The total VMT for advanced combustion diesel increases from 94 to 345 (9.5 percent), for diesel hybrids from 24 to 69 (2 percent), and for gasoline hybrids from 84 to 695 (19 percent).

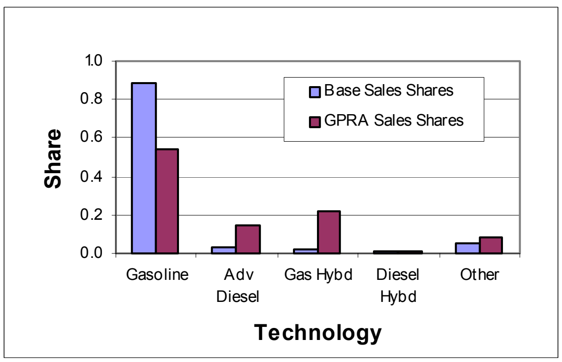


Figure 4.4. Vehicle Sales Shares in 2010

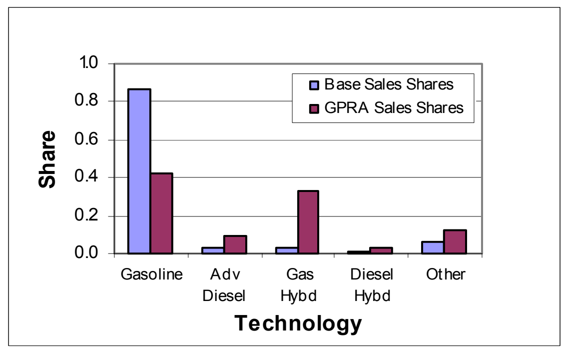
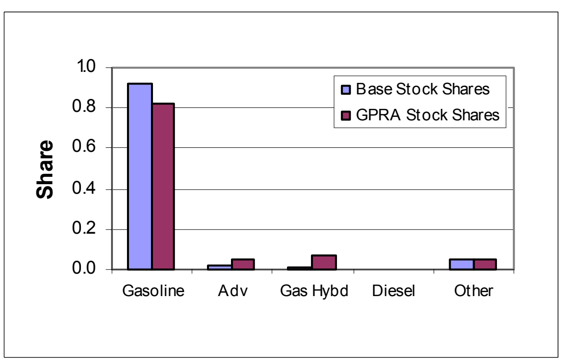


Figure 4.5. Vehicle Sales Shares in 2020



Source: NEMS-GPRA04 outputs

Figure 4.6. Vehicle Stock Shares in 2010

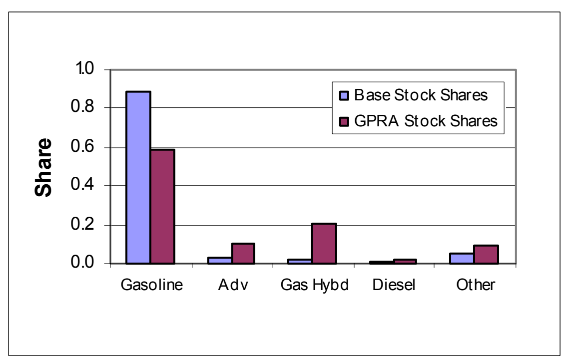


Figure 4.7. Vehicle Stock Shares in 2020

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. The total estimated amount of fossil energy savings, due to the advanced-combustion diesel technology, is about 0.13 quadrillion Btu; and, due to the hybrid-vehicle technology, is about 1.00 quadrillion Btu.

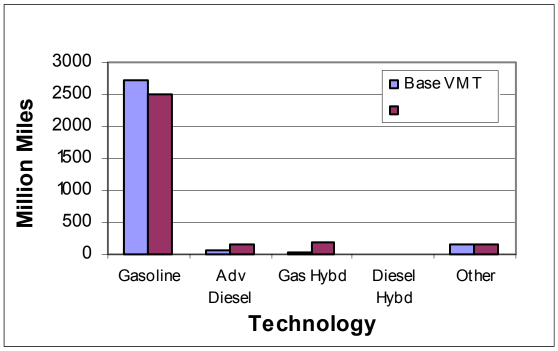
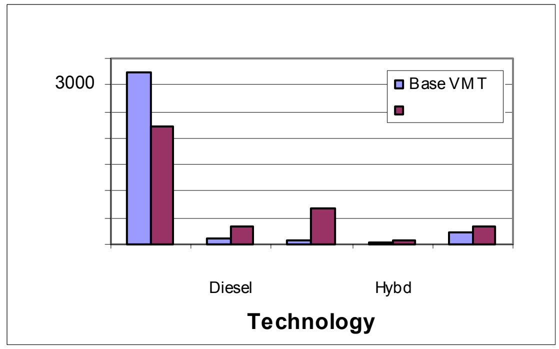


Figure 4.8. Vehicle Miles Traveled in 2010



Source: NEMS-GPRA04 outputs

Figure 4.9. Vehicle Miles Traveled in 2020

In a fully integrated NEMS-GPRA04 model run, the savings are typically somewhat less because of feedback effects that come through integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, reduced gasoline demand causes lower gasoline prices; which, in turn, leads to an increase in travel and less-efficient vehicles purchases than would otherwise have occurred absent the price change. The rebound of gasoline consumption reduces the off-line 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, which reduces the cost to drive and causes more miles to be driven. **Table 4.7** presents the total program benefits.

Table 4.7. FY 2004 Benefits Estimates for FreedomCAR and Vehicle Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Energy savings (quadrillion Btu)	0.08	0.32	1.58
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	3.0	9.4	25.5
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.3	6.4	29.8
Security			
▪ Oil savings (quadrillion Btu)	0.06	0.34	1.51
▪ Natural gas savings (quadrillion Btu)	0.00	0.00	0.00
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

FreedomCAR and Vehicle Technologies Program Specific Example

Selected vehicle attributes for large cars sold in the South Atlantic Census division for 2020 are illustrated in **Table 4.8**. The technologies other than conventional gasoline are shown as factors relative to conventional gasoline vehicles. The fuel cost of driving is an intermediate variable expressed as cost per mile, which is calculated as the projected cost of the fuel per gallon divided by the miles per gallon. It is the only factor that varies by region, while the others may change by size class. There are other attributes provided by the program (e.g. luggage space, acceleration), which are not shown here, but they have less influence in the choice of a vehicle. In addition, there are a few other behavioral indices and coefficients that are changed to represent the market-enhancement activities of the program and help remove the Baseline Case assumption of a bias against alternative-fuel vehicles.

Table 4.8. Selected Vehicle Attributes (Year 2020, South Atlantic Region, Large Cars)

	Vehicle Cost (2000$)	Fuel Cost of Driving (2000$/mile)	Vehicle Range (miles/tank)	Maintenance Cost (2000$/yr)
Gasoline	33,890	5.18	554.7	1,102
Relative Attributes to Gasoline (e.g., a value of 1.000 below signifies the same value as for gasoline)				
Advanced Diesel	1.050	0.690	1.200	1.000
Ethanol Flex	1.073	1.044	0.730	1.010
CNG Bi-Fuel	1.040	0.909	0.750	0.900
Hybrid-Gasoline	1.010	0.667	1.000	1.000
Hybrid-Diesel	1.150	0.552	1.000	1.050
CNG	1.040	0.697	0.750	0.900
Fuel Cell-Gasoline	1.350	0.555	1.000	1.000
Fuel Cell-Hydrogen	1.250	0.777	0.900	1.050
Electric	1.874	1.171	0.144	0.000

In the nested logit model, each of these attributes for the various technologies has a coefficient or weight associated with it, which determines the relative influence of the attribute. Vehicle cost is one of the most important. This follows intuition as indicated by the following example. For a conventional vehicle that is driven 12,500 miles per year, the annual fuel and operating costs total $1,750 ($648 for fuel, plus $1,102 for maintenance), while the purchase cost is $33,890.

The gasoline-hybrid vehicle, which has a relatively small cost penalty above the conventional vehicle in the Program Case, is the alternative that receives the most market share in 2020 next to conventional. The gasoline-hybrid purchase cost is 1 percent (or $339 greater), but would save $216 per year in fuel costs ($648 * (1-0.667)). The diesel hybrid, on the other hand, costs more than $5,000 more than the conventional vehicle with a fuel savings of $290 annually. The relative attractiveness of the vehicles will vary by size class and, to a lesser extent, by region.

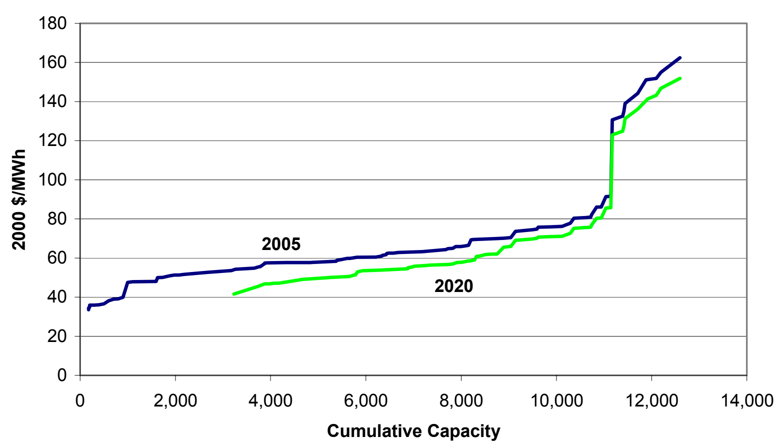
The logit function inherently represents the distribution of consumer preference, and no single vehicle type receives 100 percent of the market share within a size range and region. As shown previously, the gasoline hybrid sales share in 2020 is 33 percent averaged across all regions and size classes, while the diesel hybrid share is only 3 percent.

Geothermal Technologies Program

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal-generation technologies, including both conventional and engineered geothermal source (EGS) systems. Measuring the benefits involves projecting the market share for these technologies based on their economic and environmental characteristics.[13]

The NEMS-GPRA04 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 O&M costs. For the Program Case, an additional set of EGS sites were added to this slate.

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's cost goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report. Separate program technology goals were provided for the added EGS sites. **Figure 4.10** illustrates the supply curve of the sites in the Northwest in 2005 and 2020 that reflect the cost reductions. The lowest part of the curve is not depicted for 2020 because it represents a portion of the capacity already developed. 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.



Source: NEMS-GPRA04 inputs

Figure 4.10. Geothermal Supply Curve, Northwest Region

In addition to competing on an economic basis with other electricity-generation technologies, geothermal capacity may be constructed for its environmental benefit. PERI, using its Green

[13] See Appendix D for off-line analysis details.

Power Market Model, provided an estimate of geothermal capacity additions in response to the expanding green power markets across the country. The projections for green power geothermal installations were incorporated into NEMS-GPRA04 as planned capacity additions.

The primary energy, oil, and carbon emissions savings stem from geothermal power displacing fossil-fueled generation sources that were built in the Baseline Case. Over time, the new facilities that are constructed in the Baseline Case become more efficient as natural gas combined-cycle and combustion turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Geothermal facilities generally have high utilization rates, and the projected incremental 6.7 gigawatts of capacity in 2020 produces 53 billion kilowatt-hours of power. 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 4.9** shows the overall Geothermal Technologies Program benefits.

Table 4.9. FY 2004 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.00	0.10	0.40
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.6	1.8
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.1	1.7	7.5
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.01	0.02
▪ Natural gas savings (quadrillion Btu)	0.00	0.09	0.24
▪ Renewable electric-generating capacity (gigawatts)	0.0	1.8	6.7

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 and the production of hydrogen at a reasonable price. The FY 2004 benefits estimates focus on gasoline and hydrogen fuel cells for vehicles. The program has not yet established technology goals for stationary fuel cells, so their benefits could not be computed. As a result, the Hydrogen Program benefits are underestimated. The production side of the program was represented as success in delivering hydrogen at $2 per gallon of gasoline equivalent (inclusive of taxes). As a mid-term model, the NEMS-GPRA04 framework does not contain sufficient structure to analyze the production and delivery of hydrogen.

The fuel cell vehicles were modeled along with the FreedomCAR and Vehicle Technologies Program. The gasoline and hydrogen fuel cell vehicle costs and efficiencies were modified to reflect the program goals (see the FreedomCAR Program description for more detail regarding the modeling of vehicle choice). In addition, hydrogen availability for vehicle refueling was assumed to be 10 percent by 2018 and 25 percent by 2020. The benefits associated with fuel cell vehicles were attributed to the Hydrogen Program, based on their relative efficiencies and their share of the displaced conventional gasoline vehicles VMT. **Table 4.10** presents the overall benefits.

Table 4.10. FY 2004 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program* (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.00	0.00	0.24
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.1	3.9
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.0	0.1	4.6
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.23
▪ Natural gas savings (quadrillion Btu)	0.00	0.00	0.00
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

* Does not include any benefits from stationary fuel cells.

Industrial Technologies Program

The Industrial Technologies Program consists of hundreds of projects—covering a wide array of 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 are crosscutting 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.

Benefit estimates for these projects (see **Table 4.11**) are implemented in NEMS-GPRA04 by increasing the rate of change of technological progress in the industrial sector.[14] The process starts with a baseline rate of change of technological progress and increases it by energy source to approach a target determined by the off-line project estimates. The project target estimates are first reduced by 30 percent, as is done for estimates in other programs that cannot be modeled on an economic basis.

The industrial sector of the NEMS-GPRA04 integrating model consists of 15 industry types in nine census divisions (the detailed modeling is done at a four-census region level). The industries consist of six nonmanufacturing and nine manufacturing. The manufacturing industries are modeled through a detailed process-flow or end-use accounting structure. Each industry consists of three related and interacting modeling components, process/assembly, buildings, and

[14] Appendix C provides details of the off-line analyses.

boiler/steam/cogeneration. The model accounts for 17 main energy sources, including feedstocks and renewables.

The industrial model representation of each energy source for each process step in each industry and in each region begins with a Technology Progress Curve (TPC). The TPCs apply only to the process/assembly component and are designated for both new and existing technologies. This curve relates the amount of energy consumed per unit of output for the process over time and is sensitive to energy prices.

The benefits estimates are calculated in the model by changing the TPCs over time. The off-line energy-saving estimates by fuel type (consisting of electricity, natural gas, petroleum, steam coal, feedstocks, and steam) are used to create target energy-consumption levels. As noted above, the program's target estimates are first reduced by 30 percent. The TPCs in the model for both new and existing technologies in the process/assembly component are adjusted to approximate the target delivered energy use for each of the six energy sources when the industrial model is run alone without energy price feedbacks. The fully integrated NEMS-GPRA04 is then run 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, in turn, feed back to raise energy consumption to be a bit higher than it otherwise would have been—and lead to slightly lower program savings.

Table 4.11. FY 2004 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable Energy Savings (quadrillion Btu)	0.18	0.56	2.13
Economic			
▪ Energy Expenditure Savings (billion 2000 dollars)	1.7	4.4	20.2
Environmental			
▪ Carbon Savings (million metric tons carbon equivalent)	3.2	9.9	36.3
Security			
▪ Oil Savings (quadrillion Btu)	0.05	0.13	0.46
▪ Natural Gas Savings (quadrillion Btu)	0.11	0.30	1.11
▪ Displaced Capacity (gigawatts)	0.0	0.0	9.5

Solar Energy Technologies Program

The Solar Energy Technologies Program encompasses several technologies in thermal heat and electric markets.[15] The solar buildings component is focused on developing low-cost solar hot-water and pool heaters to displace fossil-fueled or electric alternatives. For electricity generation, photovoltaics (PVs) are being improved for both distributed and central generation applications. Concentrated solar power R&D also has been part of the Solar Energy Technologies Program, but is not included in the FY 2004 Budget Request. As a result, concentrated solar power has not been included in the GPRA 2004 benefits estimates.

The benefits for solar water and pool heaters are represented within the residential module of NEMS-GPRA04. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical use. The baseline assumptions were modified to reflect the program goals of $1,000 per unit and a backup faction of 40 percent. The costs were changed for both new and replacement water heaters. The pool heaters could not be modeled based on economics, because there is not a pool heating end use within NEMS-GPRA04. In addition, it appears that the program is not really aimed at reducing the cost for solar pool heaters, but rather making them more acceptable. Therefore, the penetration rates and energy savings estimated by the program were used to exogenously reduce water-heating demand in the residential model.

Photovoltaic systems are represented using two methods. The capital and O&M costs for utility-scale systems were modified to reflect the program's goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report. The regional capacity factors in the Baseline Case already were similar to those in the EERE report, so they were left unchanged. In addition to competing on an economic basis with other electricity-generation technologies, PVs may be constructed for their environmental benefits. PERI, using its 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. This capacity was incorporated as planned additions in NEMS-GPRA04.[16]

Estimates of primary energy, oil, and carbon emissions savings were based on displacement of energy use for water and pool heating and from electricity demand reductions and PV generation. Because PV systems rely on sunlight, they generally have relatively low capacity factors. Therefore, their energy displacement per unit of capacity is less than that for technologies such as geothermal that are operated primarily as baseload. For example, the roughly 5 GW of incremental capacity in 2020 is projected to generate 9 billion kilowatt-hours in that year. The savings associated with reduced electricity requirements depend on which types of generating plants were built in the Baseline Case. Over time, the new facilities that are constructed in the baseline become more efficient as natural gas combined-cycle and combustion-turbine technologies continue to improve. As a result, the energy and emission savings decline per kilowatt-hour of renewable generation or electricity demand reductions. Energy-expenditure savings are measured as the reduction in consumer expenditures for

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[15] Appendix D provides details of the off-line analysis for the Solar Program.

[16] The projections for green power PV installations inadvertently included the Million Solar Roofs Initiative impacts and, thus, overstate the expected capacity. However, the distributed PV technology improvements were not included. The net impact overall is likely to be an understatement of projected PV capacity and program benefits (based on GPRA05 results).

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 and pool heaters also directly reduce energy expenditures. Overall benefits of the Solar Energy Technologies Program are shown in **Table 4.12.**

Table 4.12. FY 2004 Benefits Estimates for Solar Energy Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.02	0.07	0.12
Economic			
▪ Energy expenditure savings (billion 2000 dollars)	0.2	0.5	1.4
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.3	1.3	2.4
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.01
▪ Natural gas savings (quadrillion Btu)	0.01	0.05	0.06
▪ Renewable electric-generating capacity (gigawatts)	0.2	1.0	5.0

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 composed of market enhancement, rather than R&D efforts. The major components include International; Native American Renewable Initiative; Weatherization; State and Community Grants; National Industrial Competitiveness through Energy, Environment, and Economics (NICE3); Clean Cities; Inventions and Innovations (I&I); and Gateway Deployment (Energy Star and building codes). The FY 2004 benefits approach varies by activity.[17]

The international activities are currently outside the scope of the integrated modeling framework and are not included in the benefits estimates provided here. The Native American Renewable Initiative also is not being modeled for this year. Weatherization, State and Community grants, and NICE3 are budget-driven efforts—for which benefits are roughly proportional to the size of the budget—that lead to greater adoption of energy efficiency. The Weatherization and State and Community Grants programs are represented by reducing energy consumption in the residential sector based on the program goals. A similar program-specified reduction in energy use is implemented in the industrial sector for the NICE3 program.

The Clean Cities program is represented through improved compressed natural gas (CNG) technology and greater consumer acceptance of CNG vehicles. It is modeled in conjunction with the FreedomCAR and Vehicle Technologies Program, and then the savings from the CNG vehicles are allocated to WIP. The CNG vehicles are used as a proxy for all alternative vehicles that are not part of the FreedomCAR or Hydrogen programs.

[17] Appendix B provides details of the off-line analysis of the Weatherization and Intergovernmental Program (WIP).

The Inventions and Innovation (I&I) program includes many individual grants for different technologies. Those in the industrial sector were treated in the same manner as the NICE3 through exogenous reductions in energy use. The technologies with the largest expected benefits are aluminum-head diesel engines for SUVs, high-efficiency incandescent lightbulbs, high-efficiency air conditioners, and more efficient motors for use in air conditioners. For each of these, a cost and efficiency were estimated with assistance from I&I program contractors. The technologies were then included in the technology slates in the model. The diesel engines were modeled as incremental to the FreedomCAR and Vehicle Technologies Program.

The Energy Star components of the Gateway Deployment component were represented by modifying the consumer behavior coefficients, indicating how consumers trade first-cost expenditures with 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. The other component of Gateway Deployment is a portion of the savings associated with the upgrading of building codes. Because the other portion of the building-code savings are attributed to the Building Technologies Program, the entire code effort was modeled as part of the Building Technologies Program—and then a fraction, based on the off-line estimates was allocated to WIP. Overall benefits for WIP are shown in **Table 4.13.**

Table 4.13. FY 2004 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.14	0.68	1.42
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	1.5	6.0	14.7
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent	2.5	8.9	26.3
Security			
▪ Oil savings (quadrillion Btu)	0.02	0.14	0.60
▪ Natural gas savings (quadrillion Btu)	0.11	0.23	0.40
▪ Displaced electric-generating capacity (gigawatts)	0.1	1.1	21.2

Wind and Hydropower Technologies Program

The wind component of the Wind and Hydropower Technologies Program seeks to reduce the cost and improve the performance of wind generation. The FY 2004 benefits (**Table 4.14**) are based primarily on projecting the market share for wind technologies, based on their economic characteristics.

The hydropower program goal is to reduce the environmental impact of hydroelectric facilities. Because this program is driven more by environmental than economic concerns, market penetration estimates provided by the program analysts for incremental capacity and generation are the primary source for the FY 2004 benefits estimates.

The NEMS-GPRA04 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. Wind is characterized by three wind classes, although the best wind class is assumed to develop first within each region. 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. This was increased from a limit of 12 percent that is used by EIA in the AEO2002, to a limit of 30 percent based on experience in other countries and the program expectations. Another assumption is how quickly the wind industry can expand before costs increase because of manufacturing bottlenecks. This was increased from 50 percent of installed wind capacity to 100 percent. Both of these assumptions were changed for the EERE Baseline Case and the Program Case, although they have no impact on the Baseline Case.

Table 4.14. FY 2004 Benefits Estimates for Wind and Hydropower Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Non-renewable energy savings (quadrillion Btu)	0.08	0.20	1.15
Economic			
▪ Energy expenditure savings (billion 2000 dollars)	0.6	1.4	5.4
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.2	3.2	20.9
Security			
▪ Oil savings (quadrillion Btu)	0.01	0.01	0.08
▪ Natural gas savings (quadrillion Btu)	0.05	0.16	0.64
▪ Renewable electric-generating capacity (gigawatts)	2.0	5.9	34.7

The wind R&D activities were represented by reducing the capital and O&M costs, and by increasing the performance of wind capacity to match the program cost goals, as updated in summer 2001 and modified by the final budget request. In addition to competing on an economic basis with other electricity generation technologies, wind capacity may be constructed for its environmental benefit. 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 across the country. The projections for green power wind installations were incorporated into NEMS-GPRA04 as planned capacity additions.

The expectation of the hydropower analysts is that future hydroelectric capacity and generation will decrease because of environmental concerns as facilities undergo relicensing. The program goal is to develop hydro turbines that reduce fish mortality rates and, therefore, reduce the risk of these capacity reductions. The AEO2002 projected relatively constant hydropower, implying that the technology was assumed to already be deployed, or that the issue had not been examined. As a result, the Baseline Case was modified to reflect an estimate of hydro capacity and generation lost in the absence of the fish-friendly turbines. The Program Case then returned hydropower to the prior constant levels, and the forecast benefits result from the increased hydroelectric output.

Estimates of primary energy, oil, and carbon emissions savings result from wind and hydropower displacing fossil-fueled generation sources that were built in the Baseline Case. Over time, the new facilities that are constructed in the baseline become more efficient as natural gas combined-cycle and combustion-turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Because wind and hydroelectric systems rely on intermittent resources, they generally have lower capacity factors than geothermal or biomass plants, as can be seen in the capacity factors shown in **Table 4.15**. Therefore, their energy displacement per unit of capacity is smaller. For example, the roughly 35 GW of incremental capacity in 2020 is projected to generate 35 billion kilowatt-hours in that year.

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 4.15 displays the wind technology assumptions for the Baseline Case and the Program Case. The most significant changes in the Program Case are the increased capacity factors and reduced O&M costs. As described previously, the baseline represents EIA's expectations of technology evolution, which may already include some R&D effects.

Table 4.15. Wind Technology Assumptions

		2005	2010	2015	2020
Baseline					
Average Capital Cost*	2000 $/kW	921	906	867	827
Capacity Factor - Class 6	fraction	0.39	0.42	0.42	0.42
Capacity Factor - Class 5	fraction	0.35	0.38	0.38	0.38
Capacity Factor - Class 4	fraction	0.31	0.34	0.34	0.34
Total O&M Costs	2000 $/kW-year	25.5	25.5	25.5	25.5
Program Case					
Average Capital Cost*	2000 $/kW	954	873	873	849
Capacity Factor - Class 6	fraction	0.44	0.50	0.51	0.54
Capacity Factor - Class 5	fraction	0.39	0.47	0.49	0.51
Capacity Factor - Class 4	fraction	0.31	0.40	0.46	0.47
Total O&M Costs	2000 $/kW-year	14.3	13.9	13.7	13.4

*Includes 1.07 contingency factor

The net result of the improved technology can be expressed in terms of a levelized cost in cents per kilowatt-hour. In the 2010 Program Case, the wind cost is projected to be roughly 3.1 cents per kWh, compared to 4.1 cents per kWh in the Baseline Case. Wind is generally viewed to be a fuel saver, displacing combustion of fossil fuels and related O&M. However, the levelized cost does not reflect the intermittency of wind that may lead to a reduced value in meeting peak demands, compared to other technologies. In part, its value depends on the consistency and coincidence of wind to electricity demand. In the modeling, wind is only given credit for contributing to a peak demand equivalent to 75 percent of its capacity factor. Each region has a wind profile that indicates expected generation in each season and time of day.

Box 4.1—Uses and Limitations: NEMS-GPRA04

As outlined in Chapter 1, EERE program benefits are estimated using a model of the U.S. energy economy, NEMS-GPRA04. This model is designed to represent the general structure of energy consumption, transformation, and supply. Specific technologies are represented by the fuel, or fuels, they use or the energy services they supply. Parameters within the model represent the characteristics of the technologies, such as efficiency, capital cost, O&M costs, average lifetime, and emissions, all of which are factors that influence the market penetration of the technologies. Research programs are designed to change these technology parameters; e.g., by improving efficiencies or lowering costs. Consumer and business market choices are reflected in the model through a variety of parameters. Many of these parameters reflect the trade-off between initial investment cost and energy costs over time, as expressed in terms of hurdle (discount) rates or through coefficients. In general, end-use consumers are observed to make investment decisions that imply higher hurdle rates than current interest rates. Other considerations in technology choice are also included, such as vehicle attributes pertaining to performance, availability of technologies or fuels, or previous fuel used for replacement appliances. Deployment programs act to reduce many of these barriers to cost-effective technology investments. Yet other EERE activities are aimed at changing the structure of energy markets themselves; e.g., through biorefineries or hydrogen fuels. These latter types of activities are more challenging as they require changes to the structure of the models as well.

By definition, models are simplified, mathematical representations of physical, economic, and social processes. When using a model or the results of a model, one must take into consideration the underlying assumptions of the model, the necessary simplifications that were made in constructing the model, and the intended purpose and objective of the model. Although models can be constructed for a wide range of processes, the remarks in this section deal with energy forecasting models of the type used by EERE in estimating prospective benefits.

One major misapplication in using the results of models is to regard them as predictions of the future. Because models are simplifications of the energy-economic system, they must necessarily omit certain features of energy markets, and thus they are not exact mathematical representations of the energy system. Indeed, many of the mathematical constructs in the models are derived from available data and are intended to estimate the average reaction of one part of the energy system to a change in another part of the system. In addition, behavioral characteristics are indicative of real-world tendencies rather than representations of specific outcomes. Examples of such relationships might be a reduction in passenger vehicle miles driven in response to an increase in gasoline prices, or an increase in domestic natural gas production when the market price of natural gas increases. These relationships are estimated from data to the extent possible, but they are not precisely scientific and therefore cannot be construed as exact predictors.

Energy markets also can be influenced by a number of seemingly random events that cannot be predicted. Examples of such events—or uncertainties—include severe weather, labor strikes, international disruptions, major equipment failures, and regulatory or institutional changes. These types of discontinuities are not well addressed by equilibrium models. Integrating models do assess potential ways in which, disruptions aside, markets might evolve, given assumed policies and external factors such as population growth. While the potential impacts of some future uncertainties can be explored through the use of scenario analysis that vary these assumptions, the timing and magnitude of assumptions must be made through conjecture.

When model results are used, the underlying assumptions are critically important to understanding and interpreting the output. Key assumptions for energy models can include future population growth, economic growth, fossil fuel resources, energy legislation and regulation, and improvements in energy-consuming and energy-producing technologies. Another critical assumption concerns consumer behavior. Some models may assume that consumer behavior remains as indicated by past data; others may assume shifts in behavior. All these assumptions can be important for understanding model outputs. As an example, a model with rapid improvements in and adoption of energy-efficient technologies is likely to have slower growth in energy consumption than another model that assumes slower improvement and/or penetration of the technologies. Therefore, the use of model results should be accompanied by some understanding of the major assumptions.

Box 4.1—Uses and Limitations: NEMS-GPRA04 (continued)

All energy models are simplifications of energy markets; however, they vary widely in the level of detail they incorporate. Some energy models, NEMS-GPRA04 among them, explicitly represent a detailed slate of energy-using technologies, including their capital costs, operating costs, efficiencies, and other technology characteristics, such as likely improvement in the technologies in the future. From those characteristics, the adoption and penetration of technologies are projected, based on algorithms that represent consumer response based on the capital, O&M, and fuel costs of competing technologies, technology efficiencies, discount rates, equipment replacement rates, and a variety of other consumer preference factors. In contrast, some energy models represent future technology and efficiency improvement by a relatively simple assumption about the annual rate of improvement of either energy efficiency or energy efficiency per unit of economic output. Even within models, there are differences in the representation of technologies among sectors. For example, NEMS represents technological improvement in the industrial demand sector and in the oil and natural gas production sector by using annual rates of improvement, because of the difficulty of representing individual technologies directly.

Other levels of detail that may vary between models include geographic disaggregation; time segmentation; institutional, regulatory, and infrastructure representation; customer classes; and consumer responses to different cost and performance factors, among others. Although more detail may improve the representation of energy markets, the availability of credible data to support the detail may be a limiting factor, and a highly detailed model may be more difficult to understand and validate. Also, with the degree of uncertainty in the various data and parameters, some of the finely detailed parameters included in a model may be overwhelmed and made largely irrelevant by uncertainties in the most important parameters influencing the results.

NEMS-GPRA04 represents U.S. energy markets at the regional level and incorporates detail on the structure of energy markets, including Federal and State regulations and legislation, energy infrastructure (such as natural gas pipelines), and other characteristics, such as inventory and stock turnover for energy equipment and structures. In addition, NEMS-GPRA04 represents detailed information about consumer preferences in many end-use sectors. As such, NEMS-GPRA04 is designed to respond to detailed questions on the potential impacts of legislative proposals and other institutional and economic changes. However, given its level of detail, NEMS-GPRA04 is limited in its time horizon to a period of approximately 20 years because projecting regional demographic changes, the regulatory structure of energy markets, and technology characteristics and other factors becomes more difficult and more uncertain further into the future.

EERE Baseline Case

Table 1. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2005	2010	2015	2020
Energy Consumption				
Residential				
Distillate Fuel	0.85	0.79	0.75	0.72
Kerosene	0.08	0.07	0.07	0.07
Liquefied Petroleum Gas	0.44	0.45	0.43	0.41
Petroleum Subtotal	1.37	1.31	1.25	1.20
Natural Gas	5.54	5.70	5.94	6.18
Coal	0.05	0.05	0.05	0.05
Renewable Energy 1/	0.43	0.43	0.44	0.45
Electricity	4.54	4.76	5.09	5.44
Delivered Energy	11.92	12.25	12.76	13.31
Electricity Related Losses...	9.53	9.51	9.85	10.22
Total	21.46	21.77	22.61	23.53
Commercial				
Distillate Fuel	0.42	0.42	0.42	0.42
Residual Fuel	0.12	0.12	0.13	0.13
Kerosene	0.03	0.03	0.03	0.03
Liquefied Petroleum Gas	0.08	0.09	0.09	0.10
Motor Gasoline 2/	0.03	0.03	0.03	0.03
Petroleum Subtotal	0.67	0.69	0.70	0.71
Natural Gas	3.78	4.08	4.43	4.82
Coal	0.07	0.07	0.07	0.08
Renewable Energy 3/	0.08	0.08	0.08	0.08
Electricity	4.45	4.99	5.53	6.01
Delivered Energy	9.04	9.90	10.81	11.69
Electricity Related Losses...	9.33	9.97	10.70	11.30
Total	18.37	19.87	21.51	22.99
Industrial 4/				
Distillate Fuel	1.17	1.22	1.29	1.38
Liquefied Petroleum Gas	2.50	2.66	2.85	3.00
Petrochemical Feedstocks	1.36	1.45	1.54	1.59
Residual Fuel	0.18	0.23	0.25	0.27
Motor Gasoline 2/	0.23	0.24	0.26	0.27
Other Petroleum 5/	4.36	4.77	4.99	5.17
Petroleum Subtotal	9.80	10.57	11.18	11.69
Natural Gas 6/	10.42	11.19	11.79	12.19
Metallurgical Coal	0.69	0.64	0.59	0.54
Steam Coal	1.72	1.74	1.79	1.86
Net Coal Coke Imports	0.07	0.11	0.14	0.16
Coal Subtotal	2.48	2.50	2.52	2.55
Renewable Energy 7/	2.66	2.89	3.18	3.43
Electricity	3.80	4.19	4.53	4.82
Delivered Energy	29.17	31.34	33.20	34.69
Electricity Related Losses...	7.97	8.39	8.77	9.07
Total	37.13	39.73	41.97	43.76

1/ Includes wood used for residential heating.
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.
4/ Fuel consumption includes consumption for cogeneration.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Includes lease and plant fuel and consumption by cogenerators; excludes consumption by nonutility generators.
7/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass; includes cogeneration, both for sale to the grid and for own use.

	2005	2010	2015	2020
Transportation				
Distillate Fuel	6.35	7.27	8.09	8.71
Jet Fuel 8/	3.88	4.46	5.12	5.82
Motor Gasoline 2/	17.68	19.36	20.92	22.20
Residual Fuel	1.07	1.08	1.09	1.10
Liquefied Petroleum Gas	0.02	0.02	0.02	0.03
Other Petroleum 9/	0.25	0.26	0.28	0.29
Petroleum Subtotal	29.23	32.44	35.52	38.16
Pipeline Fuel Natural Gas	0.79	0.86	0.95	1.02
Compressed Natural Gas	0.06	0.09	0.12	0.14
Renewable Energy (E85) 10/...	0.02	0.03	0.03	0.04
Liquid Hydrogen	0.00	0.00	0.00	0.00
Electricity	0.07	0.08	0.09	0.11
Delivered Energy	30.18	33.50	36.72	39.47
Electricity Related Losses...	0.15	0.16	0.18	0.20
Total	30.32	33.66	36.90	39.68
Electric Generators 13/				
Distillate Fuel	0.06	0.05	0.05	0.07
Residual Fuel	0.23	0.14	0.19	0.21
Petroleum Subtotal	0.30	0.19	0.24	0.28
Natural Gas	5.45	6.78	8.83	10.21
Steam Coal	21.34	22.54	23.17	24.09
Nuclear Power	8.10	7.87	7.49	7.44
Renewable Energy 14/	4.12	4.29	4.54	4.72
Electricity Imports	0.52	0.38	0.45	0.44
Total	39.82	42.05	44.73	47.17
Total Energy Consumption				
Distillate Fuel	8.84	9.74	10.60	11.30
Kerosene	0.13	0.13	0.12	0.12
Jet Fuel 8/	3.88	4.46	5.12	5.82
Liquefied Petroleum Gas	3.04	3.22	3.39	3.54
Motor Gasoline 2/	17.94	19.62	21.20	22.50
Petrochemical Feedstocks	1.36	1.45	1.54	1.59
Residual Fuel	1.60	1.58	1.66	1.72
Other Petroleum 12/	4.59	5.01	5.25	5.44
Petroleum Subtotal	41.37	45.21	48.88	52.04
Natural Gas	26.04	28.69	32.07	34.55
Metallurgical Coal	0.69	0.64	0.59	0.54
Steam Coal	23.17	24.40	25.08	26.07
Net Coal Coke Imports	0.07	0.11	0.14	0.16
Coal Subtotal	23.93	25.16	25.81	26.77
Nuclear Power	8.10	7.87	7.49	7.44
Renewable Energy 15/	7.31	7.72	8.28	8.71
Liquid Hydrogen	0.00	0.00	0.00	0.00
Electricity Imports	0.52	0.38	0.45	0.44
Total	107.28	115.03	122.99	129.95

8/ Includes only kerosene type.
9/ Includes aviation gas and lubricants.
10/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
11/ M85 is 85 percent methanol and 15 percent motor gasoline.
12/ Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.
13/ Includes consumption of energy by all electric power generators for grid-connected power except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Includes conventional hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes cogeneration. Excludes net electricity imports.
17/ 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.

Table 2. Energy Prices by Sector and Source
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential	13.26	13.41	13.54	13.91
Primary Energy 1/	7.30	7.24	7.37	7.49
Petroleum Products 2/	9.45	9.85	10.30	10.42
Distillate Fuel	7.68	7.94	8.43	8.55
Liquefied Petroleum Gas..	12.90	13.26	13.64	13.80
Natural Gas	6.81	6.70	6.81	6.96
Electricity	22.40	22.56	22.31	22.70
Commercial	12.83	12.78	12.97	13.31
Primary Energy 1/	5.58	5.55	5.74	5.92
Petroleum Products 2/	6.10	6.36	6.77	6.92
Distillate Fuel	5.44	5.73	6.25	6.40
Residual Fuel	3.74	3.83	3.92	4.02
Natural Gas 3/	5.55	5.48	5.64	5.84
Electricity	20.19	19.80	19.78	20.21
Industrial 4/	5.71	5.97	6.27	6.48
Primary Energy	4.48	4.75	5.04	5.19
Petroleum Products 2/	6.36	6.70	7.08	7.13
Distillate Fuel	5.54	5.89	6.52	6.72
Liquefied Petroleum Gas..	8.28	8.60	8.99	9.11
Residual Fuel	3.57	3.65	3.74	3.87
Natural Gas 5/	3.26	3.44	3.66	3.90
Metallurgical Coal	1.60	1.56	1.52	1.46
Steam Coal	1.35	1.29	1.26	1.21
Electricity	12.67	12.56	12.66	13.05
Transportation	9.59	9.98	10.03	9.99
Primary Energy	9.58	9.96	10.01	9.97
Petroleum Products 2/	9.58	9.96	10.01	9.97
Distillate Fuel 6/	9.23	10.14	10.09	9.97
Jet Fuel 7/	5.53	5.87	6.32	6.37
Motor Gasoline 8/	11.04	11.27	11.28	11.29
Residual Fuel	3.40	3.48	3.57	3.67
Liquefied Petroleum Gas9/	14.09	14.39	14.66	14.62
Natural Gas 10/	6.58	6.83	7.06	7.23
Ethanol (E85) 11/	19.20	20.58	21.07	21.19
Electricity	16.68	18.37	19.42	18.04

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 cogenerators.
5/ Excludes uses for lease and plant fuel.
6/ Low sulfur diesel fuel. 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 and State taxes and excludes county 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 2. Energy Prices by Sector and Source (cont.)
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Electric Generators 13/				
Fossil Fuel Average	1.57	1.60	1.75	1.85
Petroleum Products	3.82	3.99	4.13	4.27
Distillate Fuel	4.93	5.23	5.72	5.86
Residual Fuel	3.52	3.59	3.67	3.78
Natural Gas	3.16	3.34	3.62	3.86
Steam Coal	1.13	1.05	1.02	0.97
Average Price to All Users 14/				
Petroleum Products 2/	8.79	9.20	9.35	9.35
Distillate Fuel	8.38	9.22	9.36	9.33
Jet Fuel	5.53	5.87	6.32	6.37
Liquefied Petroleum Gas	9.04	9.35	9.68	9.76
Motor Gasoline 8/	11.04	11.27	11.28	11.29
Residual Fuel	3.46	3.54	3.64	3.74
Natural Gas	4.43	4.45	4.59	4.79
Coal	1.15	1.07	1.04	0.99
Ethanol (E85) 11/	19.20	20.58	21.07	21.19
Electricity	18.73	18.56	18.50	18.91
Non-Renewable Energy Expend. by Sector (billion 2000 dollars)				
Residential	152.47	158.48	166.83	178.97
Commercial	114.93	125.57	139.21	154.63
Industrial	123.62	135.95	150.35	162.48
Transportation	281.54	325.22	358.20	383.42
Total Non-Renewable Expend...	672.56	745.21	814.59	879.50
Trans. Renew. Expenditures...	0.40	0.58	0.73	0.84
Total Expenditures	672.96	745.79	815.32	880.34

2/ This quantity is the weighted average for all petroleum products, not just those listed below.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
13/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Table 3. Renewable Energy Generating Capability and Generation
(Gigawatts, Unless Otherwise Noted)

	2005	2010	2015	2020
Elect.Generators (excl.cogen) 1/				
Net Summer Capability				
Conventional Hydropower	79.13	78.55	78.46	78.36
Geothermal 2/	3.05	3.46	4.41	5.09
Municipal Solid Waste 3/	3.50	3.83	4.08	4.26
Wood and Other Biomass 4/	1.61	1.73	1.78	1.91
Solar Thermal	0.34	0.36	0.39	0.41
Solar Photovoltaic	0.05	0.11	0.19	0.27
Wind	6.82	7.70	8.40	8.81
Total	95.16	97.08	99.15	100.65
Generation (billion kwh)				
Conventional Hydropower	295.49	288.76	286.99	285.87
Geothermal 2/	15.67	19.25	27.10	32.88
Municipal Solid Waste 3/	24.90	27.41	29.22	30.60
Wood and Other Biomass 4/	14.56	20.23	17.92	14.60
Dedicated Plants	8.93	9.72	10.02	10.85
Cofiring	5.63	10.51	7.90	3.75
Solar Thermal	0.90	0.96	1.05	1.12
Solar Photovoltaic	0.11	0.26	0.46	0.68
Wind	16.74	19.62	21.74	23.21
Total	368.37	376.49	384.48	388.96
Cogenerators 5/				
Net Summer Capability				
Municipal Solid Waste	0.51	0.51	0.51	0.51
Biomass	5.92	6.64	7.62	8.43
Total	6.43	7.15	8.13	8.94
Generation (billion kwh)				
Municipal Solid Waste	3.29	3.29	3.29	3.29
Biomass	33.73	38.05	44.05	48.99
Total	37.02	41.34	47.34	52.29
Other End-Use Generators 6/				
Net Summer Capability				
Conventional Hydropower 7/...	0.98	0.98	0.98	0.98
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.08	0.08	0.08	0.08
Total	1.06	1.06	1.06	1.06
Generation (billion kwh)				
Conventional Hydropower 7/...	4.26	4.17	4.15	4.13
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.18	0.18	0.18	0.18
Total	4.44	4.34	4.32	4.31

1/ Includes grid-connected utilities and nonutilities other than cogenerators. These nonutility facilities include small power producers and exempt wholesale generators.
2/ Includes hydrothermal resources only (hot water and steam).
3/ Includes landfill gas.
4/ Includes projections for energy crops after 2010.
5/ Cogenerators produce electricity and other useful thermal energy.
6/ Includes 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. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.
7/ Represents own-use industrial hydroelectric power.

Table 4. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential				
Petroleum	25.9	24.6	23.4	22.6
Natural Gas	79.7	82.1	85.5	89.0
Coal	1.2	1.3	1.3	1.3
Electricity	222.9	230.5	242.6	255.9
Total	329.7	338.6	352.8	368.7
Commercial				
Petroleum	13.2	13.5	13.8	14.0
Natural Gas	54.4	58.7	63.9	69.4
Coal	1.7	1.8	1.9	2.0
Electricity	218.2	241.7	263.5	282.9
Total	287.5	315.7	343.0	368.2
Industrial 1/				
Petroleum	98.6	107.2	112.8	117.8
Natural Gas 2/	147.6	158.5	167.0	172.5
Coal	63.0	63.3	63.8	64.7
Electricity	186.4	203.3	215.9	227.1
Total	495.6	532.3	559.5	582.1
Transportation				
Petroleum 3/	560.2	622.1	681.0	731.6
Natural Gas 4/	12.2	13.6	15.4	16.7
Other 5/	0.1	0.1	0.1	0.1
Electricity	3.4	3.8	4.4	5.1
Total 3/	575.9	639.7	700.9	753.5
Total by Delivered Fuel				
Petroleum 3/	697.9	767.5	831.0	885.9
Natural Gas	294.0	313.0	331.8	347.5
Coal	65.9	66.4	67.0	68.0
Other 5/	0.1	0.1	0.1	0.1
Electricity	630.9	679.3	726.4	771.1
Total 3/	1688.7	1826.3	1956.2	2072.6
Electric Generators 6/				
Petroleum	6.2	4.0	5.1	5.8
Natural Gas	78.5	97.6	127.2	147.0
Coal	546.2	577.7	594.1	618.3
Total	630.9	679.3	726.4	771.1
Total by Primary Fuel 7/				
Petroleum 3/	704.1	771.4	836.1	891.7
Natural Gas	372.4	410.6	459.0	494.5
Coal	612.1	644.1	661.1	686.3
Other 5/	0.1	0.1	0.1	0.1
Total 3/	1688.7	1826.3	1956.2	2072.6

1/ Includes consumption by cogenerators.
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.
4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
5/ Includes methanol and liquid hydrogen.
6/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators. 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 electric power generators are distributed to the primary fuels.

EERE Portfolio Case

Table 1. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2005	2010	2015	2020
Energy Consumption				
Residential				
Distillate Fuel	0.85	0.77	0.71	0.67
Kerosene	0.08	0.07	0.07	0.06
Liquefied Petroleum Gas	0.44	0.44	0.41	0.38
Petroleum Subtotal	1.37	1.28	1.19	1.12
Natural Gas	5.52	5.63	5.73	5.88
Coal	0.05	0.05	0.05	0.05
Renewable Energy 1/	0.43	0.43	0.43	0.43
Electricity	4.48	4.56	4.78	5.05
Delivered Energy	11.84	11.95	12.19	12.52
Electricity Related Losses...	9.40	9.30	9.66	10.10
Total	21.25	21.25	21.85	22.62
Commercial				
Distillate Fuel	0.41	0.40	0.38	0.37
Residual Fuel	0.12	0.12	0.13	0.13
Kerosene	0.03	0.03	0.03	0.03
Liquefied Petroleum Gas	0.08	0.09	0.09	0.10
Motor Gasoline 2/	0.03	0.03	0.03	0.03
Petroleum Subtotal	0.67	0.67	0.66	0.67
Natural Gas	3.82	4.21	4.67	5.28
Coal	0.07	0.07	0.07	0.08
Renewable Energy 3/	0.08	0.08	0.08	0.08
Electricity	4.43	4.87	5.26	5.58
Delivered Energy	9.06	9.89	10.75	11.68
Electricity Related Losses...	9.29	9.92	10.63	11.17
Total	18.35	19.81	21.37	22.84
Industrial 4/				
Distillate Fuel	1.14	1.14	1.11	1.05
Liquefied Petroleum Gas	2.49	2.61	2.76	2.83
Petrochemical Feedstocks	1.34	1.38	1.39	1.29
Residual Fuel	0.18	0.23	0.24	0.22
Motor Gasoline 2/	0.23	0.24	0.26	0.28
Other Petroleum 5/	4.35	4.76	4.96	5.16
Petroleum Subtotal	9.74	10.37	10.72	10.84
Natural Gas 6/	10.40	11.05	11.25	11.41
Metallurgical Coal	0.69	0.65	0.60	0.56
Steam Coal	1.72	1.74	1.77	1.78
Net Coal Coke Imports	0.08	0.11	0.14	0.16
Coal Subtotal	2.49	2.50	2.51	2.50
Renewable Energy 7/	2.66	2.89	3.18	3.43
Electricity	3.73	4.02	4.17	4.27
Delivered Energy	29.01	30.83	31.84	32.45
Electricity Related Losses...	7.83	8.19	8.44	8.55
Total	36.84	39.02	40.27	41.00

1/ Includes wood used for residential heating.
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.
4/ Fuel consumption includes consumption for cogeneration.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Includes lease and plant fuel and consumption by cogenerators; excludes consumption by nonutility generators.
7/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass; includes cogeneration, both for sale to the grid and for own use.

	2005	2010	2015	2020
Transportation				
Distillate Fuel	6.38	7.62	8.92	9.68
Jet Fuel 8/	3.88	4.46	5.12	5.82
Motor Gasoline 2/	17.60	18.63	18.94	19.07
Residual Fuel	1.07	1.08	1.09	1.10
Liquefied Petroleum Gas	0.01	0.01	0.01	0.01
Other Petroleum 9/	0.25	0.26	0.28	0.29
Petroleum Subtotal	29.18	32.06	34.36	35.98
Pipeline Fuel Natural Gas	0.78	0.82	0.87	0.92
Compressed Natural Gas	0.05	0.14	0.24	0.33
Renewable Energy (E85) 10/...	0.02	0.03	0.03	0.03
Liquid Hydrogen	0.00	0.00	0.01	0.02
Electricity	0.07	0.08	0.09	0.09
Delivered Energy	30.09	33.13	35.61	37.38
Electricity Related Losses...	0.15	0.16	0.18	0.19
Total	30.24	33.30	35.78	37.57
Electric Generators 13/				
Distillate Fuel	0.06	0.04	0.05	0.05
Residual Fuel	0.20	0.09	0.10	0.07
Petroleum Subtotal	0.26	0.13	0.15	0.12
Natural Gas	5.11	5.64	6.66	6.93
Steam Coal	21.24	22.16	22.53	22.63
Nuclear Power	8.10	7.87	7.44	7.38
Renewable Energy 14/	4.22	4.99	6.03	7.61
Electricity Imports	0.46	0.30	0.39	0.32
Total	39.38	41.09	43.21	44.99
Total Energy Consumption				
Distillate Fuel	8.83	9.97	11.17	11.82
Kerosene	0.13	0.13	0.12	0.12
Jet Fuel 8/	3.88	4.46	5.12	5.82
Liquefied Petroleum Gas	3.02	3.15	3.27	3.33
Motor Gasoline 2/	17.86	18.90	19.22	19.37
Petrochemical Feedstocks	1.34	1.38	1.39	1.29
Residual Fuel	1.57	1.52	1.56	1.53
Other Petroleum 12/	4.58	5.00	5.22	5.43
Petroleum Subtotal	41.20	44.50	47.08	48.72
Natural Gas	25.68	27.50	29.43	30.75
Metallurgical Coal	0.69	0.65	0.60	0.56
Steam Coal	23.07	24.03	24.43	24.53
Net Coal Coke Imports	0.08	0.11	0.14	0.16
Coal Subtotal	23.84	24.78	25.17	25.26
Nuclear Power	8.10	7.87	7.44	7.38
Renewable Energy 15/	7.40	8.42	9.76	11.58
Liquid Hydrogen	0.00	0.00	0.01	0.02
Electricity Imports	0.46	0.30	0.39	0.32
Total	106.68	113.37	119.28	124.03

8/ Includes only kerosene type.
9/ Includes aviation gas and lubricants.
10/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
11/ M85 is 85 percent methanol and 15 percent motor gasoline.
12/ Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.
13/ Includes consumption of energy by all electric power generators for grid-connected power except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Includes conventional hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes cogeneration. Excludes net electricity imports.
17/ 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.

Table 2. Energy Prices by Sector and Source
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential	13.15	13.10	13.09	12.92
Primary Energy 1/	7.25	7.09	7.17	7.03
Petroleum Products 2/	9.45	9.87	10.18	10.26
Distillate Fuel	7.68	7.89	8.25	8.32
Liquefied Petroleum Gas..	12.90	13.42	13.61	13.75
Natural Gas	6.76	6.51	6.59	6.46
Electricity	22.27	22.27	21.72	21.16
Commercial	12.65	12.20	12.09	11.63
Primary Energy 1/	5.52	5.36	5.49	5.39
Petroleum Products 2/	6.10	6.34	6.65	6.72
Distillate Fuel	5.44	5.67	6.07	6.09
Residual Fuel	3.74	3.83	3.92	4.01
Natural Gas 3/	5.49	5.27	5.38	5.28
Electricity	19.98	19.16	18.87	18.37
Industrial 4/	5.65	5.78	5.97	5.96
Primary Energy	4.44	4.64	4.85	4.87
Petroleum Products 2/	6.36	6.71	6.97	7.05
Distillate Fuel	5.53	5.81	6.30	6.26
Liquefied Petroleum Gas..	8.27	8.76	8.98	9.19
Residual Fuel	3.56	3.64	3.73	3.85
Natural Gas 5/	3.19	3.21	3.37	3.30
Metallurgical Coal	1.60	1.55	1.52	1.46
Steam Coal	1.35	1.29	1.25	1.19
Electricity	12.53	12.12	12.07	11.83
Transportation	9.53	9.76	9.62	9.61
Primary Energy	9.51	9.74	9.59	9.60
Petroleum Products 2/	9.51	9.74	9.60	9.60
Distillate Fuel 6/	9.22	10.38	10.45	11.01
Jet Fuel 7/	5.51	5.88	6.26	6.39
Motor Gasoline 8/	10.95	10.84	10.51	10.29
Residual Fuel	3.39	3.48	3.57	3.67
Liquefied Petroleum Gas9/	13.97	14.43	14.54	14.42
Natural Gas 10/	6.27	7.28	7.89	7.94
Ethanol (E85) 11/	19.11	20.47	20.25	20.43
Electricity	16.54	18.00	18.89	16.97

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 cogenerators.
5/ Excludes uses for lease and plant fuel.
6/ Low sulfur diesel fuel. 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 and State taxes and excludes county 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 2. Energy Prices by Sector and Source (cont.)
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Electric Generators 13/				
Fossil Fuel Average	1.53	1.48	1.55	1.51
Petroleum Products	3.83	4.09	4.27	4.44
Distillate Fuel	4.92	5.16	5.56	5.53
Residual Fuel	3.52	3.57	3.63	3.72
Natural Gas	3.09	3.10	3.30	3.26
Steam Coal	1.13	1.05	1.01	0.96
Average Price to All Users 14/				
Petroleum Products 2/	8.75	9.06	9.04	9.08
Distillate Fuel	8.39	9.45	9.73	10.26
Jet Fuel	5.51	5.88	6.26	6.39
Liquefied Petroleum Gas	9.03	9.49	9.65	9.81
Motor Gasoline 8/	10.95	10.84	10.51	10.29
Residual Fuel	3.46	3.54	3.63	3.73
Natural Gas	4.38	4.29	4.43	4.38
Coal	1.15	1.07	1.03	0.98
Ethanol (E85) 11/	19.11	20.47	20.25	20.43
Electricity	18.58	18.11	17.84	17.44
Non-Renewable Energy Expend. by Sector (billion 2000 dollars)				
Residential	150.12	150.86	153.84	156.29
Commercial	113.63	119.78	128.95	134.92
Industrial	121.37	128.55	135.42	136.08
Transportation	279.02	314.79	333.59	350.57
Total Non-Renewable Expend...	664.14	713.99	751.81	777.87
Trans. Renew. Expenditures...	0.31	0.59	0.67	0.64
Total Expenditures	664.45	714.58	752.48	778.50

2/ This quantity is the weighted average for all petroleum products, not just those listed below.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
13/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Table 3. Renewable Energy Generating Capability and Generation
(Gigawatts, Unless Otherwise Noted)

	2005	2010	2015	2020
Elect.Generators (excl.cogen) 1/				
Net Summer Capability				
Conventional Hydropower	79.78	79.90	79.90	79.90
Geothermal 2/	3.10	5.25	7.97	10.84
Municipal Solid Waste 3/	3.53	3.93	4.21	4.42
Wood and Other Biomass 4/	1.66	1.92	2.13	2.47
Solar Thermal	0.34	0.36	0.39	0.41
Solar Photovoltaic	0.25	1.08	3.08	5.25
Wind	7.52	10.53	17.94	35.18
Total	96.18	102.96	115.62	138.47
Generation (billion kwh)				
Conventional Hydropower	301.24	301.09	300.47	299.89
Geothermal 2/	16.07	33.91	56.14	79.45
Municipal Solid Waste 3/	25.08	28.06	30.09	31.67
Wood and Other Biomass 4/	15.09	20.19	17.62	17.58
Dedicated Plants	9.26	11.00	12.31	14.61
Cofiring	5.84	9.19	5.31	2.97
Solar Thermal	0.90	0.96	1.05	1.12
Solar Photovoltaic	0.46	1.98	5.62	9.55
Wind	18.73	28.80	59.03	134.22
Total	377.58	415.00	470.02	573.48
Cogenerators 5/				
Net Summer Capability				
Municipal Solid Waste	0.51	0.51	0.51	0.51
Biomass	5.91	6.63	7.62	8.42
Total	6.42	7.14	8.13	8.93
Generation (billion kwh)				
Municipal Solid Waste	3.29	3.29	3.29	3.29
Biomass	33.73	38.05	44.05	48.99
Total	37.02	41.34	47.34	52.29
Other End-Use Generators 6/				
Net Summer Capability				
Conventional Hydropower 7/...	0.98	0.98	0.98	0.98
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.08	0.08	0.08	0.08
Total	1.06	1.06	1.06	1.06
Generation (billion kwh)				
Conventional Hydropower 7/...	4.33	4.32	4.32	4.31
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.18	0.18	0.18	0.18
Total	4.51	4.50	4.49	4.48

1/ Includes grid-connected utilities and nonutilities other than cogenerators. These nonutility facilities include small power producers and exempt wholesale generators.
2/ Includes hydrothermal resources only (hot water and steam).
3/ Includes landfill gas.
4/ Includes projections for energy crops after 2010.
5/ Cogenerators produce electricity and other useful thermal energy.
6/ Includes 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. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.
7/ Represents own-use industrial hydroelectric power.

Table 4. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential				
Petroleum	25.8	24.0	22.4	21.0
Natural Gas	79.5	81.1	82.6	84.7
Coal	1.2	1.3	1.3	1.3
Electricity	219.6	219.8	226.2	230.0
Total	326.0	326.3	332.5	336.9
Commercial				
Petroleum	13.1	13.1	13.0	13.1
Natural Gas	55.0	60.6	67.2	76.0
Coal	1.7	1.8	1.9	2.0
Electricity	216.9	234.6	248.9	254.1
Total	286.7	310.2	331.0	345.2
Industrial 1/				
Petroleum	97.7	104.4	106.7	106.5
Natural Gas 2/	147.3	156.7	159.3	161.7
Coal	63.1	63.3	63.7	63.5
Electricity	182.8	193.7	197.5	194.5
Total	490.8	518.1	527.1	526.2
Transportation				
Petroleum 3/	559.3	615.1	659.7	691.0
Natural Gas 4/	11.9	13.8	16.1	18.0
Other 5/	0.1	0.1	0.1	0.1
Electricity	3.4	3.8	4.1	4.3
Total 3/	574.6	632.8	680.0	713.4
Total by Delivered Fuel				
Petroleum 3/	695.8	756.6	801.9	831.6
Natural Gas	293.7	312.2	325.1	340.4
Coal	66.0	66.5	66.8	66.7
Other 5/	0.1	0.1	0.1	0.1
Electricity	622.7	652.0	676.7	682.9
Total 3/	1678.2	1787.4	1870.6	1921.7
Electric Generators 6/				
Petroleum	5.4	2.7	3.1	2.4
Natural Gas	73.6	81.3	96.0	99.8
Coal	543.7	568.0	577.7	580.6
Total	622.7	652.0	676.7	682.9
Total by Primary Fuel 7/				
Petroleum 3/	701.2	759.3	804.9	834.0
Natural Gas	367.3	393.5	421.1	440.2
Coal	609.6	634.5	644.5	647.3
Other 5/	0.1	0.1	0.1	0.1
Total 3/	1678.2	1787.4	1870.6	1921.7

1/ Includes consumption by cogenerators.
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.
4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
5/ Includes methanol and liquid hydrogen.
6/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators. 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 electric power generators are distributed to the primary fuels.

Appendix B – Building Technologies

The GPRA FY04 published documentation for Building Technologies and the Weatherization and Intergovernmental Program can be found at this link:

http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14231.pdf

The Federal Energy Management Program (FEMP) metrics are estimated via a top-down approach, which are driven by forecasts of future energy consumption and prices. Federal metrics for regular buildings are aggregated from metrics developed for the Department of Defense (DOD), Department of Energy (DOE), General Services Administration (GSA), United States Postal Service (USPS), Veterans Affairs (VA), and all other agencies grouped together. Federal metrics for buildings housing energy intensive operations are estimated separately, but as a single group for the entire federal government. Metrics are not developed for exempt buildings, by definition.

Appendix C – Industrial Technologies

GPRA 2004 Quality Metrics
Methodology and Results

OFFICE OF INDUSTRIAL TECHNOLOGIES

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Prepared for
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Washington, DC

December 20, 2002

Table of Contents

I. Overview

This report describes the results, calculations, and assumptions underlying the GPRA 2004 Quality Metrics results for all Planning Units within the Office of Industrial Technologies.

GPRA 2004 supports planning activities including the FY 2004 Budget Cycle. The Quality Metrics results essentially depict the future impacts on energy, energy costs, and the environment of EERE's FY 2004 programs assuming their logical continuation. The impacts of pre-FY 2004 program funding are therefore not included in GPRA 2004. With this said, however, the known FY 2003 program portfolio is used in GPRA 2004 as a proxy for the as yet unknown content of the actual FY 2004 EERE portfolio. It is assumed that the FY 2004 portfolio will not be so different than the FY 2003 portfolio that its benefits will vary substantially.

In the results of GPRA 2004, total OIT program energy savings for 2010 were 0.956 quads, which for comparison represents 2.4% of baseline industrial energy consumption in 2010. Year 2020 energy savings were 3.934 quads, or 9.1% of 2020 baseline industrial energy consumption. Projected energy savings in 2030 reached 8.547 quads, or 7.5% of extrapolated baseline industrial energy consumption in 2030. The results are summarized in Table 1 below; details are provided in a set of tables included as *Appendix A*.

Comparison with results of the previous GPRA study is complicated by subsequent organizational changes within EERE that have resulted in the removal of the Black Liquor Gasification program and Bio-based Products, NICE[3,] and Inventions & Innovations planning units from the Office of Industrial Technologies. This report compares the GPRA 2004 results with the previous GPRA 2003 results in two ways: (1) directly, ignoring the fact that large program components were removed between the two studies, and (2) more meaningfully, for only those program components that were considered in both GPRA studies. Both comparisons are documented in *Appendix A*.

In direct comparison with the previous GPRA study, the year-2010 savings were 33% smaller than the 1.417 quads projected in GPRA 2003. Year 2020 savings were 9.4% smaller than the 4.341 quads projected in GPRA 2003. Year-2030 savings were 58% smaller than the GPRA 2003 projection of 8.546 quads. Thus the net study result in GPRA 2004 of several programmatic and many individual analytical changes was a substantial decrease in the 2010 impacts of the OIT programs, a small decrease in mid-term 2020 impacts, and a large decline in longer-term 2030 impacts. These changes are primarily the results of:

- major re-organization of EERE resulting in the removal of the Black Liquor Gasification program and Bio-based Products, NICE[3,] and Inventions & Innovations planning units from the Office of Industrial Technologies, in addition to the normal evolving portfolio changes in the remaining planning units; and
- methodological changes: (1) in accord with EERE Performance Planning Guidance for the FY 2004-2008 Budget Cycle GPRA 2004 benefits are defined as only the accelerated benefits that would not have occurred without OIT's involvement, and (2) the market penetration curve used in the OIT Impact Projections Model was refined in a way that reduced early-year technology penetrations for many technologies.

Focusing specifically on only those OIT program components remaining after the EERE reorganization shows a more directly comparable pattern of changes. The program components that have been removed from OIT had in GPRA 2003 contributed 0.453 quad to 2010 energy savings, 1.662 quads to 2020 energy savings, and 3.746 quads to 2030 savings. Subtracting these quantities – in effect considering only those planning units included in both GPRA 2003 and GPRA 2004 -- total OIT year-2010 savings in GPRA 2004 were nearly identical (964 Tbtu in GPRA 2003 cf. 956 Tbtu in GPRA 2004); year-2020 savings were 1,256 Tbtu higher in GPRA 2004; and year-2030 savings were 1,186 Tbtu lower. Thus – as compared to the equivalent GPRA 2003 results – GPRA 2004 benefits were respectively 1% smaller for 2010, 47% higher for 2020, and 25% lower for 2030.

Seventy-nine percent of the net increases from the previous GPRA study in terms of 2020 energy savings were found in two planning elements – Best Practices (949 Tbtu cf.. 438 Tbtu) and Combustion (586 Tbtu cf. 106 Tbtu). The increase in Best Practices in based on a report by D. Jones, et. al., Oak Ridge National Laboratory, "Preliminary Estimation of Energy Management Metrics of the Best Practices Program," May 2002, with additional OIT staff assumptions. The increase in Combustion was due to correction of an order-of-magnitude error in capacity factor for the Super Boiler project. Additional, much smaller increases in year-2020 benefits were seen in Steel (61 Tbtu), Petroleum Refining (53 Tbtu), Mining (38 Tbtu), and Metal Casting (26 Tbtu).

The number of individual Impact Projections Model runs performed in support of OIT's GPRA 2004 study was 199. For comparison, GPRA 2003 was based upon 274 model runs; however, Black Liquor Gasification, Bio-based Products, NICE[3,] and Inventions & Innovations accounted for 47 runs in GPRA 2003. Additionally, a change in the Forest Products planning unit study methodology for GPRA 2004 in effect combined 37 projects into 13 aggregated model runs. Subtracting these differences makes the comparable number of projects accounted for by the GPRA 2004 study as compared to GPRA 2003 approximately equal (199 cf. 203).

In the GPRA 2004 version of the model, additional emphasis was placed upon identifying project milestones leading to commercial introduction, leading many analysts to assume later commercial introduction years than in last year's study. Probably to counter the tendency towards reduced benefits driven by this and other GPRA 2004 methodological changes cited previously, nearly all analysts (Mining is an exception) tended to choose faster market penetration curves to characterize their technologies. Thus, planning unit portfolios characterized by mostly "c" market penetration curves in GPRA 2003 have trended toward mostly "b" curves in GPRA 2004. This pattern, repeated over nearly all planning units, is responsible for a significant part of the increase in year-2020 benefits, and reflects a level of subjectivity inherent in the GPRA methodology. Each project analysis is based upon limited technical, economic, and market characterization data, and a major market driver – the selection from among four possible market penetration curve slopes – is subject to the analyst's judgement.

Table 1. Office of Industrial Technologies - GPRA 2004 QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	192	956	2,340	3,934	4,241	3,615
2. Baseline Industrial Energy Use[1] (TBtu)	37,530	39,420	41,310	43,390	45,600	47,930
3. Primary Energy Savings as Percent of Baseline (%)	0.5	2.4	5.7	9.1	9.3	7.5
4. Energy Cost Savings (B$)	1.04	5.04	11.3	17.9	20.1	18.8
5. Carbon Reduction (MMTCE)	3.38	17.4	41.5	67.9	71.6	59.8

[1]DOE/EIA, *Annual Energy Outlook 2002*, Reference Case Forecast (years 2025 and 2030 extrapolated from 2010-2020 growth trend).

II. QM Methodology and Results

A. *R&D Planning Units*

GPRA Quality Metrics were projected for individual projects within Planning Units and summed to total results for Planning Units and for OIT as a whole. 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. Model runs for individual R&D projects receiving R&D support were aggregated to obtain energy savings, value of energy saved, and emission reductions 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 one technology only 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 OIT or with other EERE programs is assumed to remain. The market penetration model used for the analysis is described in *Appendix B*, which includes a blank copy of the model output and the instructions provided for the model's use.

Estimates of the energy savings are based upon information provided to the analysts through the proposal review and contracting process that includes industry participation and review, followed up by program review of these estimates. OIT analysis by sector has focused on assessing where energy is actually consumed and to understand current and best practices for each proposed technology. The participation by industry experts in this process has been critical to helping refine the estimates.

The approximate portion of the fiscal-year 2003 budget represented by the analysis for each Planning Unit was noted but the results were not scaled to 100 percent of the FY 2003 budget. Typically, the projects analyzed represented 75 to 95 percent of the FY 2003 budget for the various Planning Units (see *Appendix A*). Projected benefits for these Planning Units do not include the effects of R&D projects completed prior to the current year. These impacts are significant and are tracked by Pacific Northwest National Laboratory in a series of surveys of equipment providers and users, most recently reported in *Office of Industrial Technologies: Summary of Program Results, 2001.*

The justification for assuming that all of the projects analyzed will succeed is two-fold. First, projects which fail are assumed to be replaced with new projects using different technical approaches to achieve similar goals, so that in the long run, the basic goals will be met by the program, assumed to be continuously funded. Second, the projects analyzed do not comprise 100 percent of the FY 2003 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 OIT's R&D portfolio are not assessed here; this scientific and technical knowledge can help to underpin additional production technology innovations in the future.

A limited-distribution, four-volume set of notebooks containing all Impact Projections Model runs supporting the GPRA 2004 process is entitled, "GPRA 2004 Quality Metrics: Supporting Spreadsheets." This set of notebooks provides over 1,400 pages of supporting documentation for the R&D project analyses which form the primary basis for the GPRA 2004 results.

1. Aluminum Industry Vision

Table 2. Aluminum Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (Trillion Btu)	0.7	22	101	199	172	144
2. Energy Cost Savings (Billion $)	0.002	0.09	0.46	1.01	0.92	0.80
3. Carbon Reduction (MMTCE)	0.01	0.55	2.65	5.25	4.24	3.21

The GPRA submission for the Aluminum Vision is based on analysis of 23 technologies related to enhancing the energy efficiency, productivity, and environmental performance of aluminum production (both primary and secondary) and fabrication (see table below). The Aluminum Team's FY 2003 budget is approximately $8.1 million. The projects listed below represent approximately 80% of the budget, compared to the 90% figure for the 21 projects analyzed for the GPRA 2002 submission.

Table 3. Summary of Project Runs – Aluminum Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Primary Aluminum Production	Inert Metal Anode	0.94	19.19	2008/b
	Potlining Additives	0.87	3.47	2005/b
	Intelligent Potroom Operation	0.10	0.40	2005/b
	Low-T Wetted Cathode Cell	3.72	55.57	2007/b
	Carbothermic Reduction	1.42	10.01	2007/c
Secondary Aluminum Production	High-Efficiency, Low-Dross Combustion System	0.08	0.98	2006/b
	Reduced Oxidative Melt Loss	1.47	11.22	2005/b
	Energy Eff Isothermal Melting	1.63	13.89	2006/b
	Energy Efficiency in Al Melting	2.02	13.22	2006/b
	Gas Fluxing of Al (Bubble Probe)	1.83	27.53	2008/b
	Processing of Aluminum Wastes	1.65	8.77	2008/b
Forming	Superior Aluminum Extrusions	0.23	2.22	2006/b
	Modeling Optimization DC Casting/Ingot Cracking	2.78	4.79	2005/a
	Spray Rolling	1.36	8.15	2006/c
	Continuous Cast Al Sheet	0.28	3.41	2007/b
	Plastic Deformation Processing	0.05	0.39	2006/b

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
	Coolant Characteristics	0.02	0.19	2006/b
	Rolling Process Design Tool	0.91	8.24	2006/b
	Formability of Cast Alloys	0.28	3.41	2007/b
	Integrated Method for Thermomechanical Processing	0.09	1.02	2007/b
	Reduction of Annealing Times	0.18	2.04	2007/b
	Surface Behavior of Al Alloys	0.05	0.46	2006/b
	Two-phase Model for Hot Deformation of Highly Alloyed Al	0.02	0.26	2007/b
	Total	21.98	198.83	N/A

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be about 22 trillion Btu, significantly lower than the GPRA submission for FY 2003 (76 trillion Btu). Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 199 trillion Btu, nearly identical to the 2020 figures in the 2003 submission (194 trillion Btu). This represents approximately one-fourth of the industry's total energy consumption (assuming the majority of U.S. smelters are operating).

Six new university-based projects have been analyzed for the FY 2004 analysis: Gas Fluxing of Aluminum (Bubble Probe), Formability of Cast Alloys, Integrated Method for Thermomechanical Processing, Reduction of Annealing Times, Surface Behavior of Aluminum Alloys, Two-Phase Model for Hot Deformation of Highly Alloyed Aluminum. Four projects (Non-Consumable Anode for Electrowinning, Vertical Flotation Melter and Scrap Dryer, Recycling Aluminum Saltcake, and Textures in Strip-Cast Aluminum Alloys) that were part of the GPRA 2003 submission have been completed (or did not receive funding this year) and have not been included in the 2004 submission.

The energy savings totals shown in the aluminum team benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget. The savings are fairly equivalent to those in GPRA 2003; the four projects dropped from last year's analysis had somewhat lower energy savings than the six new university-based projects added this year. Additionally, the GPRA methodology has changed since last year, resulting in lower energy savings for all of the projects in 2010. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

There are overlapping markets between two of the projects listed above – Carbothermic Reduction and Inert Metal Anode. Each of these technologies has been assigned approximately one-third of the total potential market for primary aluminum production.

2. Chemical Industry Vision

Table 4. Chemicals Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	7.8	67	382	787	657	410
2. Energy Cost Savings (B$)	0.027	0.23	1.35	2.89	2.72	2.11
3. Carbon Reduction (MMTCE)	0.14	1.14	6.30	12.61	10.72	7.44

Projected benefits for the Chemical Industry Vision were based on analysis of 22 active R&D projects that focus on improvements in energy efficiency and environmental performance of chemical manufacturing processes. The table below identifies these projects, grouping them into separate targets including materials technology, chemical synthesis, computational technology, process science and engineering, and biotechnology. It is estimated that the current funding for these projects represents 59% of the $14.5 million FY 2003 Chemical Industry Vision Portfolio budgdet. The Chemical Industry Vision has just closed a solicitation and several new R&D projects are expected to begin after the GPRA study is completed.

Table 5. Summary of Project Runs – Chemical Industry Vision

Impact Target	Project/Spreadsheet Run File Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Materials Technology	Alloy Selection System/ASSET (asset.04)	11.12	107.36	2005/b
	Mixed Solvent Corrosion (alloy.corrosion.model.04)			
	Corrosion Monitoring System (corrosion.monitoring.04)	7.16	60.04	2005/b
	Alloys for Ethylene Production (intermetalics.ethylene.crackers.04)	17.01	164.30	2005/b
	Metal Dusting Phenomenon (metal.dusting.04)	0.02	0.10	2005/b
	SUBTOTAL	**35.31**	**331.8**	
Chemical Synthesis	High Throughput Catalyst Screening (highthrucatalyst.04.new)	2.82	58.63	2007/b
	Selective Oxidation of Aromatic Compounds (directoxida.04)	0.32	13.3	2009/c
	Advanced Autothermal Reformer (autothermal.04)	1.23	19.68	2005/b
	Short Contact Time Reactor (shortcontactreactor.04.new)			
	SUBTOTAL	**4.37**	**91.61**	

Computational Technology	Solution Crystallization Modeling Tools (crystallizer.optimization)	1.22	7.30	2005/b
	Multi-phase Computational Fluid Dynamics (CFD) (cfdrollup1)	1.47	12.13	2004/b
	Molecular Simulation for the Chemical Industry	0.50	14.32	2008/b
	Reaction Engineering Workbench	3.05	24.88	2005/b
	Distillation Column Modeling Tools (distillation.column.model)	6.04	84.73	2007/b
	SUBTOTAL	**12.28**	**143.36**	
Process Science and Engineering				
Separations	Membranes for p-Xylene Separation (advmat.04)	1.61	52.91	2007/b
	Mesoporous Membranes for Olefin Separations (mesopormembrane.04.new)	1.24	34.50	2007/b
	Purification Process for PTA (pta.purification)	0.28	4.38	2006/b
	Membranes for Corrosive Reactions (membranes.oxidative.reactions a)(membranes.oxidative.reactions b)	0.56	13.16	2007/b
	SUBTOTAL	**3.69**	**104.95**	
Process Engineering	Enhanced Heat Exchangers for Process Heaters (dimpletube.process.heaters)	1.29	11.08	2005/b
	Ethylene Process Design Optimization (ethylene.process.04.new)	2.6	32.84	2006/b
	SUBTOTAL	**3.89**	**43.92**	
Chemical Measurement	Accelerated Characterization of Polymer Properties (microanalysis.polymer.properties)	0.93	10.23	2008/a
Bioprocesses and Biotechnology	Development of Non-Aqueous Enzymes	5.97	60.78	2006/b
	SUBTOTAL	**6.9**	**71.0**	
	Total	66.84	786.77	

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Energy consumption in the chemicals industry is very complex, involving a great number of processes manufacturing thousands of products. Hydrocarbon fuels used as chemical feedstocks, according to the 1998 MECS, accounted for about 2.7 quads of energy use, about 46% of the industry's 6 quads of primary energy use. Separations and process heating are responsible for much of the remaining energy use. It is reported that distillation, one of the most widely used separation processes in the chemical industry, accounts for as much as 40% of the industry's total energy use for heat and power. The Chemical Industry Vision focuses much of its efforts on these energy intensive processes, and on improving the efficiency and yield of chemical processes.

Total primary energy savings in 2010 for the Chemical Industry Vision are projected to be about 67 trillion Btu, approximately one-third the GPRA submission for FY 2003 (233 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 786 trillion Btu, which is at the same level as the GRPA submission for FY 2003. For comparison, year 2010 projected energy savings are about 1% of 2000 energy use in the chemicals industry (6,064 trillion Btu).

Changes from the GPRA 2003 submission are due to the deletion of 13 projects and changes in the market penetration model. The large decrease in 2010 is due primarily to changes in the model.

3. Forest Products Industry Vision

Table 6. Forest Products Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.12	14	97	267	344	371
2. Energy Cost Savings (B$)	0.0004	0.04	0.24	0.70	0.94	1.06
3. Carbon Reduction (MMTCE)	0	0.15	1.01	2.74	3.53	3.80

Projected benefits for the Forest Products Industry Vision were estimated using an analytical process very different from that used in years past. In past years, the GPRA summary submission was based on a roll-up of the results from spreadsheet analyses of the individual projects funded in the current fiscal year. For example, the FY03 GPRA submission was a rollup of 56 of 60 active R&D projects funded by the program in FY02. For the FY04 GPRA process, the analysis was focused on 13 different *energy focus areas* into which 37 active R&D projects were grouped. That is, spreadsheet analyses were done to estimate benefits of the specific focus areas (e.g., Recovery Boiler Efficiency or Paper Drying) rather than of the individual projects that address each area. In this way, overlap between projects that address similar markets is avoided and a more accurate assessment of the ultimate potential is achieved. Table Y shows the summary of GPRA 2004 benefits achievable in each of these focus areas, and a list of the projects that fall into each area. It is estimated that the 37 projects represent over 74% (more than $7.4 million) of the $10.03 million FY 2003 budget for the Forest Products Industry Vision (remainder is for new awards and non-R&D activities).

The FY04 energy savings estimates are significantly less than those projected in FY03 because black liquor gasification is not included in this year's GPRA analysis for Forest Products (the gasification projects have been moved to EERE's Office of the Biomass Program). Without gasification, the estimates are very close for the year 2020: the FY03 estimated energy savings was 257 trillion Btu and in FY04 the estimate is 266. For the year 2010, the numbers are significantly lower in FY04 (14 trillion Btu compared to almost 80 trillion Btu in FY03) due to later estimates for market introduction.

The current portfolio includes projects that were selected by competitive solicitations issued cooperatively by DOE and the American Forest & Paper Association (AF&PA). Target areas for the solicitations were developed by expert task groups and were based on the forest products industry's vision and technology roadmaps.

Table 7. Summary of Project Runs – Forest Products Industry Vision

Impact Target and Projects	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Improved Pulping Yield & Decreased Pulping Energy • Molecular Physiology of Nitrogen Allocation • Dominant Negative Mutations of Floral Genes • Genetic Augmentation of Syringyl Lignin in Low_lignin Aspen Trees • Quantifying and Predicting Wood Quality of Loblolly and Slash Pine Under Intensive Forest Management • Exploiting Genetic Variation of Fiber Components and Morphology in Juvenile Pine • Environmental Influences on Wood Chemistry and Density of Populus and Loblolly Pine • Accelerated Stem Growth Rates and Improved Fiber Properties of Loblolly Pine • Increasing Yield of Kraft Cooks Using Microwaves • Novel Pulping Technology: Directed Green Liquor Utilization (D_Glu) Pulping	1.8	35.6	2007/b
Recovery Boiler Efficiency • Materials for Kraft Recovery Boiler • Intermediate_sized, Entrained Particles • CFD Modeling, Shape Optimization and Feasibility Testing of Advanced Black Liquor Nozzle Designs • Improved Recovery Boiler Performance Through Control of Combustion, Sulfur and Alkali Chemistry • Development of Corrosion Resistant Chromium Rich Alloys for Gasifier and Kraft Recovery Boiler Applications	3.4	60.8	2007/b
Paper Drying • Multiport Cylinder Dryers • Uniform Web Drying Using Microwaves • Laboratory Development of a High Capacity Gas_Fired Paper Dryer • Development of a Continuous Process for Displacement Dewatering	2.2	46.8	2007/b
Decreased Paper Basis Weight for Paperboard • On_Line Fluidics Controlled Headbox • The Lateral Corrugator • Acoustic Foils for Enhanced Dewatering and Formation • Contactless Monitoring of Paper • Non_Contact Laser Acoustic Sensor	2.3	45.9	2007/b
Bleaching • High Selectivity Oxygen Delignification • Higher Selectivity Oxygen Delignification	1.0	18.4	2007/b
Causticizing • Use of Borate Autocausticizing to Supplement Lime Kiln and Causticizing Capacities	0.6	12.7	2007/b
VOC/HAP Emission Control • Plasma Technologies for VOCs • Improving Dryer and Press Efficiencies Through Combustion of Hydrocarbon Emissions	1.0	19.9	2007/b

Impact Target and Projects	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Improved Paper Machine Efficiency • Screenable Pressure Sensitive Adhesives • Decontamination of Process Streams Through Electrohydraulic Discharge	0.06	1.07	2007/b
Recycling OCC • Preventing Stength Loss of Kraft Fiber	0.4	7.8	2007/b
Deinking • Surfactant Spray to Improve Flotation Deinking	0.06	0.09	2007/b
Wood Boiler Efficiency • Methane de_NOX	1.0	7.1	2004/b
Lumber Drying • Microwave Treatment for Rapid Wood Drying • Wireless Microwave Wood Moisture Measurement System for Wood Drying Kilns	0.2	4.7	2007/b
Wood Panel Pressing • Fast Curing of Composite Wood Products • Rapid, Low Temperature Electron X_Ray and Gamma Beam Curable Resins	0.3	4.9	2007/b
TOTAL	**14.32**	**265.76**	

4. Glass Industry Vision

Table 8. Glass Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	1.1	8	40	68	47	18
2. Energy Cost Savings (B$)	0.004	0.03	0.16	0.29	0.21	0.08
3. Carbon Reduction (MMTCE)	0.02	0.12	0.54	0.87	0.60	0.25

Projected benefits for the Glass Industry Vision were based on analysis of 15 active R&D projects addressed to improvements in energy efficiency and environmental performance of glass manufacturing processes. The table below identifies these projects, grouping them into separate targets including modeling/simulation, sensors/control, combustion, furnace technology, and glass composition/properties/finishing. It is estimated that these projects represent approximately 90% of the latest fiscal year's R&D budget. The FY 2003 budget for Glass Industry Vision is $4.6 million.

Energy consumption in the glass melting industry is dominated by the use of natural gas in melting furnaces. Four major industry segments use somewhat differing process equipment to produce container glass, flat glass, fiber glass, and pressed/blown glass. In the United States, approximately 380 furnaces currently produce 18.16 million tons of product annually; these furnaces range in size from pressed/blown specialty glass melters under 75 TPD capacity to flat/float glass melters of more than 550 TPD capacity.

Table 9. Summary of GPRA 2004 Benefits – Glass Industry Vision

Impact Target	Project/Spreadsheet Run File Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Modeling/ Simulation	Modeling of Glass Processes (Modeling.Glass.Processes.04)	0.61	4.42	2003/c
	Validation of Coupled Combustion Space/Glass Bath Furance Simulation (Coupled.Bath.Simulation.03)	0.53	7.11	2006/b
	Process Optimization for On-line Coating of Float Glass (glasscoating.04.new)	0.0	0.12	2005/b
	Diagnostics and Modeling of High Temperature Corrosion of Refractories (Diagnostics.Corrosion.Refractories.Furnaces.03)	1.24	10.30	2005/b
	Subtotal	**2.38**	**21.95**	na
Sensors/ Control	Molybdenum Disilicide Composites for Glass Sensors (MolyDisilicideComposites.Sensor.04)	0.24	0.71	2004/b
	Monitoring/Control of Alkali Volatization and Batch Carryover (controlalkalibatch.04.new)	0.35	3.46	2005/b
	Measurement and Control of Glass Feedstocks (controllibs.market1.04,controllibs.market2.04)	0.29	2.85	2005/b
	Advanced Process Control for Glass (Auto.Sideglass.Control.04)	0.75	4.45	2004/b
	Auto Glass Process Control (Auto.Glass.Process.Control.04)			
	Subtotal	**1.63**	**11.47**	na
Furnace Technology	High-Luminosity Low Nox Burner (High-Luminosity.LowNOx.Burner.04)	0.29	0.90	2003/b
	Integrated Batch Preheater (batchpreheatcontainer.04.new, batchpreheatflat.04.new,batchpreheatspecial.04.new)	0.85	8.41	2003/b
	Glass Furnace Combustion and Melting User Facility (User.Facility.04)	1.27	11.96	2005/b
	Subtotal	**2.41**	**21.27**	na
Glass Composition/Properties/Finishing	Enhanced Cutting and Finishing of Handglass With a Laser (Laser.Cutting.ofGlass.04)	0.37	1.10	2003/b
	Integrated Ion Exchange System for High Strength Glass Products (Ion.Exchange.Strength.04)	1.02	9.70	2005/b
	Recovery/Recycling of In-house Glass Manufacturing Waste (glassrecycle.04.new)	0.30	2.68	2005/b
	Subtotal	**1.69**	**13.48**	na
	Grand Total	**8.12**	**68.17**	na

Total primary energy savings in 2010 are projected to be about 8 trillion Btu, approximately 74% lower than the GPRA submission for FY 2003 (31 trillion Btu). Year 2020 energy savings are projected to be 68 trillion Btu, approximately 14% lower than the GPRA submission for FY2003 (79 trillion Btu). For comparison, the year-2010 projected energy savings are 3% of MECS 1998 primary energy consumption in the glass industry (293 trillion Btu). Our year-2020 projected energy savings are 23% of MECS 1998 primary energy consumption in the glass industry.

Changes from the GPRA 2003 submission, which occur mostly in the near-term, are due to a change in the model. In addition, three projects have been removed from this year's submission.

5. Metal Casting Industry Vision

Table 10. Metal Casting Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.8	23	63	101	116	116
2. Energy Cost Savings B$/yr	0.03	0.11	0.31	0.53	0.61	0.62
3. Carbon Reduction (MMTCE)	0.02	0.47	1.19	1.83	2.10	2.08

Projected benefits for the Metal Casting Industry Vision were based on analysis of 29 active R&D projects to improve energy efficiency in metal casting processes. The table below identifies these projects, grouping them into separate targets areas. It is estimated that these projects represent approximately 83% of the $5.3 million FY 2003 budget the Metal Casting Industry Vision. Where appropriate, market penetration estimates took into account multiple projects addressing a particular target area. Also where appropriate, multi-phase projects were combined into one spreadsheet.

Energy consumption in the metal casting industry is dominated by the use of electricity and natural gas. Coal/coke also is used. An estimated 55% of energy used in metal casting processes is used in melting. Metal casters use a variety of furnace types including electric melting furnaces, electric arc furnaces, induction furnaces, fuel-fired furnaces and cupolas. Other energy intensive operations include molding and heat treating. The U.S. metal casting industry is diverse. Castings are produced from gray and ductile iron, steel, aluminum and aluminum-based alloys, copper, magnesium, zinc and other metals. The industry is composed of nearly 2,950 foundries and die casters manufacturing metal products using a variety of casting processes. The most common casting processes are sand casting, permanent mold casting, die casting and investment mold casting. The lost foam casting process, which has traditionally represented a small share of casting production, is seeing a rapid increases due to the deployment of research findings.

In prior years, 1994 baseline energy consumption was estimated at 200 Trillion Btu. In 1998, energy use in the foundry industry (NAICS code 3315) was 235 trillion Btu (Source: DOE/EIA 1998 MECS). If captive foundries are included, the estimated energy consumption for metal casting increases to 328 trillion Btu. The Metal Casting Industry of the Future is co-funding research to improve efficiency in the industry and to reduce energy consumption in metal casting operations. It is funding research in industry defined areas for manufacturing technologies, materials technologies, products and markets, and environmental technologies.

Total primary energy savings in 2010 are projected to be about 23.38 trillion Btu, approximately 32% less than the GPRA submission for FY 2003 (34.49 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 101.01 trillion Btu, 25% greater than the GPRA submission for FY 2003 (75.34 trillion Btu). For comparison, the year-2020 projected energy savings are 50.5% of 1994 primary energy consumption in the metal casting industry (200 trillion Btu); 43% of the 1998 energy consumption; and 13% of an informal OIT baseline projection for 2010 (264 trillion Btu).

Changes from GPRA 2003 submissions are most significant in the 2010 time frame and 2020 time frame. This is due to several factors. The model used for GPRA 2004 applies a market penetration curve that is inversed when compared to 2003. In addition, reported energy savings for GPRA 2004 represent the delta between energy saved with and without OIT involvement. This measures the role of OIT in the projected energy savings.

Table 11. Summary of Project Runs – Metal Casting Industry Vision

Impact Target	Project Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Computer-based Modeling Tools	Development of computational fluid dynamics tool for modeling bead expansion in lost foam	0.05	0.59	2004/b
	Computer modeling of the mechanical performance of die casting dies	2.03	4.48	2005/a
Die Life Extension/Die Performance	Surface Engineered Coatings for Die Casting Dies	0.01	0.05	2004/b
	Improved Design, Operation and Durability of Shot Sleeves	0.01	0.05	2007/b
	Integration of RSP Tooling in die casting	0.48	5.42	2005/b
Materials properties and performance (molds, dies, and castings)	Development Program for Natural Aging Aluminum Alloys	0.15	0.37	2005/a
	Determination of Bulk Dimensional Variation in Castings	0.34	2.92	2005/b
	Grain refinement of Permanent mold cast copper base alloys	0.14	1.64	2006/b
	Creep resistant zinc alloy development	0.23	1.77	2005/b
	Investment shell cracking	0.08	0.81	2005/b
	Service performance of welded duplex stainless steel castings	0.01	0.07	2006/b
Thin Wall/High Strength castings	Thin wall cast iron	0.10	2.38	2007/b
	Clean, machinable thin walled gray and ductile iron casting	0.36	2.19	2004/b
Advanced casting methods	Lost Foam	6.15	10.23	2004/a
	Investigation of Heat Transfer at the Mold/Metal Interface in Permanent Mold-Casting of Light Alloys	0.10	2.61	2007/b

	Metallic Reinforcement of the squeeze casting process	0.11	1.24	2005/b
Machining; inclusions, porosity reduction	Advanced Steel Technology	2.21	4.70	2005/a
	Prevention of porosity formation and other effects of gaseous elements	0.13	1.64	2006/b
	Improvements in sand/mold/cor technology: effect on casting finish	0.40	4.99	2006/b
Energy guidelines; Emissions Reduction; Byproduct Reuse	Energy consumption in die casting operations	1.80	3.99	2005/a
	Metallic Recovery and Ferrous Melting Processes	0.05	0.17	2006/a
	Non-incineration treatment to reduce benzene emissions	5.42	10.48	2005/a
	Technical data to validate foundry byproducts in hot mix asphalt	0.01	.03	2006/a
Sensors	Sensors for die casting	0.24	2.35	2005/b
Steel Foundry Practices (e.g. gating, heat treating, process re-engineering)	Re-engineering casting production systems	0.10	0.73	2004/b
	Yield Improvement in Steel Castings	2.27	30.98	2006/b
	Heat Treatment procedure qualification for steel casting	0.17	0.35	2005/a
Die Casting Practices (e.g. gating, process control, die filling, etc)	Ultrahigh speed measurement of internal die cavity temperature for process control	0.18	2.58	2006/b
	Effect of externally solidified product on wave celerity	0.08	1.21	2006/b
	Grand Total	**23.41**	**101.02**	**na**

6. Steel Industry Vision

Table 12. Steel Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	2.8	43	145	212	143	39
2. Energy Cost Savings (B$)	0.01	0.12	0.44	0.62	0.40	0.11
3. Carbon Reduction (MMTCE)	0.05	0.93	3.57	6.52	5.26	1.6

The GPRA submission for the Steel Vision is based on analysis of 27 technologies related to enhancing the productivity, energy efficiency, and environmental performance of steel manufacturing processes (see table below). The Steel Team's FY 2003 budget is approximately $10.3 million. The projects listed below represent approximately 42% of the budget, compared to the 80% figure for the 24 projects analyzed for the GPRA 2002 submission.

The mission of the OIT Steel Program is to support pre-competitive, higher-risk technologies and processes through cost-shared public-private partnerships. Revolutionary ironmaking and steelmaking technologies that will benefit the industry as a whole are ideal candidates for DOE support because of their enormous potential payoff. The DOE Steel Program has devised a strategy to foster both revolutionary ironmaking and steelmaking projects and incremental improvements to existing processes, thereby addressing long-term goals without neglecting short-term needs. The Program has also expanded the industry's fundamental base of knowledge to optimize key processes and resource efficiency. Since 2001, the Steel Program has been redirecting its portfolio to focus more on revolutionary steelmaking concepts rather than incremental improvements to existing processes in order to achieve maximum energy savings. This transition in the Program's strategy should produce dramatic drops in steelmaking energy intensity over the long term.

Table 13. Summary of Project Runs – Steel Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Processes	Advanced Process Controls for Integrated Mills	12.6	5.1	2004/a
	Hot Oxygen Injection into the Blast Furnace	3.6	1.5	2004/a
	Quantifying the Thermal Behavior of Slags	1.0	7.7	2005/b
	Automated Steel Cleanliness Tool**	1.6	1.6	2005/a
	Magnetic Gate for Molten Metal Flow Control	1.1	0.5	2004/a
	QMST	0.2	1.2	2005/b
	Investigation of Deadman/ Hearth Region of Blast Furnace	0.8	19.8	2008/b
Combustion/ Environment	NO x Emission Reduction by Oscillating Combustion	2.1	0.8	2004/a
	Dilute Oxygen Combustion	2.1	14.5	2004/b
	Nitrogen Control in EAF Steelmaking by DRI Fines Inject	2.0	17.9	2005/b
	Quality Improvement of Waste Oxide Briquettes	0.3	10.1	2009/a
	Optical Sensor for EAF Post-Combustion Control	0.5	2.5	2004/b
	Optimization of Post-Combustion in Steelmaking	1.5	7.6	2004/b
	Sustainable Steelmaking Using Biomass and Waste Oxides	1.4	25.0	2007/b
Materials	Intermetallic Alloys For Steel	0.8	10.8	2006/b

	Improved Refractory Service Life and Recycling Refractory Materials	0.8	4.2	2004/b
	Development of Submerged Entry Nozzles that Resist Clogging	2.1	14.5	2004/b
Quality	Inclusion Optimization for Next Generation Steel Products	0.3	5.1	2007/b
	Laser-Assisted Arc Welding of Advanced HSS	0.9	2.0	2006/a
	Resistance Spot Welding for HSS	0.9	2.1	2006/a
	Electromagnetic Filtration of Molten Steel	0.6	14.0	2008/b
	Controlled Thermo-Mechanical Processing of Tubes and Pipes	0.6	4.0	2007/a
	Development of Steel Foam Materials and Structures	0.6	6.5	2006/b
	Clean Steels – Advancing the State of the Art	3.2	27.3	2005/b
	Formability of HSS steels	0.4	1.8	2004/b
	Fatigue/Crash Performance HSS	0.2	1.9	2006/b
	Hydrogen and Nitrogen Control in the Ladle and Casting	1.2	2.5	2006/a
	Total	**43.4**	**212.2**	

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be 43.4 trillion Btu, compared to 70.8 trillion Btu in GPRA 2003. Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 212.5 trillion Btu, compared to 151 trillion Btu last year. For comparison, 1998 primary energy consumption for the steel industry was 1.68 quads. The projected savings in year 2010 are approximately 2.5% of the projected baseline energy use in the industry.

Three projects analyzed for GPRA 2003 were dropped from this analysis (Non-Cr Passivation, PCI Coal Combustion Behavior, and Laser-Assisted Arc Welding) because they were completed. Six new steel projects were added to the GPRA 2004 analysis. None-the-less, the primary energy savings results for 2010 are lower than in last year's analysis because most of new projects will not be commercialized until 2007. The energy savings for 2020 are much higher than last year because the new projects will result in significantly higher savings. Additionally, the GPRA methodology has changed since last year, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

The project entitled "NOx Emission Reduction by Oscillating Combustion" is being funded entirely by the steel team, even though it has potential benefits in a number of other industries. The only benefits counted in the steel team benefits roll-up are those directly attributable to steel industry applications.

There are no overlapping markets in any of the areas listed above. The Oscillating Combustion technology can be used in conjunction with Dilute Oxygen Combustion and does not represent an overlap.

The energy savings totals shown in the steel team benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget.

7. Mining Industry Vision

Table 14. Mining Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	5.4	29	100	205	339	441
2. Energy Cost Savings (B$)	0.024	0.15	0.55	1.19	2.02	2.70
3. Carbon Reduction (MMTCE)	0.11	0.60	2.00	4.05	6.99	8.72

The Mining Industry of the Future program is currently funding 28 active R&D projects. Projected benefits for the Mining Industry Vision were based on analysis of 22 of these projects that address the metal, coal, and industrial mineral mining industry through improved safety, enhanced economic competitiveness, reduced energy consumption, and reduced environmental impacts. The table below lists the projects evaluated, merging them where appropriate. These projects represent approximately 76% of the $5.1 million FY 2003 budget for the Mining Industry Vision.

Where appropriate, market penetration rates were adjusted in projects within the same impact target area to correct for any potential overlap in energy savings. The two alternative fuel projects were combined into one energy benefits spreadsheet because they are part of a multiphase research effort.

Table 15. Summary of Project Runs – Mining Industry Vision

Impact Target	Spreadsheet Run File Name	Energy Savings 2010 (Trillion Btu)	Energy Savings 2020 (Trillion Btu)	Year of Intro/Market Selector
Materials	Cellular-03	0.34	2.74	2006/c
	Grader-03	0.15	0.90	2004/b
	Imaging-03	0.21	1.37	2004/c
	Geophone-03	3.09	22.90	2004/c
Sensors	Libs-03	2.84	19.62	2004/c
Alternative Fuels	Fuelcell-03 PhaseII-03	0.36	2.82	2005/c
	Comminution-03	1.72	11.74	2005/c
Modeling	Sag-03	1.44	9.36	2004/c
Communications	Communications-03	.012	0.84	2005/c
	DMC-03	0.44	2.17	2004/b
	Analyzers-03	1.12	9.84	2005/b
Processing	Byprodrecov-03	7.17	46.84	2004/b
	Flocculation-03	0.37	2.43	2004/c
	Anode	1.65	11.76	2006/c
	Screens	4.31	31.91	2007/c
Excavation	Cutting-03	0.05	0.33	2005/c
	Bolter-03	0.69	6.06	2005/b

	Robotics-03	0.26	1.71	2004/c
	blasting-03	3.01	18.65	2004/b
	Projectile-03	0.07	0.48	2006/c
	oilpro-03	0.02	0.16	2004/b
Total		**29.3**	**204.6**	

Total primary energy savings in 2010 are projected to be about 29.3 trillion Btu. Year 2020 energy savings for the FY 2004 portfolio are projected at about 204.6 trillion Btu. For comparison, the year-2010 projected energy savings are 2.6% of 2001 primary energy consumption in the mining industry (1,125 trillion Btu) and 2.4% of an informal OIT baseline projection for 2010 (1,230 trillion Btu). Our year-2020 projected energy savings are 18.2% of 2001 primary energy consumption in the mining industry and 16.6% of the OIT-calculated baseline for 2010 (DOE's Energy Information Administration does not collect mining industry data and no baseline projection for 2020 is available).

GPRA 2004-projected energy savings in 2010 are 61% lower than in 2003 GPRA (76.1 trillion Btu); GPRA 2004 shows year-2020 savings 22% higher than in GPRA 2003. Assumptions made for the 2003 GRRA were updated with more current data. Also, market penetration rates were updated with more current data. The percent of the 2004 budget captured in GPRA remained the same as GPRA 2003 at 80%. The table above indicates the year of market introduction assumed and the letter selector assigned to characterize the technology's market penetration in the spreadsheet model.

8. Petroleum Refining Industry Vision

Table 16. Petroleum Refining Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	4.2	34	146	175	125	119
2. Energy Cost Savings (B$)	0.01	0.12	0.56	0.72	0.55	0.56
3. Carbon Reduction (MMTCE)	0.06	0.52	2.24	2.83	2.26	2.29

Projected benefits for the Petroleum Refining Industry Vision were based on analysis of all active R&D projects (six projects) addressed to improvements in refinery operations. The table below identifies these projects, grouping them into separate targets including hydrotreating, pressure vessel integrity, facility emission control, improving hydrocarbon production process control, improving combustion efficiency, and substituting membrane separation for distillation. These projects represent the $2.80 million FY 2003 budget.

Table 17. Summary of Project Runs – Petroleum Refining Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Hydrotreating Energy Use	Broadening Enzyme Selectivity and Improving Activity for Biological Desulfurization and Upgrading of Petroleum Feedstocks	1.3	17.0	2005/c

Pressure Vessel Integrity	Assuring Mechanical Integrity of Refinery Equipment Through Global On_Stream Inspection	1.5	14.5	2005/b
Facility Emission Control	Hydrocarbon Leak Detector	1.7	17.0	2005/b
Process Control of hydrocarbons	Micro_GC Controller for Petrochemical Application	1.7	12.0	2004/b
Combustion Efficiency	Rotary Burner Demonstration	26.6	81.0	2004/b
Distillation Energy Use	Energy Saving Separation Technologies for the Petroleum Industry	1.6	33.3	2005/b
	Total	34.4	174.8	na

Total primary energy savings in 2010 are projected to be about 34.4 trillion Btu, approximately -5% of the GPRA petroleum Refining submission for FY 2002 (36.1 trillion Btu). Year 2020 energy savings for the FY 2002 portfolio are projected at about 175 trillion Btu, about a 26% increase of the GPRA submission for FY 2002 (139 trillion Btu). For comparison, the "1994 Manufacturing Energy Consumption Survey" (94MECS) lists the petroleum refining industry as consuming approximately 3.153 quads for combustion and power plus 3.110 quads in the form of fuels used as feedstocks. The largest energy-consuming operations in petroleum refining are atmospheric and vacuum distillation, hydrotreating, reforming, fluid catalytic cracking and catalytic hydrocracking.

Changes in primary energy savings from the GPRA 2003 submission are due to:

- changes in the methodology for calculating the impact - The new analyses measure only the energy saved as a result of technology acceleration
- changes in the technology class and year of entry - These changes were the result of discussions with industry experts during the Petroleum Portfolio review.
- changes in the unit energy impact - These changes were a result of the industry experts input and recognize the fact that four projects have impact that extends beyond the refining industry

9. Industrial Materials Crosscut

Table 18. Industrial Materials for the Future Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	2.8	19	90	280	407	393
2. Energy Cost Savings (B$)	0.003	0.048	0.28	0.94	1.29	1.18
3. Carbon Reduction (MMTCE)	0.01	0.21	1.18	3.71	4.84	4.14

The GPRA submission for the Industrial Materials of the Future (IMF) Program is based on a spreadsheet benefits analysis of technical innovations under development by 35 projects, which are listed in the table below. The portfolio consists of 29 new projects from a competitive solicitation in 2001 and 6 projects carried over from previous years. Research in the 29 new projects is being lead by three types of research organizations – universities (11 projects), federal laboratories (10 projects), and industry (8 projects). The six projects carried over from the FY2003 GPRA analysis include Intermetallics for Ethylene Cracking;

Intermetallic Alloy Development for the Steel Industry; Intermetallic Alloy Development for Heat Treat Carburization; Boiler Tubes; Infrared Aluminum Billets Forging; and Infrared Die Heating.

Most of the technologies under development have applications in multiple industries but the benefit estimates were typically based upon a single application of a technology. In a few instances multiple applications were considered. For example, three refractories projects have applications in both the glass and aluminum industries and thus have two listings in the table below.

The 35 projects represent about $7.232 million (53%) of IMF's $13.7 million FY2003 R&D budget. The energy savings totals shown in the IMF benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget.

Table 19. Summary of Project Runs – Industrial Materials for the Future

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
H-Series Steel Alloy	Stronger and More Reliable Cast Austenitic Stainless Steel	0.8	31.9	2009/b
	Semi-Stochastic Algorithm for Optimizing Alloy Composition High-Temperature Austenitic Stainless Steels	0.1	2.8	2009/c
	Combinatorial Methods for Alloy Design and Optimization	0.1	1.2	2010/c
	Inverse Process Analysis for the Acquisition of Thermophysical Property Data	0.2	1.7	2005/c
	Ultrasonic Processing of Materials	0.0	0.1	2005/c
Cr-W(V) Steel Alloys	New Class of Fe-3Cr-W(V) Ferritic Steels	0.6	15.6	2008/b
	Fracture Toughness and Strength in a New Class of Bainitic Chromium-Tungsten Steels	0.1	3.1	2008/b
Coatings	High Density Infrared (HDI) Transient Liquid Coatings for Improved Wear and Corrosion Resistance	0.3	8.2	2008/b
	Advanced Composite Coatings	0.0	2.7	2012/c
	High Energy Density Coating of High Temperature Advanced Materials	0.0	0.2	2010/c
Carbon-Based Coatings	Ultrananocrystalline Diamond (UNCD) Coatings for SiC Multipurpose Mechanical Pumps	0.9	20.9	2008/b
Refractories	Novel Carbon Films for Next Generation Rotating Equipment	0.1	4.7	2009/b
	Ceramic and Refractory Components for Aluminum Melting and Casting (Aluminum Refractories)	0.1	3.4	2009/b
	Ceramic and Refractory Components for Aluminum Melting and Casting (Glass Refractories)	0.3	10.2	2008/b

	Modeling of Magnesia-Alumina Spinel Glass Tank Refractories	0.0	0.9	2008/b
	Advanced Nanoporous Composites for Industrial Heat Applications	0.0	0.4	2010/b
	High Density Infrared Surface Treatments of Refractories (Aluminum)	0.0	0.5	2009/b
	High Density Infrared Surface Treatments of Refractories (Glass)	0.0	0.9	2008/b
	Thermochemical Models and Databases for High Temperature Materials (Aluminum Refractories)	0.0	0.5	2009/b
	Thermochemical Models and Databases for High Temperature Materials (Glass Refractories)	0.0	0.9	2008/b
Corrosion-Resistant Materials	Stress-Assisted Corrosion in Boiler Tubes	0.5	13.7	2008/b
	Physical and Numerical Analysis of Extrusion Process for Production of Bi-Metallic Tubes	0.1	3.3	2009/b
	Co-Extrusion Technology for Tubes/Pipes	0.0	1.7	2009/b
Wear Resistant Materials	Virtual-Welded Joint Design Integrating Advanced Materials and Processing Technologies	0.5	13.8	2009/b
	Advanced Wear and Corrosion Resistant Systems through Laser Surface Alloying and Materials Simulation	0.0	0.4	2007/b
	New Class of Ultra-Hard Borides	0.4	5.4	2007/b
	Super Hard Materials	0.0	0.7	2010/b
Stand Alone – Process Materials	Novel Modified Zeolites for Energy Efficient Hydrocarbon Separations	1.3	38.1	2009/b
Stand Alone – Process Materials	Oxide-Dispersion-Strengthened Tubes for Ethylene	0.0	6.7	2014/b
Stand Alone – Chlor-Alkali Cell	Advanced Chlor-Alkali Technology	0.8	6.4	2010/c
Stand Alone – Tools & Dies	Advanced Tooling Alloys for Molds and Dies	0.1	5.6	2010/c
Stand Alone – Novel Processing	Ultrahigh Magnetic Field Processing of Materials	0.6	5.1	2007/c
Stand Alone - Ethylene cracking	Intermetallics for Ethylene Cracking	4.8	32.9	2004/c
Stand Alone - Steel casting; heat	Intermetallic Alloy Development for Steel	0.4	2.9	2005/c
Stand Alone - Steel - heat treating	Intermetallic Alloy Development for Heat Treating Carburization	3.7	21.8	2004/b
Stand Alone - Kraft	Boiler Tubes	1.7	9.6	2004/c
Stand Alone - Aluminum and titanium forging	Infrared Aluminum Billets Forging	0.1	0.5	2004/b

Stand Alone - Aluminum and steel die heating	Infrared Die Heating	0.1	0.9	2004/b
	Total	18.9	280.1	Na

Total primary energy savings in 2010 are projected to be 19 trillion Btu, about one fourth the GPRA submission for FY 2003 (74 trillion Btu). Year-2020 primary energy savings for the FY 2004 portfolio are projected to be about 280 trillion Btu, about one third more than the 207 trillion Btu result of the GPRA 2003 analysis. The year-2010 benefits are lower in this year's analysis because most of the projects are new and therefore have later commercial introduction years than last year's projects. Benefits are also lower in 2010 because changes made to the Impacts Model resulted in lower market penetration in the early years, especially for projects with commercial introductions around 2005. The year-2020 benefits are higher in this year's analysis because of the number of projects analyzed has increased from 12 to 35.

10. Sensors and Controls Crosscut

Table 20. Sensors and Controls Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.6	8	34	47	25	5
2. Energy Cost Savings (B$)	0.002	0.03	0.14	0.21	0.13	0.027
3. Carbon Reduction (MMTCE)	0.01	0.16	0.65	0.88	0.48	0.10

Projected benefits for the Sensors & Controls (S&C) Program Vision are based on analysis of 4 active R&D projects that are aimed to improve energy efficiency and environmental performance within the nine Industries of the Future (IOF) manufacturing sectors. The table below identifies these projects, grouping them into two separate targets: (1) sensors and measurement technologies and (2) control and optimization. It is estimated that these projects represent approximately 13% of the $3.8 million FY 2003 budget.

The worldwide markets for sensing technologies and for process controls are $15 billion and $26 billion a year, respectively, with the United States being the largest provider and single national market. The major share of both the sensor and the process control markets is in the manufacturing sectors targeted by the IOF Program. The high-volume use of sensor and control technologies in IOF sectors is based on the realization that significant resource/process efficiency and waste reduction can be achieved through intelligent process control using real-time measurement information. Critical to achieving the set targets of reduction in energy use and carbon emissions by the IOF vision industries is the development and delivery of sensor and control solutions for the many unmet needs as documented in the IOF technology roadmaps. The Sensors and Controls Program aims at delivering these needed solutions with broad applicability across multiple industry sectors, with a particular focus on high-risk and high-payoff technology research, development, and demonstration activities.

Table 21. Summary of Project Runs – Sensors and Controls Program

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Sensors and Measurement Technologies	Remote Material On-line Sensor	0.57	5.76	2005/b
	In-Situ, real-Time Measurement of Melt Constituents	0.94	8.29	2005/b
	Solid State Chemical Sensors for Monitoring Hydrogen	3.15	24.36	2005/b
Control and Optimization	Diagnosis and Control of Natural Gas Fired Furnaces via Flame Image Analysis	3.52	11.71	2006/a
	Total	**8.18**	**46.98**	na

Total primary energy savings in 2010 are projected to be about 8.18 trillion Btu, 10% less than the GPRA submission for FY 2003 (9.2 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 46.98 trillion Btu, 28% greater than the GPRA submission for FY 2003 (36.8 trillion Btu).

The primary energy savings results for 2010 are lower than in last year's analysis because a change in the GPRA methodology, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

Two of the ten project analyses were dropped for GPRA 2004 because they will be complete in FY02. These were the Thermal Imaging Control of Furnaces and Combustors and Cupola Furnace Control Systems. Four other projects (Tunable Diode Laser for Harsh Combustion Environments, On-line Measurement Using Laser-Based Ultrasonic System, Sensor Fusion for Intelligent Process Control, and Intelligent Extruder) were also dropped for this analysis because sufficient background data was not available. Additionally, their GPRA 2003 benefits were relatively minor as compared to the four projects in this year's analysis.

11. Combustion Crosscut

Table 22. Combustion Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0	18	144	588	857	534
2. Energy Cost Savings (B$)	0.00	0.06	0.53	2.29	3.54	2.34
3. Carbon Reduction (MMTCE)	0.00	0.26	2.12	8.58	12.49	7.76

The GPRA submission for the Combustion Program is based on analysis of 3 projects (1) SuperBoiler: PM/TM Boiler Development and Demonstration, (2) Advanced, Integrated Process Heater/Burner System, and (3) Low NOx, Low Swirl Burner. The Combustion Program's FY 2003 budget is approximately $2 million, with the projects listed below representing approximately 80% of the budget.

This budget is considerably smaller than the $14.6 million FY2002 budget, due to the EERE reorganization, which transferred the Gasification project to the Biomass Program.

Table 23. Summary of Project Runs – Combustion Program

Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Super Boiler: PM/TM Boiler Development and Demonstration	13.7	503.3	2009/b
Advanced, Integrated Process Heater/Burner System	3.9	83.8	2007/b
Low NOx, Low Swirl Burner	0.06	0.06	2004/a
Total	**17.7**	**587.2**	

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be 17.7 trillion Btu, compared to 34.2 trillion Btu in GPRA 2003. Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 587.2 trillion Btu, compared to 105.8 trillion Btu last/year.

The primary energy savings results for 2010 are lower than in last year's analysis because a change in the GPRA methodology, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement. Additionally, the GPRA energy savings for 2020 is significantly higher than last years due to a change in calculation for the Super Boiler project.

The Super Boiler is an improved gas-fired packaged boiler with high thermal efficiency and low emissions designed to replace existing boilers as they reach the end of their useful lifetimes. The technology is assumed to enter its market in 2009 with market penetration curve "b". The 2020 energy savings for this project is significantly higher than last year due to an error in previous year calculations. The SuperBoiler savings were calculated in past years using a 5% capacity factor (or 438 hours per year) whereas it should be a 50% capacity factor (or 4380 hours per year). Using the new capacity factor, therefore, increases the energy savings by a factor of 10.

The Integrated Process Heater/Burner System is for both retrofits and new advanced installation in the chemicals and petroleum industries. Market introduction in 2007 is assumed with a penetration curve "b" in the spreadsheet model. The Low NOx, Low Swirl project, added to the analysis this year, will optimize the low-swirl burner to capture the benefit of firing with partially reformed natural gas and with internal flue gas re-circulation (IFGR). Efforts will focus on designing and demonstrating a low-swirl burner with IFGR that can be scaled to large industrial boilers. Market introduction is planned for 2004, with market penetration curve "a".

B. Technical and Financial Assistance Planning Units

Two planning units – the Inventions and Innovation program and the NICE[3] program – have been removed from OIT due to reorganization since the completion of GPRA 2003. Therefore GPRA includes results for only two Technical and Financial Assistance planning units – the Industrial Analysis Center program and the Best Practices program.

The Industrial Analysis Center program and the Best Practices program were again assessed based on retrospective analysis of performance data accumulated over a period of years. Quality Metrics for these planning units assume that continuation of the programs will result in beneficial impacts proportional to documented experience at historical budget levels. These analyses assume no continuing contributions from prior program expenditures, but only assume that future expenditures will produce results proportionate to those reported for past expenditures.

1. Industrial Assessment Center (IAC) Program

Table 24. IAC Program - QM Estimation and Summary

Item	2004	2005	2006	2007	2010	2015	2020	2025	2030
1. Number of Assessment Days	750	750	750	750	750	750	750	750	750
2. Cumulative Number of Assessment Days Counted	750	1,500	2,250	3,000	5,250	5,250	5,250	5,250	5,250
3. Annual Energy Saved Per Audit (MBtu/Assessment-Year)	3686	3686	3686	3686	3686	3686	3686	3686	3686
4. Energy Saved From Assessments (TBtu)	2.76	5.53	8.29	11.06	19.35	19.35	19.35	19.35	19.35
5. IAC Assessment Replication Rate	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
6. Cumulative Number of Replications Counted	0	0	225	450	1,125	1,575	1,575	1,575	1,575
7. Annual Energy Saved From Replications (TBtu)	0	0	0.83	1.66	4.15	5.81	5.81	5.81	5.81
8. Number of Alumni Starting 25-Year Career	140	140	140	140	140	140	140	140	140
9. Number of New Energy Assessment Days Per Alumni-Year	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10. Number of New Energy Assessments Performed	70	140	210	280	490	840	1,050	1,050	1,050
11. Cumulative Number of Alumni Energy Assessments	70	210	420	700	1,960	5,460	10,500	15,750	21,000
12. Number of Aged Energy Assessments Retired	0	0	0	0	0	350	700	1,050	1,050
13. Cumulative Number of Aged Energy Assessments Retired	0	0	0	0	0	1,050	3,850	8,400	13,650
14. Number of Alumni Energy Assessments Counted	70	210	420	700	1,960	4,410	6,650	7,350	7,350

15. Annual Energy Saved From Alumni Assessments (TBtu)	0.26	0.77	1.55	2.58	7.22	16.26	24.51	27.09	27.09
16. Additional Annual Energy Saved Per Website (TBtu/Year)	1	1	1	1	1	0	0	0	0
17. Annual Energy Saved From Website (TBtu)	1	2	3	4	7	7	7	7	7
18. Total IAC Annual Energy Saved (TBtu)	4.02	8.3	13.67	19.3	37.72	48.42	56.67	59.25	59.25
19. Energy Cost Savings (B$)	0.023	0.048	0.078	0.111	0.225	0.304	0.368	0.400	0.416
20. Carbon Reduction (MMTCE)	0.069	0.147	0.248	0.361	0.712	0.894	1.029	1.076	1.076

The Industrial Assessment Center (IAC) program benefits were supported by 20 years of actual assessment and implementation data. Energy savings were calculated and summed from four sources associated with the IAC program: (1) IAC energy assessments, (2) replication assessments within firms served by IAC, (3) assessments performed by IAC student alumni, and (4) IAC website-related energy savings.

Based on historical data on 10,525 industrial site assessments, the IAC program was assumed to result in the performance of 750 assessment days annually, each of which will save, on average, 3,686 million Btu (at source) per year during seven subsequent years over which credit was counted. After growing through year 2010, the resulting national energy savings attributed to this source levels off at 19.35 trillion Btu per year, because new assessments afterward merely replace the contributions of aged assessments no longer being counted (line 4).

Based on ORNL survey results, every ten IAC Assessments were assumed to result in three replication assessments at different sites within three years of performance. The cumulative number of replicated assessments (line 6) is 0.3 times the cumulative number of IAC assessments performed (line 2), delayed by three years. The same average energy savings per Assessment (3,686 million Btu per year) were assumed.

Estimation of the contribution of assessments (or other, equivalent professional services) performed by IAC student alumni were based on a rate of graduation across the program of 140 fully-trained students each year. It was assumed that every alumni performs 0.5 energy assessment each year for 15 years after leaving the IAC program and that each assessment subsequently saves 3,686 million Btu per year. The benefits of each energy assessment (or equivalent intervention) were assumed to persist for seven years, after which the aged energy assessment was “retired” for the purposes of this estimation. Subtracting the cumulative number of aged energy Assessments “retired” (line 13) from the cumulative number of Assessments performed (line 11) gives the number of alumni assessments counted in each year (line 14). Note that in the out-years (2020 and beyond) this source contributes more energy savings than does the continuing IAC assessment program itself.

Finally, based on a preliminary study by ORNL, the contributions of the IAC website were conservatively estimated to grow at the rate of 1 trillion Btu per year. The growth of this influence was assumed to continue for seven years beginning in 2004, so that the level of savings in 2010 was continued without further increase. This contribution was considered a placeholder pending the development of further website communication benchmark data. The FY 2003 budget request is $7.7 million.

Energy cost savings (line 19), carbon reduction (line 20), and other benefits are related to energy savings by projected fuel prices and emission coefficients given in the GPRA 2004 Data Call guidance.

2. Best Practices Program

OIT's Best Practices program is designed to change the ways industrial plant managers make decisions affecting energy use by motors, drives, pumps, compressed air, steam, combustion systems, process heat and other plant utilities. The FY 2003 budget request is $9.0 million. An overall program evaluation methodology is currently under development with the help of Oak Ridge National Laboratory. Elements and preliminary metrics are shown in Table 25. A discussion of these metrics follows. Significant changes in these approaches and metrics are likely as the program continues efforts to assess the impacts of various activities and approaches.

Dissemination of Best Practices information is achieved through a wide range of communication channels and covers a panoply of technical subjects. This analysis projects future benefits based on preliminary findings of an Oak Ridge National Laboratory study of program effects in 2001. Program activities are summarized into five main groups: Plantwide Assessments, Collaborative Technology Assessments, Training, Software Tools, and Publications. Impact estimation per implementation of best practices adopted by plants due to the influence of these five program activity areas are based upon actual program findings.

The basic methodology used in each of the five areas is very similar. First the reach is estimated. By this we mean the number of individuals touched by BestPractices information. This number is then scaled back to calculate the number of plants taking action due to this information dissemination. The scale-back factors include accounting for duplicate "touches" within the same company, the percent of companies actually taking action, and a reduction factor to discount program credit due to it being but one of multiple sources of influence. In the cases of Plantwide Assessments (PWAs) and Collaborative Technology Assessments (CTAs) no scale-back factor needed to be applied.

Plantwide Assessments (PWAs) (Lines 1 - 8)

Benefits for the Plantwide Assessments were calculated based on a three-year history. Of 23 such Plantwide Assessments conducted, 14 have completed recommendation reports. Based on these reports, potential energy savings are close to 0.4 trillion Btus per year per plant. Experience from the IAC Program indicates that roughly 50% of all recommendations are actually implemented. We expect this percent to be greater for the BestPractices program where the cost of the assessment is shared with industry, thus indicating a greater level of involvement. Nonetheless, the IAC implementation rate of 50% is being used until the BestPractices program is able to document a program-specific implementation rate. Hence the number assumed for energy savings by Plantwide Assessments is 0.2 trillion Btus per plant per year (line 7).

Table 25. Best Practices Program - QM Estimation and Summary

Item	2004	2005	2006	2007	2010	2015	2020	2025	2030
1. Plantwide Assessments (PWAs)	0	7	7	7	7	7	7	7	7
2. PWA Replication	0	0	35	35	35	35	35	35	35
3. Cumulative Number of PWA Implementations	0	7	49	91	217	427	637	847	1057

4. Plants Retired From Count Each Year	0	0	0	0	0	7	42	42	42
5. Cumulative Number of Plants Retired From Count	0	0	0	0	0	7	217	427	637
6. Net Number of Plants Still Counted	0	7	49	91	217	420	420	420	420
7. Annual Energy Saved Per Plantwide Implementation (TBtu/Plant-Year)	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
8. Annual Energy Saved Through PWA Direct Implementation and Replication (TBtu)	0	1	10	18	43	84	84	84	84
9. Collaborative Technology Assessments (CTAs)	56	70	70	70	70	70	70	70	70
10. Cumulative CTAs	56	126	196	266	476	826	1176	1526	1876
11. CTA Plants Retired From Count Each Year	0.00	0.00	0.00	0.00	0.00	70.00	70.00	70.00	70.00
12. Cumulative Plants Retired From Counting	0.00	0.00	0.00	0.00	0.00	126.00	476.00	826.00	1176.00
13. Net CTA Plants Still Counted	56.00	126.00	196.00	266.00	476.00	700.00	700.00	700.00	700.00
14. Annual Energy Saved per CTA (TBtu/Plant-Year)	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186
15. Annual Energy Saved By CTAs (TBtu)	7	15	23	32	56	83	83	83	83
16. Individuals Reached Through Training	1770	2210	2210	2210	2210	2210	2210	2210	2210
17. Percent Representing Plants Taking Action	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
18. New Plants Affected Each Year	177	221	221	221	221	221	221	221	221
19. Cumulative Plants Affected	177	398	620	841	1505	2611	3717	4823	5930
20. Plants Retired From Count Each Year	0	0	0	0	0	221	221	221	221
21. Cumulative Plants Retired From Counting	0	0	0	0	0	398	1505	2611	3717
22. Net Plants Still Counted	177	398	620	841	1505	2213	2212	2212	2213
23. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
24. Annual Energy Saved By Training (TBtus)	9	20	32	43	77	113	113	113	113

25. Software Tools Distributed	17285	21606	21606	21606	21606	21606	21606	21606	21606
26. Percent Representing Plants Taking Action	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
27. New Plants Affected Each Year	1630	2037	2037	2037	2037	2037	2037	2037	2037
28. Cumulative Plants Affected	1630	3667	5704	7741	13851	24036	34220	44404	54589
29. Plants Retired From Count Each Year	0	0	0	0	0	2037	2037	2037	2037
30. Cumulative Plants Retired From Counting	0	0	0	0	0	3667	13851	24035	34220
31. Net Plants Still Counted	1630	3667	5704	7741	13851	20369	20369	20369	20369
32. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
33. Annual Energy Saved By Software Tools Distribution (TBtus)	50	112	174	236	422	621	621	621	621
34. Publications Packets Distributed	73039	77606	77606	77606	77606	77606	77606	77606	77606
35. Percent Representing Plants Taking Action	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
36. New Plants Affected Each Year	2463	2617	2617	2617	2617	2617	2617	2617	2617
37. Cumulative Plants Affected	2463	5080	7697	10314	18164	31248	44332	57415	70499
38. Plants Retired From Count Each Year	0	0	0	0	0	2617	2617	2617	2617
39. Cumulative Plants Retired From Counting	0	0	0	0	0	5080	18164	31247	44331
40. Net Plants Still Counted	2463	5080	7697	10314	18164	26168	26168	26168	26168
41. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03
42. Annual Energy Saved By Publication Distribution (TBtus)	5	9	14	19	34	49	49	49	49
43. Total Annual Energy Saved By Best Practices (TBtu)	70	158	253	348	633	950	950	950	950
44. Energy Cost Savings (B$)	0.399	0.905	1.449	2.009	3.779	5.956	6.158	6.405	6.661
45. Carbon Reduction (MMTCE)	1.22	2.80	4.54	6.34	11.57	17.15	17.01	16.99	16.97

The number of Plantwide Assessments of 7 per year was projected by the Best Practices program staff based on assumed level funding (line 1). The annual energy saved directly by large plants due to PWA implementations (line 8) was calculated by multiplying the annual energy saved by each plant (line 7) times the net number of plants still counted (line 6). The net number of plants still counted (line 6) equals the cumulative number of plants having entered the program (line3) less the cumulative number of plants retired from the count (line 5). Plants are retired from the count after 10 years.

The number of PWA replications was calculated by estimating that each industry leading large showcase plant entering the program would influence five other large-size plants to replicate Best Practices with a two-year time delay. Current grantees are showing strong signs of replicating at as many as 20 other plants. The assumption used for this exercise is a replication factor of 5. Program staff are in the process of documenting actual replication rates for each Plantwide Assessment recipient.

Collaborative Targeted Assessments (CTAs) (Lines 9 - 15)

A critical tool of BestPractices is the Collaborative Technology Assessment (CTA) whereby DOE experts in industrial energy management are available to provide targeted, in-plant technical assistance to identify specific systems areas for improvement. CTAs are used both as a vehicle for training and as a prelude to conducting a Showcase Demonstration. Companies interested in hosting a Showcase Demonstration can request a walk-through assessment (one to three days) to identify opportunities for increased savings and productivity in industrial systems such as motors, steam, compressed air, pumping, and process heating.

Annual energy saved by implementations from CTA's (line 15) is calculated by multiplying the net number of CTAs still counted (line 13) times the median effect of all CTA's performed to date (line 14). Energy savings from a typical CTA (0.1186 TBtus) was derived from results reported in a spreadsheet entitled, "Activity Report for FY 2001" written by Oak Ridge National Laboratory. This energy savings number is a refinement of past estimates, and will continue to be refined as the program documents actual savings.

BestPractices plans to conduct 56 CTAs per year, with a 25% replication rate in the following year. Hence line 9 shows 56 CTAs in 2004 with 70 conducted in each subsequent year - 56 directly with the aid of DOE and 14 as a residual replication effect from the prior year's CTAs.

Training (Lines 16 - 24)

Training activities continue to play a key role in the strategy of BestPractices. Program managers have emphasized the "Train the Trainer" approach to help leverage limited federal dollars. The reach represented in this section of the program projections is based upon past precedent, and is therefore felt to be conservative. Actual reach should be several times the numbers indicated due to the multiplier effect of the "Train the Trainer" approach.

Line 16 shows the number of individuals trained in BestPractice sponsored workshops. Note that as with the CTAs, the second year shows a 25% increase in reach due to replication effect carryover from the preceding year. So each ensuing year will show 1770 individuals trained directly by DOE sponsored instructors and 440 additional individuals reached by those previously trained (this number will be tracked and may turn out to be much bigger).

Based upon studies conducted on past training activities in motors, pumps, and compressed air, it is assumed that the number of individuals trained must be reduced by 90% to represent the actual number plants where implementations of program Best Practice recommendations occur. This accomplished by multiplying Individuals Reached Through Training (line 16) by Percent Representing Plants Taking Action (line 17). Those plants are cumulated and retired after 10 years (lines 19 - 21) to arrive at Net

Plants Still Counted (line 22). Line 22 is then multiplied times the Average Energy Saved per Plant Taking Action - 0.051 Tbtus (line 23) - to calculate the Annual Energy Saved By Training (line 24). Line 23 is a weighted average of training in Pumps, Process Heat, Steam, Compressed Air, and Motors at both the individual company and the regional level.

Software Tools Distribution (Lines 25 - 33)

BestPractices has a variety of resources to help address a company's energy management needs and to help facilitate energy efficiency decision-making. BestPractices offers a range of software tools and databases that can assist a plant manager in making a self-assessment of a plant's steam, compressed air, motor, and process heating systems. Software tools include: AirMaster+, Airmaster+ Qualification, MotorMaster+ 3.0, Pumping System Assessment Tool (PSAT), PSAT Qualification, Steam System Scoping Tool, 3E Plus, Decision Tools for Industry, and ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application. A new software tool geared toward Process Heating evaluation is due out in FY 2003.

Software Tools are distributed on CD-ROM or can be downloaded from the Internet. Although the program has a fairly good count of the number of software tools distributed, less is known about their actual use and impact. ORNL has been commissioned to explore the impact of software tool distribution. For purposes of this exercise it has been assumed that the average energy saved per plant taking an action due to software tool use is 0.03 TBtus per plant-year (line 32), or about 25% of the value of a CTA (line 14), and about 60% of the value of direct training (line 23).

The number of plants affected by the software distribution is estimated by taking the total number of pieces of software distributed (line 25), multiplying that number by the Percent Representing Plants Taking Action (line 26) to account for multiple copies going to different people at the same plant site and to account for those plants that are not ready or able to take action. A methodology analogous to that employed to derive the Training impact is then used to determine the Net Plants Still Counted (line 31), which is multiplied times Average Energy Savings (line 32) to calculate Annual Energy Savings due to Software Distribution (line 33).

Publication Dissemination (Lines 34 - 42)

BestPractices produces a variety of publications that are distributed in hardcopy or can be downloaded from the Internet. These publications include Technical Publications (e.g., Fact Sheets, Tip Sheets, Best Practices Resources, Market Assessments, Sourcebooks, and Repair Documents); Case Studies; and both the Energy Matters and OIT Times newsletters. This form of information dissemination has the broadest reach, but the least discernable direct impact on energy savings per exposure. The main purpose of most of these publications is really one of raising general awareness, interest and desire to learn more so that a plant manager might then investigate options more fully (perhaps by signing up for a training session or downloading and using a software tool).

The total number of exposure through publication dissemination is estimated to be over 73,000 in 2004 and increases to 77,600 because of the 25% replication effect (line 34). This number is multiplied by 3.4% (line 35) to estimate the total number of plants where information from the publications is applied (line 36). "Average Energy Saved per Plant Taking Action (TBtus / Plant-Year)" is shown in (line 41). This estimate of 1.87 Billion Btus (not trillion) is derived from a prior study conducted by Xenergy on the effect of motor publications and the Energy Matters newsletter. Annual Energy saved by the application of information in publications (line 42) is the product of Net Plants Still Counted (line 40) times the Average Energy Saved per Plant Taking Action (line 41).

Conclusion

Total Annual Energy Saved By Best Practices (Tbtus) (line 43) is a sum of the subtotals in the five areas previously outlined: PWA (line 8), CTAs (line 15), Training (line 24), Software Tools (line 33), and Publications (line 42). Lines 44 and 45 showing the Energy Cost Savings in Billions of Dollars and Carbon Reduction in MMTCE are derived by multiplying energy prices and carbon content factors for various fuels found in EIA *Annual Energy Outlook for 2002.*

Appendix A – FY 2004 Quality Metrics Final Summary Tables

GPRA 2004 PROJECTED PROGRAM BENEFITS - OFFICE OF INDUSTRIAL TECHNOLOGIES

Planning Element	YEAR 2010			YEAR 2020			YEAR 2030		
	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)
Aluminum	22	0.09	0.55	199	1.01	5.25	144	0.80	3.21
Chemicals	67	0.23	1.14	787	2.89	12.61	410	2.11	7.44
Forest Products	14	0.04	0.15	267	0.67	2.74	371	1.06	3.80
Glass	8	0.03	0.12	68	0.29	0.87	18	0.08	0.25
Metal Casting	23	0.11	0.47	101	0.53	1.83	116	0.62	2.08
Steel	43	0.12	0.93	212	0.62	6.52	39	0.11	1.60
Mining	29	0.15	0.60	205	1.19	4.05	458	2.82	9.06
Petroleum Refining	34	0.12	0.52	175	0.72	2.83	119	0.56	2.29
IOF Specific S/T	*240*	*0.89*	*4.48*	*2014*	*7.92*	*36.7*	*1675*	*8.16*	*29.73*
Ind. Materials	19	0.05	0.21	280	0.94	3.71	393	1.18	4.14
Sensors & Controls	8	0.03	0.16	47	0.21	0.88	5	0.03	0.10
Combustion	18	0.06	0.26	587	2.29	8.58	534	2.34	7.76
C/C R&D Subtotal	*45*	*0.14*	*0.63*	*914*	*3.44*	*13.17*	*932*	*3.55*	*12*
IAC	38	0.23	0.71	57	0.37	1.03	59	0.42	1.08
Best Practices	633	3.78	11.57	949	6.16	17.01	949	6.66	16.97
TA Subtotal	*671*	*4.01*	*12.28*	*1006*	*6.53*	*18.04*	*1008*	*7.08*	*18.05*
IOF Crosscut S/T	*716*	*4.15*	*12.91*	*1920*	*9.97*	*31.21*	*1940*	*10.63*	*30.05*
Total	**956**	**5.04**	**17.39**	**3934**	**17.89**	**67.91**	**3615**	**18.79**	**59.78**

8-30-02

GPRA 2004 PROJECTED PROGRAM BENEFITS - OIT PLUS ELEMENTS NO LONGER IN OIT

Planning Element	YEAR 2010			YEAR 2020			YEAR 2030		
	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)
Aluminum	22	0.09	0.55	199	1.01	5.25	144	0.80	3.21
Chemicals	67	0.23	1.14	787	2.89	12.61	410	2.11	7.44
Forest Products	14	0.04	0.15	267	0.67	2.74	371	1.06	3.80
B.L. Gasification*	26	0.13	0.54	621	3.50	12.08	966	5.67	18.79
Glass	8	0.03	0.12	68	0.29	0.87	18	0.08	0.25
Metal Casting	23	0.11	0.47	101	0.53	1.83	116	0.62	2.08
Steel	43	0.12	0.93	212	0.62	6.52	39	0.11	1.60
Mining	29	0.15	0.60	205	1.19	4.05	458	2.82	9.06
Bio-based Products*	76	0.13	0.45	948	2.66	10.05	1,832	8.69	28.22
Petroleum Refining	34	0.12	0.52	175	0.72	2.83	119	0.56	2.29
IOF Specific S/T	*342*	*1.15*	*5.47*	*3583*	*14.08*	*58.83*	*4473*	*22.52*	*76.74*
Ind. Materials	19	0.05	0.21	280	0.94	3.71	393	1.18	4.14
Sensors & Controls	8	0.03	0.16	47	0.21	0.88	5	0.03	0.10
Combustion	18	0.06	0.26	587	2.29	8.58	534	2.34	7.76
C/C R&D Subtotal	*45*	*0.14*	*0.63*	*914*	*3.44*	*13.17*	*932*	*3.55*	*12*
IAC	38	0.23	0.71	57	0.37	1.03	59	0.42	1.08
Inv. & Innov.*	207	1.07	3.95	2,190	13.78	42.72	1,558	11.03	30.61
NICE3*	5	0.02	0.08	45	0.22	0.76	38	0.19	0.62
Best Practices	633	3.78	11.57	949	6.16	17.01	949	6.66	16.97
TA Subtotal	*883*	*5.1*	*16.31*	*3241*	*20.53*	*61.52*	*2604*	*18.3*	*49.28*
IOF Crosscut S/T	*928*	*5.24*	*16.94*	*4155*	*23.97*	*74.69*	*3536*	*21.85*	*61.28*
Total	**1270**	**6.39**	**22.41**	**7738**	**38.05**	**133.52**	**8009**	**44.37**	**138.02**

*Shown only for comparison with earlier years. These planning elements will not be included in OIT GPRA 2004 portfolio.

GPRA 2004 QUALITY METRIC (QM) TRENDS – OIT PROGRAMS

Planning Element	2010 Energy Savings (TBtu)			2020 Energy Savings (TBtu)			2030 Energy Savings (TBtu)		
	'02 QM	'03 QM	'04 QM	'02 QM	'03 QM	'04 QM	'02 QM	'03 QM	'04 QM
Aluminum	78	76	22	238	194	199	479	365	144
Chemicals	112	233	67	592	786	787	1,221	1,652	410
Forest Products w/o B.L.	101	80	14	330	258	267	600	487	371
Glass	21	31	8	81	79	68	145	130	18
Metal Casting	18	35	23	71	75	101	130	117	116
Steel	59	71	43	178	151	212	263	219	39
Mining	28	76	29	118	167	205	204	239	458
Petroleum Ref.	120	36	34	466	122	175	767	234	119
IOF Specific S/T	*537*	*638*	*240*	*2074*	*1832*	*2014*	*3809*	*3443*	*1675*
Industrial Materials	22	74	19	86	207	280	146	362	393
Sensors & Controls	6	9	8	23	37	47	32	47	5
Combustion	21	34	18	103	106	587	190	183	534
C/C R&D Subtotal	*49*	*117*	*45*	*212*	*350*	*914*	*368*	*592*	*932*
IAC	44	40	38	61	58	57	62	59	59
Best Practices	175	169	633	338	438	949	501	707	949
TA Subtotal	*219*	*209*	*671*	*399*	*496*	*1006*	*563*	*766*	*1008*
IOF Crosscut S/T	*268*	*326*	*716*	*611*	*846*	*1920*	*931*	*1358*	*1940*
Total	805	964	956	2685	2678	3934	4740	4801	3615

Explanation of increases from GPRA 2003:

- Combustion – Analysts report that correction of an order-of-magnitude capacity factor error in GPRA 2003 worksheet for the Super Boiler project causes the increase.
- Best Practices – Increase is based upon a report by D. Jones, et. al., Oak Ridge National Laboratory, "Preliminary Estimation of Energy Management Metrics for the Best Practices Program," May 2002, with additional OIT staff assumptions.

GPRA 2004 QM TRENDS – OIT PLUS ELEMENTS NO LONGER IN OIT

Planning Element	2010 Energy Savings (TBtu)			2020 Energy Savings (TBtu)		
	2002 QM	2003 QM	2004 QM	2002 QM	2003 QM	2004 QM
Aluminum	78	76	22	238	194	199
Chemicals	112	233	67	592	786	787
Forest Products w/ B.L.*	277	187	40	1500	971	888
Forest Products w/o B.L.	101	80	14	330	258	267
Black Liquor Gasification*	176	107	26	1,170	713	621
Glass	21	31	8	81	79	68
Metal Casting	18	35	23	71	75	101
Steel	59	71	43	178	151	212
Mining	28	76	29	118	167	205
Bio-based Products*	15	189	76	100	545	948
Petroleum Ref.	120	36	34	466	122	175
IOF Specific S/T	*728*	*934*	*342*	*3344*	*3090*	*3583*
Industrial Materials	22	74	19	86	207	280
Sensors & Controls	6	9	8	23	37	47
Combustion	21	34	18	103	106	587
C/C R&D Subtotal	*49*	*117*	*45*	*212*	*350*	*914*
IAC	44	40	38	61	58	57
Inv. & Innov.*	21	112	207	108	283	2,190
NICE3*	9	45	5	44	121	45
Best Practices	175	169	633	338	438	949
TA Subtotal	*249*	*366*	*883*	*551*	*900*	*3241*
IOF Crosscut S/T	*298*	*483*	*928*	*763*	*1250*	*4155*
Total	1026	1417	1270	4107	4340	7738

*Planning elements not reported with OIT for GPRA 2004. These are included here only for comparison with prior years.

GPRA 2004 QUALITY METRIC (QM) TRENDS – % OF BUDGET REPRESENTED

Planning Element	% of Budget Represented			
	2001 QM	2002 QM	2003 QM	2004 QM
Aluminum	88	90	95	80
Chemicals	73	88	97	59
Forest Products	88	96	98	74
Glass	54	90	86	90
Metal Casting	52	81	95	83
Steel	45	60	80	42
Mining	42	70	80	76
Petroleum Ref.	63	90	86	100
Industrial Materials	70	60	75	53
Sensors & Controls	90	90	90	73
Combustion	na	na	60	80
IAC	na	na	na	na
Best Practices	na	na	na	na

Appendix B – Technology Impact Projections Model

A copy of the Excel-based Impact Projections Model spreadsheet system is available as a separate file called *GPRA 2004shell v5.3 06212002*.

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 Office of Industrial Technologies (OIT). 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 should use the Technology Impact Projections model to estimate program benefits. Use of the model across all projects allows OIT to estimate the benefits of its projects in a consistent manner. The model allows you to enter key information about your proposed technology and its expected market, and then calculates the potential energy savings, cost savings, emission reductions and other project benefits.

Please provide your best estimate for each piece of information required to complete the spreadsheet (highlighted with light yellow shading). Be realistic about your estimates: if you are awarded a contract, you will be required to update this information annually. Note that not all inputs are necessarily applicable or available for all possible technologies. If you can only estimate the differential between the proposed new and the current state-of-the-art technology, reflect that in the spreadsheet by setting values for the current technology to "0". Also note that the Supplementary Table ("Additional Data" tab) only appears if non-zero values are entered for use of feedstocks, biomass, waste, or "other" energy forms. This table requests information on emission factors and costs for those energy forms.

Description

Provide an overview of the project/technology. This includes the project name, OITIS number (once project is funded), who prepared the estimates, program manager, planning unit, lab and industry contacts, and data sources.

Also provide a short summary of the technology upon which benefit estimates are based. Describe what constitutes a typical process unit for your technology, in terms of annual output (production capacity times duty factor). For simplicity, the analysis will assume that all units in the industry have the same capacity. A realistic, average, or typical unit capacity should be 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 should be equal in output capacity, even if, in reality, the new technology might have a different 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 non-physical technique. In such cases, a unit should be 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 would then be compared with annual energy consumption required by existing techniques.

Unit Inputs

Please provide key information on the performance of single installed units or applications of your technology. The performance of the new technology should be consistent with the performance goals in your proposal. For comparison, provide information on the performance of the best available technology for the application, not the average of all in-place technology units.

Energy Use

Please provide energy use per year for the new and conventional units, by fuel. Please also indicate the price of any feedstock, biomass, waste, and other fuels on the supplementary table (Additional Data tab). Prices for waste used as fuels may be negative, reflecting the avoided cost of conventional waste disposal.

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 non-energy 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 by-products. Examples of such fuels are refinery fuel gas, blast furnace gas, hog & 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. Note that the primary equivalent of direct electricity consumption includes losses in electricity generation and distribution.

Energy use may be entered in physical units (e.g., billion cubic feet of natural gas) or primary units (trillion Btu). The exception is electricity use, which has to be entered as site energy consumption (either in billion kwh or trillion btu). Physical units is the default value for all energy use. To change to trillion btu, select the appropriate fuel (electricity, natural gas, etc.) and then select either physical units or trillion Btu from the pull down list.

Environmental

Environmental impacts of your new technology can generally be divided into impacts that are a direct result of energy savings and non-energy-savings-related emissions impacts. The energy-savings-related environmental emissions are calculated automatically by the spreadsheet from the energy savings (and fuel substitutions or use of biomass) and typical emissions factors for fossil fuels and electricity use. If your technology results in changes to consumption of feedstocks, biomass, wastes, or other fuels then you will need to enter appropriate emission factors for those fuels on the supplementary table.

Please provide estimates for non-combustion related emissions and non-energy-related waste production associated with the new and conventional technologies.

Other Greenhouse Emissions Displaced
Estimate of the amount of greenhouse emissions other than CO2, Nox, and VOCs if germane to your technology. These could include methane, perflourocarbons, or other gases. Identify which gas in the Description sheet.

Cost and Lifetime

Please provide rough estimates of the initial capital cost, operation and maintenance costs, non-energy variable costs, and lifetime associated with your technology new and old on a per-unit basis. Non-energy costs should include improvements to productivity that may not be captured in the O&M costs.

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 to the likely actual market, and estimate when and the rate at which the new technology will penetrate the market.

Total Market

The next step in projecting the overall potential impact of your technology is to identify the total market: the number of units that perform the same task as your proposed technology. Only the domestic U.S. market should be included. World market and export potential are important factors which may be considered separately, but this analysis is to estimate domestic energy and emissions reduction impacts.

Number of Installed Units in US Market
Please define that market as narrowly as possible: i.e. the smallest group of applications that covers all potential applications that you may have some data for. 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. Please provide a citation for the number of units in the comments section. Please also indicate for which year the data that you provided applies.

Annual Market Growth Rate
This should be based on an EIA or industry growth projection for the relevant industry. Please provide a citation for the growth rate in the comments section.

Market Share

Market share is a function of the potential accessible market share and the likely market share.

Potential Accessible Market Share
Please estimate 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 only be applicable 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, your 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 your estimate 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.

Savings Attributed to Program

In some instances a program may be developing a technology in conjunction with another OIT, EERE, or DOE program. If this is the case, please 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% has been entered in the model.

Market Penetration

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.

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. Please note that two values for a commercial introduction year are requested. One should reflect when the technology is projected to be introduced if the program proceeds as expected (With OIT case). The other should reflect when the technology would have entered the market if the program had not been involved (Without OIT case). If the technology would not have been commercially introduced without the program, then enter a year of 2050 for the Without OIT case. The difference in commercial introduction years for the With OIT and Without OIT cases is referred to as the acceleration period.

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. Of importance is the major portion of the "s" curve where the new technology is penetrating the market and benefits are being reaped. The rate at which technologies penetrate their markets varies significantly: penetrations 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 economic, environmental, competitive position, productivity, regulatory, and other factors.

To assist you, 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. In Table I, circle the class (column) which you believe your technology best fits for each characteristic (row). 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, one can, based on best judgment and experience, select the most likely class (rate) at which the new technology may penetrate the market. This may be a "subjective average" of the circled best fits, 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 in the future for other reasons. The proposer should insert into the spread sheet 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 I.

For additional assistance, Table II 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.

Expenditure Inputs

The benefits of a project need to be assessed relative to its costs. Please provide information on the level of funding for the project by EERE, other government agencies, and the private sector for the appropriate years. This should be entered under the "With OIT" area on the expenditure inputs sheet. Nominal dollar values should be entered.

Background

Please provide calculations that support the information entered into the unit inputs and market inputs sheets.

Impact Projections

The spreadsheet, based on the unit performance, market size, commercial introduction, acceleration period, and penetration rate class, calculates the estimated benefits which the new technology may bring to the industry and to the nation. Annual, cumulative and lifetime benefits are calculated for energy savings, cost savings, and emission reductions.

Table I. Selecting the Market Penetration Rate Class

Characteristic	A	B	C	D	E
Time to Saturation (ts)	5 yrs	10 yrs	20 yrs	40 yrs	>40 yrs
Technology Factors					
Payback* discretionary	<<1 yrs	<1 yrs	1-3 yrs	3-5 yrs	>5 yrs
Payback* non-discretionary	<<1 yrs	< 1 yrs	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	++	++	++	+	O / -
Impact on plant productivity	++	++	++	+	O / -
Technology experience	New to US only	New to US only	New to industry	New	New
Industry Factors					
Growth (%p.a.)	>5%	>5%	2-5%	1-2%	<1%
Attitude to risk	open	open	cautious	conservative	averse
External Factors	forcing	forcing	driving	none	none
Gov't regulation					
Other					

* Payback is defined as capital outlay for new technology divided by savings before taxes and depreciation. In the case of Discretionary investments (i.e. replacements of existing equipment before the end of its economic life), capital outlay is total cost of new technology. In the case of non-discretionary investments (i.e. replacements of existing equipment at the end of its economic life and new installations), capital is the capital cost of the new technology - capital cost of current technology.

Table II. Examples

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	
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, Hightop 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

Appendix D – Renewables Technologies

Final Documentation Report for

FY2004 GPRA Metrics

Subtask 5

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared for:

National Renewable Energy Laboratory
and
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:

Princeton Energy Resources International

February 2003

Table of Contents

Overview of FY 2004 Benefits Analysis

The Office of Energy Efficiency and Renewable Energy's (EERE) Renewable and Distributed Energy R&D programs manage research in two broad areas: 1) Energy Supply Technologies; and 2) Electricity Delivery. Several different approaches are required to estimate the benefits of this wide array of programs. The analytical approaches used for FY 2004 are documented in this report, as are the results of these analyses. This chapter provides a broad overview of the approaches taken for each of the two EERE research areas. Greater detail for each EERE Renewable and Distributed Energy program is provided later in this report in program-specific discussions.

Energy Supply Technology Programs

EERE manages six renewable energy technology programs – photovoltaics (PV), biopower, wind, geothermal, solar buildings and hydropower. The five electricity-generating technologies (not including hydropower which is not part of this analysis) were analyzed within the segmentation framework shown in Figure 1. The Solar Buildings program benefits, although shown in Figure 1, were analyzed using a different approach because solar building technologies produce thermal energy and not electricity. This different approach is described later in this report in the Solar Programs chapter. The benefits of the Distributed Energy and Electric Reliability (DEER) program are also estimated as part of the framework shown in Figure 1.

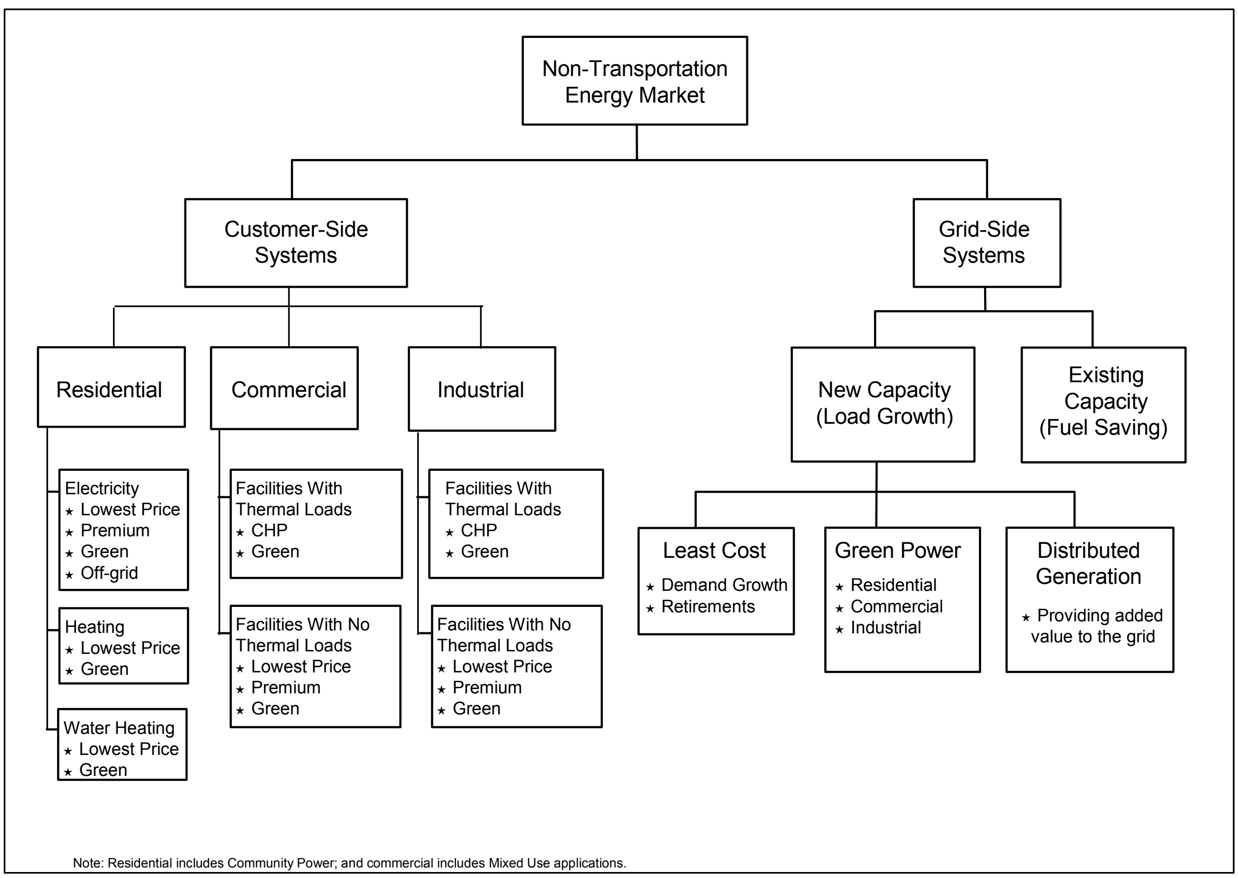

Figure 1 – Market Segmentation for EERE's Renewable and Distributed Energy Programs' Benefits Analysis

The U.S. non-transportation energy market was segmented into: 1) Grid-Side Systems -- systems that are on the grid side of the meter, and owned by utilities or other power suppliers; and 2) Customer-Side Systems -- systems installed at customer locations on the customer side of the meter. Figure 2 shows how the various market segments were analyzed to calculate EERE's Renewable and Distributed Energy programs benefits.

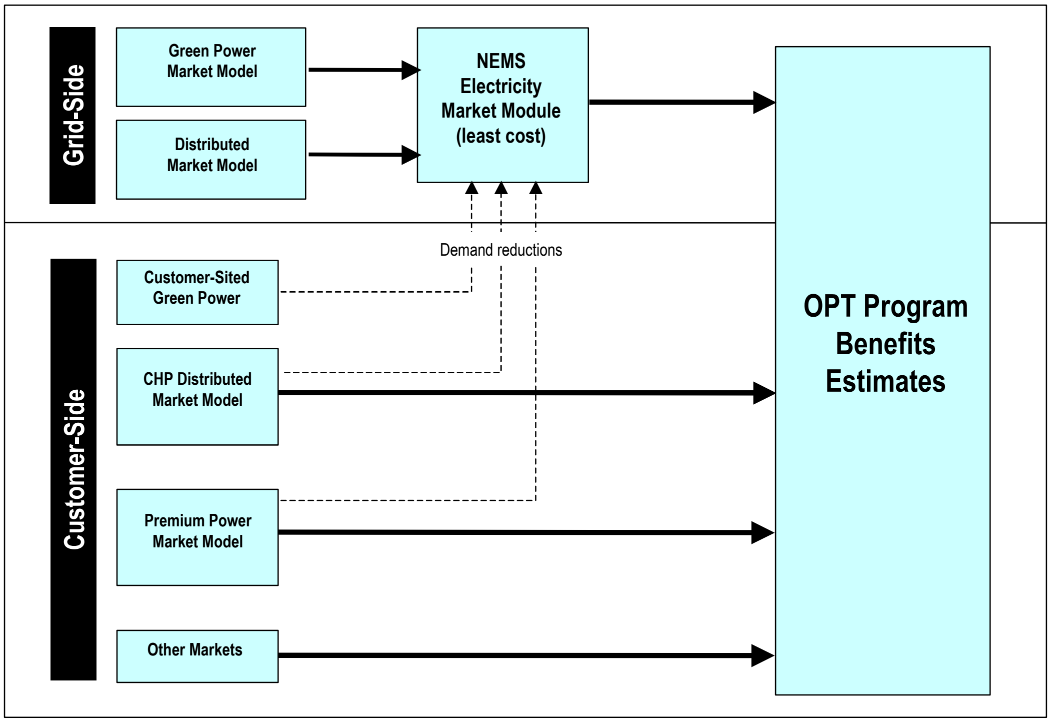

Figure 2 - Analysis Framework for Estimating EERE's Renewable and Distributed Energy Programs Benefits

<u>Grid-Side Market Segment</u>

Figure 3 shows a detailed breakout of the Grid-Side Market segment. The five electricity-generating technologies fall into three primary market segments as follows:

Least-Cost Power

The least cost segment refers to the bulk power market, which has traditionally been the province of the regulated utility industry. In analyzing this segment, growing demand and the need to replace retiring plants is met by projecting the installation of a mixture of power plants. The mixture chosen to meet this growing demand may have many attributes, but the primary one is that the lowest-cost option is typically selected through a detailed analysis process that compares all available options, both renewable and conventional.

Although this segment of the market may in the future be implemented through competitive bidding into a power pool or through bilateral contracts between suppliers and consumers, it will still be likely that the lowest cost option will capture the largest portion of the market. This segment of the market also includes renewables that could be installed to supply electricity at a cost lower than the variable operating cost of existing capacity (commonly referred to as the fuel-saving mode).

For EERE's Renewable and Distributed Energy programs analyses, the National Energy Modeling System (NEMS) is used to estimate future generating technology use in this market segment. This is the same analysis approach as that used by EIA for the Annual Energy Outlook, and EIA's Annual Energy Outlook (AEO) 2002 reference case is used as the baseline for this analysis. OnLocation, Inc. (OnLocation) runs NEMS for EERE, making significant modifications to EIA's technology assumptions and EIA's approaches to characterizing renewables' ability to compete in the competitive market creating NEMS-GPRA04. These changes are believed to characterize EERE's renewable technologies more accurately. An important change, which is common to all five generating technologies, is the use of technology data from the EPRI/DOE *Renewable Energy Technology Characterizations* report, or program updates to this report. The difference from the NEMS-GPRA04 run and the baseline AEO02 run represents the program's expected impact on the market.

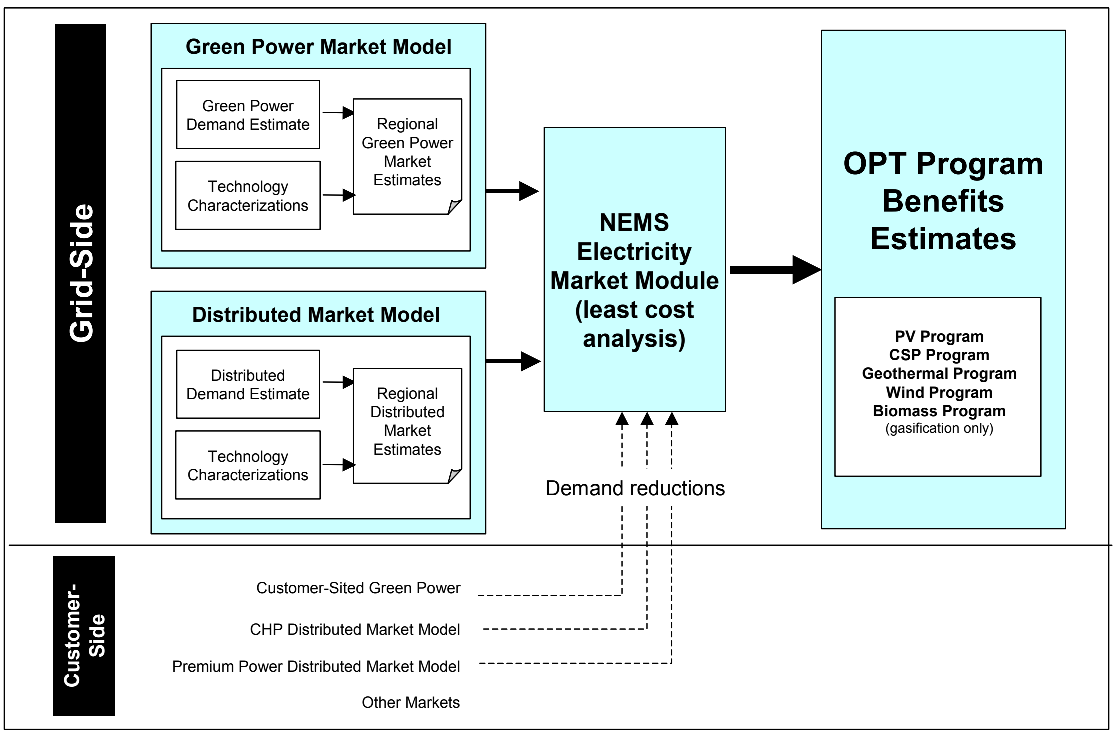

Figure 3 - Analysis Detail for Grid-Side Market Benefits Estimates

A variety of technology-specific changes have also been made. These changes had the greatest impact on the wind and geothermal technology projections, resulting in increased penetration of each when compared to the AEO projections. The technology-specific changes made are described in this report in the appropriate program discussion in later chapters.

Green Power

EERE sponsored the development of a Green Power Market Model (GPMM) by Princeton Energy Resources International (PERI). In this model, the projected green power market size is allocated to the various EERE renewable technologies using an algorithm similar to that, which is used by NEMS. The allocation is performed using a logit function approach to calculating market sharing. The logit function uses the various competing technologies' levelized cost of energy to determine which will be chosen by green power suppliers in a particular region to meet the demand for green power in that region.

The size and timing of the overall green market are key assumptions made for this analysis. The set of assumptions for electricity market restructuring from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*, a recent report by Blair Swezey et al. completed for the National Renewable Energy Laboratory (NREL), continued to be used for this year's analysis. (4) These assumptions include the dates for initiation of market restructuring as well as the assumed green power penetration rates, a change in the time periods tracked in the analysis, and a new method for calculating funds from program participants.

Several changes from last year's assumptions have been included this year. New technology characterizations for wind, class 4 and 6 data averaged, and CSP, trough and power tower data, were taken from program revisions to the *Renewable Energy Technology Characterizations*. Additionally, the regional economic sectors' energy consumption and prices were updated according to the new Energy Information Administration's (EIA) assumptions for the *Annual Energy Outlook 2002* (AEO 2002). Finally, PERI included both additions and subtractions to the green capacity values for the Million Solar Roofs (MSR) capacity additions, and EIA "floors" builds.

A detailed discussion of this analysis and its results can be found in Appendix C. The results of the GPMM runs were explicitly included in the NEMS runs by specifying the green capacity as planned capacity. The effect of this exogenous determination is to reduce future levels of new demand such that when NEMS is run the projections of new conventional capacity and new least-cost renewables are lower than in the base case where no green capacity is explicitly included.

Distributed Generation

Grid-Side Distributed Generation Market benefits are realized when technologies are strategically installed in locations where they can provide benefits to the distribution system beyond the basic commodity supply benefits. An example of such a benefit is the ability to defer, or potentially avoid, a distribution system upgrade. This Distributed Generation Market has yet to materialize for renewables, although a number of EERE programs are working to facilitate renewable penetration into this sub-segment.

<u>Customer-Side Market Segment</u>

Figure 4 shows a detailed breakout of the Customer-Side Market segment.

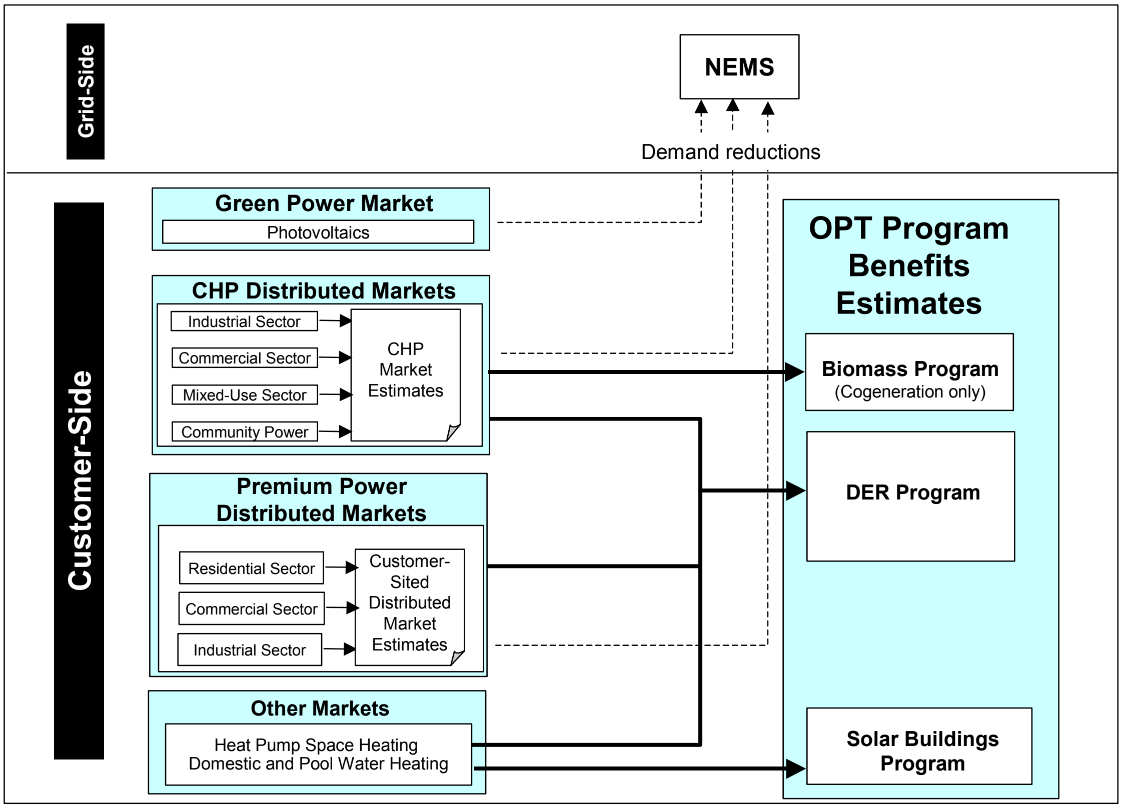

Figure 4 - Analysis Detail for Customer-Side Benefits Estimates.

Green Power

Photovoltaics (PV) was the sole option examined for residential and commercial customer-side green power installations. Although other renewable technologies may well be installed in the residential and commercial sub-segments in the future, PV appears to be at the moment the only technology with significant early market momentum, largely due to the Million Solar Roofs (MSR) program. There may also be small numbers of customer-sited PV systems that are not actually owned by the customer. The extent of PV penetration into the customer-sited market segment was projected to be very closely tied to the 2010 goal of the MSR program.

Overall, although customer-sited PV systems represented the vast majority of projected PV installations for the FY 2004 benefits analysis, customer-sited renewables accounted for only a small portion of all projected renewable penetration.

Combined Heat and Power

The Customer-Side Market segment also includes combined heat and power (CHP, or cogeneration) applications. In these applications, commercial and industrial facilities are equipped to produce both power and thermal energy. The DEER program's benefits are estimated by the NEMS for this market segment. Also estimated as part of the CHP market, biomass cogeneration in the industrial market sub-segment was the other customer-sited renewable technology analyzed. Biomass cogeneration is reported as part of the DEER benefits, and not in the biopower program's benefits totals. This application is particularly suitable to pulp and paper mills, where a prevalence of free fuel, in the form of biomass waste, and the need for process heat makes cogeneration particularly attractive. This market opportunity for biopower increased rapidly in the 1980s with the enactment of PURPA, but as PURPA expired and sites with the greatest potential had been used, the market opportunity has leveled off. The Energy Information Administration (EIA) using NEMS projects only modest future expansion in this sub-segment. The other biopower technologies: direct-fired, and gasification-based generation are electricity-generating technologies and are handled under the grid-side market segment.

Premium Power Distributed

On the Customer-Side, there are opportunities for providing power in applications where the customer is willing to pay a premium for higher quality power, for power with higher reliability, or for power with greater certainty of future price stability. There is no projected penetration of renewable energy power technologies into this market segment for GPRA reporting. More-conventional technologies, using natural gas, were deemed more likely to be used for premium power applications for the foreseeable future. Although not modeled, it should be noted that some "conventional" DEER technologies could also meet the needs of this market.

Other Markets

Other Markets in the Customer-Side Market include markets for solar domestic hot water (SDHW) and solar pool heating (SPH) technologies. These two technologies comprise the Solar Buildings program and represent almost the entire end use for solar thermal collectors. Benefits are derived from the natural gas and electricity displaced that conventionally fuels these heating requirements.

Electricity Delivery Programs

The benefits of the EERE electricity delivery programs cannot be estimated within the framework described above, and must be estimated using various techniques developed by program personnel or their contractors. Many of the programs formerly reported separately under Electricity Delivery Programs, such as High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation, have been incorporated into the new DEER program. As such, the benefits of these programs are reported under the DEER program. DEER benefits are calculated from the CHP capacity and generation additions modeled in NEMS. Additionally, the Hydrogen program does not receive any credit for hydrogen fuel cell penetration expected in the CHP market. This capacity is credited to the DEER program.

Table 1 summarizes the current status of programs formerly reported under the Electricity Delivery Programs, and the approaches now used to characterize their benefits for this analysis.

Table 1. Approaches Used For Prior Benefits Estimates of EERE Electricity Delivery Programs.

Program Element	Benefits Estimation Approach
Hydrogen	For FY2004, the program's benefit analysis was done by characterizations from OTT. In year's past, OPT had PERI do an off-line analysis of fuel cell and electric cars, with a portion of the benefits given to the hydrogen program. A market penetration model was developed to estimate the penetration of fuel cell-powered passenger cars and SUVs into both high-value and ZEV mandate markets. In the FY2003 analysis, the Hydrogen program claimed a portion of the benefits of the DER program from 2015 to 2030, with the reasoning that hydrogen technologies are expected to penetrate in this market segment in the form of hydrogen-fueled fuel cells. However, in the FY2004, all hydrogen fuel cell capacity penetration is credited to the DEER program.
High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation	These programs are now included in the DEER program. All benefits are characterized in the DEER program chapter.

Program Summary Tables

A summary of the estimated benefits from the Energy Supply Technology Programs is presented in Table 2. The table shows capacity projections which are cumulative, but that have been calculated against the *AEO 2002* baseline. In other words, these results do not include the installed capacity base as of the end of 2002 or the capacity projected in the *AEO 2002*. These capacity projections form the basis for the estimation of the various GPRA metrics for the five generating technology programs: Photovoltaics, Biomass, Wind, Geothermal and DEER.

Annual electricity production for each technology was estimated in NEMS from these capacity projections, and from appropriate capacity factors for each technology. From the annual energy production, primary energy displacement, energy cost savings, carbon displacement, NOx displacement, and SOx displacement were calculated. The *GPRA Data Call: Fiscal Year 2004* guidance document (Appendix D) was used as the source for information on fuel mix displaced, emissions factors, average grid heat rates, fuel prices, etc.

Table 2. Summary of Benefits Estimates for Energy Supply Technology Programs

	2005	2010	2015	2020	2025	2030
Cumulative Capacity Installed above AEO 2002 Baseline (thousands of MW)						
Photovoltaics	0.20	0.95	2.95	4.95	7.00	9.00
Biopower	0.05	0.19	0.37	0.55	0.75	0.90
Wind	1.50	4.65	19.2	33.8	48.5	63.0
Geothermal	0.05	1.80	4.20	6.65	9.10	11.6
Distributed Energy and Electric Reliability	2.30	7.45	16.3	25.0	33.8	42.6
Annual Energy Production (billions of kilowatt-hours/year)						
Photovoltaics	0.35	1.75	5.30	8.85	12.4	16.0
Biopower[1]	0.32	1.30	2.45	3.65	4.85	6.05
Wind	8.05	22.8	85.5	148	211	273
Geothermal	0.40	14.6	34.2	54.0	73.5	93.0
Distributed Energy and Electric Reliability	16.7	54.0	117	180	243	307

1) Biomass Direct Electricity Displaced does not include generation from cofiring capacity, as this is not new capacity, but rather is considered to be a fuel switch for existing or planned capacity, which is addressed as fossil energy displacement.

Table 2. Summary of Benefits Analyses for Energy Supply Technology Programs (cont.)

	2005	2010	2015	2020	2025	2030
Annual Primary Energy Displacement (Trillion Btu/year)						
Total Solar Program	4.00	23.0	66.7	113	164	219
Solar Buildings	0.30	7.45	22.9	42.7	66.0	92.0
Photovoltaics	3.70	15.6	43.8	70.0	98.0	127
Biopower[2]	3.55	12.2	21.5	30.3	40.2	50.0
Wind	59.0	157	655	1,115	1,610	2,105
Geothermal	4.25	132	283	425	580	735
Distributed Energy and Electric Reliability	177	294	550	775	1,045	1,315
Annual Energy Cost Savings (billions of dollars/year)						
Total Solar Program	10.0	52.7	176	322	494	696
Solar Buildings	0.75	17.1	60.5	122	199	294
Photovoltaics	9.20	35.7	116	200	296	403
Biopower	-1.65	-13.9	-18.1	-14.8	-8.05	5.15
Wind	146	359	1,725	3,180	4,840	6,695
Geothermal	10.6	301	745	1,215	1,745	2,340
Distributed Energy and Electric Reliability	0.50	1.55	3.35	5.25	7.05	8.80
Annual Carbon Displacement (million metric tons of carbon equivalent/year)						
Total Solar Program	0.08	0.48	1.31	2.20	3.20	4.25
Solar Buildings	0.01	0.16	0.46	0.85	1.30	1.80
Photovoltaics	0.07	0.32	0.85	1.35	1.90	2.45
Biopower	0.07	0.25	0.43	0.60	0.80	0.95
Wind	1.10	3.20	13.0	21.7	31.3	40.9
Geothermal	0.08	2.70	5.60	8.25	11.3	14.3
Distributed Energy and Electric Reliability	2.60	7.70	14.4	20.1	27.1	34.1

2) Biopower benefits are cited in terms of Fossil Fuel Energy Displaced because biomass is, itself, a primary energy source.

Table 2. Summary of Benefits Analyses for Energy Supply Technology Programs (cont.)

	2005	2010	2015	2020	2025	2030
Annual SO_x Displacement (millions of metric tons/year)						
Total Solar Program	0.001	0.007	0.019	0.030	0.043	0.057
Solar Buildings	0.000	0.002	0.007	0.011	0.017	0.024
Photovoltaics	0.001	0.005	0.012	0.018	0.026	0.033
Biopower	0.001	0.003	0.004	0.005	0.007	0.009
Wind	0.014	0.049	0.185	0.292	0.421	0.551
Geothermal	0.001	0.041	0.080	0.111	0.152	0.193
Distributed Energy and Electric Reliability	0.050	0.181	0.337	0.469	0.633	0.796
Annual NO_x Displacement (millions of metric tons/year)						
Total Solar Program	0.001	0.004	0.012	0.019	0.028	0.038
Solar Buildings	0.000	0.001	0.004	0.007	0.011	0.016
Photovoltaics	0.001	0.003	0.008	0.012	0.017	0.022
Biopower	0.000	0.002	0.003	0.004	0.005	0.006
Wind	0.010	0.029	0.117	0.192	0.277	0.362
Geothermal	0.001	0.025	0.050	0.073	0.100	0.126
Distributed Energy and Electric Reliability	0.024	0.077	0.142	0.198	0.266	0.335

FY2004 GPRA METRICS
SOLAR PROGRAM
SUB-PROGRAM: SOLAR BUILDINGS

Table 1. Summary of Solar Buildings Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Thousands of systems above Baseline)						
DHW	3.50	202	764	1,526	2,365	3,277
Pool Heating	3.50	40.9	93	159	243	350
Total (may not add due to rounding)	7.00	243	857	1,685	2,608	3,627
Annual Benefits						
Energy Displaced (TBtu)	0.30	7.45	22.9	42.7	66.0	92.0
Energy Cost Savings (millions of 2000 $)	0.75	17.1	60.5	122	199	294
Carbon Displaced (MMCTE)	0.01	0.16	0.46	0.85	1.30	1.80

Market Segments

The solar buildings program includes technologies for solar domestic hot water (SDHW) and solar pool heating (SPH) in residential and commercial buildings. According to EIA data,[1] SPH is the largest end use for solar thermal collectors, representing 95% of the total square feet shipped in 1999. SDHW accounted for nearly all the rest of the market, with only 0.5% for other uses such as space heating. The residential market accounts for more than 90% of each of these end uses. The FY2004 GPRA projections differ from those of FY2003 by including only market quantities and impacts due to DOE programs; specifically, they include only the low-cost polymer solar domestic water heater and the solar pool heater produced in colors other than black to allow wider architectural acceptance. Conventional SDHW and black SPH systems are counted in the baseline. As discussed below, the SDHW is assumed to compete with electric water heating, and the SPH competes with natural gas.

Princeton Energy Resources International (PERI) performed this exogenous model with the resulting penetration reported to OnLocation for inclusion in the NEMS baseline (AEO02) and program (GPRA-NEMS04) runs. OnLocation reduced the results of exogenous models for all programs by 30% across the board as a way of conservatively accounting for likely economic interactions within markets that often cannot be specifically identified without fuller modeling. The unit penetrations reported in Table 1, and the resulting benefits, represent this 30% reduction from the PERI modeled values, which are presented in the remainder of this section.

System Definition and Economics

Solar Domestic Hot Water

Typical residential SDHW systems have collector area ranging from 40 to 80 square feet, depending on geographic location, and costs ranging from $1,800 to $3,600.[2,3] Other studies show similar costs for conventional solar systems, although thermosiphon or integral collector storage (ICS) systems are available for about half that cost in package units with perhaps 20 square feet or less of collector area. The SWAP program in Florida recently installed 24 to 32 square foot direct pumped or ICS systems in low-income homes for $1400 to $1750.[4,5] A detailed analysis of a "traditional" ICS system found a total installed cost of $2800.[6] Note that 80% of solar collector sales (by square feet) went to five states: Florida (44%), California (25%), Arizona (5%), Hawaii (3%), and Nevada (3%).[7] Because most installations are in warmer climates, for this GPRA analysis it is reasonable to assume a cost of $3000 for an average SDHW system using 50 square feet of conventional collector technology.

The analysis assumes the introduction in 2005 of a low-cost polymer collector, which the Solar Buildings Program began developing in 1998 and which is now in prototype testing by two manufacturers. Because this is a storage-type collector, applications would be in milder climates. Existing flat-plate collectors cost about $17 per square foot[8], or about $42 per square foot after manufacturer profit and markups by the distributor and dealer/contractor, and the storage tank and other equipment add an additional $1200 or more.[9] The goal of the DOE program is to reduce the hardware and installation cost by half, using a lower-cost collector and storage tank and simpler installation techniques. Excluding marketing costs, it is estimated that the new system could be sold for $1000. Marketing for the conventional system, sold on an individual basis, is estimated at $800.[6] If the new system could be sold on a mass basis to builders, the marketing cost could be reduced greatly, by perhaps half for the overall market, giving a total cost of $1500 per unit, ranging down to $1000 for large purchases by builders.

For this GPRA analysis, the energy saved by the SDHW system is assumed to be 2,752 kWh per year. Because the warmer areas of the country have lower hot water use per capita and warmer supply water temperature, the actual water-heating load across the country is not uniform. This number corresponds to the national-average site electricity savings calculated by ADL, averaging the cases of high and medium water draw.[10] The ADL analysis was based on simulation model runs for five cities corresponding to the five DOE climate zones, although their method for determining the national average was not disclosed. A recent report by Antares, using data apparently based on the experience of the Sacramento Municipal Utility District, assumes an energy savings of 2,544 kWh per year, 8% lower than that used here.[11]

The solar fraction of an SDHW system is the percentage of water heating energy supplied by solar energy. For a typical SDHW system, the solar fraction is 60%, with the remaining 40% supplied by an auxiliary system, usually an electric heater. System cost decreases if the solar fraction drops below 50% and increases greatly if it is pushed to 80% or higher. The energy savings of 2,752 kWh corresponds to the 60% solar energy supplied by an SDHW system in a household with an average water heating load of 4,583 kWh, typical of a moderate U.S. climate.

Based on this annual energy savings and a residential electricity cost of $0.083/kWh in 2000 (AEO 2002, Table A3), the energy cost savings is $228 per year, giving a simple payback of 13 years for a $3000 current system. However, including an O&M cost for the solar system of $30 annually (based on maintenance once each three years)[12] raises the simple payback to 15 years, a number approaching the system lifetime of 15-30 years. The payback period decreases, however, in states of high electricity cost; for example, above $0.12/kWh (as in much of California or in Hawaii[13]) the payback is less than 10 years, with O&M included. For the polymer system, assuming an installed cost of $1400 per unit, the payback is cut in half, from 15 to 7.5 years, or only 5 years if marketing costs are minimal due to mass purchase.

In comparison with a gas water heater of 60% efficiency, the annual energy savings is $120 at a gas price of $7.64/MMBtu (AEO 2002, Table A3), making the payback greater than 30 years for the current SDHW system. Accordingly, the SDHW is not expected to compete well with natural gas. However, as Antares points out, recent rates of large California utilities are in the range of $16/MMBtu,[11] bringing the payback down to 14 years for a current system and similarly reduced for the polymer SDHW, comparable to the electric case. Nevertheless, in this GPRA analysis, which is based on EIA national energy price projections, only displacement of electric water heaters by SDHW is considered.

Solar Pool Heating

The SPH system consists of an unglazed solar collector, usually plastic. Water is circulated using the pool's existing pump, and the pool provides its own thermal storage. A "rule of thumb" is that the area of an SPH collector area must equal about 50 to 100% of the pool area to provide all the pool water heating requirements, and using a pool cover will reduce the SPH area required, so it is reasonable to assume an average of 75%.[14] For the average residential pool size of 576 square feet, as quoted by DOE's Reduce Swimming Pool Energy Costs (RSPEC) program, the required collector size is 432 square feet, the number used in the FY2003 and earlier GPRA analyses. However, the Solar Energy Industries Association (SEIA) states that the average SPH is 300 square feet, which will be used here.[15]

The present analysis assumes a typical residential SPH system cost of $3500, or just under $12 per square foot, based on SEIA data.[15] The FY2003 and earlier GPRA analyses assumed $4000. Note that according to EIA, the average price of the collector alone in 1999 was $2.08 per square foot, presumably wholesale.[8] This would imply that the final cost, including dealer mark-up and installation, is more than five times the collector price reported by EIA.

A typical SPH lifetime is 10 to 15 years[14] for a plastic or rubber collector, with the main problem being degradation by ultraviolet light. Because the system is so simple, there is little or no maintenance beyond that normally given to the pool's circulating system. Accordingly, this analysis assumes zero O&M costs for the SPH.[16]

Energy performance certifications of unglazed solar pool heating panels indicate that they produce an average of 1000 Btu per square foot per day, according to the Florida Solar Energy Center and the Solar Rating and Certification Corporation.[15,17] Assuming, as does SEIA, a very conservative use of five months per year, the 300 square foot SPH produces 150,0000 Btu/ft^2/year, or a total of 45 MMBtu/yr of thermal energy.

The energy displacement achieved was checked by estimating the solar resource available in a highly favorable location, Miami in this analysis. In that location, a latitude tilt collector receives 177 kWh/ft^2 annually of solar insolation, which is equivalent to 604,278 Btu/ft^2 annually. For six months of operation per year (during shoulder months), it was assumed that the solar insolation was 65% of the total annual. Combining this 65% factor with an annual average efficiency of 70%, one calculates a pool heating demand displacement of 275,000 Btu/ft^2/yr. This is nearly twice the average estimate above.

This GPRA analysis will use the conservative estimate of 150,000 Btu/ft^2/yr. Assuming that gas is displaced and that the gas burner would average an efficiency of 75%, the solar pool collector is assumed to displace 200,000Btu/ft^2/yr. Finally, with an average collector size of 300 ft^2, the annual displacement of primary energy is estimated to be 60 MMBtu (600 therms) per pool. At a natural gas price of \$7.64/MMBtu (AEO 2002, Table A3), this yields a payback of 7.6 years. Note that GPRA analyses for FY2003 and earlier assumed a much larger energy displacement of 1600 therms for a somewhat larger system of 432 ft^2.

In more favorable locations, the payback period would be shorter, about 4 years or less, making the SPH quite attractive. SEIA states that the payback is routinely two to three years. The FEMP program reports that SPH paybacks are frequently 2 to 4 years.[18]

The relatively static nature in prices of residential electricity and natural gas to 2030, to \$0.0774/kWh and \$7.22/MMBtu, respectively, will keep paybacks in this same range for future installations. However, local price increases will reduce the payback period.

The DOE program will develop SPH collector material by 2005 that can be made in various colors other than black, increasing the potential market by allowing greater architectural choices, while maintaining performance and cost.

This analysis does not consider non-residential pools, for which there are certainly some solar applications. For example, *Solar Today* mentions recent installations in the Bahamas and Mexico.[19] According to EIA[1], only 10% of the low-temperature collector shipments in 1997 went to non-residential markets, so their impact on national energy savings is small. The size of these commercial or municipal systems can be 10,000 square feet or more, raising questions of siting and pipe runs. Indoor pools in the U.S. now commonly use integrated heat pump systems for water heating, dehumidification, and air conditioning.

Installation Scenario

<u>Solar Domestic Hot Water</u>

According to EIA, a total of 400,000 square feet of solar collectors for medium-temperature liquids was shipped in 1999, excluding exports[1]. This corresponds to 6,200 to 10,000 SDHW units of common size (40 to 64 square feet). Based on data from the Solar Energy Industries

Association and assuming 50 square feet per system, the SDHW installations are estimated to be 8,448 units for 1998 and 8,000 units for 1999.[20]

In relative terms, this number is quite low. As ADL[21] points out, the overall target market of electric water heating installations is 4 million annually, of which 1.3 million are in single-family households. The ADL chart, "Proposed program goals are based on realistic market penetrations," goes on to state a target of 25,000 SDHW units for an unspecified year, presumably about 2003. EIA data[22] indicate that in 1983, the peak of the domestic SDHW market, the total square footage of medium-temperature collectors sold domestically was 9 million, corresponding to about 140,000 SDHW units (assuming 64 square feet each) or more. By the late 1980s more than a million units had been installed.[23]

The analysis described here assumes a baseline of 8,000 units per year of conventional SDHW sales. Although this number might be expected to grow somewhat over the years, it is also subject to decrease from competition with the polymer system, so for simplicity it is assumed constant. The polymer SDHW market was estimated by Antares[11] based on both new residential construction and retrofit primarily in 9 southern states, displacing electricity only. The fraction of the potential market taken by the polymer SDHW increases from an initial 4% in 2006 to 25% by 2010 and then a maximum of 50% by 2030. After a rapid start-up, annual growth of sales (annual increase in the number of installations in a given year when compared to the number of systems installed in the prior year) averages nearly 20% per year during 2010 - 2015 and finally declines to 2% per year by 2030. As a result, the annual installation rate follows an S-shaped curve. This GPRA scenario would achieve the ADL target level of 25,000 installations per year around 2007. The annual installations are estimated to rise to 228,000 by 2020 and 269,000 by 2030.

On a cumulative basis, the GPRA scenario reaches 500,000 installations by 2012, a strong contribution by solar thermal systems to the DOE Million Solar Roofs Program target. Cumulative installations exceed one million by 2020 and finally reach 4 million before 2030, or roughly 3-4% of single-family households.

This installation scenario is not directly tied to economics. As discussed above, the simple payback for the SDHW is in the range of 10-13 years. Previous renewable energy analyses for DOE[24] have used market penetration targets based on payback, ranging from 100% for a payback of 1 year or less down to zero penetration for a payback of 20 years or greater. For example, a payback of 3 years corresponds to 89%, 5 years to 66.5%, 7 years to 34%, 10 years to 15%, and 12 years to 9%. This implies that the projected market penetration is not unreasonable. Several programs and policies, none of which are modeled in this GPRA analysis, are likely to increase the market attractiveness of SDHW:

- The Database of State Incentives for Renewable Energy reports that 40 states are providing financial incentives for active solar water heating systems, up from the 30 states reported by EIA for 1996.[25,26] The impact of a tax credit is strong, as shown by the history of prior Federal and state tax credits in stimulating the solar water heating market from the mid-1970s to early 1980s. The Clinton Administration's proposed FY2000 Climate Change Budget originally included a 15% tax credit for rooftop solar systems, with a maximum credit of $1,000 for solar water heating systems placed in service from 2000-2004. In the Bush Administration, pending energy bills in both the Senate and the House include a 15% residential solar energy tax credit for 5 years for solar thermal systems.[27]

- The Energy Efficient Mortgage allows the cost of improvements that reduce the energy bill to be included in the home mortgage, thereby offering a lower interest rate and longer term of repayment that could stimulate the market for SDHW systems on both new and existing homes.

- As a part of utility restructuring and regulatory changes, System Benefit Charges or Renewable Portfolio Standards may be used to promote energy efficiency and renewable energy technologies, including solar water heating, although it is unclear what form these programs might take. On the other hand, to the extent that utility restructuring reduces electricity rates, it makes SDHW less attractive.

Solar Pool Heating

RSPEC data indicate that there are 5.6 million residential pools in the U.S., of which half are assumed to be heated. The National Spa and Pool Institute (NSPI) reports 3.6 million in-ground residential pools. NSPI also reports annual sales of 172,000 new in-ground pools in 1998, up from 120,000 in 1994, or about 5% of the existing stock. In-ground pools are more likely to be heated than aboveground pools. These two sources, taken together, suggest that there are some 2 million heated residential pools in the U.S.

The *Solar Today* and *Home Energy* articles both state that as of the late 1990s there were 300,000 solar pool heaters installed in the U.S. According to both NSPI and EIA[1], 8.1 million square feet of pool collectors were sold in 1999, up from 7.2 million square feet in 1998. After subtracting exports and assuming an average system size of 300 square feet, this corresponds to 25,480 SPH systems in 1999, compared with 23,174 units for 1998. Based on Solar Energy Industries Association data, the installations for 2001 are estimated to be 33,000 units, or about one-fifth of the 180,000 pool heating systems sold annually.[15] This amounts to less than 2% of the total potential market on an annual basis, or about 20% of the annual new pool sales, suggesting that the SPH market is established but far from saturated. Data for the First Quarter 2002 showed a strong increase, indicating that for the preceding 12 months sales were nearly 35,000 units.[28]

As discussed above, simple paybacks for SPH systems are often four years or less. Therefore, it is reasonable to expect a high level of market penetration. From the method used in previous renewable energy analyses and mentioned above, market adoption rates could be in the range of 75% or higher.

The SPH baseline assumes that installations have a flat 5% escalation rate (compared to prior year levels), comparable to the current growth rate in number of pools. This is a conservative estimate, given that for the last 3 years growth has been an average of 10-15% annually. Starting from the annual installation rate of 38,000 in 2004, this leads to an annual installation level of

83,000 in 2020 and 135,000 in 2030. Cumulative installations from 2004 grow to 0.3 million in 2010, 1.0 million in 2020, and 2.1 million in 2030.

The DOE program expands the market from this baseline by developing SPH collectors in colors other than black. Some 42 million Americans now live in community associations, which have increased from 10,000 in 1970 to over 200,000 today. A 2000 survey of 13 solar contractors in Arizona, California, and Florida installing 3,800 SPH systems per year, 65% of which are in areas subject to community association restrictions, found that architectural controls by these associations often limit the use of roof-top solar collectors.[29] Greater choice of color would offer a better chance of approval. Assuming that half of the potential SPH market nationwide is in such areas and that half of those could be approved with a color choice, then the impact of the DOE program is to add about 25% to annual installations.

Accordingly, the DOE program portion of the total SPH market is assumed to start from the annual installation rate of 5,000 in 2005 and grow to an annual installation level of 21,000 in 2020 and 34,000 in 2030. Cumulative installations grow to 0.06 million in 2010, 0.2 million in 2020, and 0.5 million in 2030.

Benefits

For purposes of this analysis, SDHW displaces electricity and SPH displaces natural gas. Based on the projections of SDHW and SPH installations from PERI, reduced by 30% by OnLocation, the primary energy, emissions, cost, and fuel displaced are calculated using the assumptions stated in the *GPRA Data Call: Fiscal Year 2004* (Appendix D). Table 2 shows the results of this analysis.

Table 2. Solar Program Benefits from the Water and Pool Heating Program

	2005	2010	2015	2020	2025	2030
DHW (thousands of units)	3.50	202	764	1,526	2,365	3,277
Pool Heating (thousands of units)	3.50	40.9	93	159	243	350
Energy Cost Savings (millions of 2000 $)	0.75	17.1	60.5	122	199	294
Carbon Emissions Displaced (MMTCE/year)	0.01	0.16	0.46	0.85	1.30	1.80
SO_2 Displaced (MMTCE/year)	0.000	0.002	0.007	0.011	0.017	0.024
NO_x Displaced (MMTCE/year)	0.000	0.001	0.004	0.007	0.011	0.016
Primary Energy Displaced (trillion Btu/year)	0.30	7.45	22.9	42.7	66.0	92.0
Direct Electricity Displaced (billion kWh/year)	0.01	0.55	2.10	4.20	6.50	9.00
Natural Gas Displaced (billion cubic ft/yr)	0.21	2.40	5.45	9.35	14.3	20.7

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FY2004 GPRA METRICS
SOLAR PROGRAM
SUB-PROGRAM: PHOTOVOLTAICS

Table 1. Summary of Photovoltaic Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.11	0.39	0.50	0.50	0.50	0.50
Green	0.07	0.07	0.23	0.39	0.48	0.60
Million Solar Roofs Initiative	0.02	0.50	2.25	4.10	6.00	7.90
Total (may not add due to rounding)	0.20	0.95	2.95	5.00	7.00	9.00
Annual Benefits						
Energy Displaced (TBtu)	3.70	15.6	43.8	70.0	98.0	127
Energy Cost Savings (millions of 2000 $)	9.20	35.7	116	200	296	403
Carbon Displaced (MMCTE)	0.07	0.32	0.85	1.35	1.90	2.45
Technology Indicators[1]						
Cost ($/kW)	2,930	2,150	2,055	1,615		
Capacity Factor (%)	20.8	20.7	20.7	20.7		
Levelized Cost of Energy (cents/kWh in constant 1997$)	20.4	12.8	12.0	9.55		
1) Based on weighting of Rooftop, Central Station Flat Plate and Central Station Concentrator technologies. *Renewable Energy Technology Characterization* data used for NEMS analysis (this report is currently being updated and the values may change).						

Market Segments

In FY 2004 analysis, the photovoltaic (PV) program is expected to penetrate the market through three market segments: the green power market, the least cost power market, and the recently completed Million Solar Roofs (MSR) initiative.

- Green Power - PV has an important role to play in the future green power market. However, at present, because it is significantly more expensive to install than several other green power options, few utilities or energy service providers are likely to choose PV as a way of meeting customer demand for green power. The GPMM reflects this fact by predicting very little penetration by PV in the green power market. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101). The MSR projections, described below, have been added to the results of the GPMM for inclusion in NEMS. Also, there is an additional 250 MW of central station PV "floor" capacity that is "assumed by EIA to be installed for reasons in addition to least-cost electricity supply" between 2001 and 2020. This "floor" capacity addition is prorated for 2004 to 2020 and subtracted from the GPMM and MSR numbers, as the "floor" capacity is viewed as EIA's attempt to account for these other penetration pathways. This final result was then "hard-wired" into NEMS by OnLocation. This analysis does not reflect the additional demand consumers may have for solar energy because it provides increased reliability of service, an emergency source of power, and/or an improvement in load management capabilities. As a result, the benefits reported here understate the likely demand for solar energy.

- Least Cost Power - This segment is unlikely to provide much market opportunity for PV due to the high COEs projected for the foreseeable future. To develop this estimate, NEMS was run using a composite cost and performance trajectory, reflecting the lowest COE in a given period, taken from the *Renewable Energy Technology Characterizations.* The maximum share for intermittent generation and the short-term cost multipliers that indicate how quickly the industry can increase without cost penalties are modified based on analysis undertaken by the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, and Princeton the Energy Resources International.

- Million Solar Roofs Initiative - The Million Solar Roofs initiative, which is scheduled to end in FY 2003, targeted the application of this technology to compete with retail electricity prices, not the very low competitive grid prices. The realization of MSR goals for PV, 600,000 systems installed by 2010, form the basis for the power penetration projected for MSR that are added to the GPMM projections to calculate FY 2004 benefits. Table 2 contains the MSR projections. 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 Program Capacity Projections

	Annual Growth Rate (% above prior year)	Incremental Annual Capacity (MW)	Cumulative Capacity above 2003 baseline (MW)
2000	20%	25	-
2001	21%	30	-
2002	22%	37	-
2003	23%	45	-
2004	24%	56	56
2005	25%	70	127
2007	26%	89	215
2007	27%	113	328
2008	28%	144	472
2009	29%	186	658
2010	30%	242	900
2011	20%	290	1,190
2012	15%	334	1,523
2013	10%	367	1,890
2014	5%	385	2,275
2015	0%	385	2,660
2016	0%	385	3,046
2017	0%	385	3,431
2018	0%	385	3,816
2019	0%	385	4,201
2020	0%	385	4,586

Benefits

- Primary Energy Displaced — Photovoltaics displace conventional electricity on a kWh for kWh basis. The lower capacity factor of photovoltaics does mean, however, that the energy production of a GW of PV is not equivalent to the output of the same capacity of conventional coal capacity. In calculating energy displacement an average grid heat rate is assumed according to the *GPRA Data Call: Fiscal Year 2004*, declining over time by about 25% from 10,713 Btu/kWh.

- Energy Cost Savings — Energy cost savings are derived from energy displacement and average costs of producing electricity according to the *GPRA Data Call: Fiscal Year 2004* were used.

- Carbon Displacement — PV systems displace the carbon that would have been emitted by conventional power plants in producing the electricity. Average grid carbon emission factors according to the *GPRA Data Call: Fiscal Year 2004* are used and declining grid heat rates work again to lower the carbon emissions factor.

FY2004 GPRA METRICS
BIOMASS POWER

Table 1. Summary of Biopower Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.00	0.00	0.02	0.11	0.26	0.41
Green	0.05	0.19	0.35	0.44	0.47	0.49
Other Biopower Initiatives	0.00	0.00	0.00	0.00	0.00	0.00
Total (may not add due to rounding)	0.05	0.19	0.37	0.55	0.73	0.90
Annual Benefits						
Fossil Fuel Energy Displaced[1] (TBtu)	3.55	12.2	21.5	30.3	40.2	50.0
Energy Cost Savings (millions of 2000 $)	-1.65	-13.9	-18.1	-14.8	-8.05	5.15
Carbon Displaced (MMCTE)	0.07	0.25	0.43	0.60	0.80	0.95
1) Biopower benefits are cited in terms of Fossil Fuel Energy Displaced because biomass has energy content associated with it.						
Technology Indicators[2]						
Cost ($/kW)	1,600	1,420	1,315	1,215		
Capacity Factor (%)	80	80	80	80		
Levelized Cost of Energy (cents/kWh in constant 1997$)	6.7	6.4	6.0	5.5		
2) Based on weighting of Gasification and Direct-fired technologies. *Renewable Energy Technology Characterization* data used for NEMS analysis. Levelized COE includes feedstock cost of $2.50/GJ at a heat rate of 9730 kJ/kWh in 2005 and 2010 and of 8760 kJ/kWh in 2015 and 2020.						

Market Segments

Biopower systems are expected to penetrate in two market segments: the green power market and the least cost power market. This expectation is due largely to biopower's competitive cost of energy.

- Green Power - In the GPMM, gasification and direct-fired technologies were considered. Gasification is an emerging technology that is expected to penetrate modestly in the Green Power market segment. Direct-fired biopower is a well-established technology expected to be used primarily in cogeneration applications at industrial locations, which are modeled under the DEER program analysis, but also expects some penetration through the green power market. Because biomass-generated electricity is so competitive economically and the resource widely available, it is projected to be installed as a green power option in every region of the country. Due to the revisions in the assumptions of sectoral energy consumption and prices, the estimates of green power capacity additions have been lowered for all technologies, when compared to last year's results. The cost and performance data in the *Renewable Energy Technology Characterizations* were used for both technologies. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101).

- Least Cost Power - Gasification is the only technology modeled in NEMS, representing the most likely technology configuration to be installed in future utility-scale biopower systems. Project contingency factors in NEMS have been set to zero (from their default value of 7%).

Benefits are calculated assuming that the gasification technology replaces a natural gas-fired turbine and the direct-fired technology displaces a coal boiler. Industrial biomass cogeneration applications are accounted for under the DEER program, and the biopower program is not given any credit for this capacity. The results of the analyses and key technology indicators are shown in Table 1. The results of the GPRA 2004 analysis have decreased in comparison to the GPRA 2003 reported figures.

FY2004 GPRA METRICS
WIND

Table 1. Summary of Wind Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.80	2.05	14.8	29.2	43.8	58.3
Green	0.70	2.60	4.35	4.60	4.70	4.95
Distributed	Included in green power					
Total (may not add due to rounding)	1.50	4.65	19.2	33.8	48.5	63.0
Annual Benefits						
Energy Displaced (TBtu)	59.0	157	655	1,115	1,610	2,105
Energy Cost Savings (millions of 2000 $)	146	359	1,725	3,180	4,840	6,695
Carbon Displaced (MMCTE)	1.10	3.20	13.0	21.7	31.3	40.9
Technology Indicators[1]						
Cost ($/kW)	900	835	825	805		
Capacity Factor (%)	42.0	48.1	48.7	50.5		
Levelized Cost of Energy (cents/kWh in constant 1997$)	3.0	2.6	2.6	2.5		

1) *Technology Indicators* data represents a weighted average of new wind turbine characteristics for Class 4 (5.8 m/s average wind speeds) and Class 6 (6.7 m/s) sites, as defined by program planning documents for the Low Wind Speed Turbine project. Weighting changes from 20/80 for class 4/class 6 in 2004 to 75/25 in 2030.

Note: The capacity, generation and benefits reported in the FY2004 Budget Submission documentation for this program include both wind and hydropower estimates. However, the results presented in this report include only the amount of capacity projected to be installed for wind technologies. Hydropower capacity and generation additions have been excluded from this report, and as such, the values shown here differ from those reported in the FY2004 Budget Submission documentation.

Note: The program's hydropower technology goal of reducing fish mortality associated with hydropower production is largely intended to improve the potential for relicensing of existing facilities, so that this existing capacity is not lost. As such, this goal is effectively incorporated into the NEMS-GPRA04 program case as relicensed capacity: the AEO 2002 Reference Case assumes relatively constant hydroelectric capacity, which requires essentially all existing hydroelectric facilities to be successfully relicensed. Based on analysis undertaken for the Idaho National Engineering Laboratory, the Baseline is revised to remove 1.0 GW and 5 BkWh of hydroelectric power by 2007, increasing to 1.5 GW and 7 BkWh by 2020 to reflect the levels of expected loss of capacity due to concerns related to fish-kill. This hydropower is then re-introduced in the program case.

Market Segments

Wind technologies are expected to be installed in two market segments:

- Green Power - Wind is one of the main competitors in the green power market segment. This market segment and the model used to analyze it are described in Appendix C. Wind, as one of the lowest-cost renewable technologies, competes successfully with the other technologies and thus captures about 63% (40% when MSR and floor capacity is included) of the green market in 2020. There are already several examples of wind energy being installed to meet the demands for green power. The GPMM is regional and wind penetrated every region extensively, except for the South Atlantic and East South Central regions, where wind is excluded from the model due to low resource potential.

- Least Cost Power - This segment has traditionally been considered to have the largest potential for market penetration (as measured by rated capacity) for wind energy. This market segment continues to provide the largest portion of projected penetration, accounting for 86% of the projected capacity additions of wind power by 2020. Market penetration estimates were developed using NEMS, which competes wind against all other generators in this segment. The NEMS analyses were performed by OnLocation. Green power estimates were explicitly included in NEMS prior to the least cost runs because NEMS does not yet effectively predict penetration into that segment. The program goals for wind technologies are modeled directly in NEMS-GPRA04 by incorporating the capital costs, operations and maintenance (O&M) cost, and capacity factors consistent with the program's low wind speed technology goal of 3 cents per kWh by 2012 into the model. For both the Baseline and GPRA cases, the maximum share of electricity generation allowed from intermittent sources was raised from the 12 percent used by EIA to 30 percent, based on experience in other countries. Short-term cost multipliers that indicate how quickly the industry can increase production without driving up the production costs are modified as a result of consultation with NREL, LBNL, and PERI, based on worldwide experience. Thus, the expansion of wind energy without cost penalties associated with manufacturing constraints was increased from 50 percent of installed capacity to 100 percent to reflect the fact that the industry is global and has shown the capability to expand rapidly in the last several years. The benefits estimates are conservative because the wind resource curve in the NEMS model involves assumptions that significantly increase the capital cost of developing new wind resources in ways that are inconsistent with market conditions in nations that have already significantly expanded wind production. Finally, the Production Tax Credit is assumed to run through 2003.

FY2004 GPRA METRICS
GEOTHERMAL

Table 1. Summary of Geothermal Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.00	1.60	3.80	6.05	8.45	10.8
Green	0.05	0.21	0.42	0.60	0.65	0.70
Enhanced Geothermal Systems	0.00	0.00	0.00	0.00	0.00	0.00
Total (may not add due to rounding)	0.05	1.80	4.20	6.65	9.10	11.6
Annual Benefits						
Energy Displaced (TBtu)	4.25	132	283	425	580	735
Energy Cost Savings (millions of 2000 $)	10.6	301	745	1,215	1,745	2,340
Carbon Displaced (MMCTE)	0.08	2.70	5.60	8.25	11.3	14.3
Technology Indicators*						
Cost ($/kW)	1,430	1,215	1,165	1,115		
Capacity Factor (%)	93.0	95.0	95.5	96.0		
Levelized Cost of Energy (cents/kWh in constant 1997$)	2.9	2.4	2.3	2.1		
*Weighted average of Flash and Binary Geothermal technologies, based on capacity projections. Data taken from *Renewable Energy Technology Characterization* report. These are provided for comparative purposes only, since the NEMS analysis of geothermal uses site-specific cost data.						

Market Segments

Geothermal power is expected to penetrate in two market segments: the green power market and the least cost power market. No distributed uses of geothermal were projected, although there is emerging industry interest in such applications, and a new DOE program to explore small-scale modular geothermal plant technology development (<5 MW).

- Green Power - Flash, Binary, and Enhanced Geothermal Systems (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 in those regions, leading to significant penetration in those two regions. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101).

- Least Cost Power - NEMS was run to estimate market penetration into the competitive bulk power marketplace for Geothermal Flash technology. The program goals for geothermal technology improvements are modeled directly in NEMS-GPRA04 by incorporating the capital and operation and maintenance (O&M) cost reductions. The model also takes into account site availability and maximum development per site per year for conventional and Enhanced Geothermal Systems (EGS) geothermal capacity. The conventional geothermal characteristics modeled are from the EPRI/DOE *Renewable Energy Technology Characterizations* report, and the EGS characteristics are developed by Princeton Energy Resources International (PERI). The NEMS model represents individual geothermal sites with different characteristics, with the lowest cost sites being developed first. For the GPRA 2004 analysis, OnLocation has eliminated the construction delay between projects (both large and small) at individual sites. NEMS' limits on amounts of capacity that can be built in any single year at one location have been increased to 100 MW from the prior 50 MW limit. OnLocation has also implemented a code change that better represents the mix of high and low resource areas that are represented in NEMS.

FY2004 GPRA METRICS
DISTRIBUTED ENERGY AND ELECTRIC RELIABILITY PROGRAM

Table 1. Summary of Overall Distributed Program Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Total	2.30	7.45	16.3	25.0	33.8	42.6
Annual Benefits						
Energy Displaced (TBtu)	117	294	550	775	1,045	1,315
Energy Cost Savings (millions of 2000 $)	0.50	1.55	3.35	5.25	7.05	8.80
Carbon Displaced (MMCTE)	2.60	7.70	14.4	20.1	27.1	34.1

Market Segments

The Distributed Energy and Electric Reliability (DEER) Program sponsors a wide range of research activities, including advanced turbines and microturbines, natural gas engines, PEM fuel cells, thermally activated technologies, and combined heat and power (CHP) among others. Many of the programs formerly reported separately under Electricity Delivery Programs, such as High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation, have been incorporated into the new DEER program. As such, the benefits of these programs are reported under the DEER program. DEER benefits are calculated from the CHP capacity and generation additions modeled in NEMS. Additionally, the Hydrogen program does not receive any credit for hydrogen fuel cell penetration expected in the CHP market. This capacity is credited to the DEER program.

Because of the diversity of the program's efforts and the broad array of market opportunities that present themselves to the various DEER technologies, EERE has used a simplified approach to calculating the benefits of the DEER program. That approach is based on the fact that the overwhelmingly largest benefit will come from the installation of combined heat and power (CHP) systems. Therefore, an analysis of the potential of CHP systems in the U.S. market place was undertaken for GPRA 2004. The results of that analysis were used as a surrogate for the total program benefits.

For the GPRA 2004 benefits analysis, EERE used NEMS commercial and industrial sector CHP analysis modules. The NEMS-GPRA04 baseline limits the rate of new technology adoption and the maximum share of DG technologies based on the extent to which future markets are expected to be able to accommodate these technologies. The program goals for development of distributed electricity technologies (microturbines, reciprocating gas engines, and IC engines at 800 kW and 3,000 kW) are modeled directly in NEMS-GPRA04 by incorporating the improved costs, efficiencies, and other attributes in NEMS-GPRA04 for the program case. The portions of the program designed to enhance the ability of electricity markets to absorb and manage DG are modeled by increasing the maximum CHP market share. Because NEMS-GPRA04 cannot model markets for high-temperature superconductivity (HTS) products, the benefits from these products are modeled directly as reductions in transmission and distribution losses for electricity systems, based on estimates by Energetics of kilowatt-hour reductions from HTS generators, transformers, cables, and motors. The portions of the program that reduce market barriers to consumer investment are addressed by adjusting the model's consumer acceptance curves (market adoption rates by payback period) for CHP.

Not all kWh of electricity have equal value to consumers. Market experience suggests that at least a portion of consumers are willing to pay more for electricity that is more reliable, of higher quality, locally controllable, available during emergency, or cleaner. While market information was available to incorporate the impact of "green power" preferences in these benefit estimates, they do not include consumer purchases based on preferences for improved reliability, load management, or power quality advantages of distributed generation. As a result, these benefit estimates are likely based on an underestimate of the demand for these products under baseline market assumptions.

Results

The results of the NEMS CHP analysis are shown in Table 2 for capacity and Table 3 for generation. NEMS projects that 7.45 GW of additional capacity, above revised AEO 2002 baseline, will be installed by 2010. The bulk of those installations, 7.21 GW, are projected to be in the industrial sector. The NEMS analysis for CHP is based on payback calculated from average prices, and is documented by the Energy Information Administration.

A determination of the fuel-use of these technologies was required to calculate the benefits from CHP introduction. Industrial applications are split between natural gas, coal, oil and biomass. Natural gas is by far the most dominant fuel choice, accounting for 69%-81% of total CHP capacity projections in the NEMS-GPRA04 and AEO02 baseline runs, and 100% of the projected benefits (i.e., the difference between these runs). Industrial biomass cogeneration represents about 10% of total CHP capacity, however no additional biomass is projected by the NEMS-GPRA04 run above the revised AEO02 baseline, and therefore biomass cogeneration receives no benefits for capacity additions. The analysis assumes 100% natural gas use for commercial applications.

Table 2. Cumulative CHP Capacity Additions above AEO 2002 baseline for GPRA 2004

Cumulative Capacity Additions (GW)	2005	2010	2015	2020	2025	2030
Industrial- Biopower	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Natural Gas	2.21	7.21	15.7	23.9	32.1	40.3
Industrial- Coal	0.00	0.00	0.00	0.00	0.00	0.00
Industrial- Oil	0.00	0.00	0.00	0.00	0.00	0.00
Industrial- Total	2.21	7.21	15.7	23.9	32.1	40.3
Commercial- Total	0.10	0.24	0.54	1.14	1.68	2.24
DEER- Total	2.30	7.45	16.3	25.0	33.8	42.6

Table 3. Generation from CHP Capacity Additions above AEO 2002 baseline for GPRA 2004

Cumulative Capacity Additions (GW)	2005	2010	2015	2020	2025	2030
Industrial- Biopower	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Natural Gas	16.0	52.0	113	172	231	290
Industrial- Coal	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Oil	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Total	16.0	52.0	113	172	231	290
Commercial- Total	0.69	1.75	3.87	8.23	12.1	16.1
DEER- Total	16.7	53.8	117	180	243	307

Benefits from the generation displaced from the grid are then calculated using the following procedures. Both industrial and commercial energy balance calculations are performed, as these sectors have different energy efficiencies and prices. The energy consumed on-site with CHP is netted out against the energy that was used on-site prior to the implementation of CHP and the energy supplied in the form of electricity by the grid. The energy content of the displaced electricity is calculated using both electricity generation and end-use consumption heat rates. The latter is used to calculate the net primary energy displacement and cost savings, as this is the amount of energy that is displaced at the site. However, since the emissions displaced are produced not on site, but rather at the point of generation, the energy content of the electricity at generation must be calculated as well to realize the true net emissions savings. Emissions from CHP systems using natural gas are generally low. Benefits of energy cost savings, carbon emissions savings, and are then calculated in accordance with the GPRA FY2004 guidance document.

Appendix A. Market Segmentation

The market segmentation used in the analysis is shown in Figure A1. At the highest level, the market was divided into: 1) Grid-Side Systems -- systems that are on the grid side of the meter, and owned by utilities or other power suppliers; and 2) Customer-Side Systems -- systems installed at customer locations on the customer side of the meter.

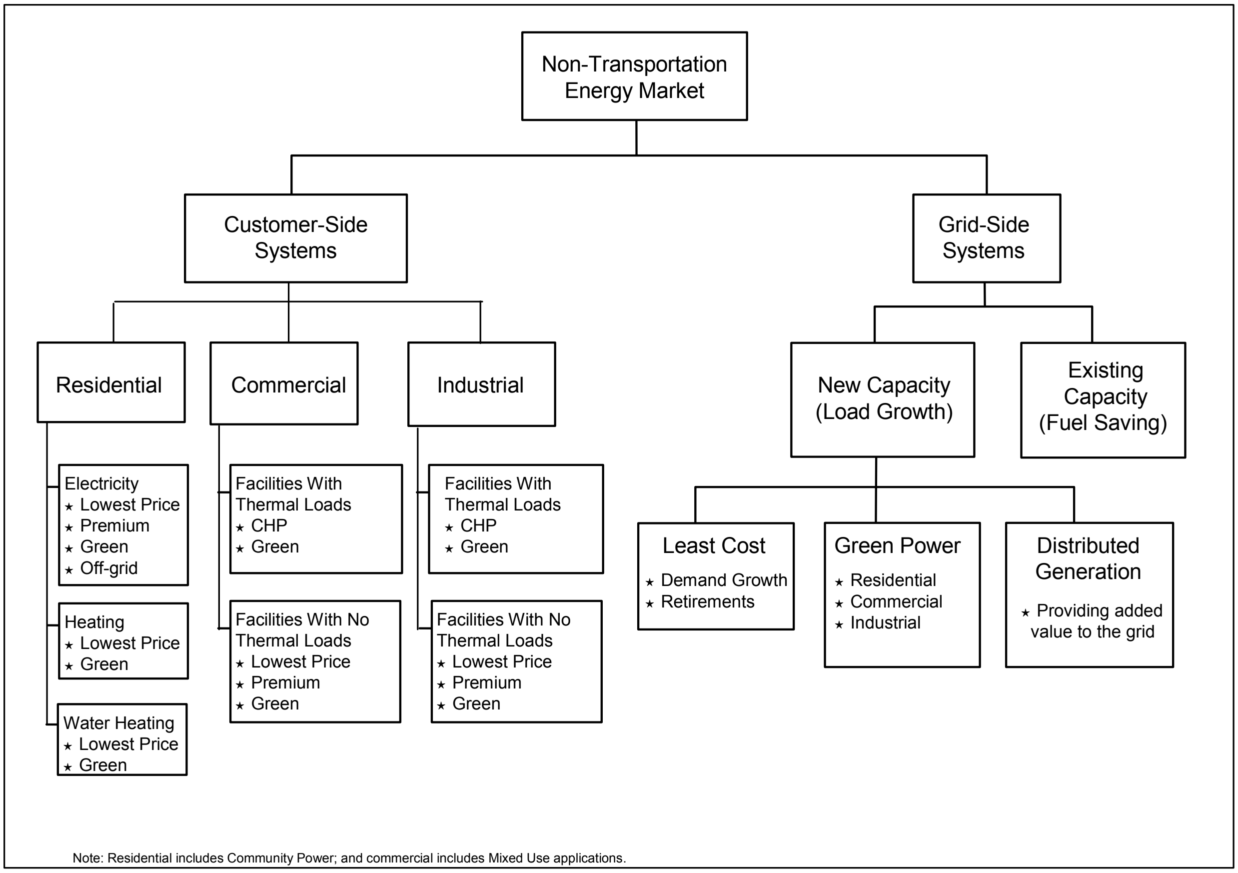

Figure A1. Market Segmentation of EERE Programs.

<u>Grid-Side Systems Segment</u>

The grid-side power segment includes power plants installed at either the transmission system level or at the distribution system level. This segment has traditionally been the realm of the regulated utility and, since 1978, the qualifying facility (QF). For modeling purposes, Grid-Side Power was subdivided into two sub-elements -- new capacity and existing capacity. The former considers capacity additions required to meet demand growth and those required to satisfy capacity needs created by plant retirements. The existing capacity subsegment consider those instances when the costs of generation from either biomass co-firing or intermittent wind and solar plants are less than the variable costs of operating existing plant capacity. This is commonly termed the fuel-saving market.

New capacity requirements have traditionally been met by new plants installed as a result of utility planning processes. As electricity markets are restructured, new business arrangements for satisfying this demand will emerge, but this segment will continue to represent the bulk of the capacity and generation supplied to the grid. (In the evolving restructured market, "merchant" power plants will also be constructed that compete with less-efficient, more-costly existing capacity. The analysis assumed that merchant renewable plants will be few in number.) This least cost subsegment could, in principle, be satisfied by capacity installed at either transmission system level voltages or at distributed system voltages. The former will typically be larger systems (central station) and the latter will be smaller systems (dispersed throughout the distribution system). The analysis characterized the costs and performance of both large and small plant sizes and allowed them to compete as appropriate for new capacity requirements. It must be emphasized that in this subsegment the distribution-level systems are installed solely for their capacity and generation value. No additional benefits to the utility system are considered. Plants that offer such "distributed benefits" are explicitly included in the Distributed Generation subsegment (see discussion later).

Green Power is a term that describes the public's apparent interest in renewable generation as a responsible alternative to conventional energy supply. Customers can acquire *Green Power* either by purchasing it from a supplier, or by installing their own system. The market segmentation reflects both of these options. (Note -- the customer-side green subsegment, shown in Figure A1, was explored for photovoltaics.) The *Green Power* subsegment of the Grid-Side Power segment is an evolving market that the analysis examined explicitly. It included two closely related marketing mechanisms for offering end-users the opportunity to purchase power that is generated by environmentally responsible means. *Green Pricing* is a mechanism by which regulated electric utilities have an approved tariff under which their customers can chose to pay additional monies to ensure that green electricity will be provided by their utility. However, more generally under a deregulated utility supply system, *Green Marketing* programs will include a variety of opportunities through which customers pay a premium to ensure that they are "buying" electricity from green sources.

The *Distributed Generation* subsegment of the Grid-Side Systems segment is also a specialized market. The Distributed Generation portion of the analysis accounted for those site-specific instances where small-scale generating systems or storage systems provide cost-saving benefits to the grid that go beyond pure capacity and generation values. These system benefits are often described as being valuable in supporting weak elements of the distribution system, or as helping alleviate pressures on the distribution system due to rapid load growth on parts of the system. Because this subsegment is just now developing, no installations which are directly attributable to distribution systems were projected.

Customer-Side Systems Segment

The Customer-Side Systems segment was analyzed in three sub-segments: residential, commercial, and industrial, including cogeneration.

Elements of the residential segment include: 1) systems that are owned because they are less-expensive than purchased alternatives (the lowest price element); 2) systems that offer added value to the owner beyond the basic commodity value of electricity, e.g., a desire to have reliable power independent of grid supply -- this value-added element could also have a green component (the value-added element); 3) systems that are green and are purchased for that reason, despite the fact that they are more expensive (the green element); and 4) systems that meet off-grid needs where conventional supplies are either unavailable or prohibitively expensive (the off-grid element).

The commercial and industrial subsegments mirror the residential, although there may be fewer opportunities for the off-grid market element. Cogeneration is defined as a separate element in the industrial subsegment because it is analyzed as a distinct market and was modeled in the National Energy Modeling System (NEMS) Industrial Demand Module and credited to the DEER program.

Appendix B. Overview of Modeling Framework

Table B1 shows the suite of models and analytical tools that EERE used for the analysis. The four Renewable Energy Technology Programs were analyzed using NEMS and the Green Power Market Model. The Solar Buildings program used an exogenous model, prepared by Princeton Energy Resources International. Customer-side Photovoltaics penetration, under the Million Solar Roofs program, was estimated using an exogenous model. The DEER program was modeled in NEMS alone, using the CHP capacity and generation additions as the basis for DEER benefits.

Table B1. Overview of EERE Analysis Approach

EERE Program Element	**NEMS**	**Green Power Market Model**	**Exogenous Models**
Solar Buildings			
Photovoltaics			
Biomass			
Wind			
Geothermal			
Distributed Energy and Electric Reliability			

Appendix C. Green Power Market Model

Introduction

The Green Power Market Model (GPMM or the model) identifies and analyzes the potential generating capacity additions for electricity production that will result from "green power" (either green marketing or pricing) programs, which are not captured in the "least-cost" analyses performed by the National Energy Modeling System (NEMS). Princeton Energy Resources International, LLC (PERI) originally constructed the GPMM in August and September 2000, as a sub-module, with the results hard wired into NEMS as planned capacity. This year's model, based in Microsoft Excel 97, is consistent with efforts from last year, with several changes documented herein. Several significant changes were incorporated last year that were not changed for this year's analysis, including a more detailed and regionalized set of assumptions for electricity market restructuring. These assumptions come from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*, a recent report by Blair Swezey et al. completed for the National Renewable Energy Laboratory (NREL). The assumptions include the dates for initiation of market restructuring as well as the assumed green power penetration rates, a change in the time periods tracked in the analysis, and a new method for calculating funds from program participants.

Green technologies are marketed as energy production in a cleaner, safer, and renewable fashion. However, the definitions of what constitutes a green technology and how it should be marketed are quite ambiguous in the early deregulation arena. Several agencies and organizations have identified this ambiguity and have offered suggestions. The American Wind Energy Association's (AWEA) *Principles of Green Marketing* was developed in an "effort to foster a credible market in environmentally-preferable electric services… that results in meaningful changes in the electric system as whole." Lawrence Berkeley National Laboratory's (LBNL) *Green Power Certification* report points out the need for creation of certification programs to validate retailers' claims of providing green energy. Several organizations have begun to certify green power marketing claims and sales agreements in areas with competitive access to power available, including the Center for Resource Solutions' (CRS) Green-e program, the Scientific Certification Services' (SCS) Environmentally Preferable Power program, and the Environmental Resource Trust's EcoPower program.

The Green Power Network, a part of the US Department of Energy (DOE), defines both green power and green power marketing on their web page. It states that the "essence of green power marketing is to provide market-based choices for electricity consumers to purchase power from environmentally preferred sources. The term "green power" is used to define power generated from renewable energy sources, such as wind and solar power, geothermal, hydropower and various forms of biomass."

For purposes of this analysis, the term "green marketing" refers to selling green power in the competitive marketplace, in which multiple suppliers and service offerings exist. Green marketing programs occur in restructured markets that were formerly served by either investor-owned utilities (IOU) or public utility companies (PUC) and give the customer the option of paying a market price (higher if necessary) to ensure that their electricity demand is met by green power. "Green pricing" programs, on the other hand, represent the programs sponsored by utilities that give customers the opportunity to pay extra to support the development and operation of green power sources. Those utilities, both IOUs and PUCs, which remain regulated in our analysis have the option of providing "green pricing" programs.

The Model

Technologies:

The model projects additional capacity and electricity generated from green technologies for the periods 2004 to 2008 and 2009 to 2010, and then five-year periods to 2030. Sixteen individual technologies, comprising five technology types, were selected as both green and commercially viable for this analysis. The technologies, listed below, can be grouped into categories based on both the availability of power, Dispatchable or Intermittent, and on resource use. These are:

Dispatchable:

1) Biomass:	- Direct-Fired Biomass
	- Biomass Gasification
	- Landfill Gas
2) Geothermal:	- Flash Geothermal
	- Binary Geothermal
	- Hot Dry Rock
3a) Concentrated Solar Power:	- Solar Thermal Trough
	- Solar Thermal Dish- Hybrid
	- Solar Central Receiver

Intermittent:

3b) Concentrated Solar Power	- Solar Central Receiver (Intermittent)
	- Solar Thermal Dish- Stand Alone
4) Photovoltaics:	- Residential PV (Neighborhood)
	- Central Station PV (Thin Film)
	- Concentrator PV
5) Wind:	- Wind Turbines

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. Generally, the additional capacity needed to maintain stability of power comes in the form of diesel generators or gas turbines, for which the model calculated these additional costs. However, since green power programs only guarantee that a certain 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 back-up generation to provide a continuous source of power. Developers are assumed to build the sites in least cost fashion (without back-up) and take the "green" electrons when and from where they are able. The "firm up" costs are now set to zero in the model, which effectively removes the competitive advantage, and therefore the distinction, of dispatchable sources over intermittents.

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. PERI has elected to use US Census regions as the breakdown, as the availability of regional data for the model often takes this format. Eight regions (South Atlantic and East South Central have been combined) are modeled independently, and then summed to produce national results. 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 thirteen divisions used in NEMS. The NEMS divisions are based on the North American Electric Reliability Council's regions. The names of these regions, and the conversion formulas from the census region breakdown are documented in the model.

The state-by-state restructuring and penetration assumptions taken from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (the NREL report) are summed across these regions, and are pro-rated based on the loads of the electric market in each state compared to the region as a whole.

Revisions to the FY04 Model:
Several revisions to the FY03 GPMM have been made in the update for FY04. The reporting of years has been changed from 2003-7 and 2008-10 to 2004-8 and 2009-10, with the five-year increments thereafter to 2030 remaining consistent. New technology characterizations for wind, class 4 and 6 data averaged, and CSP, trough and power tower data, were taken from program revisions to the *Renewable Energy Technology Characterizations, EPRI-TR109496* report (TC report). All other technologies remained consistent in using the TC report. All technology cost figures were converted to 2000$, using GPD price deflators from http://w3.access.gpo.gov/usbudget/fy2001/sheets/hist10z1.xls.

Most of the major assumptions of the GPMM remained unchanged. The model still incorporates extensive revisions to the assumptions included for the FY03 model. Many of these assumptions, including the rates at which electricity markets restructure, and the participation levels of customers in these new markets were taken from *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy, NREL/TP-620-30101* (the NREL report).

The regional economic sectors' energy consumption and prices were updated according to the new Energy Information Administration's (EIA) assumptions for the *Annual Energy Outlook 2002, DOE/EIA-0383(2002)* (AEO2002). The regional energy consumption and prices were taken from tables 1-20 of AEO2002 Supplemental Data Tables. Tables 1-3, on the following pages, show the differences in regional energy consumption and prices for the residential, commercial and industrial sectors between the FY03 and the FY04 models.

Table 1. Residential Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Residential Energy Consumption (Quads)	2020 Residential Energy Consumption (Quads)	1999/2000 Residential Energy Prices (2000$/MMBtu)	2020 Residential Energy Prices (2000$/MMBtu)
National	FY03	3.91	5.80	23.95	22.50
	FY04	4.07	5.70	24.36	22.55
New England	FY03	0.14	0.20	33.26	29.84
	FY04	0.14	0.19	34.04	30.97
Mid. Atlantic	FY03	0.38	0.50	31.74	28.34
	FY04	0.38	0.49	32.22	29.03
E. N. Central	FY03	0.56	0.82	23.33	20.61
	FY04	0.58	0.83	23.24	20.99
W.N. Central	FY03	0.29	0.40	20.87	20.32
	FY04	0.30	0.41	22.04	20.16
S. Atlantic & E.S. Central	FY03	1.27	1.95	22.00	21.88
	FY04	1.35	1.95	23.29	21.09
W.S. Central	FY03	0.57	0.90	21.10	20.89
	FY04	0.61	0.87	21.87	20.90
Mountain	FY03	0.23	0.38	22.38	22.41
	FY04	0.25	0.39	21.73	22.69
Pacific	FY03	0.46	0.66	25.37	23.65
	FY04	0.46	0.59	25.64	25.49

Table 2. Commercial Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Commercial Energy Consumption (Quads)	2020 Commercial Energy Consumption (Quads)	1999/2000 Commercial Energy Prices (2000$/MMBtu)	2020 Commercial Energy Prices (2000$/MMBtu)
National	FY03	3.70	5.61	21.86	18.39
	FY04	3.91	6.12	22.11	20.33
New England	FY03	0.16	0.22	28.23	19.99
	FY04	0.14	0.19	28.55	23.81
Mid. Atlantic	FY03	0.47	0.63	16.78	14.02
	FY04	0.49	0.63	28.25	24.73
E. N. Central	FY03	0.56	0.82	21.15	17.64
	FY04	0.55	0.74	20.68	19.50
W.N. Central	FY03	0.25	0.37	19.24	17.67
	FY04	0.28	0.41	18.11	17.16
S. Atlantic & E.S. Central	FY03	1.06	1.67	19.24	18.00
	FY04	1.11	1.95	20.15	19.07
W.S. Central	FY03	0.46	0.70	18.91	17.72
	FY04	0.49	0.72	19.07	18.52
Mountain	FY03	0.25	0.42	18.54	18.12
	FY04	0.28	0.52	18.77	19.32
Pacific	FY03	0.49	0.79	24.90	18.68
	FY04	0.56	0.95	26.64	23.01

Table 3. Industrial Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Industrial Energy Consumption (Quads)	2020 Industrial Energy Consumption (Quads)	1999/2000 Industrial Energy Prices (2000$/MMBtu)	2020 Industrial Energy Prices (2000$/MMBtu)
National	FY03	3.63	4.81	13.29	11.79
	FY04	3.65	4.83	13.50	13.04
New England	FY03	0.09	0.11	22.40	15.15
	FY04	0.09	0.11	22.64	18.15
Mid. Atlantic	FY03	0.30	0.37	20.65	16.34
	FY04	0.29	0.36	17.05	16.88
E. N. Central	FY03	0.77	0.99	12.77	11.71
	FY04	0.78	1.00	13.13	13.44
W.N. Central	FY03	0.27	0.35	12.35	11.11
	FY04	0.29	0.36	12.36	11.36
S. Atlantic & E.S. Central	FY03	0.98	1.30	12.57	11.76
	FY04	1.00	1.31	12.82	12.45
W.S. Central	FY03	0.56	0.76	11.50	11.98
	FY04	0.56	0.77	11.70	12.58
Mountain	FY03	0.24	0.34	12.10	11.29
	FY04	0.24	0.33	11.47	11.69
Pacific	FY03	0.41	0.59	15.11	10.54
	FY04	0.41	0.59	15.70	13.17

As can be seen from Tables 1-3, some notable differences occur in the economic sector demand assumptions in energy consumption and prices. In the residential sector, Table 1, the residential energy consumption for the nation increased 2% in the beginning (1999-2000), from 3.91 to 4.07 Quads, but decreased 4% at the end (2020), from 5.80 to 5.70 Quads, of the analysis period. This reduced the growth rate of energy consumption for the country as a whole, which in turn reduces the average monthly electric bills, the pool of green money, and the total capacity built to meet green power market demand. The national residential energy prices (in 2000$) increased only slightly, 2%, for the beginning of the analysis and did not effectively change for the end of the period. On a regional level for the residential sector, the largest differences were seen in the Pacific region, where energy consumption in 2020 decreased by 11% while prices rose 8% in 2020.

Table 2 shows the commercial sector demand assumptions. The most noted change is increases of 68% and 76%, respectively, of the Middle Atlantic region's commercial energy prices in 1999-2000 and 2020. Other significant changes include a reduction in commercial energy consumption in the New England and East North Central regions, while consumption levels increased in the Mountain and Pacific regions.

Table 3 shows the industrial sector demand assumptions, which remained the most consistent from FY03 to FY04. The current energy prices (1999-2000) for the Middle Atlantic region dropped 17%. On the other hand, future energy prices (2020) increased by 25% and 20%, respectively, for the Pacific and New England regions.

The regional residential household data is used to calculate the size of the potential green power market for the residential sector. This data was updated for the FY04 model from a file sent by John Cymbalski, of the EIA. ("Regional hhs- updated from J Cymbalski 6-5-02.xls") The regional household data generally increased or decreased by only 1% to 2%, with the exception of the Pacific and West South Central regions, which had the largest deviation, increases of 5.3% and 4.9%, respectively, in 2020. Increasing households in a region has the effect of generating a larger potential green electric market and therefore more green revenues, which would increase GPMM capacity builds in that region.

The commercial floorspace and industrial gross output are used to determine the number of commercial and industrial establishments, respectively. Similar to the number of households, the number of establishments, combined with electric market restructuring and participation levels from the NREL report, determines the size of the potential green power markets for the commercial and industrial sectors, and therefore the GPMM capacity builds in each region. National data for commercial floorspace and industrial gross output was taken from Tables 22 and 23 of AEO2002 Supplemental Data Tables. These tables do not provide regional data of commercial floorspace or industrial gross output. Therefore, regional data was calculated on the basis of the national data and the regional percentages of the national total for these inputs in the FY03 model.

In addition to the economic sector demand data assumptions changed, a few other minor changes were made to the model. The regional limit on the amount of landfill gas (LFG) was modified so that only 2/5 of the five-year regional limit of 70 MW was allowed for the two-year period from 2009 to 2010.

PERI included both additions and subtractions to the green capacity values for the Million Solar Roofs (MSR) capacity additions, and EIA "floors" builds, Tables 4-6. The MSR capacity additions, Table 4, are added to the green model numbers in the reporting of the PV-residential green capacity.

Table 4. Million Solar Roofs Initiative Incremental Capacity Additions in GPMM04

Year Period	MSR Capacity Additions (above 2003 Baseline)
2004-2008	472
2009-2010	428
2011-2015	1,761
2016-2020	1,926
2021-2025	1,926
2026-2030	1,926
Total for 2004-2030	8,439

An additional 250 MW of central station PV and 54.5 MW of central station solar thermal "floors" capacity from 2001 to 2020 are "assumed by EIA to be installed for reasons in addition to least-cost electricity supply". These "floors" capacity additions, Table 5, are prorated for 2004 to 2020 and regionally divided.

Table 5. EIA "Floors" Incremental Capacity Additions for PV and Solar Thermal in NEMS

Year Period	EIA PV "Floors" Capacity Additions (above 2003 Baseline)	EIA Solar Thermal "Floors" Capacity Additions (above 2003 Baseline)
2004-2008	62.5	13.6
2009-2010	25.0	5.5
2011-2015	62.5	13.6
2016-2020	62.5	13.6
2021-2025	0.0	0.0
2026-2030	0.0	0.0
Total for 2004-2030	212.5	46.3

These amounts are then subtracted from the green power builds 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), Table 6. As can be seen in Table 6, all of the Solar Thermal "floors" additions were subtracted from the GPMM04 results. At the same time, only a portion of the PV "floors" additions in the first two time periods were subtracted due to less capacity being built in each of the regions by the GPMM04 then was added by the "floors" capacity.

Table 6. EIA "Floors" Incremental Capacity Additions Subtracted from the GPMM04

Year Period	EIA PV "Floors" Capacity Additions Subtracted from GPMM04 (above 2003 Baseline)	EIA Solar Thermal "Floors" Capacity Additions Subtracted from GPMM04 (above 2003 Baseline)
2004-2008	17.8	13.6
2009-2010	22.6	5.5
2011-2015	62.5	13.6
2016-2020	62.0	13.6
2021-2025	0.0	0.0
2026-2030	0.0	0.0
Total for 2004-2030	164.9	46.3

Results

Comparison of Final Results:

Table 7 and 8 show the final results of the GPMM03 and GPMM04 that were hardwired into the NEMS AL01 and AL02 runs, respectively. However, due to the changes that are detailed in this report, including MSR additions and subtracting out EIA "floors" additions, these tables are not directly comparable. Table 9 shows the results of the GPMM04 without including MSR additions and subtracting out EIA "floors" additions.

Table 10 is then calculated as the difference between Table 7 and Table 9, and shows the changes in the results of the GPMM due to changes in the assumptions, rather than due to changes in the methodologies. As can be seen in Table 10, the total additions are relatively stable, with most of the changes seen between technologies. Wind and CSP see large increases while the other technologies all lose capacity gains. This is due to the revised technology characterization data for wind and solar thermal, lowering the capital costs and cost of energy, and therefore making these choices more attractive in the model.

Table 7. Results of the GPMM03- Cumulative Capacity Additions Relative to 2002 Baseline

	2010	**2020**	**2030**
Biomass (incl. LFG)	388	823	972
Geothermal	261	694	820
CSP	209	609	703
PV	143	668	963
Wind	2,418	4,462	4,842
Total	3,419	7,256	8,299

Table 8. Results of the GPMM04- Cumulative Capacity Additions Relative to 2003 Baseline

	2010	**2020**	**2030**
Biomass (incl. LFG)	287	673	802
Geothermal	209	600	705
CSP*	257	801	970
PV*	968	4,973	9,045
Wind	2,632	4,601	4,948
Total	4,353	11,648	16,470

Table 9. Results of the GPMM04- Cumulative Capacity Additions Relative to 2003 Baseline Without Methodology Changes from the GPMM03.

	2010	2020	2030
Biomass (incl. LFG)	287	673	802
Geothermal	209	600	705
CSP*	276	847	1,017
PV*	108	551	771
Wind	2,632	4,601	4,948
Total	3,512	7,272	8,242

Table 10. Difference in the Results of the GPMM04 Compared to the GPMM03 Without Methodology Changes from the GPMM03.

	2010	2020	2030
Biomass (incl. LFG)	-101	-149	-170
Geothermal	-52	-95	-115
CSP	67	238	313
PV	-35	-117	-191
Wind	214	139	106
Total	93	17	-56

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GPRA Representation of the Distributed Energy and Electric Reliability (DEER) Program

The DEER Program encompasses many technologies and markets. The GPRA benefits were estimated by focusing on gas-fired combined heat and power (CHP) systems within building and industrial applications. Distributed generation (DG) applications that are motivated by the need for electric reliability will be primarily systems that produce only electricity and are used in back-up mode. We currently do not have the analytical tools to asses this market. Its absence from the benefits estimates may result in an underestimation of DG capacity, although not the energy or emission savings because these systems run for few hours per year and generally have similar or lower efficiencies than larger central station plants. To the extent that the central grid relies on DG for emergency power, avoided central station capacity may be underestimated as well.

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, transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

The NEMS-GPRA04 framework uses a cashflow model to evaluate the DG technologies within the building sector. Assuming a 20 percent down payment, debt and interest payments are computed over a loan period of 20 years, along with associated taxes and tax benefits. Annual fixed maintenance costs are also included. Fuel costs are computed based on the delivered cost of natural gas and the technology efficiency. Netted against the fuel cost is the value of the useful waste heat produced as computed 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 (assuming 7125 hours of operation) 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 power rate. The number of years until positive cash flow is reached determines the market share in new buildings[1]. The market share, as shown below, drops off sharply as the number of years increases to reflect the high rates of return generally expected for energy related projects by commercial building owners. The market share for existing buildings is assumed to be a fraction of the share for new.

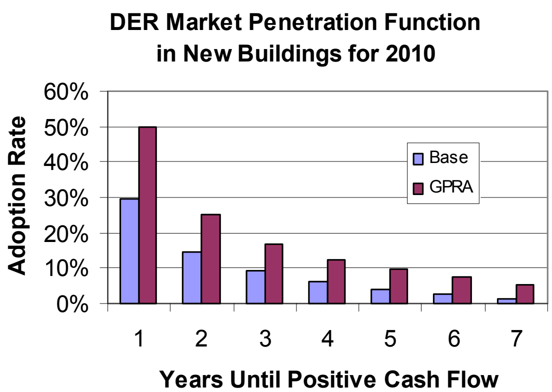
The analysis is performed for each of 11 building types in 9 regions. Even so, this is a fairly high level of aggregation, and therefore the model does not capture the niche markets that DG may fill. The current version also does not take into account the electricity and thermal seasonal and diurnal load shapes. It therefore may overestimate the value of both products by assuming that the CHP systems runs at full operation most of the time and that the electricity and heat can be used continuously. On the other hand, the DG systems are represented in discrete sizes, and some average building loads are too small to use the heat and electricity produced by the minimum 100 kW system, which makes the DG systems uneconomic.

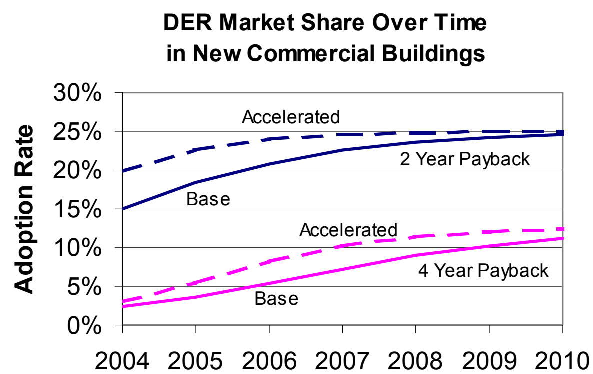
[1] With the accelerated depreciation positive cash is more likely to be reached sooner, although in some cases, the project can return to being uneconomic once the tax benefits are used.

The DEER program facilitates the development of the DG 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.

The Baseline used for the GPRA analysis already includes some DG technological advancement[2]. It was beyond the scope and schedule for this year's analysis to separate how much of the Baseline improvements might stem from government R&D efforts, and therefore should be removed. As a result, the GPRA benefits may be underestimated for the smaller commercial sector systems. To test the impact, we performed a sensitivity test taking out these improvements for the commercial sector CHP technologies. At the extreme of static year 2000 commercial CHO technology characteristics, DG capacity decreases by roughly 2 GW from the baseline. Although not in the AEO2002, the Baseline also assumes that small combined heat and power systems receive favorable tax treatment in terms of accelerated depreciation.

The DEER program's impact on consumer adoption rates was represented in several ways. The maximum market share that can be achieved in new buildings was increased from 30 percent in the Baseline to 50 percent in the GPRA case. The graph on the left below shows how the ultimate market share for new buildings varies by payback year. In addition, there is an adoption rate parameter that was accelerated to reflect faster market maturity in the GPRA case, as shown in the graph to the right.





The market share for the existing building stock is tied to the market share computed for new buildings. The baseline assumption is that the existing stock share is one-fiftieth of the new share, while in the GPRA case the existing share is increased gradually from one-fiftieth to one-thirtieth of the new share. The share for the existing stock of buildings is considerably smaller than the market share for new buildings, because the entire existing stock will not make investments in CHP in a single year.

An economic competition for CHP systems is also performed in the industrial sector. All of the industrial CHP technologies improve over time in the GPRA case compared to the Baseline. The technology characteristics for the smaller internal combustion systems were take from the draft EERE Technology Characteristics report[3], while the larger system improvements are the intended EIA assumptions[4]. For the industrial CHP systems, as well as the for commercial sector, it was assumed that the DEER program will

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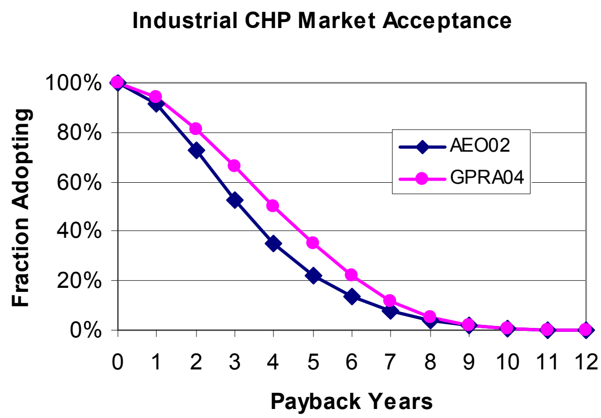
[2] The Annual Energy Outlook 2002 assumes improved CHP technologies in the commercial sector. The input files for the industrial sector CHP systems show improvements as well, but a coding error led to these being unused and the technology characteristics remain at their year 2000 values.
[3] Add source.
[4] The assumptions in the AEO2002 input files as described in footnote 2.

enhance consumer acceptance and lower hurdles to adoption. This was reflected in the model by shifting the function determining the adoption rates as a function of payback years.



The incremental DG capacity and generation that results from this representation of the DEER program activities is shown in the table below, along with the projected total quantities. Of the 25 GW of incremental capacity, roughly half of the increase is expected from commercial building applications and half from generally larger industrial applications. The DG increase in the building sector is proportionally much larger, because there is currently relatively little DG in this sector.

In the Baseline case, the commercial sector is projected to satisfy roughly 3 percent of its total electricity demand with distributed CHP generation and the industrial sector 15 percent. With the DEER program, the share rises to 8 percent in the commercial sector and 20 percent in the industrial sector.

Distributed Combined Heat and Power						
	Capacity (GW)			Generation (BkWh)		
	2005	2010	2020	2005	2010	2020
Baseline						
Buildings	1.3	2.3	7.4	9	16	53
Industry	29.0	33.0	41.2	173	202	259
Total*	30.3	35.2	48.5	183	218	312
GPRA Case						
Buildings	2.1	5.4	20.3	15	39	146
Industry	30.5	37.3	53.2	184	233	347
Total*	32.6	42.7	73.6	199	272	493
Incremental						
Buildings	0.8	3.2	13.0	6	22	93
Industry	1.5	4.3	12.1	11	31	88
Total*	2.3	7.4	25.0	17	54	180

* excludes non-traditional large QF cogenerators

The DEER program benefits 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 DG, 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 2 GW of additional capacity retired by 2020 in the GPRA case. Roughly 27 GW of central station investments are avoided by the additional DG. In the Baseline, roughly 90 percent of new utility and IPP additions from 2005 to 2020 are projected to be natural gas fired, so roughly 90 percent of those avoided investments are natural gas fired.

In total, distributed generation makes up roughly 12 percent of new capacity additions from 2005 to 2020 in the Baseline. This share increases to 18 percent in the GPRA case. For the later period of just 2015 to 2020, the distributed share rises from 16 percent in the Baseline to 26 percent in the GPRA case.

The energy and carbon emission reduction benefits that stem from distributed generation are computed as the decrease in traditional central station non-renewable energy consumption and associated carbon emissions net of the energy and emissions from the DG. 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 become more efficient as the gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour. For example, in 2010 the average non-renewable energy avoided is at a rate of 9500 Btu/kWh, and by 2020 the value is reduced to 7800 Btu/kWh.

The benefits estimates for the High Temperature Superconductivity (HTS) program, another component of the DEER Program, were based on an analysis performed by a contractor for the program office. The estimates provided of kilowatt-hour reductions from HTS generators, transformers, cables, and motors were represented in NEMS by reducing T&D losses.

FY04 GPRA Benefits Estimates for DEER* (NEMS-GPRA04)

	2005	2010	2020
Capacity (GW)	2.3	7.4	25.0
Generation (GWh)	16.7	53.8	180.1
Energy Savings (quads)	0.08	0.19	0.46
Oil Savings (quads)	0.00	0.01	0.02
Carbon Savings (MMT)	1.4	3.4	8.5
Energy Expenditure Savings (B2000$)	0.7	3.1	9.0

* Includes all credit for increased fuel cells although some sharing with the Hydrogen Program may occur.

GPRA Representation of the Hydrogen Program

The Hydrogen Program is targeted towards the introduction of fuel cells for both stationary and vehicular applications and the production of hydrogen at a reasonable price. The GPRA benefits estimates focus on gasoline and hydrogen fuel cells for vehicles. The Hydrogen Program has not yet established technology goals for stationary fuel cells, so benefits could not be computed. As a result, the benefits are underestimated. The production side of the program was represented as success in delivering hydrogen at $2.00 per gallon of gasoline equivalent (inclusive of taxes). As mid-term model, the NEMS-GPRA04 framework does not contain sufficient structure to analyze the production and delivery of hydrogen.

The fuel cell vehicles were modeled along with the FreedomCAR and Technologies Program. The gasoline and hydrogen fuel cell vehicle costs and efficiencies were modified to reflect the program goals (see the FreedomCAR Program description for more detail about the modeling of vehicle choice). The benefits associated with fuel cells were then attributed to the Hydrogen Program based on their relative efficiencies and their share of the displaced conventional gasoline vehicles VMT.

FY04 GPRA Benefits Estimates for Hydrogen* (NEMS-GPRA04)

	2005	2010	2020
Energy Savings (quads)	0.00	0.00	0.11
Oil Savings (quads)	0.00	0.00	0.11
Carbon Savings (MMT)	0.0	0.1	2.2
Energy Expenditure Savings (B2000$)	0.0	0.1	2.0

* Does not yet include any benefits from stationary fuel cells.

GPRA Representation of the Biomass Program

The Biomass Program is comprised of four major elements: bio-products, bio-power, black liquor gasification, and cellulosic ethanol. The methodology for computing the GPRA benefits estimates varied depending on the type of program and the relevant components of the NEMS-GPRA04 framework.

The bio-products component seeks to develop biomass based chemical products through innovative refining processes. The use of biomass would displace the traditional reliance on petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, the NEMS-GPRA04 does not have sufficient detail within its representation of this industry to explicitly model bio-products. Energy savings were estimated off-line based on a simplified market penetration approach (Fisher Pry curves) by the program office. These results were then modified to reflect an assumption of 15 percent per year from 2010. This more conservative approach was used, because EERE does not yet have a market-based model of bioproducts growth. The energy savings by fuel are subtracted from industrial energy consumption projected by NEMS-GPRA04. The model is then used to compute the other GPRA benefits metrics of primary energy savings, carbon emission reductions, and energy expenditure savings.

The main thrust of the bio-power program is to develop and verify gasification technologies which enable the increased efficiency of bio-power generation from the current 20 percent efficiency to 30-35 percent efficiency. In estimating the GPRA benefits, the biomass generation capital and O&M costs were modified to reflect the program's goals, as reflected in the EERE/EPRI Technology Characteristics report. These costs and the biomass heat rates were very similar to those already in the Baseline, although the projected increase in biomass capacity is quite small in the Baseline. In addition to competing on an economic basis with other electricity generation technologies, biomass capacity may be constructed for its environmental benefits. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including biomass, in response to the expanding green power markets in many places across the country. The projections for green power biomass installations were incorporated into NEMS-GPRA04 as the planned capacity additions. The majority of projected biomass generating capacity for GPRA stems from the green power additions.

Black liquor and hog fuel gasification systems use waste fuels produced by the pulp and paper industry. The goal of the program is to replace relatively inefficient existing boilers and cogeneration systems with a more efficient gasification process. The increased steam and electricity output from the same waste fuel input will displace fossil fueled steam and generation. The program office provided penetration rates for black liquor gasification based on a recently updated analysis of age-related boiler rebuilding and replacement rates, and an estimate of market share for BLGCC. As a percent of total stock (which takes into account both replacement rates and BLGCC market share), the BLGCC is projected to reach 0.3 percent in 2010, 23 percent in 2020 and 84 percent by 2035 of black liquor use. The BLGCC market share was applied to new stock as well in the assumption that the new black liquor production would likely be from expansions of existing mills. These estimates for the penetration rate of black liquor gasification (BLGG) and the technology efficiency were used to modify the biomass cogeneration efficiencies over time, because NEMS-GPRA04 does not perform an economic competition for the black liquor technologies. The primary energy savings result from reduced fossil fuel consumption for steam production and for reduced demand for electricity purchased from the grid.

Cellulosic ethanol program is aimed at reducing the cost of producing ethanol from biomass other than corn, which is the current feedstock. The cellulosic ethanol production costs are assumed to improve in the Baseline to a similar degree as expected to be achieved with the program funding, but the growth in projected production is assumed to be constrained. For the GPRA benefits estimates, these constraints are relaxed, so that cellulosic ethanol production equals the program goals (assuming other Baseline assumptions), which were developed using EERE's ethanol analytic model. NEMS-GPRA04 then adjusts the overall level of ethanol purchased by accounting for the price impacts of competing sources of demand for biomass (e.g., gasification to produce electricity). Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline through enhanced blending. For these GPRA projections, a large portion of the cellulosic ethanol displaced corn ethanol which does not lead to energy savings. The cellulosic ethanol does lead to additional carbon emission savings through an off-line adjustment that takes into account for its lower life-cycle carbon emissions that is not incorporated in NEMS-GPRA04.

FY04 GPRA Benefits Estimates for Biomass (NEMS-GPRA04)			
	2005	**2010**	**2020**
Capacity (GW)	0.0	0.2	0.5
Generation (GWh)	0.3	1.3	3.7
Cellulosic Ethanol Production (Bil. gallons)	0.00	0.70	2.70
Energy Savings (quads)	0.05	0.11	0.45
Oil Savings (quads)	0.01	0.05	0.22
Carbon Savings (MMT)	0.7	2.0	9.7
Energy Expenditure Savings (B2000$)	0.0	0.4	3.2

GPRA Representation of the Geothermal Technologies Program

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

The NEMS-GPRA04 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 O&M costs. For the GPRA program case, an additional set of EGS sites were added to this slate.

The 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, as reflected in the EERE/EPRI Technology Characteristics report. 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 relaxed from 25 MW or 50 MW (depending on year) to 100 MW per year.

In addition to competing on an economic basis with other electricity generation technologies, geothermal capacity may be constructed for its environmental benefit. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including geothermal, in response to the expanding green power markets in many places across the country. The projections for green power geothermal installations were incorporated into NEMS-GPRA04 as the planned capacity additions.

The primary energy, oil, and carbon emissions savings all stem from geothermal power displacing fossil-fueled generation sources that were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. 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.

The renewable programs have been modeled together, and the GPRA benefits are allocated to each proportional to their generation share.

FY04 GPRA Benefits Estimates for Geothermal (NEMS-GPRA04)			
	2005	**2010**	**2020**
Capacity (GW)	0.0	1.8	6.7
Generation (GWh)	0.4	14.8	54.6
Energy Savings (quads)	0.00	0.11	0.41
Oil Savings (quads)	0.00	0.01	0.02
Carbon Savings (MMT)	0.1	1.8	7.3
Energy Expenditure Savings (B2000$)	0.0	0.6	1.7

GPRA Representation of the Solar Energy Technologies Program

The Solar Program encompasses several technologies in thermal heat and electric markets. The solar buildings component is focused on developing low cost solar hot water and pool heaters to displace fossil-fueled alternatives. For electricity generation, photovoltaics are being improved for both distributed and central generation applications, and the Solar Program is working to accelerate PV adoption through the Million Solar Roofs Initiative. Concentrated Solar Power R&D has also been part of the Solar Program but is not included in the FY04 budget request except at a close-out level. As a result, CSP has not been included in the GPRA04 benefits estimates.

The GPRA benefits for solar water and pool heaters are represented within the residential module of NEMS-GPRA04. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical usage. The baseline assumptions are modified to reflect the program goal of $1000 per unit and a backup fraction of 40 percent. The costs are changed for both new and replacement water heaters.

The pool heaters could not be modeled based on economics, because there is not a pool heating end-use within NEMS-GPRA04. In addition, it appears that the program is not really aimed at reducing the cost for solar pool heaters, but rather making them more acceptable by producing them in colors other than black. Therefore, the penetration rates and energy savings estimated by the program office were used to exogenously reduce water heating demand in the residential model.

Photovoltaic systems are represented using two methods. The capital and O&M costs were modified to reflect the program's goals, as reflected in the EERE/EPRI Technology Characteristics report. The regional capacity factors in the Baseline were already a similar to those in the EERE report, so they were left unchanged. In addition to competing on an economic basis with other electricity generation technologies, PVs may be constructed for their environmental benefits. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including PVs, in response to the expanding green power markets in many places across the country. The projections for green power PV installations was combined with the Million Solar Roofs installation goals to determine the planned PV capacity additions that were incorporated into NEMS-GPRA04. All of the projected PV capacity for GPRA stems from the green power and MSRI additions.

Estimates of primary energy, oil, and carbon emissions savings result from direct displacement of fossil fuels for water and pool heating and from electricity demand reductions and PV generation. The savings associated with reduced electricity requirements depend on which types of generating plants were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings decline per kilowatt-hour of renewable generation or electricity demand reductions. 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 and pool heaters also directly reduce energy expenditures.

FY04 GPRA Benefits Estimates for Solar (NEMS-GRPA04)

	2005	2010	2020
Capacity (GW)	0.2	1.0	5.0
Generation (GWh)	0.4	1.7	8.9
Energy Savings (quads)	0.02	0.09	0.12
Oil Savings (quads)	0.00	0.01	0.01
Carbon Savings (MMT)	0.3	1.6	2.4
Energy Expenditure Savings (B2000$)	0.1	0.7	1.2

GPRA Representation of the Wind and Hydropower Technologies Program

The wind component of the Wind and Hydropower Program seeks to reduce the cost and improve the performance of wind generation. The GPRA benefits are based primarily on projecting the market share for wind technologies based on their economic characteristics. The hydropower program goal is to reduce the environmental impact of hydroelectric facilities. Because this program is driven more by environmental than economic concerns, a program office estimate for the market penetration is the primary source for the GPRA benefits estimate.

The NEMS-GPRA04 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. Wind is characterized by three wind classes, although the best wind class is assumed to developed first within each region. 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. This was raised from a limit of 12 percent that is used by EIA in the AEO2002 to a limit of 30 percent based on experience in other countries and the program office expectations. Another assumption is how quickly the wind industry can expand before costs rise due to manufacturing bottlenecks. This was raised from 50 percent of installed wind capacity to 100 percent. Both of these assumptions were changed for the Baseline and GPRA cases, although they have no impact on the Baseline case.

The wind program was represented by reducing the capital and O&M costs for wind to match the program cost goals, as updated in the summer of 2001. In addition to competing on an economic basis with other electricity generation technologies, wind capacity may be constructed for its environmental benefit. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including wind, in response to the expanding green power markets in many places across the country. The projections for green power wind installations were incorporated into NEMS-GPRA04 as the planned capacity additions.

The expectation of the hydropower program office is that future hydro capacity and generation will decrease due to environmental concerns as facilities undergo relicensing. The program goal is to develop hydro turbines that reduce fish mortality rates and therefore reduce the risk of these capacity reductions. The original Baseline projected relatively constant hydropower, implying that the technology was already assumed to be deployed or that the issue had not been examined. As a result, the final Baseline for GPRA was modified to reflect an estimate of hydro capacity and generation lost in the absence of the fish-friendly turbines. The GPRA program case then returned hydropower to the prior constant levels, and the benefits result from the increased hydro output.

Estimates of primary energy, oil, and carbon emissions savings stem from wind and hydropower displacing fossil-fueled generation sources that were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. 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.

The renewable programs have been modeled together, and the GPRA benefits are allocated to each proportional to their generation share.

FY04 GPRA Benefits Estimates for Wind & Hydropower (NEMS-GPRA04)

	2005	2010	2020
Capacity (GW)	1.3	4.6	37.6
Generation (GWh)	5.0	17.3	156.5
Energy Savings (quads)	0.05	0.13	1.17
Oil Savings (quads)	0.01	0.01	0.07
Carbon Savings (MMT)	0.8	2.1	21.0
Energy Expenditure Savings (B2000$)	0.2	0.8	4.8

Appendix E – Vehicle Technologies

Heavy Vehicle Technology Quality Metrics and GPRA Benefits Analysis Methodology Final Report (Revised)

Prepared for:

U.S. Department of Energy

Office of Planning, Budget Formulation &Analysis

July 2003

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List of Exhibits

1.0 Introduction:

This report describes the approach and findings of the Quality Metrics and GPRA assessment of the Heavy Vehicle Technologies Program of EERE. The scope of the effort included:

- Characterizing baseline and advanced technology vehicles for Class 3 – 6 and Class 7 and 8 trucks,
- Estimating the market potential of technologies that improve fuel efficiency and/or involve the use of alternative fuels,
- Determining the initial petroleum and greenhouse gas emissions reductions associated with the advanced technologies.

This report contains a description of the basis from which the analysis methodology was developed, a discussion of the models used to estimate market potential and initial or 'first order' benefits, and a presentation of the benefits estimated as a result of the adoption of the advanced technologies. These initial estimates, along with market penetration and other results are then modeled as part of the EERA-wide integrated analysis to provide final benefit estimates reported in the FY04 Budget Request.

2.0 Background:

This analysis of the initial benefits expected from achieving the Heavy Vehicle Technologies Program goals was developed based on three primary reference sources:

- Vehicle characteristics and use information—as obtained from the 1997 Vehicle Inventory and Use Survey (VIUS). This provides information on both vehicle performance characteristics, such as fuel economy; and also vehicle use patterns such as miles travelled per year. (Ref. 1)
- Truck operator investment requirements—as provided by a survey of Owner-Operators performed by the American Trucking Associations in 1995. (Ref. 2)
- Vehicle performance and cost characteristics for advanced technologies—as identified by the EERE Program Managers.

Important "background" information such as energy prices and baseline technology fuel economies are based on Annual Energy Outlook (Reference Case) prepared by the Energy Information Administration (Ref. 3).

The methodology involves a disaggregation of heavy vehicle types according to usage patterns. This has enabled the identification of the vehicle types that accumulate the greatest vehicle miles travelled; and therefore offer the best opportunity for economic return; i.e. pay-back on an investment in an energy conserving technology.

In prior years, the Heavy Vehicle Technologies Program had focused on one efficiency technology, the LE-55 Engine and one alternative fuels technology (natural gas). As a result, the market segmentation also identifies travel distributions for heavy vehicles that utilize central refueling sites, and those that do not, as it was judged that central refueling would be conducive to using an alternative fuel such as natural gas.

3.0 Approach:

3.1 Market Segmentation Analysis

"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. VIUS data were examined for all vehicles in use and vehicles two years old or less. The Heavy Truck vehicle market was parsed by the Analytic Team into three types that account for similar usage and annual vehicle mile usage patterns. The vehicle type segments are:

- Type 1 – multi-stop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, garbage collection, dump, and concrete delivery;
- Type 2 – platform, livestock, auto transport, oil-field, grain, and tank;
- 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 reduces the potential efficiency benefits of aerodynamic improvements in that sector. For similar reasons, fuel economy improvements due to advanced tires also would be limited for Type 1 vehicles.

As compared to long distance, over the road travel, Type 2 vehicles tend to be used in local or regional delivery; and, as a result, will realize little fuel economy benefit from aerodynamic improvements. Distances travelled by Type 2 vehicles are typically greater than Type 1, which makes them a somewhat better market sector for advanced tires.

In general, Type 3 vehicles are the best candidates for both tire and aerodynamic improvement technologies. Refueling characteristics; i.e. central-source refueling or non-central source also were considered as centrally-refueled vehicles would find an alternative fuel source more practical than vehicles that always refuel at road-side facilities.

Heavy vehicle characteristics are summarized in Exhibit 3-1. 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. One of the more interesting findings was the significant difference in fuel economy among the vehicle types with Type 3 heavy vehicles exhibiting an average fuel economy nearly twice as high as Type 1 heavy vehicles (8.90 vs 4.55 MPG).

Exhibit 3-1: Heavy Vehicle Characteristics

Vehicle Type	Average Annual Miles (1)	Fuel Economy (MPG)	Percent Centrally Refueled (1)
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	8.90	42.0%

Note 1: Vehicles 2 years old or less

In addition to the market characterization, historical market penetration data was obtained from VIUS surveys for energy conserving technologies including radial tires, aerodynamic devices, and fan clutches. This data was utilized in the calibration of the rate of efficiency technology adoption in the model. (Ref. 1).

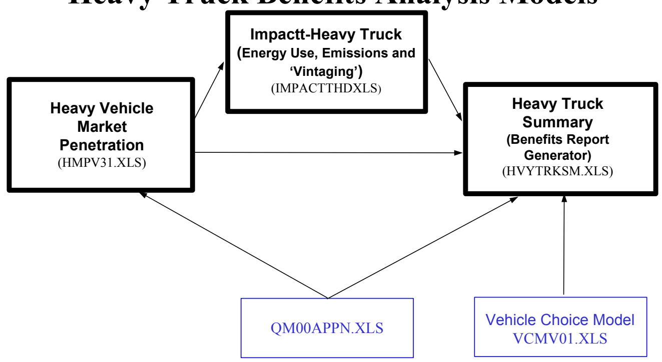
3.2 Heavy Vehicle Benefits Analysis Overview

Initial benefits estimates are generated through the linkage of three spreadsheet models:

- The Heavy Vehicle market Penetration (HVMP) model
- Integrated Market Penetration And Cost of Transportation Technologies (IMPACTT) model, and
- Heavy Truck Summary (HVS) model.

The relationship of these three models is indicated in Exhibit 3-2[1].

Exhibit 3-2:
Heavy Truck Benefits Analysis Models



Values for technology performance attributes and cost are input into the Heavy Vehicle Market Penetration (HVMP) model. This includes estimates for current technology fuel economy. Energy prices and projections used in the HVMP are linked to the values in the Quality Metrics Light Vehicle Results Model (QM00APPN.XLS). The HVMP 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.

The market penetration results are supplied through a link to the Impactt-Heavy Truck model. This 'accounting' model calculates 'first order' energy savings, criteria and carbon pollution effects, and the rate of market penetration of the new technologies into the entire fleet of Class 3 through 8 trucks.

These interim results are linked to the Heavy Truck Summary model in which various reports of the energy, emissions, and economic benefits attributable to the use of the advanced technologies

[1] The Heavy Vehicle Market Penetration 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).

IMPACTT was originally developed by Marianne Mintz, Argonne National Laboratory (ANL). The version of the model used for the Heavy Vehicle Analyses has been modified by Moore, et al, TA Engineering, with assistance from 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. Quality Metrics Light Vehicle Results Model was developed initially by John Maples, ORNL and since been modified extensively by Elyse Steiner, NREL and other NREL analysts.

The Vehicle Choice Model was developed as a collaborative effort of ANL, ORNL, and NREL analysts. It is based on a national survey of consumer attribute preferences conducted by ANL.

are calculated. Energy price factors and projections from the Annual Energy Outlook Reference Case are used by the Heavy Truck Summary model to calculate cost savings (Ref. 3).

3.3 Heavy Vehicle Market Penetration Model

Exhibit 3-3 explains the HVMP model's calculation method for Class 7 & 8, type 1 vehicles. The

Exhibit 3-3: HVMP Market Share Calculation Methodology

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

calculation method for the other 3 vehicle types and classes is highly analogous.

The HVMP 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 discounted expected energy savings of that technology over a specified time period in relation to specified payback periods.

Exhibit 3-4 shows the payback distribution assumed in the HVMP model. This payback distribution was generated using data taken from a survey of 224 motor carriers conducted by the American Trucking Association. (Ref. 2) The survey found that, for example, 16.4% of the truck operators responding require a payback of one year on an investment.

Exhibit 3-4: Heavy Vehicle Payback Period Market Distribution

Number of Years	Percent of Motor Carriers
1	16.4%
2	61.7%
3	15.5%
4	6.4%

The new technology cost and the expected efficiency improvements are exogenous inputs. Energy savings are calculated using the following data and assumptions:

- Annual vehicle miles traveled;
- Fuel efficiency (mpg) without new technology (Ref. 1);
- Fuel efficiency (mpg) with new technology; these are specified as multipliers 'times' conventional mpg to limit the effort dedicated to estimating future conventional vehicle technology changes.
- Projected fuel price – diesel, ethanol, and CNG (Ref. 3);
- Incremental cost of new technology over time (economies of scale);
- Discount rate; and
- Payback period.

Values assigned for each are indicated in the Appendix, which contains a printout of the complete HVMP model.

In the HVMP model, the truck classes are segmented according to refueling location (i.e. central or multiple locations). The data analysis revealed that all vehicle segments have central refueling occurring at least forty percent (40.1%) of the time. As vehicles age, central refueling declines. This may be explained by the transition from larger fleet operations to small independent owner operators as centrally refueled vehicles age.

Eleven travel distance categories for medium trucks and twenty-one for heavy trucks are represented in the model. These categories were determined using travel distributions developed with the VIUS data by ORNL (Ref. 4).

Exhibits 3-5 and 3-6 show the distribution for Centrally and Non-Centrally refueled vehicles. Type 3 vehicles display the greatest amount of annual travel of all heavy vehicle classes. Centrally refueled vehicles travel less per year than non-centrally refueled vehicles. In the non-centrally 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.

Exhibit 3-5: Type 3 Heavy Vehicle Travel Distribution – Central Refueling

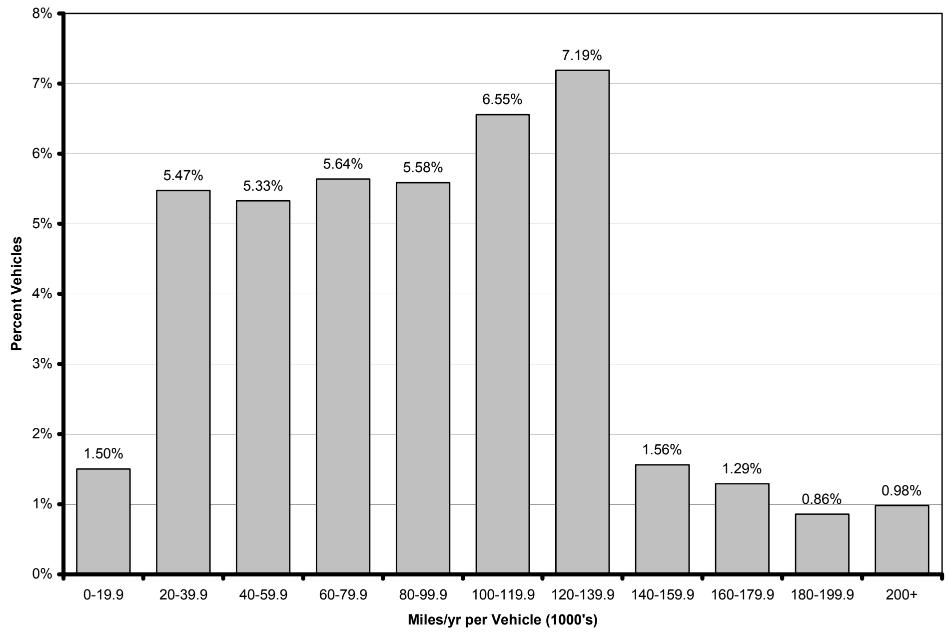
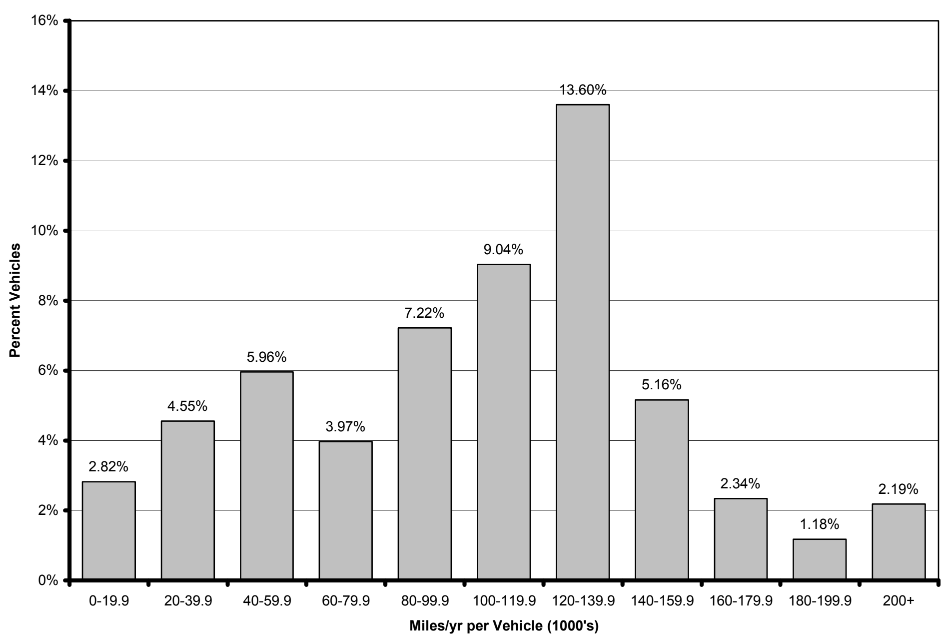


Exhibit 3-6: Type 3 Heavy Vehicle Travel Distribution – Non-Central Refueling



The technology performance assumptions and truck utilization patterns are used to determine payback performance for the advanced technologies in each type and class of vehicle. The model then calculates composite market penetrations and fuel economy values.

3.4 IMPACTT Heavy Truck

This model is a version of the IMPACTT tools developed by M. Mintz of ANL (Ref. 5). Fuel economies and market penetrations determined in HVMP are inputs to this model, which determines initial energy savings due to the expected market penetration of the advanced technologies in Medium and Heavy Vehicles. The model also has the capability of estimating criteria emissions savings, and carbon reduction. In addition, it projects the portion of the Medium and Heavy Vehicle *fleet* that are advanced technologies.

3.3 Heavy Truck Summary

This report generator provides nine tables of the first order benefits for the period covering 2000 through 2030.

Specific results are generated for the following:

- Class 3 – 8 Energy and Emissions Reductions
- Technology Market Penetrations
- Sales and Stocks of Advanced Technology Vehicles
- Heavy Vehicle Energy Use—including a breakdown by Class and Technology
- CO_2 Emissions and Emissions Reduction
- NOx, CO, and Non-methane Hydrocarbon Emissions and Emission Reductions, and
- Value of Emissions Reductions (both Carbon and Criteria Pollutants)

4.0 Results

Principal results for QM04 analysis are provided in Exhibits 4-1 through 4-5 below.

These are reproduced from the Heavy Truck Summary Model.

Exhibit 4-1: Summary Class 3 - 8 Energy and Emission Reductions

	Energy Reduction			Alternative	Petroleum	Carbon Reduction						Energy Cost Savings			Incremental
	Total	Class 3-6	Class 7-8	Fuel Use	Reduction	Total	Class 3-6	Class 7-8	Emission Reductions (1000 tons)			Total	Class 3-6	Class 7-8	Vehicle Cost
Year	mmb/d	mmb/d	mmb/d	mmb/d	mmb/d	(MMTCe)	(MMTCe)	(MMTCe)	NOx	CO	NMHC	million 2000$	million 2000$	million 2000$	million 2000$
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.06	0.06	0.00	0.25
2004	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.011	0.015	0.003	0.53	0.47	0.06	2.51
2005	0.001	0.000	0.001	0.000	0.001	0.047	0.006	0.041	0.163	0.186	0.041	21.66	2.72	18.94	169.12
2006	0.003	0.000	0.002	0.000	0.003	0.106	0.006	0.099	0.298	0.343	0.098	50.03	3.01	47.02	88.80
2007	0.004	0.000	0.004	0.000	0.004	0.190	0.011	0.179	0.547	0.612	0.176	93.96	5.37	88.59	115.20
2008	0.007	0.000	0.007	0.000	0.007	0.301	0.017	0.285	0.877	0.968	0.279	150.31	8.29	142.02	147.67
2009	0.011	0.001	0.010	0.000	0.011	0.448	0.024	0.424	1.310	1.441	0.413	224.63	12.02	212.61	188.23
2010	0.015	0.001	0.014	0.000	0.015	0.641	0.034	0.607	1.882	2.064	0.591	325.54	17.21	308.33	239.63
2011	0.021	0.001	0.020	0.000	0.021	0.897	0.047	0.850	2.640	2.892	0.827	458.20	23.97	434.23	305.83
2012	0.029	0.001	0.027	0.000	0.029	1.205	0.062	1.142	3.547	3.881	1.108	611.64	31.61	580.03	358.01
2013	0.037	0.002	0.036	0.000	0.037	1.582	0.081	1.501	4.633	5.068	1.447	803.67	41.03	762.65	420.82
2014	0.048	0.002	0.046	0.000	0.048	2.048	0.104	1.943	5.949	6.514	1.865	1,032.99	52.63	980.36	493.11
2015	0.062	0.003	0.059	0.000	0.062	2.629	0.136	2.493	7.585	8.325	2.393	1,330.07	68.81	1,261.26	574.61
2016	0.076	0.004	0.072	0.000	0.076	3.191	0.171	3.020	9.145	10.079	2.916	1,608.70	86.12	1,522.58	535.76
2017	0.088	0.005	0.083	0.000	0.088	3.725	0.208	3.517	10.590	11.733	3.422	1,871.27	104.41	1,766.86	535.23
2018	0.100	0.006	0.094	0.000	0.100	4.234	0.248	3.986	11.925	13.294	3.914	2,128.23	124.52	2,003.71	544.79
2019	0.112	0.007	0.105	0.000	0.112	4.712	0.294	4.418	13.136	14.767	4.402	2,355.96	146.93	2,209.03	561.74
2020	0.122	0.008	0.114	0.000	0.122	5.159	0.345	4.814	14.203	16.126	4.875	2,581.52	172.51	2,409.01	592.70
2021	0.138	0.010	0.128	0.000	0.138	5.813	0.423	5.390	15.889	18.234	5.575	2,946.19	214.54	2,731.66	746.06
2022	0.158	0.012	0.146	0.000	0.158	6.684	0.524	6.160	18.165	21.036	6.482	3,430.39	269.01	3,161.38	865.19
2023	0.185	0.015	0.170	0.000	0.185	7.806	0.646	7.160	21.092	24.590	7.607	4,056.63	335.83	3,720.79	974.27
2024	0.218	0.019	0.199	0.000	0.218	9.207	0.797	8.411	24.831	29.090	9.013	4,843.96	419.04	4,424.91	1,061.82
2025	0.257	0.023	0.234	0.000	0.257	10.858	0.991	9.867	29.459	34.705	10.782	5,781.88	527.76	5,254.12	1,096.60
2026	0.295	0.028	0.267	0.000	0.295	12.449	1.176	11.273	33.947	40.107	12.456	6,717.58	634.40	6,083.18	1,000.14
2027	0.332	0.032	0.300	0.000	0.332	14.015	1.365	12.650	38.466	45.552	14.132	7,662.34	746.52	6,915.82	1,022.08
2028	0.368	0.037	0.331	0.000	0.368	15.549	1.560	13.989	43.018	51.037	15.809	8,611.45	863.88	7,747.57	1,043.74
2029	0.403	0.042	0.362	0.000	0.403	17.037	1.759	15.278	47.447	56.408	17.449	9,556.15	986.59	8,569.55	1,065.46
2030	0.437	0.046	0.390	0.000	0.437	18.449	1.961	16.488	51.507	61.408	18.984	10,479.51	1,113.74	9,365.77	1,085.18
Cumulative Total From Year 2000 to Year															
2005	0.001	0.000	0.001	0.000	0.001	0.048	0.007	0.041	0.175	0.204	0.044	22.25	3.25	19.00	171.89
2010	0.041	0.002	0.039	0.000	0.041	1.733	0.099	1.635	5.089	5.632	1.600	866.72	49.15	817.56	951.40
2015	0.239	0.013	0.226	0.000	0.239	10.093	0.529	9.565	29.442	32.311	9.239	5,103.29	267.20	4,836.09	3,103.79
2020	0.737	0.042	0.694	0.000	0.737	31.114	1.794	29.320	88.441	98.310	28.768	15,648.97	901.68	14,747.28	5,874.01

Exhibit 4-2: Market Penetration of Advanced Technologies in Heavy Vehicles

	Class 7-8 Type 1		Class 7-8 Type 2		Class 7-8 Type 3		CLASS 7-8 Final		CLASS 3-6 Final	
Year	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED
2000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2002	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2003	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2004	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2005	0.2%	0.0%	1.2%	0.0%	2.4%	0.0%	1.8%	0.0%	0.3%	0.0%
2006	0.3%	0.0%	1.7%	0.0%	3.3%	0.0%	2.4%	0.0%	0.4%	0.0%
2007	0.4%	0.0%	2.3%	0.0%	4.4%	0.0%	3.2%	0.0%	0.5%	0.0%
2008	0.5%	0.0%	3.0%	0.0%	5.6%	0.0%	4.1%	0.0%	0.6%	0.0%
2009	0.7%	0.0%	3.9%	0.0%	7.1%	0.0%	5.2%	0.0%	0.8%	0.0%
2010	0.9%	0.0%	5.1%	0.0%	9.1%	0.0%	6.7%	0.0%	1.0%	0.0%
2011	1.2%	0.0%	6.6%	0.0%	11.8%	0.0%	8.7%	0.0%	1.3%	0.0%
2012	1.6%	0.0%	8.3%	0.0%	14.5%	0.0%	10.8%	0.0%	1.6%	0.0%
2013	2.2%	0.0%	10.7%	0.0%	17.9%	0.0%	13.5%	0.0%	2.0%	0.0%
2014	2.9%	0.0%	13.8%	0.0%	22.4%	0.0%	17.0%	0.0%	2.7%	0.0%
2015	2.6%	0.0%	18.4%	0.0%	27.8%	0.0%	21.2%	0.0%	3.6%	0.0%
2016	4.2%	0.0%	18.1%	0.0%	27.6%	0.0%	21.3%	0.0%	4.0%	0.0%
2017	4.1%	0.0%	18.0%	0.0%	27.5%	0.0%	21.2%	0.0%	4.4%	0.0%
2018	4.1%	0.0%	17.9%	0.0%	27.4%	0.0%	21.1%	0.0%	4.8%	0.0%
2019	4.1%	0.0%	17.9%	0.0%	27.3%	0.0%	21.1%	0.0%	5.6%	0.0%
2020	4.2%	0.0%	18.2%	0.0%	27.7%	0.0%	21.4%	0.0%	6.4%	0.0%
2025	18.6%	0.0%	54.7%	0.0%	66.5%	0.0%	55.3%	0.0%	14.6%	0.0%
2030	20.1%	0.0%	56.7%	0.0%	69.8%	0.0%	58.0%	0.0%	16.0%	0.0%

Exhibit 4-3: Heavy Vehicle (Class 3-8) Sales and Stocks of Advanced Technology Vehicles

	SALES				STOCKS				STOCKS (Percent of Total)			
	3-6		7&8		3-6		7&8		3-6		7&8	
Year	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced
2000	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2001	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2002	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2003	14	0	0	0	14	0	0	0	0.0%	0.0%	0.0%	0.0%
2004	97	0	23	0	111	0	23	0	0.0%	0.0%	0.0%	0.0%
2005	566	0	5,810	0	677	0	5,833	0	0.0%	0.0%	0.1%	0.0%
2006	821	0	8,223	0	1,496	0	14,038	0	0.0%	0.0%	0.3%	0.0%
2007	1,140	0	11,214	0	2,630	0	25,199	0	0.1%	0.0%	0.5%	0.0%
2008	1,508	0	15,201	0	4,125	0	40,288	0	0.1%	0.0%	0.7%	0.0%
2009	2,008	0	20,538	0	6,110	0	60,616	0	0.1%	0.0%	1.1%	0.0%
2010	2,787	0	27,723	0	8,859	0	87,971	0	0.2%	0.0%	1.5%	0.0%
2011	3,781	0	37,752	0	12,576	0	125,080	0	0.3%	0.0%	2.1%	0.0%
2012	4,665	0	47,413	0	17,139	0	171,380	0	0.4%	0.0%	2.8%	0.0%
2013	6,013	0	59,932	0	22,996	0	229,584	0	0.5%	0.0%	3.6%	0.0%
2014	7,880	0	75,881	0	30,646	0	302,881	0	0.6%	0.0%	4.6%	0.0%
2015	10,715	0	95,903	0	41,026	0	395,033	0	0.8%	0.0%	5.9%	0.0%
2016	12,240	0	97,361	0	52,790	0	487,080	0	1.0%	0.0%	7.1%	0.0%
2017	13,406	0	96,857	0	65,539	0	576,638	0	1.2%	0.0%	8.2%	0.0%
2018	14,954	0	98,191	0	79,606	0	665,075	0	1.5%	0.0%	9.2%	0.0%
2019	17,740	0	100,285	0	96,173	0	752,627	0	1.7%	0.0%	10.2%	0.0%
2020	20,908	0	105,159	0	115,554	0	841,520	0	2.0%	0.0%	11.1%	0.0%
2021	24,915	0	134,262	0	138,510	0	955,365	0	2.4%	0.0%	12.4%	0.0%
2022	29,980	0	169,837	0	166,008	0	1,100,015	0	2.8%	0.0%	14.1%	0.0%
2023	34,504	0	210,610	0	197,406	0	1,280,315	0	3.3%	0.0%	16.1%	0.0%
2024	40,834	0	253,636	0	234,395	0	1,497,944	0	3.9%	0.0%	18.5%	0.0%
2025	51,498	0	289,206	0	281,184	0	1,744,877	0	4.6%	0.0%	21.1%	0.0%
2030	60,253	0	321,557	0	522,781	0	2,962,059	0	8.1%	0.0%	32.7%	0.0%

Exhibit 4-4: Heavy Vehicle (Class 3-8) Energy Use

Year	Base Case Energy Use, Trillion BTUs			Class 3-6 Technology Energy Use, Trillion BTUs				Class 7&8 Technology Energy Use, Trillion BTUs				Current & Enhanced Energy Use	Energy Savings	Energy Savings by Program, Trillion BTUs	
	Class 3-6	Class 7-8	Total	Class 3-6 Conv.	Current Program	Enhanced Program	Total	Class 7-8 Conv.	Current Program	Enhanced Program	Total	Trillion BTUs	Trillion BTUs	Current Program	Enhanced Program
2000															
2001	835.8	3,903.2	4,739.0	835.8	0.0	0.0	835.8	3,903.2	0.0	0.0	3,903.2	4,739.0	0.0	0.0	0.0
2002	840.6	4,069.2	4,909.7	840.6	0.0	0.0	840.6	4,069.2	0.0	0.0	4,069.2	4,909.7	0.0	0.0	0.0
2003	855.6	4,238.5	5,094.1	855.6	0.0	0.0	855.6	4,238.5	0.0	0.0	4,238.5	5,094.1	0.0	0.0	0.0
2004	864.7	4,361.5	5,226.2	864.7	0.0	0.0	864.7	4,361.5	0.0	0.0	4,361.5	5,226.2	0.1	0.1	0.0
2005	874.8	4,438.8	5,313.6	874.5	0.0	0.0	874.5	4,430.5	6.3	0.0	4,436.8	5,311.3	2.3	2.3	0.0
2006	876.1	4,479.5	5,355.6	875.5	0.3	0.0	875.8	4,459.4	15.1	0.0	4,474.5	5,350.3	5.3	5.3	0.0
2007	882.8	4,543.3	5,426.1	881.8	0.5	0.0	882.3	4,507.3	27.1	0.0	4,534.3	5,416.6	9.5	9.5	0.0
2008	895.3	4,613.4	5,508.7	893.7	0.8	0.0	894.5	4,556.3	42.8	0.0	4,599.2	5,493.6	15.1	15.1	0.0
2009	910.5	4,706.9	5,617.4	908.2	1.1	0.0	909.3	4,621.9	63.7	0.0	4,685.6	5,594.9	22.4	22.4	0.0
2010	928.4	4,808.6	5,737.1	925.2	1.6	0.0	926.7	4,687.2	91.0	0.0	4,778.2	5,705.0	32.1	32.1	0.0
2011	949.7	4,930.5	5,880.2	945.2	2.2	0.0	947.4	4,760.4	127.5	0.0	4,887.9	5,835.3	45.0	45.0	0.0
2012	967.3	5,032.5	5,999.8	961.3	2.9	0.0	964.2	4,804.1	171.2	0.0	4,975.3	5,939.5	60.4	60.4	0.0
2013	981.0	5,141.1	6,122.1	973.2	3.8	0.0	977.0	4,840.7	225.2	0.0	5,065.9	6,042.9	79.3	79.3	0.0
2014	994.6	5,248.2	6,242.8	984.4	5.0	0.0	989.4	4,858.5	292.2	0.0	5,150.8	6,140.2	102.6	102.6	0.0
2015	1,009.3	5,359.5	6,368.9	996.0	6.5	0.0	1,002.5	4,858.9	375.7	0.0	5,234.6	6,237.1	131.8	131.8	0.0
2016	1,024.7	5,472.7	6,497.5	1007.9	8.3	0.0	1,016.2	4,865.1	456.2	0.0	5,321.4	6,337.5	159.9	159.9	0.0
2017	1,042.3	5,595.1	6,637.4	1021.7	10.2	0.0	1,031.9	4,885.8	533.0	0.0	5,418.8	6,450.7	186.7	186.7	0.0
2018	1,060.6	5,719.7	6,780.3	1,035.9	12.3	0.0	1,048.2	4,913.6	606.4	0.0	5,519.9	6,568.1	212.2	212.2	0.0
2019	1,079.0	5,838.6	6,917.6	1,049.6	14.7	0.0	1,064.3	4,942.0	675.1	0.0	5,617.1	6,681.4	236.2	236.2	0.0
2020	1,091.6	5,942.9	7,034.5	1,056.8	17.4	0.0	1,074.3	4,962.1	739.5	0.0	5,701.6	6,775.9	258.6	258.6	0.0
2021	1,134.1	6,088.3	7,222.4	1,091.7	21.1	0.0	1,112.9	4,986.0	832.2	0.0	5,818.2	6,931.1	291.4	291.4	0.0
2022	1,178.1	6,238.0	7,416.1	1,126.3	25.6	0.0	1,151.8	4,973.5	955.8	0.0	5,929.3	7,081.1	335.0	335.0	0.0
2023	1,224.2	6,391.3	7,615.5	1,161.0	30.7	0.0	1,191.8	4,916.4	1,116.1	0.0	6,032.5	7,224.2	391.3	391.3	0.0
2024	1,272.0	6,549.0	7,821.0	1,195.1	37.0	0.0	1,232.1	4,812.1	1,315.4	0.0	6,127.4	7,359.5	461.5	461.5	0.0
2025	1,321.5	6,709.2	8,030.7	1,226.8	45.0	0.0	1,271.8	4,669.2	1,545.5	0.0	6,214.7	7,486.5	544.2	544.2	0.0
2026	1,344.4	6,840.6	8,184.9	1,233.1	52.3	0.0	1,285.4	4,507.9	1,767.7	0.0	6,275.5	7,561.0	624.0	624.0	0.0
2027	1,367.8	6,974.5	8,342.3	1,239.9	59.5	0.0	1,299.4	4,355.8	1,984.7	0.0	6,340.5	7,639.9	702.5	702.5	0.0
2028	1,391.6	7,111.1	8,502.7	1,246.8	66.6	0.0	1,313.4	4,214.9	2,195.1	0.0	6,410.0	7,723.3	779.4	779.4	0.0
2029	1,415.8	7,250.5	8,666.3	1,254.1	73.6	0.0	1,327.7	4,086.3	2,398.4	0.0	6,484.7	7,812.4	853.9	853.9	0.0
2030	1,440.5	7,392.6	8,833.1	1,261.7	80.5	0.0	1,342.2	3,973.1	2,593.1	0.0	6,566.2	7,908.4	924.7	924.7	0.0
Cumulative Total From Year 2000 to Year															
2005	4,271	21,011	25,283	4,271	0	0	4,271	21,011	6	0	21,009	25,280	2	2	0
2010	8,765	44,163	52,928	8,755	4	0	8,760	44,163	246	0	44,081	52,841	87	87	0
2015	13,667	69,875	83,541	13,615	25	0	13,640	69,875	1,438	0	69,395	83,035	506	506	0
2020	18,965	98,444	117,409	18,787	88	0	18,875	98,444	4,448	0	96,974	115,849	1,559	1,559	0
2025	25,095	130,420	155,514	24,588	247	0	24,835	130,420	10,213	0	127,096	151,932	3,583	3,583	0
2030	32,055	165,989	198,044	30,824	580	0	31,403	165,989	21,152	0	159,173	190,577	7,467	7,467	0

Exhibit 4-5: Heavy Vehicle (Class 3-8) CO2 Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS			TOTAL REDUCTION		
	Reduction			Reduction					
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.5	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.5
2004	3.9	0.5	4.4	0.0	0.0	0.0	3.9	0.5	4.4
2005	22.9	163.0	185.9	0.0	0.0	0.0	22.9	163.0	185.9
2006	24.4	395.9	420.3	0.0	0.0	0.0	24.4	395.9	420.3
2007	41.8	712.7	754.4	0.0	0.0	0.0	41.8	712.7	754.4
2008	64.1	1,132.2	1,196.3	0.0	0.0	0.0	64.1	1,132.2	1,196.3
2009	92.4	1,686.5	1,779.0	0.0	0.0	0.0	92.4	1,686.5	1,779.0
2010	130.8	2,414.4	2,545.2	0.0	0.0	0.0	130.8	2,414.4	2,545.2
2011	181.2	3,383.3	3,564.5	0.0	0.0	0.0	181.2	3,383.3	3,564.5
2012	240.4	4,545.8	4,786.2	0.0	0.0	0.0	240.4	4,545.8	4,786.2
2013	311.7	5,973.6	6,285.3	0.0	0.0	0.0	311.7	5,973.6	6,285.3
2014	402.7	7,734.1	8,136.9	0.0	0.0	0.0	402.7	7,734.1	8,136.9
2015	525.0	9,921.5	10,446.5	0.0	0.0	0.0	525.0	9,921.5	10,446.5
2016	659.2	12,017.8	12,676.9	0.0	0.0	0.0	659.2	12,017.8	12,676.9
2017	801.9	13,996.1	14,798.0	0.0	0.0	0.0	801.9	13,996.1	14,798.0
2018	955.7	15,863.7	16,819.4	0.0	0.0	0.0	955.7	15,863.7	16,819.4
2019	1,133.6	17,583.9	18,717.5	0.0	0.0	0.0	1,133.6	17,583.9	18,717.5
2020	1,329.5	19,158.8	20,488.4	0.0	0.0	0.0	1,329.5	19,158.8	20,488.4
2021	1,632.9	21,449.5	23,082.3	0.0	0.0	0.0	1,632.9	21,449.5	23,082.3
2022	2,022.6	24,513.0	26,535.6	0.0	0.0	0.0	2,022.6	24,513.0	26,535.6
2023	2,494.7	28,494.0	30,988.7	0.0	0.0	0.0	2,494.7	28,494.0	30,988.7
2024	3,076.0	33,472.4	36,548.4	0.0	0.0	0.0	3,076.0	33,472.4	36,548.4
2025	3,828.4	39,265.5	43,093.9	0.0	0.0	0.0	3,828.4	39,265.5	43,093.9
2030	7,584.8	65,618.4	73,203.2	0.0	0.0	0.0	7,584.8	65,618.4	73,203.2
Cumulative Total From Year 2000 to Year									
2005	27.3	163.5	190.8	0.0	0.0	0.0	27.3	163.5	190.8
2010	380.7	6,505.3	6,886.1	0.0	0.0	0.0	380.7	6,505.3	6,886.1
2015	2,041.8	38,063.6	40,105.3	0.0	0.0	0.0	2,041.8	38,063.6	40,105.3
2020	6,921.6	116,683.9	123,605.5	0.0	0.0	0.0	6,921.6	116,683.9	123,605.5
2025	19,976.2	263,878.2	283,854.4	0.0	0.0	0.0	19,976.2	263,878.2	283,854.4
2030	47,944.4	528,771.1	576,715.5	0.0	0.0	0.0	47,944.4	528,771.1	576,715.5

References

1. 1997 Vehicle Inventory and Use Survey, EC97TV-US U.S. Bureau of the Census, Washington, D. C., 1999.
2. 1997 Return on Investment Survey, American Trucking Association, Arlington Va., 1997.
3. "Annual Energy Outlook 2002, With Projections to 2020," Energy Information Agency, Department of Energy, Washington, D. C., Publication DOE/EIA-0383 (2002). (Website address: http://www.eia.doe.gov/bookshelf.html *(Library/Archives-Forecasting)*.
4. Personal Communication with Stacy Davis, ORNL, November 2001
5. Mintz, M. M. and Saricks, "IMPACTT5A Model: Enhancements and modifications since December 1994," Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, Argonne, Illinois, September 1998.

Appendix

Overview of Heavy Vehicle Market Penetration Model (HVMP)

The HVMP is a spreadsheet model that currently operates in Excel (Office 2000 and associated versions). It consists of nine spreadsheets linked to other models. It is operated by user specifying inputs and then initiating macros that perform iterative calculations to determine market shares by technology in percents of new vehicle sales. The spreadsheets are reproduced on the following pages. In some cases the spreadsheets take up several pages. These are presented in sequence with an arrow to indicate the relationship of the current page to the following page.

1. **Inputs**-user specifies incremental technology cost and relative fuel efficiency for current and advanced technology(ies). These inputs are specified by year to 2035 and separately for Class 7 & 8 and Classes 3 through 6 vehicles.
2. **Fuel Prices**—array of fuel price information. Typically linked to other AEO-source files.
3. **Market Data (6 pages)**—Distribution of vehicle usage patterns from 1997 VIUS
4. **Type 1 (7 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for “Type 1” Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
5. **Type 2 (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for “Type 2” Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
6. **Type 3 (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for “Type 3” Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
7. **Med (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for “Medium”, i.e., Class 3 through 6 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
8. **New MPG (2 pages)**—Shows the effect of new technology penetrations on the fleet fuel economy by vehicle class.
9. **Market Penetration (1 page)**—Summarizes the market penetration of new technologies in units of new vehicle sales percentage. Lists market shares for each Class 7 & 8 vehicle type, Class 7 & 8 composite and Classes 3 through 6 (composite).

Inputs

COST AND EFFICIENCY ESTIMATES FOR HEAVY VEHICLE ADVANCED TECHNOLOGIES

Combined Run: Current and Enhanced Program

Cost: Incremental vehicle price of added technology

Efficiency Ratio: Ratio of advanced vehicle fuel mpg compared to conventional vehicle

(Run uses base fuel economies from S. Davis VIUS Analysis)

	CLASS 7 & 8					CLASS 3-6			
	CURRENT		ENHANCED			CURRENT		ENHANCED	
Year	Cost	Efficiency Ratio	Cost	Efficiency Ratio	Year	Cost	Efficiency Ratio	Cost	Efficiency Ratio
1995	100,000	0.01	100,000	1.00	1995	20,000	1.00	100,000	1.00
1996	100,000	0.21	100,000	1.00	1996	19,000	1.00	100,000	1.00
1997	100,000	0.41	100,000	1.00	1997	18,000	1.00	100,000	1.00
1998	100,000	0.60	100,000	1.00	1998	17,000	1.00	100,000	1.00
1999	100,000	0.80	100,000	1.00	1999	16,000	1.00	100,000	1.00
2000	100,000	1.00	100,000	1.00	2000	15,000	1.00	100,000	1.00
2001	82,000	1.09	100,000	1.00	2001	14,000	1.20	100,000	1.20
2002	64,000	1.17	100,000	1.00	2002	13,000	1.40	100,000	1.40
2003	46,000	1.26	100,000	1.00	2003	12,000	1.60	100,000	1.60
2004	28,000	1.34	100,000	1.00	2004	11,000	1.80	100,000	1.80
2005	10,000	1.43	100,000	1.00	2005	10,000	2.00	100,000	2.00
2006	9,500	1.43	100,000	1.07	2006	9,800	2.00	100,000	2.10
2007	9,000	1.43	100,000	1.14	2007	9,600	2.00	100,000	2.20
2008	8,500	1.43	100,000	1.21	2008	9,400	2.00	100,000	2.30
2009	8,000	1.43	100,000	1.28	2009	9,200	2.00	100,000	2.40
2010	7,500	1.43	100,000	1.35	2010	9,000	2.00	100,000	2.50
2011	7,000	1.43	100,000	1.45	2011	8,800	2.00	100,000	2.50
2012	6,500	1.43	100,000	1.55	2012	8,600	2.00	100,000	2.50
2013	6,000	1.43	100,000	1.66	2013	8,400	2.00	100,000	2.50
2014	5,500	1.43	100,000	1.76	2014	8,200	2.00	100,000	2.50
2015	5,000	1.43	100,000	1.86	2015	8,000	2.00	100,000	2.50
2016	5,000	1.43	100,000	1.86	2016	7,800	2.00	100,000	2.50
2017	5,000	1.43	100,000	1.86	2017	7,600	2.00	100,000	2.50
2018	5,000	1.43	100,000	1.86	2018	7,400	2.00	100,000	2.50
2019	5,000	1.43	100,000	1.86	2019	7,200	2.00	100,000	2.50
2020	5,000	1.43	100,000	1.86	2020	7,000	2.00	100,000	2.50
2021	4,600	1.43	100,000	1.86	2021	6,800	2.00	100,000	2.50
2022	4,200	1.43	100,000	1.86	2022	6,600	2.00	100,000	2.50
2023	3,800	1.43	100,000	1.86	2023	6,400	2.00	100,000	2.50
2024	3,400	1.43	100,000	1.86	2024	6,200	2.00	100,000	2.50
2025	3,000	1.43	100,000	1.86	2025	6,000	2.00	100,000	2.50
2026	3,000	1.43	100,000	1.86	2026	6,000	2.00	100,000	2.50
2027	3,000	1.43	100,000	1.86	2027	6,000	2.00	100,000	2.50
2028	3,000	1.43	100,000	1.86	2028	6,000	2.00	100,000	2.50
2029	3,000	1.43	100,000	1.86	2029	6,000	2.00	100,000	2.50
2030	3,000	1.43	100,000	1.86	2030	6,000	2.00	100,000	2.50
2031	3,000	1.43	80,250	1.86	2031	6,000	2.00	100,000	2.50
2032	3,000	1.43	60,500	1.86	2032	6,000	2.00	100,000	2.50
2033	3,000	1.43	40,750	1.86	2033	6,000	2.00	100,000	2.50
2034	3,000	1.43	21,000	1.86	2034	6,000	2.00	100,000	2.50
2035	3,000	1.43	1,250	1.86	2035	6,000	2.00	100,000	2.50

Fuel Prices

Transportation Energy Prices												
AEO'01												
	2000 Dollars per Million Btu						2000 Dollars per Gallon Gasoline Equivalent					
Year	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol
1995	9.23	8.03	12.62	5.77	15.14	18.96	1.15	1.11	1.58	0.72	1.89	2.37
1996	9.89	8.90	12.62	5.41	15.33	17.73	1.24	1.23	1.58	0.68	1.92	2.36
1997	9.59	8.37	12.64	6.17	15.40	16.50	1.20	1.16	1.58	0.77	1.93	2.36
1998	9.37	8.18	12.61	5.69	15.08	15.26	1.17	1.13	1.58	0.71	1.89	2.35
1999	9.56	8.46	12.73	5.56	14.91	14.03	1.20	1.17	1.59	0.70	1.86	2.34
2000	12.20	10.81	11.70	8.04	21.78	17.33	1.52	1.50	1.46	1.00	2.72	1.80
2001	12.15	10.46	11.90	8.26	21.03	16.89	1.52	1.45	1.49	1.03	2.63	1.76
2002	10.98	9.84	12.15	6.11	20.19	16.44	1.37	1.36	1.52	0.76	2.52	1.73
2003	10.93	9.23	12.40	6.39	18.25	16.00	1.37	1.28	1.55	0.80	2.28	1.69
2004	10.92	9.27	12.77	6.56	17.41	15.55	1.36	1.29	1.60	0.82	2.18	1.66
2005	11.02	9.23	13.04	6.64	16.56	15.11	1.38	1.28	1.63	0.83	2.07	1.62
2006	11.24	9.43	13.24	6.69	16.20	14.66	1.41	1.31	1.66	0.84	2.02	1.58
2007	11.22	9.87	13.29	6.73	16.67	14.22	1.40	1.37	1.66	0.84	2.08	1.55
2008	11.25	9.96	13.02	6.81	17.24	13.77	1.41	1.38	1.63	0.85	2.16	1.51
2009	11.29	10.01	13.03	6.85	17.73	13.33	1.41	1.39	1.63	0.86	2.22	1.48
2010	11.27	10.14	13.06	6.89	18.20	12.88	1.41	1.41	1.63	0.86	2.27	1.44
2011	11.30	10.19	13.02	6.95	18.59	12.69	1.41	1.41	1.63	0.87	2.32	1.43
2012	11.31	10.13	13.01	7.01	18.86	12.50	1.41	1.41	1.63	0.88	2.36	1.42
2013	11.29	10.14	13.05	7.06	19.11	12.30	1.41	1.41	1.63	0.88	2.39	1.41
2014	11.28	10.06	13.11	7.09	19.28	12.11	1.41	1.40	1.64	0.89	2.41	1.40
2015	11.28	10.09	12.99	7.13	19.27	11.92	1.41	1.40	1.62	0.89	2.41	1.39
2016	11.27	10.06	13.06	7.16	19.11	11.62	1.41	1.40	1.63	0.89	2.39	1.38
2017	11.26	10.02	13.17	7.19	18.86	11.31	1.41	1.39	1.65	0.90	2.36	1.37
2018	11.27	10.03	13.19	7.22	18.64	11.01	1.41	1.39	1.65	0.90	2.33	1.36
2019	11.28	9.97	13.17	7.24	18.28	10.70	1.41	1.38	1.65	0.90	2.29	1.35
2020	11.28	9.98	13.20	7.28	17.91	10.40	1.41	1.38	1.65	0.91	2.24	1.34
2021	11.42	10.11	13.33	7.31	17.90	10.18	1.43	1.40	1.67	0.91	2.24	1.34
2022	11.57	10.24	13.47	7.34	17.89	9.95	1.45	1.42	1.68	0.92	2.24	1.34
2023	11.71	10.37	13.60	7.37	17.88	9.73	1.46	1.44	1.70	0.92	2.24	1.34
2024	11.86	10.50	13.74	7.40	17.87	9.50	1.48	1.46	1.72	0.92	2.23	1.34
2025	12.00	10.62	13.87	7.43	17.86	9.28	1.50	1.47	1.73	0.93	2.23	1.34
2026	12.16	10.77	14.01	7.46	17.85	9.28	1.52	1.49	1.75	0.93	2.23	1.34
2027	12.32	10.91	14.15	7.49	17.84	9.28	1.54	1.51	1.77	0.94	2.23	1.34
2028	12.48	11.05	14.29	7.52	17.83	9.28	1.56	1.53	1.79	0.94	2.23	1.34
2029	12.64	11.19	14.44	7.55	17.82	9.28	1.58	1.55	1.80	0.94	2.23	1.34
2030	12.80	11.33	14.58	7.58	17.81	9.28	1.60	1.57	1.82	0.95	2.23	1.34
2031	12.96	11.47	14.72	7.61	17.80	9.28	1.62	1.59	1.84	0.95	2.23	1.34
2032	13.12	11.62	14.86	7.64	17.79	9.28	1.64	1.61	1.86	0.95	2.22	1.34
2033	13.28	11.76	15.01	7.67	17.78	9.28	1.66	1.63	1.88	0.96	2.22	1.34
2034	13.44	11.90	15.15	7.70	17.77	9.28	1.68	1.65	1.89	0.96	2.22	1.34
2035	13.60	12.04	15.29	7.73	17.76	9.28	1.70	1.67	1.91	0.97	2.22	1.34
	0.16	0.14	0.14	0.03	-0.01	0.00						
DOE/EIA-0383(97), Annual Energy Outlook 1997, Reference Case Forecast Table A3. Energy Prices by Sector and Source, pgs. 100 and 101.												
Prices Include Federal and State taxes and exclude county and local taxes.												
Ethanol: Programs goals as stated in 1997 Budget.												

Market Data (1)

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 1					
Vehicle Age 2 or Less					
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00					
	Vehilces		Percent		1
VMT (1000)	Central	Non-Central	Central	Non-Central	
0	0	0	0.00%	0.00%	
5	2095	1126	2.14%	1.15%	
10	5085	3421	5.21%	3.50%	
15	6669	3807	6.83%	3.90%	
20	8260	3799	8.46%	3.89%	
25	5560	3003	5.69%	3.07%	
30	6042	3743	6.19%	3.83%	
35	2646	2094	2.71%	2.14%	
40	2728	2095	2.79%	2.14%	
45	2230	1957	2.28%	2.00%	
50	3432	1853	3.51%	1.90%	
55	1922	1092	1.97%	1.12%	
60	2167	1445	2.22%	1.48%	
65	950	1281	0.97%	1.31%	
70	1280	862	1.31%	0.88%	
75	1166	745	1.19%	0.76%	
80	1156	1160	1.18%	1.19%	
85	606	768	0.62%	0.79%	
90	1084	1148	1.11%	1.18%	
95	474	474	0.49%	0.49%	
100	1643	1582	1.68%	1.62%	
105	320		0.33%	0.00%	
110	456	668	0.47%	0.68%	
115		342	0.00%	0.35%	
120	155	329	0.16%	0.34%	
125	233		0.24%	0.00%	
130			0.00%	0.00%	
135			0.00%	0.00%	
140		517	0.00%	0.53%	
145			0.00%	0.00%	
150			0.00%	0.00%	
155			0.00%	0.00%	
160			0.00%	0.00%	
165			0.00%	0.00%	
170			0.00%	0.00%	
175			0.00%	0.00%	
180			0.00%	0.00%	
185			0.00%	0.00%	
190			0.00%	0.00%	
195			0.00%	0.00%	
200			0.00%	0.00%	
201+			0.00%	0.00%	
Total	58359	39311	59.8%	40.2%	
	97670				
	17.8%				

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 2					
Vehicle Age 2 or Less					
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00					
	Vehilces		Percent		1
VMT (1000)	Central	Non-Central	Central	Non-Central	
0	0	0	0.00%	0.00%	
5	970	1488	0.78%	1.20%	
10	2156	2814	1.74%	2.27%	
15	2410	4169	1.95%	3.37%	
20	1572	2699	1.27%	2.18%	
25	3204	2357	2.59%	1.90%	
30	2054	2286	1.66%	1.85%	
35	2077	1453	1.68%	1.17%	
40	2057	2285	1.66%	1.85%	
45	2370	1211	1.91%	0.98%	
50	1892	2537	1.53%	2.05%	
55	1812	966	1.46%	0.78%	
60	3026	1940	2.44%	1.57%	
65	2423	1833	1.96%	1.48%	
70	1441	1812	1.16%	1.46%	
75	1648	1261	1.33%	1.02%	
80	1732	3003	1.40%	2.43%	
85	1306	1311	1.06%	1.06%	
90	1734	2642	1.40%	2.13%	
95	1450	2314	1.17%	1.87%	
100	3201	7882	2.59%	6.37%	
105	924	2386	0.75%	1.93%	
110	1126	3835	0.91%	3.10%	
115	1387	1902	1.12%	1.54%	
120	1935	5453	1.56%	4.41%	
125	941	2464	0.76%	1.99%	
130	657	2841	0.53%	2.30%	
135	219	1269	0.18%	1.03%	
140	701	1342	0.57%	1.08%	
145	185	551	0.15%	0.45%	
150	585	1353	0.47%	1.09%	
155	575	349	0.46%	0.28%	
160	550	506	0.44%	0.41%	
165			0.00%	0.00%	
170			0.00%	0.00%	
175			0.00%	0.00%	
180		316	0.00%	0.26%	
185			0.00%	0.00%	
190			0.00%	0.00%	
195			0.00%	0.00%	
200			0.00%	0.00%	
201+	461	162	0.37%	0.13%	
Total	50781	72992	41.0%	59.0%	
	123773				
	22.6%				

Market Data (2)

VMT (1000)						VMT (1000)				
0	0.0%	0.0%	0.00	0.00		0	0.0%	0.0%	0.00	0.00
5	15.1%	13.5%	0.76	0.67		5	17.5%	17.6%	0.88	0.88
10	36.7%	41.0%	3.67	4.10		10	38.9%	33.2%	3.89	3.32
15	48.2%	45.6%	7.22	6.84		15	43.5%	49.2%	6.53	7.38
	13849	8354	11.65	11.60			5536	8471	11.30	11.58
20	36.7%	30.1%	7.34	6.01		20	17.6%	30.7%	3.53	6.14
25	24.7%	23.8%	6.18	5.94		25	36.0%	26.8%	8.99	6.70
30	26.8%	29.6%	8.05	8.88		30	23.1%	26.0%	6.92	7.80
35	11.8%	16.6%	4.11	5.80		35	23.3%	16.5%	8.16	5.78
	22508	12639	25.68	26.63			8907	8795	27.60	26.42
40	26.5%	29.9%	10.58	11.98		40	25.3%	32.6%	10.12	13.06
45	21.6%	28.0%	9.73	12.59		45	29.1%	17.3%	13.12	7.79
50	33.3%	26.5%	16.64	13.24		50	23.3%	36.2%	11.63	18.12
55	18.6%	15.6%	10.25	8.58		55	22.3%	13.8%	12.26	7.59
	10312	6997	47.21	46.39			8131	6999	47.13	46.56
60	39.0%	33.3%	23.37	20.01		60	35.4%	28.3%	21.26	17.00
65	17.1%	29.6%	11.10	19.22		65	28.4%	26.8%	18.45	17.40
70	23.0%	19.9%	16.11	13.93		70	16.9%	26.5%	11.81	18.53
75	21.0%	17.2%	15.72	12.90		75	19.3%	18.4%	14.48	13.81
	5563	4333	66.30	66.05			8538	6846	66.00	66.75
80	34.8%	32.7%	27.86	26.14		80	27.8%	32.4%	22.27	25.92
85	18.3%	21.6%	15.52	18.39		85	21.0%	14.1%	17.84	12.02
90	32.7%	32.3%	29.39	29.10		90	27.9%	28.5%	25.08	25.65
95	14.3%	13.4%	13.56	12.68		95	23.3%	25.0%	22.14	23.71
	3320	3550	86.32	86.32			6222	9270	87.33	87.30
100	67.9%	61.0%	67.92	61.03		100	48.2%	49.2%	48.22	49.25
105	13.2%	0.0%	13.89	0.00		105	13.9%	14.9%	14.62	15.65
110	18.9%	25.8%	20.74	28.35		110	17.0%	24.0%	18.66	26.36
115	0.0%	13.2%	0.00	15.17		115	20.9%	11.9%	24.03	13.67
	2419	2592	102.55	104.56			6638	16005	105.53	104.92
120	39.9%	100.0%	47.94	120.00		120	51.6%	45.3%	61.89	54.41
125	60.1%	0.0%	75.06	0.00		125	25.1%	20.5%	31.35	25.61
130	0.0%	0.0%	0.00	0.00		130	17.5%	23.6%	22.76	30.71
135	0.0%	0.0%	0.00	0.00		135	5.8%	10.6%	7.88	14.24
	388	329	123.00	120.00			3752	12027	123.88	124.97

Market Data (3)

140	#DIV/0!	100.0%	#DIV/0!	140.00		140	34.3%	37.3%	47.97	52.26
145	#DIV/0!	0.0%	#DIV/0!	0.00		145	9.0%	15.3%	13.11	22.22
150	#DIV/0!	0.0%	#DIV/0!	0.00		150	28.6%	37.6%	42.89	56.45
155	#DIV/0!	0.0%	#DIV/0!	0.00		155	28.1%	9.7%	43.56	15.05
	0	517	#DIV/0!	140.00			2046	3595	147.53	145.99
160	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		160	100.0%	100.0%	160.00	160.00
165	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		165	0.0%	0.0%	0.00	0.00
170	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		170	0.0%	0.0%	0.00	0.00
175	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		175	0.0%	0.0%	0.00	0.00
	0	0	#DIV/0!	167.50			550	506	160.00	160.00
180	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		180	#DIV/0!	100.0%	#DIV/0!	180.00
185	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		185	#DIV/0!	0.0%	#DIV/0!	0.00
190	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		190	#DIV/0!	0.0%	#DIV/0!	0.00
195	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		195	#DIV/0!	0.0%	#DIV/0!	0.00
	0	0	#DIV/0!	187.50			0	316	#DIV/0!	180.00
200	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		200	0.0%	0.0%	0.00	0.00
225	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		225	100.0%	100.0%	225.00	225.00
	0	0	#DIV/0!	#DIV/0!			461	162	225.00	225.00
Total						Total				
		TYPE 1						TYPE 2		
VMT	Central	Non-Central	Central	Non-Central		VMT	Central	Non-Central	Central	Non-Central
0-19.9	11651	11605	14.18%	8.55%	#####	0-19.9	11301	11582	4.47%	6.84%
20-39.9	25683	26635	23.04%	12.94%	#####	20-39.9	27602	26417	7.20%	7.11%
40-59.9	47205	46388	10.56%	7.16%	#####	40-59.9	47127	46560	6.57%	5.65%
60-79.9	66299	66047	5.70%	4.44%	#####	60-79.9	66002	66748	6.90%	5.53%
80-99.9	86319	86318	3.40%	3.63%	7.03%	80-99.9	87332	87302	5.03%	7.49%
100-119.9	102547	104556	2.48%	2.65%	5.13%	100-119.9	105527	104924	5.36%	12.93%
120-139.9	123003	120000	0.40%	0.34%	0.73%	120-139.9	123881	124969	3.03%	9.72%
140-159.9	147500	140000	0.00%	0.53%	0.53%	140-159.9	147527	145986	1.65%	2.90%
160-179.9	167500	167500	0.00%	0.00%	0.00%	160-179.9	160000	160000	0.44%	0.41%
180-199.9	187500	187500	0.00%	0.00%	0.00%	180-199.9	187500	180000	0.00%	0.26%
200+	212500	212500	0.00%	0.00%	0.00%	200+	225000	225000	0.37%	0.13%
					#####					

Market Data (4)

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 3
Vehicle Age 2 or Less
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00

	Vehilces		Percent	
VMT (1000)	Central	Non-Central	Central	Non-Central
0	0	0	0.00%	0.00%
5	992	2415	0.30%	0.74%
10	1668	2540	0.51%	0.78%
15	2253	4249	0.69%	1.30%
20	5372	3213	1.65%	0.98%
25	3705	4804	1.13%	1.47%
30	4236	4181	1.30%	1.28%
35	4565	2671	1.40%	0.82%
40	5572	3484	1.71%	1.07%
45	3993	3862	1.22%	1.18%
50	4782	9041	1.46%	2.77%
55	3047	3080	0.93%	0.94%
60	4099	4511	1.26%	1.38%
65	3120	2385	0.96%	0.73%
70	8200	3590	2.51%	1.10%
75	2998	2473	0.92%	0.76%
80	5837	5536	1.79%	1.70%
85	3746	6443	1.15%	1.97%
90	4599	7105	1.41%	2.18%
95	4050	4488	1.24%	1.37%
100	9632	12363	2.95%	3.79%
105	5394	3439	1.65%	1.05%
110	4371	8494	1.34%	2.60%
115	2009	5211	0.62%	1.60%
120	12702	17135	3.89%	5.25%
125	4001	10150	1.23%	3.11%
130	4358	13665	1.33%	4.18%
135	2412	3467	0.74%	1.06%
140	1899	4071	0.58%	1.25%
145	1205	1632	0.37%	0.50%
150	1094	9778	0.34%	2.99%
155	906	1378	0.28%	0.42%
160	2027	2619	0.62%	0.80%
165	678	1325	0.21%	0.41%
170	831	2235	0.25%	0.68%
175	689	1478	0.21%	0.45%
180	949	2309	0.29%	0.71%
185	516	601	0.16%	0.18%
190		958	0.00%	0.29%
195	1340		0.41%	0.00%
200	1639	1966	0.50%	0.60%
201+	1560	5171	0.48%	1.58%
Total	137046	189516	42.0%	58.0%
	326562			
	59.6%			

Class 3-6 Vehicle Distribution by Annual VMT and Primary Refueling
Vehicle Age 2 or Less
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00

	Vehilces		Percent	
VMT (1000)	Central	Non-Central	Central	Non-Central
0	11054	18352	2.96%	4.92%
5	16924	40557	4.53%	10.87%
10	19827	36129	5.31%	9.68%
15	20225	30780	5.42%	8.25%
20	19598	19704	5.25%	5.28%
25	17261	29072	4.62%	7.79%
30	9028	8932	2.42%	2.39%
35	7313	11853	1.96%	3.18%
40	5152	8780	1.38%	2.35%
45	3318	7572	0.89%	2.03%
50	1790	2504	0.48%	0.67%
55	2611	2031	0.70%	0.54%
60	2827		0.76%	0.00%
65	2390	1118	0.64%	0.30%
70	904		0.24%	0.00%
75	3241	2078	0.87%	0.56%
80			0.00%	0.00%
85	462		0.12%	0.00%
90			0.00%	0.00%
95	849	903	0.23%	0.24%
100	3841	2963	1.03%	0.79%
100+	980	300	0.26%	0.08%
Total	149595	223628	40.08%	59.92%
	373223			

Market Data (5)

VMT (1000)						VMT (1000)				
0	0.0%	0.0%	0.00	0.00		0	16.2%	14.6%	0.00	0.00
5	20.2%	26.2%	1.01	1.31		5	24.9%	32.2%	1.24	1.61
10	34.0%	27.6%	3.40	2.76		10	29.1%	28.7%	2.91	2.87
15	45.9%	46.2%	6.88	6.92		15	29.7%	24.5%	4.46	3.67
	4913	9204	11.28	11.00			68030	125818	8.62	8.15
20	30.0%	21.6%	6.01	4.32		20	36.8%	28.3%	7.37	5.67
25	20.7%	32.3%	5.18	8.08		25	32.4%	41.8%	8.11	10.45
30	23.7%	28.1%	7.11	8.44		30	17.0%	12.8%	5.09	3.85
35	25.5%	18.0%	8.94	6.29		35	13.7%	17.0%	4.81	5.96
	17878	14869	27.24	27.12			53200	69561	25.38	25.93
40	32.0%	17.9%	12.81	7.16		40	40.0%	42.0%	16.01	16.81
45	23.0%	19.8%	10.33	8.93		45	25.8%	36.3%	11.60	16.31
50	27.5%	46.4%	13.75	23.22		50	13.9%	12.0%	6.95	5.99
55	17.5%	15.8%	9.63	8.70		55	20.3%	9.7%	11.16	5.35
	17394	19467	46.52	48.01			12871	20887	45.72	44.47
60	22.3%	34.8%	13.35	20.89		60	30.2%	0.0%	18.12	0.00
65	16.9%	18.4%	11.01	11.96		65	25.5%	35.0%	16.59	22.74
70	44.5%	27.7%	31.17	19.39		70	9.7%	0.0%	6.76	0.00
75	16.3%	19.1%	12.21	14.31		75	34.6%	65.0%	25.96	48.76
	18417	12959	67.74	66.55			9362	3196	67.43	71.50
80	32.0%	23.5%	25.61	18.79		80	0.0%	0.0%	0.00	0.00
85	20.5%	27.3%	17.46	23.23		85	35.2%	0.0%	29.95	0.00
90	25.2%	30.1%	22.70	27.13		90	0.0%	0.0%	0.00	0.00
95	22.2%	19.0%	21.10	18.09		95	64.8%	100.0%	61.52	95.00
	18232	23572	86.88	87.24			1311	903	91.48	95.00
100	45.0%	41.9%	45.00	41.90		100	79.7%	90.8%	79.67	90.81
105	25.2%	11.7%	26.46	12.24		105	20.3%	9.2%	21.34	9.65
110	20.4%	28.8%	22.46	31.67		110	0.0%	0.0%	0.00	0.00
115	9.4%	17.7%	10.79	20.31		115	0.0%	0.0%	0.00	0.00
	21406	29507	104.71	106.11			4821	3263	101.02	100.46
120	54.1%	38.6%	64.94	46.29		120	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
125	17.0%	22.9%	21.31	28.56		125	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
130	18.6%	30.8%	24.14	39.99		130	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
135	10.3%	7.8%	13.87	10.54		135	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	23473	44417	124.25	125.39			0	0	127.50	127.50

Market Data (6)

140	37.2%	24.1%	52.09	33.81		140	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
145	23.6%	9.7%	34.23	14.04		145	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
150	21.4%	58.0%	32.15	87.00		150	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
155	17.8%	8.2%	27.51	12.67		155	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	5104	16859	145.99	147.51			0	0	147.50	147.50		
160	48.0%	34.2%	76.76	54.73		160	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
165	16.0%	17.3%	26.48	28.55		165	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
170	19.7%	29.2%	33.44	49.62		170	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
175	16.3%	19.3%	28.54	33.78		175	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	4225	7657	165.22	166.68			0	0	167.50	167.50		
180	33.8%	59.7%	60.90	107.45		180	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
185	18.4%	15.5%	34.03	28.74		185	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
190	0.0%	24.8%	0.00	47.06		190	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
195	47.8%	0.0%	93.16	0.00		195	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	2805	3868	188.09	183.25			0	0	187.50	187.50		
200	51.2%	27.5%	102.47	55.09		200	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
225	48.8%	72.5%	109.72	163.02		225	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	3199	7137	212.19	218.11			0	0	212.50	212.50		
Total						Total						
TYPE 3						CLS 3-6						
VMT	Central	Non-Central	Central	Non-Central		VMT	Central	Non-Central	Central	Non-Central		
0-19.9	11283	10996	1.50%	2.82%	4.32%	0-19.9	8618	8153	18.23%	33.71%	51.94%	
20-39.9	27236	27122	5.47%	4.55%	10.03%	20-39.9	25381	25930	14.25%	18.64%	32.89%	
40-59.9	46525	48009	5.33%	5.96%	11.29%	40-59.9	45723	44470	3.45%	5.60%	9.04%	
60-79.9	67741	66553	5.64%	3.97%	9.61%	60-79.9	67435	71502	2.51%	0.86%	3.36%	
80-99.9	86882	87237	5.58%	7.22%	12.80%	80-99.9	91476	95000	0.35%	0.24%	0.59%	
100-119.9	104710	106110	6.55%	9.04%	15.59%	100-119.9	101016	100460	1.29%	0.87%	2.17%	
120-139.9	124250	125390	7.19%	13.60%	20.79%	120-139.9	127500	127500	0.00%	0.00%	0.00%	
140-159.9	145986	147510	1.56%	5.16%	6.73%	140-159.9	147500	147500	0.00%	0.00%	0.00%	
160-179.9	165215	166680	1.29%	2.34%	3.64%	160-179.9	167500	167500	0.00%	0.00%	0.00%	
180-199.9	188086	183254	0.86%	1.18%	2.04%	180-199.9	187500	187500	0.00%	0.00%	0.00%	
200+	212191	218113	0.98%	2.19%	3.17%	200+	212500	212500	0.00%	0.00%	0.00%	
					100.00%						100.00%	

Type 1 (1)

TYPE 1: Multi-stop or Step Van; Beverage; Utility; Winch or Crane; Wrecker; Pole, Logging, Pipe; Service; Garbage; Dump; Cement Mixer; Yard Tractor and Other

Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline

Fuel Type	**Ethanol**
Discount Rate	**10.0%**
Annual VMT	212500
Fuel Efficiency Escalation Factor:	1.00

	Baseline	ADV. Diesel	ADV. Diesel	Ethanol	Ethanol	Ethanol	**ANNUAL DOLLAR SAVINGS**		**NPV of Advanced Diesel Savings**			
	Fuel Efficiency	Efficiency	Adjusted	Efficiency	Adjusted	Fuel	**OF TECHNOLOGY**		Payback Periods (years)			
Year	MPG	Improvement	MPG	Improvement	MPG	Cost	ADV. Diesel	Alt. Fuel	1	2	3	4
1995	4.50	0.01	0.05	1.00	4.50	2.37	-5206692.09	-59323.82	-4733356.45	-4915876.92	-4957087.20	-4973494.56
1996	4.52	0.21	0.94	1.00	4.52	2.36	-220849.77	-52889.05	-200772.52	-246103.83	-264151.92	-270541.73
1997	6.58	0.41	2.67	1.00	6.58	2.36	-54850.89	-38725.13	-49864.44	-69717.34	-76746.14	-76746.14
1998	6.58	0.60	3.97	1.00	6.58	2.35	-24022.01	-39253.23	-21838.19	-29569.87	-29569.87	-27035.85
1999	6.58	0.80	5.28	1.00	6.58	2.34	-9355.33	-37676.11	-8504.84	-8504.84	-5717.42	-1300.05
2000	6.58	1.00	6.58	1.00	6.58	1.80	0.00	-9727.36	0.00	3066.16	7925.27	13713.81
2001	6.58	1.09	7.15	1.00	6.58	1.76	3710.05	-10117.88	3372.78	8717.80	15085.19	22340.79
2002	6.58	1.17	7.71	1.00	6.58	1.73	6467.47	-11736.40	5879.52	12883.66	20864.82	29353.17
2003	6.58	1.26	8.28	1.00	6.58	1.69	8475.01	-13318.99	7704.55	16483.83	25821.01	34494.78
2004	6.58	1.34	8.84	1.00	6.58	1.66	10622.93	-11976.72	9657.21	19928.10	29469.26	38548.62
2005	6.58	1.43	9.41	1.00	6.58	1.62	12427.79	-10988.01	11297.99	21793.26	31780.56	40942.51
2006	6.58	1.43	9.41	1.07	7.04	1.58	12699.27	-5575.96	11544.79	22530.82	32608.97	41817.34
2007	6.58	1.43	9.41	1.14	7.50	1.55	13293.10	354.29	12084.63	23170.60	33299.80	42627.51
2008	6.58	1.43	9.41	1.21	7.96	1.51	13414.02	4254.21	12194.56	23336.68	33597.17	42972.05
2009	6.58	1.43	9.41	1.28	8.42	1.48	13481.97	7595.40	12256.33	23542.87	33855.24	43175.40
2010	6.58	1.43	9.41	1.35	8.88	1.44	13656.71	10968.66	12415.19	23758.80	34010.97	43336.35
2011	6.58	1.43	9.41	1.45	9.55	1.43	13725.77	13840.65	12477.97	23755.36	34013.28	43272.05
2012	6.58	1.43	9.41	1.55	10.23	1.42	13645.64	15869.61	12405.13	23688.84	33873.48	43159.03
2013	6.58	1.43	9.41	1.66	10.90	1.41	13653.29	17907.72	12412.08	23615.19	33829.29	43083.43
2014	6.58	1.43	9.41	1.76	11.57	1.40	13555.76	19362.47	12323.41	23558.93	33738.48	42959.39
2015	6.58	1.43	9.41	1.86	12.24	1.39	13594.98	21076.89	12359.07	23556.58	33699.58	42925.52
2016	6.58	1.43	9.41	1.86	12.24	1.38	13548.98	21097.56	12317.26	23474.56	33623.10	42799.37
2017	6.58	1.43	9.41	1.86	12.24	1.37	13500.33	21109.41	12273.03	23436.43	33530.33	42714.71
2018	6.58	1.43	9.41	1.86	12.24	1.36	13507.71	21307.57	12279.74	23383.03	33485.84	42788.13
2019	6.58	1.43	9.41	1.86	12.24	1.35	13434.98	21239.32	12213.62	23326.72	33559.23	42979.43
2020	6.58	1.43	9.41	1.86	12.24	1.34	13446.85	21452.43	12224.41	23480.18	33842.40	43380.50
2021	6.58	1.43	9.41	1.86	12.24	1.34	13619.48	22026.52	12381.35	23779.79	34271.70	43927.72
2022	6.58	1.43	9.41	1.86	12.24	1.34	13792.11	22600.62	12538.28	24079.39	34701.01	44474.93
2023	6.58	1.43	9.41	1.86	12.24	1.34	13964.74	23174.71	12695.22	24379.00	35130.31	45034.56
2024	6.58	1.43	9.41	1.86	12.24	1.34	14137.37	23748.81	12852.16	24678.60	35573.27	45607.83
2025	6.58	1.43	9.41	1.86	12.24	1.34	14310.00	24322.90	13009.09	24993.23	36031.24	46196.12
2026	6.58	1.43	9.41	1.86	12.24	1.34	14500.80	24957.43	13182.55	25324.37	36505.73	46800.93
2027	6.58	1.43	9.41	1.86	12.24	1.34	14691.60	25591.95	13356.00	25655.51	36980.23	47405.74
2028	6.58	1.43	9.41	1.86	12.24	1.34	14882.40	26226.47	13529.46	25986.65	37454.72	48010.55
2029	6.58	1.43	9.41	1.86	12.24	1.34	15073.20	26860.99	13702.91	26317.79	37929.21	48615.37
2030	6.58	1.43	9.41	1.86	12.24	1.34	15264.00	27495.51	13876.37	26648.93	38403.70	49220.18
2031	6.58	1.43	9.41	1.86	12.24	1.34	15454.80	28130.03				
2032	6.58	1.43	9.41	1.86	12.24	1.34	15645.60	28764.55				

Type 1 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-53930.74	-97640.70	-126735.46	-153545.95	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-48080.95	-80085.19	-109576.72	-135310.01	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35204.67	-67645.35	-95951.97	-102595.89	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35684.75	-66822.03	-74130.34	-81040.99	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-34251.01	-42290.15	-49891.87	-57907.99	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8843.06	-17204.94	-26022.68	-35119.72	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9198.07	-18897.58	-28904.33	-37084.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10669.46	-21676.89	-30675.17	-38180.13	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-12108.17	-22006.29	-30261.74	-34070.20	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10887.93	-19968.93	-24158.23	-23916.24	0.00	0.00	-0.05	-0.38	100000	0.00	0.00	0.00	0.00	100.0
-9989.10	-14597.33	-14331.15	-11425.46	-0.13	-1.18	-2.18	-3.09	100000	0.00	0.00	0.00	0.00	98.6
-5069.05	-4776.25	-1580.00	3607.76	-0.22	-1.37	-2.43	-3.40	100000	0.00	0.00	0.00	0.00	97.6
322.08	3837.96	9544.49	17036.24	-0.34	-1.57	-2.70	-3.74	100000	0.00	0.00	0.00	0.00	95.9
3867.46	10144.65	18385.57	27838.92	-0.43	-1.75	-2.95	-4.06	100000	0.00	0.00	0.00	0.00	94.6
6904.91	15969.92	26368.60	37207.76	-0.53	-1.94	-3.23	-4.40	100000	0.00	0.00	0.00	0.00	93.0
9971.51	21410.07	33333.14	45564.35	-0.66	-2.17	-3.53	-4.78	100000	0.00	0.00	0.00	0.00	90.7
12582.41	25697.79	39152.13	52376.96	-0.78	-2.39	-3.86	-5.18	100000	0.00	0.00	0.00	0.00	88.1
14426.91	29226.69	43774.00	58169.80	-0.91	-2.64	-4.21	-5.64	100000	0.00	0.00	0.00	0.00	85.2
16279.75	32281.79	48117.17	62527.09	-1.07	-2.94	-4.64	-6.18	100000	0.00	0.00	0.00	0.00	80.9
17602.25	35021.16	50872.08	65290.08	-1.24	-3.28	-5.13	-6.81	100000	0.00	0.00	0.00	0.00	75.4
19160.81	36596.81	52456.62	67009.97	-1.47	-3.71	-5.74	-7.59	100000	0.00	0.00	0.00	0.00	66.4
19179.60	36625.39	52634.08	67140.82	-1.46	-3.69	-5.72	-7.56	100000	0.00	0.00	0.00	0.00	66.8
19190.37	36799.93	52757.34	67409.64	-1.45	-3.69	-5.71	-7.54	100000	0.00	0.00	0.00	0.00	67.2
19370.52	36923.67	53041.20	68085.61	-1.46	-3.68	-5.70	-7.56	100000	0.00	0.00	0.00	0.00	67.1
19308.47	37037.75	53586.60	69023.13	-1.44	-3.67	-5.71	-7.60	100000	0.00	0.00	0.00	0.00	67.7
19502.21	37705.94	54686.12	70514.76	-1.44	-3.70	-5.77	-7.68	100000	0.00	0.00	0.00	0.00	67.6
20024.11	38702.31	56113.81	72334.57	-1.69	-4.17	-6.45	-8.55	100000	0.00	0.00	0.00	0.00	55.7
20546.02	39698.67	57541.50	74154.38	-1.99	-4.73	-7.26	-9.59	100000	0.00	0.00	0.00	0.00	37.2
21067.92	40695.04	58969.19	76015.45	-2.34	-5.42	-8.24	-10.85	100000	0.00	0.00	0.00	0.00	6.1
21589.83	41691.40	60442.28	77921.93	-2.78	-6.26	-9.46	-12.41	100000	0.00	0.00	0.00	0.00	-51.2
22111.73	42737.70	61965.31	79878.34	-3.34	-7.33	-11.01	-14.40	100000	0.00	0.00	0.00	0.00	-171.2
22688.57	43838.94	63543.27	81889.69	-3.39	-7.44	-11.17	-14.60	100000	0.00	0.00	0.00	0.00	-187.9
23265.41	44940.17	65121.23	83901.03	-3.45	-7.55	-11.33	-14.80	100000	0.00	0.00	0.00	0.00	-205.6
23842.24	46041.41	66699.19	85912.38	-3.51	-7.66	-11.48	-15.00	100000	0.00	0.00	0.00	0.00	-224.4
24419.08	47142.64	68277.15	87923.73	-3.57	-7.77	-11.64	-15.21	100000	0.00	0.00	0.00	0.00	-244.3
24995.92	48243.88	69855.11	89935.07	-3.63	-7.88	-11.80	-15.41	100000	0.00	0.00	0.00	0.00	-265.4

Type 1 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels						
Payback Periods (years)								Payback Periods (years)						
1		2		3		4		1		2		3		4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.5	99.5	95.4	95.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
98.6	77.5	77.5	21.7	21.7	-110.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
97.6	70.6	70.6	-3.9	0.0	-190.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
95.9	61.7	61.7	-38.8	0.0	-309.5	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
94.6	52.7	52.7	-81.6	0.0	-467.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
93.0	40.2	40.2	-143.3	0.0	-702.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
90.7	22.6	22.6	-232.9	0.0	-1078.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
88.1	0.5	0.5	-364.2	0.0	-1669.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
85.2	-30.8	0.0	-564.4	0.0	-2704.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80.9	-78.4	0.0	-923.6	0.0	-4722.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
75.4	-156.7	0.0	-1587.4	0.0	-8966.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.4	-299.1	0.0	-3000.4	0.0	-19576.5	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.8	-292.4	0.0	-2953.2	0.0	-19086.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.2	-289.4	0.0	-2896.9	0.0	-18763.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.1	-285.1	0.0	-2870.2	0.0	-19042.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.7	-280.7	0.0	-2914.3	0.0	-19789.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.6	-292.9	0.0	-3090.5	0.0	-21452.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
55.7	-536.8	0.0	-6219.4	0.0	-51531.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37.2	-1026.6	0.0	-14143.1	0.0	-145961.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6.1	-2138.7	0.0	-37968.5	0.0	-515849.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5113.9	0.0	-128599.3	0.0	-2462305.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-15160.2	0.0	-604899.5	0.0	-17917471.4	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-16942.3	0.0	-708572.8	0.0	-21919592.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-18932.3	0.0	-830011.3	0.0	-26815638.8	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-21154.6	0.0	-972259.3	0.0	-32805279.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-23636.3	0.0	-1138882.6	0.0	-40132783.3	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-26407.5	0.0	-1334058.1	0.0	-49096978.8	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 1 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.1%	2.2%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.3%	12.0%	78.2%	100.0%	26.1%	26.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.6%	18.0%	100.0%	100.0%	33.3%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.0%	27.4%	100.0%	100.0%	39.1%	39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.5%	38.4%	100.0%	100.0%	46.0%	46.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.0%	54.8%	100.0%	100.0%	56.2%	56.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.9%	77.2%	100.0%	100.0%	70.2%	70.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.1%	99.6%	100.0%	100.0%	84.2%	84.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.7%	100.0%	100.0%	100.0%	84.7%	84.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9.5%	100.0%	100.0%	100.0%	85.2%	85.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13.7%	100.0%	100.0%	100.0%	85.8%	85.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22.2%	100.0%	100.0%	100.0%	87.2%	87.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.8%	100.0%	100.0%	100.0%	87.2%	87.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.4%	100.0%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.5%	100.0%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20.9%	100.0%	100.0%	100.0%	87.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.0%	100.0%	100.0%	100.0%	87.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
34.6%	100.0%	100.0%	100.0%	89.3%	89.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
58.8%	100.0%	100.0%	100.0%	93.2%	93.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.7%	100.0%	100.0%	100.0%	99.1%	99.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.6%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 1 (5)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	3.1%	6.7%	11.8%	17.3%	26.1%	0.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.1%	4.2%	9.4%	15.7%	22.5%	33.3%	0.1%
0.0%	0.0%	0.1%	0.4%	1.6%	2.8%	5.9%	13.1%	20.1%	29.2%	39.1%	0.2%
0.0%	0.0%	0.1%	0.5%	1.9%	3.6%	7.9%	16.5%	24.9%	34.6%	46.0%	0.2%
0.0%	0.0%	0.1%	0.6%	2.4%	4.7%	10.6%	20.5%	31.2%	39.9%	56.2%	0.3%
0.0%	0.0%	0.3%	0.7%	3.1%	6.4%	14.3%	26.0%	36.7%	48.3%	70.2%	0.4%
0.0%	0.0%	0.3%	1.6%	4.1%	8.7%	18.0%	32.6%	42.9%	59.2%	84.2%	0.6%
0.0%	0.0%	0.4%	2.0%	5.5%	12.0%	22.6%	37.7%	52.3%	73.2%	84.7%	0.7%
0.0%	0.0%	0.5%	2.6%	7.9%	16.1%	29.3%	45.4%	66.0%	84.5%	85.2%	1.0%
0.0%	0.0%	0.6%	3.6%	11.5%	21.2%	36.1%	58.0%	83.2%	84.9%	85.8%	1.3%
0.0%	0.1%	1.5%	5.4%	16.6%	29.0%	45.2%	76.7%	84.8%	85.6%	87.2%	1.9%
0.0%	0.1%	1.5%	5.3%	16.5%	28.7%	44.7%	76.0%	84.8%	85.5%	87.2%	1.9%
0.0%	0.1%	1.5%	5.3%	16.2%	28.5%	44.5%	75.7%	84.8%	85.5%	87.1%	1.9%
0.0%	0.1%	1.5%	5.3%	16.1%	28.4%	44.3%	75.2%	84.8%	85.5%	87.1%	1.9%
0.0%	0.1%	1.5%	5.3%	16.2%	28.4%	44.0%	74.7%	84.7%	85.5%	87.0%	1.9%
0.0%	0.1%	1.6%	5.5%	16.5%	29.1%	44.8%	76.0%	84.7%	85.5%	87.0%	2.0%
0.0%	0.1%	2.1%	8.5%	22.6%	36.6%	59.1%	84.6%	85.3%	86.6%	89.3%	2.6%
0.0%	0.1%	3.1%	13.3%	31.7%	47.0%	79.7%	85.2%	86.4%	88.7%	93.2%	3.7%
0.0%	0.4%	4.9%	19.3%	40.3%	65.5%	84.8%	86.2%	88.7%	92.7%	99.1%	5.0%
0.0%	0.5%	8.5%	29.0%	56.5%	84.5%	85.6%	88.6%	93.1%	99.0%	99.9%	7.0%
0.0%	1.4%	15.2%	40.0%	83.6%	85.2%	87.5%	93.6%	99.9%	99.9%	#####	9.5%
0.0%	1.5%	15.8%	41.3%	84.4%	85.3%	87.8%	94.3%	99.9%	99.9%	#####	9.7%
0.0%	1.5%	16.3%	42.7%	84.5%	85.4%	88.1%	94.9%	99.9%	100.0%	#####	9.8%
0.0%	1.6%	17.1%	44.1%	84.5%	85.6%	88.4%	95.6%	99.9%	100.0%	#####	10.0%
0.0%	1.6%	17.8%	45.6%	84.6%	85.7%	88.8%	96.3%	99.9%	100.0%	#####	10.2%
0.0%	1.7%	18.5%	47.2%	84.6%	85.8%	89.1%	97.0%	99.9%	100.0%	#####	10.4%

Type 1 (6)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Centrally Refueled Alternative Fuels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 1 (7)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.8%	2.8%	5.3%	11.8%	17.3%	26.1%	0.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.3%	3.8%	7.5%	15.7%	22.5%	33.3%	0.2%
0.0%	0.0%	0.1%	0.4%	1.6%	3.0%	5.3%	10.5%	20.1%	29.2%	39.1%	0.2%
0.0%	0.0%	0.1%	0.5%	1.9%	3.9%	7.0%	13.9%	24.9%	34.6%	46.0%	0.3%
0.0%	0.0%	0.1%	0.6%	2.4%	5.1%	9.5%	17.4%	31.2%	39.9%	56.2%	0.4%
0.0%	0.0%	0.1%	0.7%	3.1%	7.0%	12.9%	21.8%	36.7%	48.3%	70.2%	0.5%
0.0%	0.0%	0.3%	1.6%	4.1%	9.5%	16.7%	27.5%	42.9%	59.2%	84.2%	0.7%
0.0%	0.0%	0.4%	2.0%	5.5%	13.0%	20.8%	34.0%	52.3%	73.2%	84.7%	0.9%
0.0%	0.0%	0.5%	2.6%	7.9%	17.3%	27.0%	39.8%	66.0%	84.5%	85.2%	1.2%
0.0%	0.0%	0.6%	3.6%	11.5%	22.6%	34.5%	49.7%	83.2%	84.9%	85.8%	1.6%
0.0%	0.1%	1.5%	5.3%	16.6%	30.9%	42.4%	66.1%	84.8%	85.6%	87.2%	2.3%
0.0%	0.1%	1.4%	5.2%	16.5%	30.6%	42.0%	65.4%	84.8%	85.5%	87.2%	2.2%
0.0%	0.1%	1.4%	5.2%	16.2%	30.4%	41.8%	65.0%	84.8%	85.5%	87.1%	2.2%
0.0%	0.1%	1.4%	5.2%	16.1%	30.2%	41.6%	64.6%	84.8%	85.5%	87.1%	2.2%
0.0%	0.1%	1.4%	5.2%	16.2%	30.2%	41.3%	64.1%	84.7%	85.5%	87.0%	2.2%
0.0%	0.1%	1.5%	5.4%	16.5%	31.0%	42.0%	65.4%	84.7%	85.5%	87.0%	2.3%
0.0%	0.1%	2.0%	8.3%	22.6%	38.1%	54.8%	84.4%	85.3%	86.6%	89.3%	3.0%
0.0%	0.3%	2.9%	13.1%	31.7%	49.6%	74.6%	84.8%	86.4%	88.7%	93.2%	4.0%
0.0%	0.4%	4.5%	19.1%	40.3%	69.4%	84.7%	85.7%	88.7%	92.7%	99.1%	5.3%
0.0%	0.6%	7.8%	28.7%	56.5%	84.6%	85.4%	87.4%	93.1%	99.0%	99.9%	7.0%
0.0%	1.6%	14.3%	39.7%	83.6%	85.4%	87.1%	91.3%	99.9%	99.9%	100.0%	9.1%
0.0%	1.6%	15.0%	40.9%	84.4%	85.5%	87.3%	91.9%	99.9%	99.9%	100.0%	9.2%
0.0%	1.7%	15.6%	42.2%	84.5%	85.6%	87.6%	92.4%	99.9%	100.0%	100.0%	9.3%
0.0%	1.8%	16.1%	43.6%	84.5%	85.7%	87.9%	93.0%	99.9%	100.0%	100.0%	9.5%
0.0%	1.8%	16.7%	45.1%	84.6%	85.9%	88.1%	93.6%	99.9%	100.0%	100.0%	9.6%
0.0%	1.9%	17.5%	46.7%	84.6%	86.0%	88.4%	94.2%	99.9%	100.0%	100.0%	9.7%

TYPE 2: Platform with devices; Low-boy platform; Basic platform; Livestock; Automobile Transport; Oilfield; Grain; Tank truck for liquids or gases; Tank truck for dry bulk

Please enter one of the following alternative fuel types: LPG, CNG, Electricity (=Hybrid), Ethanol, Gasoline

Fuel Type	**Ethanol**
Discount Rate	**10.0%**
Annual VMT	225000
Fuel Efficiency Escalation Factor:	1.00

Year	Baseline Fuel Efficiency MPG	ADV. Diesel Efficiency Improvement	ADV. Diesel Adjusted MPG	Ethanol Efficiency Improvement	Ethanol Adjusted MPG	Ethanol Fuel Cost	**ANNUAL DOLLAR SAVINGS OF TECHNOLOGY** ADV. Diesel	Alt. Fuel	**NPV of Advanced Diesel Savings** Payback Periods (years) 1	2	3	4
1995	6.10	0.01	0.06	1.00	6.10	2.37	-4066943.68	-46337.79	-3697221.53	-3840500.98	-3882785.87	-3899621.07
1996	6.10	0.21	1.27	1.00	6.10	2.36	-173368.13	-41518.16	-157607.39	-204120.78	-222639.50	-229195.94
1997	6.79	0.41	2.76	1.00	6.79	2.36	-56281.20	-39734.95	-51164.73	-71535.32	-78747.40	-78747.40
1998	6.79	0.60	4.10	1.00	6.79	2.35	-24648.42	-40276.81	-22407.65	-30340.94	-30340.94	-27740.85
1999	6.79	0.80	5.45	1.00	6.79	2.34	-9599.28	-38658.57	-8726.62	-8726.62	-5866.51	-1333.95
2000	6.79	1.00	6.79	1.00	6.79	1.80	0.00	-9981.02	0.00	3146.11	8131.93	14071.42
2001	6.79	1.09	7.37	1.00	6.79	1.76	3806.80	-10381.72	3460.73	8945.12	15478.56	22923.36
2002	6.79	1.17	7.96	1.00	6.79	1.73	6636.12	-12042.45	6032.84	13219.62	21408.90	30118.59
2003	6.79	1.26	8.54	1.00	6.79	1.69	8696.00	-13666.30	7905.46	16913.67	26494.33	35394.28
2004	6.79	1.34	9.13	1.00	6.79	1.66	10899.93	-12289.03	9909.03	20447.76	30237.71	39553.83
2005	6.79	1.43	9.71	1.00	6.79	1.62	12751.86	-11274.54	11592.60	22361.55	32609.28	42010.14
2006	6.79	1.43	9.71	1.07	7.27	1.58	13030.42	-5721.36	11845.84	23118.35	33459.30	42907.78
2007	6.79	1.43	9.71	1.14	7.74	1.55	13639.73	363.53	12399.76	23774.80	34168.14	43739.08
2008	6.79	1.43	9.71	1.21	8.22	1.51	13763.81	4365.14	12512.55	23945.22	34473.26	44092.61
2009	6.79	1.43	9.71	1.28	8.69	1.48	13833.53	7793.46	12575.93	24156.78	34738.06	44301.26
2010	6.79	1.43	9.71	1.35	9.17	1.44	14012.82	11254.69	12738.93	24378.34	34897.85	44466.41
2011	6.79	1.43	9.71	1.45	9.86	1.43	14083.69	14201.57	12803.35	24374.82	34900.23	44400.43
2012	6.79	1.43	9.71	1.55	10.55	1.42	14001.47	16283.43	12728.61	24306.56	34756.78	44284.46
2013	6.79	1.43	9.71	1.66	11.24	1.41	14009.32	18374.69	12735.75	24230.99	34711.44	44206.89
2014	6.79	1.43	9.71	1.76	11.94	1.40	13909.24	19867.38	12644.77	24173.26	34618.26	44079.62
2015	6.79	1.43	9.71	1.86	12.63	1.39	13949.48	21626.50	12681.35	24170.85	34578.34	44044.87
2016	6.79	1.43	9.71	1.86	12.63	1.38	13902.29	21647.71	12638.45	24086.69	34499.87	43915.43
2017	6.79	1.43	9.71	1.86	12.63	1.37	13852.37	21659.86	12593.07	24047.57	34404.68	43828.55
2018	6.79	1.43	9.71	1.86	12.63	1.36	13859.94	21863.19	12599.95	23992.77	34359.03	43903.89
2019	6.79	1.43	9.71	1.86	12.63	1.35	13785.31	21793.16	12532.10	23934.99	34434.34	44100.18
2020	6.79	1.43	9.71	1.86	12.63	1.34	13797.50	22011.83	12543.18	24092.46	34724.88	44511.71
2021	6.79	1.43	9.71	1.86	12.63	1.34	13974.63	22600.90	12704.21	24399.88	35165.38	45073.19
2022	6.79	1.43	9.71	1.86	12.63	1.34	14151.76	23189.96	12865.24	24707.30	35605.89	45634.68
2023	6.79	1.43	9.71	1.86	12.63	1.34	14328.89	23779.03	13026.27	25014.71	36046.39	46208.90
2024	6.79	1.43	9.71	1.86	12.63	1.34	14506.02	24368.09	13187.29	25322.13	36500.89	46797.12
2025	6.79	1.43	9.71	1.86	12.63	1.34	14683.15	24957.16	13348.32	25644.96	36970.81	47400.75
2026	6.79	1.43	9.71	1.86	12.63	1.34	14878.93	25608.23	13526.30	25984.73	37457.67	48021.33
2027	6.79	1.43	9.71	1.86	12.63	1.34	15074.71	26259.29	13704.28	26324.51	37944.54	48641.92
2028	6.79	1.43	9.71	1.86	12.63	1.34	15270.48	26910.36	13882.26	26664.29	38431.40	49262.50
2029	6.79	1.43	9.71	1.86	12.63	1.34	15466.26	27561.43	14060.23	27004.06	38918.27	49883.08
2030	6.79	1.43	9.71	1.86	12.63	1.34	15662.03	28212.49	14238.21	27343.84	39405.13	50503.66
2031	6.79	1.43	9.71	1.86	12.63	1.34	15857.81	28863.56				
2032	6.79	1.43	9.71	1.86	12.63	1.34	16053.58	29514.63				
2033	6.79	1.43	9.71	1.86	12.63	1.34	16249.36	30165.69				
2034	6.79	1.43	9.71	1.86	12.63	1.34	16445.13	30816.76				
2035	6.79	1.43	9.71	1.86	12.63	1.34	16640.91	31467.83				

Type 2 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-42125.27	-76437.79	-106291.24	-133800.85	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-37743.78	-70582.58	-100843.14	-127247.46	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-36122.68	-69409.30	-98454.05	-105271.22	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-36615.28	-68564.51	-76063.40	-83154.25	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35144.15	-43392.93	-51192.87	-59418.02	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9073.65	-17653.59	-26701.25	-36035.52	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9437.93	-19390.36	-29658.05	-38051.63	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10947.68	-22242.14	-31475.07	-39175.73	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-12423.91	-22580.13	-31050.86	-34958.62	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-11171.85	-20489.64	-24788.19	-24539.89	0.00	0.00	-0.08	-0.41	100000	0.00	0.00	0.00	0.00	100.0
-10249.58	-14977.98	-14704.85	-11723.40	-0.16	-1.24	-2.26	-3.20	100000	0.00	0.00	0.00	0.00	82.7
-5201.24	-4900.80	-1621.20	3701.83	-0.25	-1.43	-2.52	-3.52	100000	0.00	0.00	0.00	0.00	72.0
330.48	3938.04	9793.38	17480.48	-0.38	-1.64	-2.80	-3.86	100000	0.00	0.00	0.00	0.00	54.1
3968.31	10409.19	18865.00	28564.86	-0.47	-1.82	-3.06	-4.19	100000	0.00	0.00	0.00	0.00	39.7
7084.96	16386.36	27056.20	38178.00	-0.57	-2.02	-3.34	-4.54	100000	0.00	0.00	0.00	0.00	22.8
10231.53	21968.37	34202.35	46752.51	-0.70	-2.25	-3.65	-4.93	100000	0.00	0.00	0.00	0.00	-1.1
12910.51	26367.89	40173.07	53742.76	-0.83	-2.48	-3.99	-5.34	100000	0.00	0.00	0.00	0.00	-29.1
14803.12	29988.81	44915.47	59686.66	-0.96	-2.74	-4.35	-5.81	100000	0.00	0.00	0.00	0.00	-60.7
16704.27	33123.59	49371.89	64157.57	-1.12	-3.04	-4.79	-6.37	100000	0.00	0.00	0.00	0.00	-107.3
18061.25	35934.39	52198.64	66992.62	-1.30	-3.40	-5.29	-7.01	100000	0.00	0.00	0.00	0.00	-166.6
19660.45	37551.12	53824.50	68757.35	-1.54	-3.83	-5.92	-7.81	100000	0.00	0.00	0.00	0.00	-264.7
19679.74	37580.45	54006.59	68891.61	-1.53	-3.82	-5.90	-7.78	100000	0.00	0.00	0.00	0.00	-260.8
19690.79	37759.54	54133.06	69167.44	-1.52	-3.81	-5.88	-7.77	100000	0.00	0.00	0.00	0.00	-256.6
19875.63	37886.51	54424.32	69861.03	-1.52	-3.80	-5.87	-7.78	100000	0.00	0.00	0.00	0.00	-257.2
19811.96	38003.56	54983.95	70823.00	-1.51	-3.79	-5.89	-7.82	100000	0.00	0.00	0.00	0.00	-251.1
20010.75	38689.18	56112.14	72353.54	-1.51	-3.82	-5.94	-7.90	100000	0.00	0.00	0.00	0.00	-252.1
20546.27	39711.53	57577.06	74220.80	-1.76	-4.30	-6.64	-8.80	100000	0.00	0.00	0.00	0.00	-382.3
21081.78	40733.87	59041.98	76088.06	-2.06	-4.88	-7.48	-9.87	100000	0.00	0.00	0.00	0.00	-587.1
21617.30	41756.22	60506.90	77997.66	-2.43	-5.58	-8.49	-11.16	100000	0.00	0.00	0.00	0.00	-933.6
22152.81	42778.56	62018.40	79953.85	-2.88	-6.45	-9.74	-12.76	100000	0.00	0.00	0.00	0.00	-1579.0
22688.33	43852.15	63581.14	81961.28	-3.45	-7.55	-11.32	-14.80	100000	0.00	0.00	0.00	0.00	-2948.3
23280.21	44982.10	65200.25	84025.08	-3.51	-7.66	-11.49	-15.01	100000	0.00	0.00	0.00	0.00	-3140.7
23872.08	46112.05	66819.36	86088.87	-3.57	-7.77	-11.65	-15.21	100000	0.00	0.00	0.00	0.00	-3344.9
24463.96	47242.00	68438.47	88152.67	-3.63	-7.89	-11.81	-15.42	100000	0.00	0.00	0.00	0.00	-3561.6
25055.84	48371.95	70057.57	90216.46	-3.69	-8.00	-11.97	-15.63	100000	0.00	0.00	0.00	0.00	-3791.5
25647.72	49501.90	71676.68	92280.26	-3.75	-8.11	-12.14	-15.83	100000	0.00	0.00	0.00	0.00	-4035.4

Type 2 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels					
Payback Periods (years)								Payback Periods (years)					
1		2		3		4		1		2		3	
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.2	99.2	94.9	94.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
82.7	75.6	75.6	14.1	14.1	-135.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
72.0	68.1	68.1	-14.5	1.0	-226.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
54.1	58.4	58.4	-53.9	1.0	-364.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
39.7	48.5	48.5	-102.4	1.0	-548.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
22.8	34.6	34.6	-172.8	1.0	-824.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	15.1	15.1	-275.9	1.0	-1272.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-9.7	1.0	-428.3	1.0	-1981.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-44.8	1.0	-662.6	1.0	-3236.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-98.7	1.0	-1087.3	1.0	-5717.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-188.2	1.0	-1881.8	1.0	-11016.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-352.5	1.0	-3598.0	1.0	-24516.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-344.8	1.0	-3540.3	1.0	-23886.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-341.3	1.0	-3471.4	1.0	-23473.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-336.4	1.0	-3438.9	1.0	-23831.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-331.2	1.0	-3492.8	1.0	-24790.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-345.4	1.0	-3708.3	1.0	-26926.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-630.2	1.0	-7576.6	1.0	-66134.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1209.9	1.0	-17569.8	1.0	-192415.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-2548.2	1.0	-48349.1	1.0	-702685.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-6202.4	1.0	-168972.5	1.0	-3493492.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-18865.5	1.0	-827409.5	1.0	-26771057.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-21141.1	1.0	-973217.7	1.0	-32923367.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-23689.5	1.0	-1144717.2	1.0	-40489547.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-26543.6	1.0	-1346434.8	1.0	-49794518.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-29740.0	1.0	-1583694.8	1.0	-61237875.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-33319.6	1.0	-1862759.7	1.0	-75311042.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 2 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**		adv	**16.4%**	**61.7%**	**15.5%**	**6.4%**		afv
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.2%	2.3%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.6%	13.6%	86.7%	99.8%	28.5%	28.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.2%	20.5%	99.4%	99.9%	34.8%	34.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.8%	31.4%	99.6%	100.0%	41.8%	41.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.1%	43.9%	99.8%	100.0%	49.9%	49.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12.1%	62.1%	99.9%	100.0%	62.2%	62.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
80.2%	85.7%	99.9%	100.0%	87.9%	87.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
84.0%	99.3%	100.0%	100.0%	96.9%	96.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
87.2%	99.6%	100.0%	100.0%	97.6%	97.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90.4%	99.8%	100.0%	100.0%	98.3%	98.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.1%	99.9%	100.0%	100.0%	98.8%	98.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.6%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.5%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.4%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.4%	99.9%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.3%	99.9%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.3%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
97.1%	100.0%	100.0%	100.0%	99.5%	99.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
98.4%	100.0%	100.0%	100.0%	99.7%	99.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.2%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.7%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Class 7-8 Type 2 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	2.8%	5.8%	8.4%	15.8%	28.5%	0.4%
0.0%	0.0%	0.0%	0.3%	0.6%	2.1%	3.8%	8.2%	11.8%	20.3%	34.8%	0.6%
0.0%	0.0%	0.1%	0.3%	1.5%	2.8%	5.3%	11.5%	15.7%	26.3%	41.8%	0.8%
0.0%	0.0%	0.1%	0.4%	1.8%	3.5%	7.0%	15.0%	19.3%	32.6%	49.9%	1.0%
0.0%	0.0%	0.1%	0.5%	2.2%	4.7%	9.5%	18.6%	24.2%	37.3%	62.2%	1.3%
0.0%	0.0%	0.1%	0.6%	2.9%	6.3%	12.9%	23.4%	30.7%	44.7%	87.9%	1.8%
0.0%	0.0%	0.3%	1.4%	3.8%	8.6%	16.7%	29.5%	36.1%	54.7%	96.9%	2.3%
0.0%	0.0%	0.4%	1.8%	5.1%	11.8%	20.8%	35.4%	42.5%	70.0%	97.6%	2.8%
0.0%	0.0%	0.4%	2.3%	7.2%	16.0%	27.0%	42.1%	53.0%	95.2%	98.3%	3.5%
0.0%	0.0%	0.6%	3.1%	10.5%	21.0%	34.5%	53.5%	70.7%	97.4%	98.8%	4.5%
0.0%	0.1%	1.4%	4.6%	15.5%	28.8%	42.6%	76.0%	96.8%	98.3%	99.2%	6.1%
0.0%	0.1%	1.4%	4.5%	15.4%	28.5%	42.3%	74.6%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.5%	15.3%	28.3%	42.1%	73.7%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.5%	15.2%	28.1%	41.8%	73.3%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.6%	15.3%	28.1%	41.6%	72.1%	96.7%	98.2%	99.2%	5.9%
0.0%	0.1%	1.4%	4.7%	15.6%	28.9%	42.3%	73.5%	96.7%	98.2%	99.2%	6.1%
0.0%	0.1%	1.9%	7.2%	21.2%	36.4%	55.7%	96.9%	97.7%	98.8%	99.5%	7.7%
0.0%	0.3%	2.7%	11.4%	29.8%	47.0%	86.3%	97.9%	98.5%	99.3%	99.7%	10.1%
0.0%	0.4%	4.2%	17.3%	38.6%	67.2%	97.3%	98.7%	99.1%	99.6%	99.9%	12.4%
0.0%	0.6%	7.3%	25.8%	54.0%	96.9%	98.3%	99.3%	99.5%	99.8%	99.9%	15.6%
0.0%	1.6%	13.4%	37.0%	92.2%	98.2%	99.1%	99.6%	99.8%	99.9%	100.0%	18.9%
0.0%	1.6%	14.1%	38.1%	94.9%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	19.2%
0.0%	1.7%	14.9%	39.3%	96.6%	98.4%	99.2%	99.7%	99.8%	99.9%	100.0%	19.4%
0.0%	1.8%	15.4%	40.5%	96.8%	98.5%	99.3%	99.7%	99.8%	99.9%	100.0%	19.5%
0.0%	1.9%	15.9%	41.8%	96.9%	98.5%	99.3%	99.7%	99.8%	100.0%	100.0%	19.7%
0.0%	1.9%	16.5%	43.1%	97.0%	98.6%	99.4%	99.8%	99.9%	100.0%	100.0%	19.8%

Type 2 (6)

Class 7-8 Type 2 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	2.9%	5.6%	8.4%	14.0%	28.5%	0.8%
0.0%	0.0%	0.0%	0.3%	0.6%	2.1%	4.0%	7.8%	11.8%	17.7%	34.8%	1.1%
0.0%	0.0%	0.1%	0.4%	1.5%	2.7%	5.5%	11.0%	15.7%	22.9%	41.8%	1.5%
0.0%	0.0%	0.1%	0.4%	1.8%	3.5%	7.3%	14.5%	19.3%	28.5%	49.9%	2.0%
0.0%	0.0%	0.1%	0.5%	2.2%	4.6%	9.9%	18.0%	24.2%	34.4%	62.2%	2.5%
0.0%	0.0%	0.1%	0.7%	2.9%	6.2%	13.4%	22.6%	30.7%	40.2%	87.9%	3.4%
0.0%	0.0%	0.3%	1.5%	3.8%	8.4%	17.1%	28.5%	36.1%	48.3%	96.9%	4.4%
0.0%	0.0%	0.3%	1.8%	5.1%	11.5%	21.4%	34.7%	42.5%	60.4%	97.6%	5.5%
0.0%	0.0%	0.4%	2.4%	7.2%	15.7%	27.8%	41.0%	53.0%	86.6%	98.3%	7.2%
0.0%	0.0%	0.5%	3.3%	10.5%	20.6%	35.1%	51.8%	70.7%	97.0%	98.8%	9.2%
0.0%	0.1%	1.3%	4.8%	15.5%	28.2%	43.6%	72.1%	96.8%	97.9%	99.2%	12.3%
0.0%	0.1%	0.7%	4.8%	15.4%	28.0%	43.2%	71.0%	96.7%	97.9%	99.2%	12.1%
0.0%	0.1%	0.7%	4.7%	15.3%	27.8%	43.0%	70.4%	96.7%	97.9%	99.2%	12.0%
0.0%	0.1%	0.7%	4.7%	15.2%	27.6%	42.8%	70.0%	96.7%	97.9%	99.2%	12.0%
0.0%	0.1%	0.7%	4.8%	15.2%	27.6%	42.5%	69.0%	96.7%	97.8%	99.2%	11.9%
0.0%	0.1%	0.8%	5.0%	15.6%	28.3%	43.2%	70.4%	96.7%	97.9%	99.2%	12.2%
0.0%	0.1%	1.8%	7.6%	21.1%	36.0%	57.3%	96.7%	97.7%	98.6%	99.5%	15.9%
0.0%	0.1%	2.6%	12.0%	29.8%	46.2%	89.0%	97.8%	98.5%	99.1%	99.7%	21.3%
0.0%	0.3%	4.0%	17.9%	38.6%	65.8%	97.4%	98.6%	99.1%	99.5%	99.9%	25.8%
0.0%	0.5%	6.9%	26.8%	53.9%	96.8%	98.4%	99.2%	99.5%	99.8%	99.9%	31.7%
0.0%	1.4%	12.7%	37.9%	92.1%	98.1%	99.1%	99.6%	99.8%	99.9%	100.0%	35.8%
0.0%	1.4%	13.5%	39.1%	94.9%	98.2%	99.2%	99.7%	99.8%	99.9%	100.0%	36.2%
0.0%	1.5%	14.2%	40.3%	96.6%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	36.4%
0.0%	1.6%	14.9%	41.6%	96.8%	98.4%	99.3%	99.7%	99.8%	99.9%	100.0%	36.6%
0.0%	1.6%	15.4%	43.0%	96.9%	98.5%	99.3%	99.7%	99.8%	99.9%	100.0%	36.7%
0.0%	1.7%	16.0%	44.4%	97.0%	98.6%	99.4%	99.7%	99.9%	99.9%	100.0%	36.8%

Type 3 (1)

TYPE 3: Insulated; Non-refrigerated; Insulated Refrigerated; Drop Frame, Open Top, Basic Enclosed

Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline

Fuel Type **Ethanol**
Discount Rate **10.0%**
Annual VMT 218113

Fuel Efficiency Escalation Factor: 1.00

Year	Baseline Fuel Efficiency MPG	ADV. Diesel Efficiency Improvement	ADV. Diesel Adjusted MPG	Ethanol Efficiency Improvement	Ethanol Adjusted MPG	Ethanol Fuel Cost	**ANNUAL DOLLAR SAVINGS OF TECHNOLOGY** ADV. Diesel	Alt. Fuel	**NPV of Advanced Diesel Savings** Payback Periods (years) 1	2	3	4
1995	7.00	0.01	0.07	1.00	7.00	2.37	-3435577.02	-39144.15	-3123251.84	-3244288.08	-3284049.03	-3299879.35
1996	7.00	0.21	1.46	1.00	7.00	2.36	-146453.85	-35072.73	-133139.87	-176876.91	-194290.27	-200455.36
1997	7.00	0.41	2.84	1.00	7.00	2.36	-52921.83	-37363.20	-48110.75	-67265.44	-74047.04	-74047.04
1998	7.00	0.60	4.23	1.00	7.00	2.35	-23177.18	-37872.72	-21070.16	-28529.92	-28529.92	-26085.02
1999	7.00	0.80	5.61	1.00	7.00	2.34	-9026.31	-36351.07	-8205.73	-8205.73	-5516.35	-1254.33
2000	7.00	1.00	7.00	1.00	7.00	1.80	0.00	-9385.26	0.00	2958.33	7646.54	13231.51
2001	7.00	1.09	7.60	1.00	7.00	1.76	3579.57	-9762.04	3254.16	8411.20	14554.66	21555.09
2002	7.00	1.17	8.20	1.00	7.00	1.73	6240.02	-11323.64	5672.74	12430.55	20131.02	28186.71
2003	7.00	1.26	8.81	1.00	7.00	1.69	8176.95	-12850.57	7433.59	15904.11	24765.37	33134.09
2004	7.00	1.34	9.41	1.00	7.00	1.66	10249.33	-11555.51	9317.57	19064.95	28270.55	37030.60
2005	7.00	**1.42**	**9.94**	**1.00**	**7.00**	**1.62**	11794.34	-10601.57	10722.12	20848.28	30484.34	39324.07
2006	7.00	1.43	10.01	1.07	7.49	1.58	12252.65	-5379.86	11138.77	21738.43	31462.14	40346.66
2007	7.00	1.43	10.01	1.14	7.98	1.55	12825.59	341.83	11659.63	22355.71	32128.67	41128.34
2008	7.00	1.43	10.01	1.21	8.47	1.51	12942.26	4104.59	11765.69	22515.95	32415.58	41460.76
2009	7.00	1.43	10.01	1.28	8.96	1.48	13007.82	7328.27	11825.29	22714.88	32664.58	41656.95
2010	7.00	1.43	10.01	1.35	9.45	1.44	13176.41	10582.91	11978.55	22923.22	32814.83	41812.25
2011	7.00	1.43	10.01	1.45	10.16	1.43	13243.05	13353.89	12039.13	22919.91	32817.06	41750.20
2012	7.00	1.43	10.01	1.55	10.88	1.42	13165.73	15311.49	11968.85	22855.72	32682.18	41641.16
2013	7.00	1.43	10.01	1.66	11.59	1.41	13173.12	17277.92	11975.56	22784.66	32639.55	41568.22
2014	7.00	1.43	10.01	1.76	12.31	1.40	13079.01	18681.51	11890.01	22730.38	32551.93	41448.55
2015	7.00	**1.43**	**10.01**	**1.86**	**13.02**	**1.39**	13116.85	20335.63	11924.41	22728.11	32514.39	41415.87
2016	7.00	1.43	10.01	1.86	13.02	1.38	13072.48	20355.58	11884.07	22648.98	32440.61	41294.15
2017	7.00	1.43	10.01	1.86	13.02	1.37	13025.54	20367.01	11841.40	22612.19	32351.09	41212.47
2018	7.00	1.43	10.01	1.86	13.02	1.36	13032.66	20558.20	11847.87	22560.66	32308.17	41283.31
2019	7.00	1.43	10.01	1.86	13.02	1.35	12962.48	20492.35	11784.07	22506.34	32378.98	41467.88
2020	7.00	1.43	10.01	1.86	13.02	1.34	12973.94	20697.96	11794.49	22654.40	32652.19	41854.85
2021	7.00	1.43	10.01	1.86	13.02	1.34	13140.50	21251.87	11945.90	22943.47	33066.39	42382.82
2022	7.00	1.43	10.01	1.86	13.02	1.34	13307.05	21805.77	12097.32	23232.54	33480.60	42910.78
2023	7.00	1.43	10.01	1.86	13.02	1.34	13473.61	22359.68	12248.74	23521.61	33894.81	43450.73
2024	7.00	1.43	10.01	1.86	13.02	1.34	13640.17	22913.58	12400.16	23810.68	34322.19	44003.84
2025	7.00	1.43	10.01	1.86	13.02	1.34	13806.73	23467.49	12551.57	24114.23	34764.05	44571.44
2026	7.00	1.43	10.01	1.86	13.02	1.34	13990.82	24079.69	12718.93	24433.73	35221.86	45154.98
2027	7.00	1.43	10.01	1.86	13.02	1.34	14174.91	24691.90	12886.28	24753.22	35679.66	45738.52
2028	7.00	1.43	10.01	1.86	13.02	1.34	14359.00	25304.10	13053.64	25072.72	36137.47	46322.06
2029	7.00	1.43	10.01	1.86	13.02	1.34	14543.09	25916.31	13220.99	25392.21	36595.27	46905.60
2030	7.00	1.43	10.01	1.86	13.02	1.34	14727.18	26528.52	13388.34	25711.71	37053.07	47489.14
2031	7.00	1.43	10.01	1.86	13.02	1.34	14911.27	27140.72				
2032	7.00	1.43	10.01	1.86	13.02	1.34	15095.36	27752.93				
2033	7.00	1.43	10.01	1.86	13.02	1.34	15279.45	28365.13				
2034	7.00	1.43	10.01	1.86	13.02	1.34	15463.54	28977.34				
2035	7.00	1.43	10.01	1.86	13.02	1.34	15647.63	29589.54				

Type 3 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-35585.59	-64571.32	-92642.85	-118510.43	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-31884.30	-62762.98	-91217.32	-116045.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-33966.55	-65266.32	-92577.42	-98987.68	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-34429.75	-64471.96	-71523.24	-78190.85	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-33046.43	-40802.84	-48137.21	-55871.41	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8532.05	-16599.86	-25107.48	-33884.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8874.59	-18232.97	-27887.79	-35780.36	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10294.22	-20914.53	-29596.35	-36837.37	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-11682.34	-21232.34	-29197.46	-32871.97	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10505.01	-19266.64	-23308.60	-23075.13	0.00	0.00	-0.01	-0.32	100000	0.00	0.00	0.00	0.00	100.0
-9637.79	-14083.95	-13827.13	-11023.64	-0.07	-1.08	-2.05	-2.93	100000	0.00	0.00	0.00	0.00	92.5
-4890.78	-4608.27	-1524.43	3480.87	-0.17	-1.29	-2.31	-3.25	100000	0.00	0.00	0.00	0.00	81.2
310.75	3702.98	9208.82	16437.09	-0.30	-1.48	-2.57	-3.57	100000	0.00	0.00	0.00	0.00	65.6
3731.45	9787.87	17738.96	26859.85	-0.38	-1.65	-2.81	-3.88	100000	0.00	0.00	0.00	0.00	53.2
6662.07	15408.27	25441.24	35899.19	-0.48	-1.84	-3.08	-4.21	100000	0.00	0.00	0.00	0.00	38.7
9620.82	20657.09	32160.84	43961.89	-0.60	-2.06	-3.38	-4.57	100000	0.00	0.00	0.00	0.00	18.3
12139.90	24794.02	37775.18	50534.90	-0.72	-2.27	-3.69	-4.96	100000	0.00	0.00	0.00	0.00	-5.4
13919.53	28198.81	42234.50	56124.01	-0.84	-2.52	-4.03	-5.41	100000	0.00	0.00	0.00	0.00	-32.0
15707.20	31146.47	46424.93	60328.06	-1.00	-2.80	-4.44	-5.93	100000	0.00	0.00	0.00	0.00	-70.7
16983.19	33789.50	49082.95	62993.89	-1.16	-3.13	-4.92	-6.54	100000	0.00	0.00	0.00	0.00	-119.6
18486.94	35309.73	50611.76	64653.29	-1.38	-3.55	-5.50	-7.28	100000	0.00	0.00	0.00	0.00	-199.4
18505.07	35337.31	50782.99	64779.54	-1.38	-3.53	-5.49	-7.26	100000	0.00	0.00	0.00	0.00	-196.2
18515.46	35505.71	50901.91	65038.90	-1.37	-3.52	-5.47	-7.24	100000	0.00	0.00	0.00	0.00	-192.9
18689.27	35625.09	51175.78	65691.09	-1.37	-3.51	-5.46	-7.26	100000	0.00	0.00	0.00	0.00	-193.4
18629.41	35735.16	51702.00	66595.64	-1.36	-3.50	-5.48	-7.29	100000	0.00	0.00	0.00	0.00	-188.4
18816.33	36379.86	52762.86	68034.82	-1.36	-3.53	-5.53	-7.37	100000	0.00	0.00	0.00	0.00	-189.2
19319.88	37341.18	54140.34	69790.62	-1.60	-3.99	-6.19	-8.21	100000	0.00	0.00	0.00	0.00	-293.8
19823.43	38302.50	55517.82	71546.43	-1.88	-4.53	-6.97	-9.22	100000	0.00	0.00	0.00	0.00	-455.6
20326.98	39263.83	56895.30	73342.05	-2.22	-5.19	-7.92	-10.43	100000	0.00	0.00	0.00	0.00	-723.8
20830.53	40225.15	58316.58	75181.48	-2.65	-6.00	-9.09	-11.94	100000	0.00	0.00	0.00	0.00	-1211.3
21334.08	41234.65	59786.04	77069.09	-3.18	-7.04	-10.59	-13.86	100000	0.00	0.00	0.00	0.00	-2214.0
21890.63	42297.16	61308.51	79009.70	-3.24	-7.14	-10.74	-14.05	100000	0.00	0.00	0.00	0.00	-2352.5
22447.18	43359.66	62830.97	80950.30	-3.30	-7.25	-10.89	-14.25	100000	0.00	0.00	0.00	0.00	-2498.9
23003.73	44422.17	64353.44	82890.91	-3.35	-7.36	-11.05	-14.44	100000	0.00	0.00	0.00	0.00	-2653.7
23560.28	45484.67	65875.90	84831.52	-3.41	-7.46	-11.20	-14.64	100000	0.00	0.00	0.00	0.00	-2817.4
24116.83	46547.18	67398.36	86772.13	-3.46	-7.57	-11.35	-14.83	100000	0.00	0.00	0.00	0.00	-2990.6

Type 3 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels						
Payback Periods (years)								Payback Periods (years)						
1		2		3		4		1		2		3		4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.9	99.9	96.2	96.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
92.5	80.4	80.4	32.4	32.4	-77.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
81.2	73.7	73.7	9.1	9.1	-147.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
65.6	65.9	65.9	-20.6	1.0	-245.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
53.2	58.0	58.0	-56.7	1.0	-373.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
38.7	47.1	47.1	-108.3	1.0	-561.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
18.3	31.8	31.8	-182.3	1.0	-860.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	12.8	12.8	-289.7	1.0	-1322.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-13.8	1.0	-451.5	1.0	-2118.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-54.0	1.0	-737.7	1.0	-3644.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-119.4	1.0	-1258.0	1.0	-6785.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-236.6	1.0	-2344.0	1.0	-14446.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-231.2	1.0	-2308.0	1.0	-14095.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-228.7	1.0	-2265.1	1.0	-13865.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-225.2	1.0	-2244.8	1.0	-14065.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-221.6	1.0	-2278.4	1.0	-14598.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-231.5	1.0	-2412.5	1.0	-15781.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-429.3	1.0	-4760.4	1.0	-36800.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-819.0	1.0	-10549.0	1.0	-100543.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1684.5	1.0	-27399.1	1.0	-339987.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-3937.0	1.0	-88975.0	1.0	-1536196.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-11282.0	1.0	-396458.2	1.0	-10425055.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-12562.1	1.0	-461836.6	1.0	-12663543.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-13986.2	1.0	-537993.3	1.0	-15382677.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-15570.3	1.0	-626705.3	1.0	-18685662.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-17332.3	1.0	-730042.3	1.0	-22697863.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-19292.4	1.0	-850415.6	1.0	-27571561.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 3 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.0%	1.9%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.2%	9.8%	65.0%	99.7%	22.7%	22.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.7%	15.1%	91.8%	99.8%	30.2%	30.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.7%	22.8%	99.4%	99.9%	36.3%	36.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.9%	31.8%	99.6%	100.0%	42.1%	42.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.3%	45.7%	99.8%	100.0%	51.1%	51.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.3%	65.8%	99.9%	100.0%	65.0%	65.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
80.8%	88.1%	99.9%	100.0%	89.5%	89.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
84.3%	99.4%	100.0%	100.0%	97.0%	97.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
88.0%	99.6%	100.0%	100.0%	97.8%	97.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
91.1%	99.8%	100.0%	100.0%	98.4%	98.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.1%	99.9%	100.0%	100.0%	99.0%	99.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.0%	99.9%	100.0%	100.0%	99.0%	99.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.9%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.9%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.8%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.8%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
96.1%	100.0%	100.0%	100.0%	99.3%	99.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
97.7%	100.0%	100.0%	100.0%	99.6%	99.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
98.8%	100.0%	100.0%	100.0%	99.8%	99.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.5%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 3 (5)

Class 7-8 Type 3 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels

(thousands of miles)

0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Final Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.1%	0.4%	1.4%	2.5%	4.8%	8.2%	14.4%	20.8%	0.8%
0.0%	0.0%	0.0%	0.3%	0.6%	1.8%	3.4%	6.8%	11.8%	18.6%	27.7%	1.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.4%	4.7%	9.6%	15.8%	24.0%	34.4%	1.5%
0.0%	0.0%	0.1%	0.4%	1.6%	3.0%	6.2%	12.8%	19.4%	29.8%	39.4%	1.9%
0.0%	0.0%	0.1%	0.5%	2.0%	4.0%	8.4%	16.2%	24.4%	35.3%	47.1%	2.3%
0.0%	0.0%	0.1%	0.6%	2.5%	5.3%	11.5%	20.4%	30.9%	41.6%	59.2%	3.0%
0.0%	0.0%	0.3%	1.4%	3.3%	7.2%	15.3%	25.7%	36.2%	50.3%	78.7%	3.9%
0.0%	0.0%	0.3%	1.8%	4.4%	10.0%	19.0%	32.5%	42.7%	63.3%	96.7%	4.9%
0.0%	0.0%	0.4%	2.3%	6.1%	14.0%	24.7%	38.2%	53.3%	89.5%	97.6%	6.2%
0.0%	0.0%	0.5%	3.1%	9.0%	18.5%	32.6%	47.3%	71.2%	97.2%	98.2%	7.7%
0.0%	0.1%	0.7%	4.5%	13.6%	25.3%	39.8%	64.1%	96.8%	98.1%	98.8%	9.6%
0.0%	0.1%	0.7%	4.5%	13.4%	25.1%	39.5%	63.3%	96.8%	98.0%	98.8%	9.6%
0.0%	0.1%	0.7%	4.4%	13.3%	24.9%	39.3%	62.9%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.4%	13.3%	24.7%	39.1%	62.5%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.5%	13.4%	24.8%	38.9%	61.9%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.6%	13.8%	25.4%	39.5%	63.1%	96.7%	98.0%	98.8%	9.6%
0.0%	0.1%	1.7%	7.1%	18.9%	33.8%	51.2%	93.5%	97.7%	98.6%	99.2%	12.0%
0.0%	0.1%	2.3%	11.2%	26.5%	42.4%	72.7%	97.5%	98.5%	99.2%	99.6%	14.9%
0.0%	0.3%	3.6%	17.0%	35.8%	59.0%	97.0%	98.4%	99.1%	99.5%	99.8%	18.7%
0.0%	0.5%	6.0%	25.4%	48.5%	95.0%	98.1%	99.1%	99.5%	99.8%	99.9%	22.4%
0.0%	1.4%	11.1%	36.7%	78.5%	97.9%	99.0%	99.6%	99.8%	99.9%	#####	25.3%
0.0%	1.4%	11.8%	37.7%	87.8%	98.0%	99.0%	99.6%	99.8%	99.9%	#####	26.0%
0.0%	1.5%	12.5%	38.9%	90.2%	98.1%	99.1%	99.6%	99.8%	99.9%	#####	26.2%
0.0%	1.6%	13.1%	40.0%	92.9%	98.2%	99.2%	99.6%	99.8%	99.9%	#####	26.5%
0.0%	1.6%	13.8%	41.3%	95.5%	98.3%	99.2%	99.7%	99.8%	99.9%	#####	26.7%
0.0%	1.7%	14.6%	42.6%	96.6%	98.4%	99.3%	99.7%	99.9%	99.9%	#####	26.9%

Type 3 (6)

Class 7-8 Type 3 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels

(thousands of miles)

0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Final Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.5%	2.6%	5.0%	8.6%	12.9%	22.7%	1.6%
0.0%	0.0%	0.0%	0.3%	0.6%	1.9%	3.6%	7.1%	12.3%	17.0%	30.2%	2.2%
0.0%	0.0%	0.1%	0.3%	0.7%	2.5%	4.9%	10.0%	16.2%	22.0%	36.3%	2.9%
0.0%	0.0%	0.1%	0.4%	1.6%	3.2%	6.5%	13.3%	20.0%	27.4%	42.1%	3.7%
0.0%	0.0%	0.1%	0.5%	2.0%	4.2%	8.8%	16.8%	25.1%	33.6%	51.1%	4.7%
0.0%	0.0%	0.1%	0.6%	2.6%	5.7%	12.0%	21.1%	31.8%	39.0%	65.0%	6.1%
0.0%	0.0%	0.3%	0.7%	3.3%	7.7%	15.7%	26.6%	36.9%	46.6%	89.5%	7.9%
0.0%	0.0%	0.3%	1.7%	4.4%	10.6%	19.6%	33.4%	43.7%	57.9%	97.0%	9.6%
0.0%	0.0%	0.4%	2.1%	6.2%	14.8%	25.4%	39.1%	54.8%	79.9%	97.8%	11.7%
0.0%	0.0%	0.5%	2.9%	9.1%	19.3%	33.4%	48.8%	74.0%	96.9%	98.4%	14.6%
0.0%	0.1%	1.3%	4.2%	13.8%	26.5%	40.7%	66.5%	96.9%	97.8%	99.0%	18.2%
0.0%	0.1%	0.7%	4.1%	13.6%	26.2%	40.4%	65.7%	96.9%	97.8%	99.0%	18.0%
0.0%	0.1%	0.7%	4.1%	13.5%	26.0%	40.2%	65.2%	96.8%	97.8%	98.9%	18.0%
0.0%	0.1%	0.7%	4.1%	13.5%	25.9%	40.0%	64.8%	96.8%	97.8%	98.9%	17.9%
0.0%	0.1%	0.7%	4.1%	13.6%	25.9%	39.8%	64.1%	96.8%	97.7%	98.9%	17.8%
0.0%	0.1%	0.8%	4.3%	14.1%	26.6%	40.4%	65.4%	96.8%	97.8%	98.9%	18.1%
0.0%	0.1%	1.8%	6.5%	19.1%	34.7%	52.6%	95.6%	97.8%	98.5%	99.3%	22.6%
0.0%	0.1%	2.6%	10.4%	26.9%	43.9%	75.8%	97.6%	98.5%	99.1%	99.6%	27.5%
0.0%	0.3%	4.0%	16.0%	36.1%	61.6%	97.1%	98.5%	99.1%	99.5%	99.8%	33.0%
0.0%	0.5%	6.9%	23.9%	49.1%	96.6%	98.2%	99.1%	99.5%	99.7%	99.9%	37.8%
0.0%	0.8%	12.7%	35.4%	80.6%	98.0%	99.0%	99.6%	99.8%	99.9%	100.0%	41.2%
0.0%	1.4%	13.5%	36.3%	88.3%	98.1%	99.1%	99.6%	99.8%	99.9%	100.0%	41.9%
0.0%	1.5%	14.2%	37.4%	91.1%	98.2%	99.1%	99.6%	99.8%	99.9%	100.0%	42.2%
0.0%	1.5%	14.9%	38.4%	93.8%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	42.5%
0.0%	1.6%	15.4%	39.6%	96.4%	98.4%	99.2%	99.7%	99.9%	99.9%	100.0%	42.8%
0.0%	1.7%	16.0%	40.8%	96.7%	98.5%	99.3%	99.7%	99.9%	99.9%	100.0%	42.9%

Med (1)

Classes 3-6												
	Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline											
	Fuel Type	**Ethanol**										
	Discount Rate	**10.0%**										
	Annual VMT	212500										
	Baseline	ADV. Diesel	ADV. Diesel	Ethanol	Ethanol	Ethanol	**ANNUAL DOLLAR SAVINGS**		**NPV of Advanced Diesel Savings**			
	Fuel Efficiency	Efficiency	Adjusted	Efficiency	Adjusted	Fuel	**OF TECHNOLOGY**		Payback Periods (years)			
Year	MPG	Improvement	MPG	Improvement	MPG	Cost	ADV. Diesel	Alt. Fuel	1	2	3	4
1995	8.82	1.00	8.82	1.00	8.82	2.37	0.00	-30269.13	0.00	0.00	0.00	0.00
1996	8.86	1.00	8.86	1.00	8.86	2.36	0.00	-26997.80	0.00	0.00	0.00	0.00
1997	8.90	1.00	8.90	1.00	8.90	2.36	0.00	-28630.49	0.00	0.00	0.00	0.00
1998	8.92	1.00	8.92	1.00	8.92	2.35	0.00	-28964.24	0.00	0.00	0.00	3890.66
1999	8.94	1.00	8.94	1.00	8.94	2.34	0.00	-27722.96	0.00	0.00	4279.73	10539.81
2000	9.00	1.00	9.00	1.00	9.00	1.80	0.00	-7111.78	0.00	4707.70	11593.79	19281.49
2001	9.02	1.20	10.82	1.20	10.82	1.76	5696.32	-454.63	5178.47	12753.17	21209.64	30340.63
2002	9.04	1.40	12.66	1.40	12.66	1.73	9165.38	3063.11	8332.16	17634.29	27678.37	37885.35
2003	9.06	1.60	14.49	1.60	14.49	1.69	11255.57	5209.32	10232.34	21280.83	32508.51	42915.68
2004	9.08	1.80	16.34	1.80	16.34	1.66	13368.68	8546.41	12153.34	24503.79	35951.68	46821.71
2005	9.10	2.00	18.20	2.00	18.20	1.62	14944.04	10970.97	13585.49	26178.17	38135.21	49080.17
2006	9.12	2.00	18.24	2.10	19.15	1.58	15237.15	12896.83	13851.95	27004.69	39044.15	50020.53
2007	9.14	2.00	18.28	2.20	20.11	1.55	15914.81	15468.28	14468.01	27711.41	39785.43	50879.80
2008	9.16	2.00	18.32	2.30	21.07	1.51	16024.52	16796.38	14567.74	27849.16	40052.97	51179.09
2009	9.18	2.00	18.36	2.40	22.03	1.48	16070.52	17903.10	14609.56	28033.75	40272.49	51309.51
2010	9.20	2.00	18.40	2.50	23.00	1.44	16243.26	19180.60	14766.60	28229.22	40369.94	51389.03
2011	9.22	2.00	18.44	2.50	23.05	1.43	16289.76	19394.85	14808.87	28163.67	40284.67	51201.16
2012	9.24	2.00	18.48	2.50	23.10	1.42	16159.30	19254.71	14690.27	28023.38	40031.51	50955.68
2013	9.26	2.00	18.52	2.50	23.15	1.41	16133.06	19322.55	14666.41	27875.36	39891.94	50755.38
2014	9.28	2.00	18.56	2.50	23.20	1.40	15982.83	19141.96	14529.84	27748.08	39697.86	50498.65
2015	9.30	2.00	18.60	2.50	23.25	1.39	15994.07	19283.84	14540.06	27684.82	39565.69	50348.78
2016	9.32	2.00	18.64	2.50	23.30	1.38	15905.15	19224.95	14459.23	27528.19	39389.59	50091.21
2017	9.34	2.00	18.68	2.50	23.35	1.37	15813.44	19160.00	14375.85	27423.40	39195.18	49882.86
2018	9.36	2.00	18.72	2.50	23.40	1.36	15787.53	19226.20	14352.30	27301.25	39057.71	49828.74
2019	9.38	2.00	18.76	2.50	23.45	1.35	15668.23	19105.18	14243.85	27175.95	39024.09	49877.38
2020	9.40	2.00	18.80	2.50	23.51	1.34	15647.84	19181.50	14225.31	27258.26	39196.88	50131.35
2021	9.45	2.00	18.90	2.50	23.62	1.34	15769.87	19485.84	14336.25	27468.74	39496.65	50511.22
2022	9.50	2.00	18.99	2.50	23.74	1.34	15890.31	19786.68	14445.74	27676.44	39792.47	50886.06
2023	9.54	2.00	19.09	2.50	23.86	1.34	16009.16	20084.04	14553.78	27881.40	40084.36	51269.94
2024	9.59	2.00	19.18	2.50	23.98	1.34	16126.43	20377.96	14660.39	28083.64	40387.78	51664.16
2025	9.64	2.00	19.28	2.50	24.10	1.34	16242.13	20668.45	14765.58	28300.13	40704.15	52070.14
2026	9.69	2.00	19.38	2.50	24.22	1.34	16376.81	20996.59	14888.01	28532.43	41035.03	52489.47
2027	9.74	2.00	19.47	2.50	24.34	1.34	16509.75	21320.96	15008.86	28761.72	41361.60	52903.33
2028	9.78	2.00	19.57	2.50	24.46	1.34	16640.95	21641.57	15128.14	28988.02	41683.91	53311.77
2029	9.83	2.00	19.67	2.50	24.58	1.34	16770.45	21958.47	15245.86	29211.35	42001.99	53714.84
2030	9.88	2.00	19.77	2.50	24.71	1.34	16898.24	22271.68	15362.04	29431.75	42315.88	54112.58
2031	9.93	2.00	19.86	2.50	24.83	1.34	17024.35	22581.23				
2032	9.98	2.00	19.96	2.50	24.96	1.34	17148.78	22887.15				
2033	10.03	2.00	20.06	2.50	25.08	1.34	17271.55	23189.47				
2034	10.08	2.00	20.16	2.50	25.21	1.34	17392.68	23488.21				
2035	10.13	2.00	20.27	2.50	25.33	1.34	17512.18	23783.40				

Med (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-27517.39	-49829.62	-71340.14	-91123.10	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-24543.46	-48205.02	-69966.28	-88901.44	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-26027.72	-49965.10	-70793.78	-75651.22	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-26331.12	-49242.66	-54585.85	-54896.37	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-25202.69	-31080.20	-31421.77	-29329.63	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-6465.26	-6840.99	-4539.63	-981.60	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-413.30	2118.19	6032.03	11869.34	0.00	0.00	0.00	-0.40	100000	0.00	0.00	0.00	0.00	100.0
2784.64	7089.86	13510.90	21004.23	0.00	0.00	-0.52	-1.08	100000	0.00	0.00	0.00	0.00	100.0
4735.74	11798.89	20041.54	28850.25	0.00	-0.44	-1.20	-1.90	100000	0.00	0.00	0.00	0.00	100.0
7769.46	16836.38	26525.96	37091.01	-0.07	-1.15	-2.15	-3.11	100000	0.00	0.00	0.00	0.00	99.3
9973.61	20632.15	32253.70	43725.85	-0.70	-2.27	-3.77	-5.14	100000	0.00	0.00	0.00	0.00	89.9
11724.39	24508.10	37127.46	49355.52	-0.82	-2.55	-4.14	-5.58	100000	0.00	0.00	0.00	0.00	87.2
14062.07	27943.37	41394.23	54494.84	-1.01	-2.85	-4.53	-6.07	100000	0.00	0.00	0.00	0.00	82.6
15269.43	30065.38	44476.05	57722.99	-1.14	-3.10	-4.89	-6.53	100000	0.00	0.00	0.00	0.00	78.7
16275.54	32127.27	46698.91	59850.14	-1.28	-3.38	-5.29	-7.02	100000	0.00	0.00	0.00	0.00	73.9
17436.90	33465.70	47932.05	61129.62	-1.46	-3.70	-5.73	-7.56	100000	0.00	0.00	0.00	0.00	66.9
17631.68	33544.66	48061.98	61136.20	-1.64	-4.03	-6.19	-8.14	100000	0.00	0.00	0.00	0.00	58.2
17504.28	33473.33	47854.97	61026.09	-1.83	-4.39	-6.70	-8.80	100000	0.00	0.00	0.00	0.00	48.0
17565.96	33385.75	47873.99	61004.88	-2.06	-4.81	-7.31	-9.57	100000	0.00	0.00	0.00	0.00	31.9
17401.78	33338.83	47782.82	60869.36	-2.30	-5.31	-8.02	-10.48	100000	0.00	0.00	0.00	0.00	10.0
17530.76	33419.15	47814.33	60946.09	-2.64	-5.92	-8.89	-11.59	100000	0.00	0.00	0.00	0.00	-29.4
17477.22	33311.93	47756.86	60805.96	-2.81	-6.24	-9.37	-12.18	100000	0.00	0.00	0.00	0.00	-55.3
17418.18	33307.60	47661.61	60762.83	-2.99	-6.62	-9.89	-12.86	100000	0.00	0.00	0.00	0.00	-89.5
17478.37	33267.77	47679.11	60988.20	-3.22	-7.03	-10.49	-13.66	100000	0.00	0.00	0.00	0.00	-140.6
17368.34	33220.82	47860.82	61375.38	-3.45	-7.49	-11.20	-14.59	100000	0.00	0.00	0.00	0.00	-205.4
17437.72	33541.72	48407.75	62125.42	-3.74	-8.09	-12.07	-15.71	100000	0.00	0.00	0.00	0.00	-311.7
17714.40	34067.03	49156.46	63074.89	-4.12	-8.81	-13.11	-17.04	100000	0.00	0.00	0.00	0.00	-505.6
17987.89	34586.27	49896.54	64013.37	-4.56	-9.64	-14.30	-18.57	100000	0.00	0.00	0.00	0.00	-842.1
18258.22	35099.51	50628.02	64968.98	-5.06	-10.62	-15.70	-20.36	100000	0.00	0.00	0.00	0.00	-1472.3
18525.42	35606.78	51381.84	65944.34	-5.66	-11.77	-17.36	-22.48	100000	0.00	0.00	0.00	0.00	-2772.5
18789.50	36142.06	52160.81	66942.30	-6.38	-13.15	-19.35	-25.04	100000	0.00	0.00	0.00	0.00	-5805.7
19087.81	36708.44	52968.07	67966.01	-6.44	-13.27	-19.52	-25.24	100000	0.00	0.00	0.00	0.00	-6179.2
19382.69	37268.29	53766.01	68977.87	-6.50	-13.38	-19.68	-25.45	100000	0.00	0.00	0.00	0.00	-6571.0
19674.16	37821.66	54554.70	69977.99	-6.56	-13.49	-19.84	-25.66	100000	0.00	0.00	0.00	0.00	-6981.5
19962.25	38368.60	55334.21	70966.45	-6.62	-13.61	-20.00	-25.86	100000	0.00	0.00	0.00	0.00	-7411.5
20246.98	38909.16	56104.62	71943.34	-6.68	-13.72	-20.16	-26.06	100000	0.00	0.00	0.00	0.00	-7861.3

Med (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels						
Payback Periods (years)								Payback Periods (years)						
1		2		3		4		1		2		3		4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	95.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	93.2	93.2	80.5	80.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	94.5	94.5	76.9	76.9	43.2	43.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
99.3	78.4	78.4	23.8	23.8	-113.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
89.9	13.0	13.0	-322.5	1.0	-1588.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
87.2	-18.5	1.0	-516.4	1.0	-2545.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
82.6	-62.7	1.0	-813.7	1.0	-4202.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
78.7	-111.0	1.0	-1219.7	1.0	-6718.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
73.9	-183.8	1.0	-1878.6	1.0	-11045.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.9	-296.4	1.0	-2964.5	1.0	-19181.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
58.2	-452.2	1.0	-4786.5	1.0	-34284.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
48.0	-695.7	1.0	-8000.8	1.0	-66177.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
31.9	-1114.1	1.0	-14854.1	1.0	-143753.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10.0	-1906.2	1.0	-30370.0	1.0	-354775.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-3618.6	1.0	-72583.5	1.0	-1076988.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5040.5	1.0	-116695.8	1.0	-1952118.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-7371.6	1.0	-196727.5	1.0	-3832033.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-11187.8	1.0	-358555.6	1.0	-8521342.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-17835.0	1.0	-727566.4	1.0	-21622850.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-32379.5	1.0	-1737833.4	1.0	-66521400.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-66916.8	1.0	-4918477.1	1.0	-251336958.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-154300.6	1.0	-16311365.0	1.0	-1162858457.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-408222.2	1.0	-65949471.1	1.0	-6971250963.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1286955.5	1.0	-345556399.1	1.0	-58150120847.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5140337.8	1.0	-2538043738.8	1.0	-745750918714.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5773453.1	1.0	-2994663628.5	1.0	-919704851360.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-6474786.9	1.0	-3525845693.9	1.0	-1131142380474.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-7250474.7	1.0	-4142403269.6	1.0	-1387425697821.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-8107067.1	1.0	-4856492592.8	1.0	-1697209043686.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-9051543.6	1.0	-5681745483.2	1.0	-2070634752658.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Med (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	2.3%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	3.0%	9.8%	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	2.5%	12.5%	50.9%	6.7%	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.1%	11.3%	75.7%	99.8%	25.3%	25.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.3%	87.9%	99.9%	100.0%	76.8%	76.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.6%	99.4%	100.0%	100.0%	84.1%	84.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8.4%	99.7%	100.0%	100.0%	84.8%	84.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11.1%	99.8%	100.0%	100.0%	85.3%	85.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.0%	99.9%	100.0%	100.0%	86.0%	86.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.7%	99.9%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
31.5%	100.0%	100.0%	100.0%	88.8%	88.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
44.5%	100.0%	100.0%	100.0%	90.9%	90.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
65.7%	100.0%	100.0%	100.0%	94.4%	94.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90.9%	100.0%	100.0%	100.0%	98.5%	98.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.5%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.6%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.7%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Med (5)

Classes 3-6 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.5%	0.7%	1.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.0%	2.5%	3.9%	6.7%	0.0%
0.0%	0.0%	0.0%	0.3%	0.6%	1.5%	3.5%	6.6%	11.6%	16.8%	25.3%	0.0%
0.0%	0.0%	0.3%	1.6%	4.9%	7.5%	18.6%	29.8%	39.2%	53.0%	76.8%	0.2%
0.0%	0.0%	0.3%	2.0%	6.7%	10.5%	23.9%	35.6%	48.5%	68.0%	84.1%	0.2%
0.0%	0.0%	0.4%	2.6%	9.4%	14.4%	30.7%	42.7%	61.6%	84.3%	84.8%	0.3%
0.0%	0.0%	0.5%	3.3%	12.4%	17.6%	35.4%	50.7%	74.0%	84.3%	85.3%	0.4%
0.0%	0.0%	0.6%	4.3%	15.9%	21.8%	41.0%	62.0%	84.0%	84.8%	86.0%	0.5%
0.0%	0.1%	1.4%	5.7%	19.7%	27.4%	49.7%	76.4%	84.5%	85.4%	87.1%	0.6%
0.0%	0.1%	1.7%	7.7%	24.6%	33.6%	60.6%	84.1%	85.0%	86.3%	88.8%	0.8%
0.0%	0.1%	2.1%	10.5%	30.9%	38.6%	74.4%	84.6%	85.7%	87.4%	90.9%	1.0%
0.0%	0.1%	2.8%	14.6%	36.7%	46.6%	84.1%	85.2%	86.7%	89.3%	94.4%	1.2%
0.0%	0.3%	3.8%	19.0%	44.6%	59.4%	84.7%	86.0%	88.3%	92.1%	98.5%	1.6%
0.0%	0.4%	5.7%	25.8%	58.3%	78.0%	85.5%	87.6%	91.4%	96.9%	99.9%	2.1%
0.0%	0.5%	7.0%	30.1%	67.0%	84.0%	86.0%	88.7%	93.5%	99.4%	99.9%	2.4%
0.0%	0.5%	8.7%	34.3%	77.3%	84.4%	86.7%	90.2%	95.9%	99.9%	#####	2.6%
0.0%	0.6%	11.1%	38.2%	84.1%	84.7%	87.7%	92.4%	98.9%	99.9%	#####	2.8%
0.0%	1.4%	14.3%	43.7%	84.4%	85.2%	89.0%	94.9%	99.9%	100.0%	#####	3.2%
0.0%	1.7%	17.9%	52.8%	84.9%	85.8%	91.2%	98.3%	99.9%	100.0%	#####	3.6%
0.0%	2.3%	22.8%	66.6%	85.6%	86.9%	94.6%	99.9%	100.0%	100.0%	#####	4.2%
0.0%	3.0%	30.0%	83.3%	86.6%	88.7%	99.0%	99.9%	100.0%	100.0%	#####	5.0%
0.0%	4.3%	36.6%	84.5%	88.4%	91.7%	99.9%	100.0%	100.0%	100.0%	#####	5.5%
0.0%	6.5%	46.0%	85.2%	91.5%	96.3%	100.0%	100.0%	100.0%	100.0%	#####	6.2%
0.1%	10.3%	62.3%	86.3%	96.4%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.4%
0.1%	10.7%	63.9%	86.4%	96.9%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.5%
0.1%	11.1%	65.4%	86.6%	97.3%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.7%
0.1%	11.5%	67.0%	86.7%	97.7%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.8%
0.1%	11.8%	68.5%	86.8%	98.2%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.9%
0.1%	12.2%	70.0%	87.0%	98.6%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	8.0%

Med (6)

Classes 3-6 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.5%	0.7%	1.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.0%	2.5%	3.9%	6.7%	0.0%
0.0%	0.0%	0.0%	0.3%	0.7%	1.5%	3.5%	6.6%	11.6%	16.8%	25.3%	0.0%
0.0%	0.0%	0.1%	1.9%	5.7%	7.4%	18.6%	29.8%	39.2%	53.0%	76.8%	0.1%
0.0%	0.0%	0.3%	2.5%	8.0%	10.3%	23.9%	35.6%	48.5%	68.0%	84.1%	0.1%
0.0%	0.0%	0.4%	3.2%	11.1%	14.1%	30.7%	42.7%	61.6%	84.3%	84.8%	0.2%
0.0%	0.0%	0.5%	4.2%	14.5%	17.3%	35.4%	50.7%	74.0%	84.3%	85.3%	0.2%
0.0%	0.0%	0.6%	5.5%	17.9%	21.4%	41.0%	62.0%	84.0%	84.8%	86.0%	0.3%
0.0%	0.1%	0.7%	7.5%	22.3%	26.9%	49.7%	76.4%	84.5%	85.4%	87.1%	0.4%
0.0%	0.1%	1.6%	10.1%	27.9%	33.3%	60.6%	84.1%	85.0%	86.3%	88.8%	0.5%
0.0%	0.1%	1.9%	13.6%	34.1%	38.2%	74.4%	84.6%	85.7%	87.4%	90.9%	0.7%
0.0%	0.3%	2.5%	17.7%	39.9%	45.9%	84.1%	85.2%	86.7%	89.3%	94.4%	0.8%
0.0%	0.3%	3.4%	23.0%	49.5%	58.4%	84.7%	86.0%	88.3%	92.1%	98.5%	1.1%
0.0%	0.4%	5.0%	31.3%	65.4%	76.8%	85.5%	87.6%	91.4%	96.9%	99.9%	1.5%
0.0%	0.5%	6.1%	34.9%	74.7%	84.0%	86.0%	88.7%	93.5%	99.4%	99.9%	1.6%
0.0%	0.6%	7.7%	38.7%	83.9%	84.3%	86.7%	90.2%	95.9%	99.9%	100.0%	1.8%
0.0%	0.7%	9.8%	44.0%	84.3%	84.7%	87.7%	92.4%	98.9%	99.9%	100.0%	2.0%
0.0%	1.5%	12.8%	51.5%	84.7%	85.1%	89.0%	94.9%	99.9%	100.0%	100.0%	2.4%
0.0%	1.9%	16.3%	63.1%	85.2%	85.8%	91.2%	98.3%	99.9%	100.0%	100.0%	2.8%
0.0%	2.4%	20.8%	78.6%	86.0%	86.8%	94.6%	99.9%	100.0%	100.0%	100.0%	3.3%
0.0%	3.3%	27.3%	84.3%	87.3%	88.6%	99.0%	99.9%	100.0%	100.0%	100.0%	3.9%
0.0%	4.7%	34.7%	84.9%	89.5%	91.5%	99.9%	100.0%	100.0%	100.0%	100.0%	4.6%
0.0%	7.2%	42.7%	85.8%	93.1%	96.0%	100.0%	100.0%	100.0%	100.0%	100.0%	5.5%
0.0%	11.3%	57.2%	87.3%	98.5%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.2%
0.1%	11.8%	58.7%	87.5%	98.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.4%
0.1%	12.2%	60.1%	87.6%	99.3%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.5%
0.1%	12.6%	61.6%	87.8%	99.8%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.7%
0.1%	13.0%	63.0%	88.0%	99.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.8%
0.1%	13.4%	64.5%	88.2%	99.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	8.0%

New MPG (1)

	Class 3-6				Class 7&8 Type 1				Class 7&8 Type 2			
Year	Conventional	Hybrid	Ethanol	New Average	Conv. Diesel	Adv. Diesel	Ethanol	New Average	Conv. Diesel	Adv. Diesel	Ethanol	New Average
2000	9.00	9.00	9.00	9.00	6.58	6.58	6.58	6.58	6.79	6.79	6.79	6.79
2001	9.02	10.82	10.82	9.02	6.58	7.15	6.58	6.58	6.79	7.37	6.79	6.79
2002	9.04	12.66	12.66	9.04	6.58	7.71	6.58	6.58	6.79	7.96	6.79	6.79
2003	9.06	14.49	14.49	9.06	6.58	8.28	6.58	6.58	6.79	8.54	6.79	6.79
2004	9.08	16.34	16.34	9.08	6.58	8.84	6.58	6.58	6.79	9.13	6.79	6.79
2005	9.10	18.20	18.20	9.11	6.58	9.41	6.58	6.58	6.79	9.71	6.79	6.82
2006	9.12	18.24	19.15	9.14	6.58	9.41	7.04	6.59	6.79	9.71	7.27	6.82
2007	9.14	18.28	20.11	9.16	6.58	9.41	7.50	6.59	6.79	9.71	7.74	6.84
2008	9.16	18.32	21.07	9.19	6.58	9.41	7.96	6.59	6.79	9.71	8.22	6.85
2009	9.18	18.36	22.03	9.21	6.58	9.41	8.42	6.59	6.79	9.71	8.69	6.87
2010	9.20	18.40	23.00	9.25	6.58	9.41	8.88	6.60	6.79	9.71	9.17	6.90
2011	9.22	18.44	23.05	9.28	6.58	9.41	9.55	6.60	6.79	9.71	9.86	6.93
2012	9.24	18.48	23.10	9.31	6.58	9.41	10.23	6.61	6.79	9.71	10.55	6.96
2013	9.26	18.52	23.15	9.36	6.58	9.41	10.90	6.62	6.79	9.71	11.24	7.02
2014	9.28	18.56	23.20	9.40	6.58	9.41	11.57	6.64	6.79	9.71	11.94	7.08
2015	9.30	18.60	23.25	9.47	6.58	9.41	12.24	6.63	6.79	9.71	12.63	7.19
2016	9.32	18.64	23.30	9.51	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2017	9.34	18.68	23.35	9.55	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2018	9.36	18.72	23.40	9.59	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2019	9.38	18.76	23.45	9.65	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2020	9.40	18.80	23.51	9.71	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2021	9.45	18.90	23.62	9.82	6.58	9.41	12.24	6.69	6.79	9.71	12.63	7.31
2022	9.50	18.99	23.74	9.94	6.58	9.41	12.24	6.74	6.79	9.71	12.63	7.50
2023	9.54	19.09	23.86	10.05	6.58	9.41	12.24	6.79	6.79	9.71	12.63	7.67
2024	9.59	19.18	23.98	10.19	6.58	9.41	12.24	6.87	6.79	9.71	12.63	7.92
2025	9.64	19.28	24.10	10.40	6.58	9.41	12.24	6.97	6.79	9.71	12.63	8.13
2026	9.69	19.38	24.22	10.47	6.58	9.41	12.24	6.98	6.79	9.71	12.63	8.15
2027	9.74	19.47	24.34	10.54	6.58	9.41	12.24	6.98	6.79	9.71	12.63	8.16
2028	9.78	19.57	24.46	10.60	6.58	9.41	12.24	6.99	6.79	9.71	12.63	8.17
2029	9.83	19.67	24.58	10.67	6.58	9.41	12.24	7.00	6.79	9.71	12.63	8.18
2030	9.88	19.77	24.71	10.74	6.58	9.41	12.24	7.00	6.79	9.71	12.63	8.19

New MPG (2)

	Class 7&8 Type 3				Class 7&8			
Year	Conv. Diesel	Adv. Diesel	Ethanol	New Average	Conv. Diesel	Adv. Dsl	Ethanol	New Average
2000	7.00	7.00	7.00	7.00	6.87	6.87	6.87	6.87
2001	7.00	7.60	7.00	7.00	6.87	7.46	6.87	6.87
2002	7.00	8.20	7.00	7.00	6.87	8.06	6.87	6.87
2003	7.00	8.81	7.00	7.00	6.87	8.65	6.87	6.87
2004	7.00	9.41	7.00	7.00	6.87	9.24	6.87	6.87
2005	7.00	9.94	7.00	7.05	6.87	9.79	6.87	6.91
2006	7.00	10.01	7.49	7.07	6.87	9.83	7.35	6.92
2007	7.00	10.01	7.98	7.09	6.87	9.83	7.84	6.94
2008	7.00	10.01	8.47	7.12	6.87	9.83	8.32	6.96
2009	7.00	10.01	8.96	7.15	6.87	9.83	8.80	6.98
2010	7.00	10.01	9.45	7.20	6.87	9.83	9.28	7.01
2011	7.00	10.01	10.16	7.26	6.87	9.83	9.98	7.06
2012	7.00	10.01	10.88	7.32	6.87	9.83	10.68	7.10
2013	7.00	10.01	11.59	7.40	6.87	9.83	11.38	7.16
2014	7.00	10.01	12.31	7.50	6.87	9.83	12.08	7.24
2015	7.00	10.01	13.02	7.64	6.87	9.83	12.79	7.34
2016	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.34
2017	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.34
2018	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.33
2019	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.33
2020	7.00	10.01	13.02	7.64	6.87	9.83	12.79	7.34
2021	7.00	10.01	13.02	7.81	6.87	9.83	12.79	7.47
2022	7.00	10.01	13.02	8.02	6.87	9.83	12.79	7.64
2023	7.00	10.01	13.02	8.29	6.87	9.83	12.79	7.84
2024	7.00	10.01	13.02	8.55	6.87	9.83	12.79	8.05
2025	7.00	10.01	13.02	8.75	6.87	9.83	12.79	8.23
2026	7.00	10.01	13.02	8.79	6.87	9.83	12.79	8.26
2027	7.00	10.01	13.02	8.81	6.87	9.83	12.79	8.28
2028	7.00	10.01	13.02	8.83	6.87	9.83	12.79	8.29
2029	7.00	10.01	13.02	8.85	6.87	9.83	12.79	8.30
2030	7.00	10.01	13.02	8.86	6.87	9.83	12.79	8.31

Market Penetration

Market Penetration of Advanced Diesels and Alternative Fuels in Heavy Vehicles

	Class 7-8 Type 1		Class 7-8 Type 2		Class 7-8 Type 3		CLASS 7-8 Final		CLASS 3-6 Final	
Year	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced
2000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2002	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2003	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2004	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2005	0.2%	0.0%	1.2%	0.0%	2.4%	0.0%	1.8%	0.0%	0.3%	0.0%
2006	0.3%	0.0%	1.7%	0.0%	3.3%	0.0%	2.4%	0.0%	0.4%	0.0%
2007	0.4%	0.0%	2.3%	0.0%	4.4%	0.0%	3.2%	0.0%	0.5%	0.0%
2008	0.5%	0.0%	3.0%	0.0%	5.6%	0.0%	4.1%	0.0%	0.6%	0.0%
2009	0.7%	0.0%	3.9%	0.0%	7.1%	0.0%	5.2%	0.0%	0.8%	0.0%
2010	0.9%	0.0%	5.1%	0.0%	9.1%	0.0%	6.7%	0.0%	1.0%	0.0%
2011	1.2%	0.0%	6.6%	0.0%	11.8%	0.0%	8.7%	0.0%	1.3%	0.0%
2012	1.6%	0.0%	8.3%	0.0%	14.5%	0.0%	10.8%	0.0%	1.6%	0.0%
2013	2.2%	0.0%	10.7%	0.0%	17.9%	0.0%	13.5%	0.0%	2.0%	0.0%
2014	2.9%	0.0%	13.8%	0.0%	22.4%	0.0%	17.0%	0.0%	2.7%	0.0%
2015	2.6%	0.0%	18.4%	0.0%	27.8%	0.0%	21.2%	0.0%	3.6%	0.0%
2016	4.2%	0.0%	18.1%	0.0%	27.6%	0.0%	21.3%	0.0%	4.0%	0.0%
2017	4.1%	0.0%	18.0%	0.0%	27.5%	0.0%	21.2%	0.0%	4.4%	0.0%
2018	4.1%	0.0%	17.9%	0.0%	27.4%	0.0%	21.1%	0.0%	4.8%	0.0%
2019	4.1%	0.0%	17.9%	0.0%	27.3%	0.0%	21.1%	0.0%	5.6%	0.0%
2020	4.2%	0.0%	18.2%	0.0%	27.7%	0.0%	21.4%	0.0%	6.4%	0.0%
2021	5.6%	0.0%	23.7%	0.0%	34.6%	0.0%	27.0%	0.0%	7.5%	0.0%
2022	7.7%	0.0%	31.3%	0.0%	42.4%	0.0%	33.7%	0.0%	8.9%	0.0%
2023	10.3%	0.0%	38.2%	0.0%	51.7%	0.0%	41.3%	0.0%	10.1%	0.0%
2024	14.0%	0.0%	47.4%	0.0%	60.3%	0.0%	49.1%	0.0%	11.7%	0.0%
2025	18.6%	0.0%	54.7%	0.0%	66.5%	0.0%	55.3%	0.0%	14.6%	0.0%
2026	18.9%	0.0%	55.3%	0.0%	67.8%	0.0%	56.3%	0.0%	14.9%	0.0%
2027	19.2%	0.0%	55.8%	0.0%	68.4%	0.0%	56.8%	0.0%	15.2%	0.0%
2028	19.5%	0.0%	56.1%	0.0%	69.0%	0.0%	57.2%	0.0%	15.4%	0.0%
2029	19.8%	0.0%	56.4%	0.0%	69.5%	0.0%	57.7%	0.0%	15.7%	0.0%
2030	20.1%	0.0%	56.7%	0.0%	69.8%	0.0%	58.0%	0.0%	16.0%	0.0%

LIGHT VEHICLE ATTRIBUTES FOR GPRA 2004 BENEFITS MODELING
By Elyse Steiner, NREL

The vehicle attributes for the car and light truck technologies were based on the Office of FreedomCAR and Vehicle Technologies program goals and discussions with transportation program managers. They represent the best estimates available at the time of the modeling (summer of 2002). These attributes have been documented for the past several years and continue to be refined each year, as necessary. The table below contains the attribute values used for the 2004 GPRA transportation program modeling. The values shown in the table are ratios relative to a conventional ICE of the same type. Attributes include the following:

- Vehicle Price
- Range
- Maintenance Cost
- Luggage Space
- Acceleration
- Top Speed
- Fuel Economy

There were several technology changes made from the previous year. The higher fuel economy (2X) hybrid electric vehicle was defined as a diesel-fueled HEV. Flex fuel (E-85) and electric vehicles were not modeled in the 2004 version. Also, 2b trucks were separated from other light trucks in the model. Several updates were made to the actual values in the table compared to the previous year. Those values can be found in the 2003 GPRA methodology report on the EERE website (http://www.ott.doe.gov/facts/pdfs/appendix2003.pdf). No methodology report for 2004 has been written.

LDV ATTRIBUTES - Ratio to Conventional																							
	SMALL CAR					LARGE CAR					MINIVAN				SUV					CARGO (incl. 2b) TRUCK			
	Market Intro.	--->			Market Mature	Market Intro.	--->			Market Mature	Market Intro.	--->		Market Mature	Market Intro.	--->			Market Mature	Market Intro.	--->		Market Mature
Advanced Diesel	**2004**	**2010**				**2005**	**2010**				**2006**	**2010**			**2004**	**2010**				**2003**	**2008**		
Vehicle Price	1.07	1.07				1.07	1.05				1.08	1.07			1.08	1.07				1.10	1.07		
Range	1.20	1.20				1.20	1.20				1.20	1.20			1.20	1.20				1.20	1.20		
Maintenance Cost	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Acceleration	1.10	1.10				1.10	1.10				1.10	1.10			1.10	1.10				1.10	1.10		
Top Speed	0.85	0.85				0.80	0.80				0.80	0.80			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		
Fuel Economy	1.40	1.40				1.40	1.40				1.40	1.40			1.40	1.40				1.40	1.40		
CNG (dedicated)	**2006**	**2015**				**2007**	**2015**				**2008**	**2015**			**2008**	**2015**				**2007**	**2015**		
Vehicle Price	1.08	1.08				1.04	1.04				1.05	1.05			1.05	1.05				1.10	1.10		
Range	0.66	0.66				0.75	0.75				0.75	0.75			0.75	0.75				0.75	0.75		
Maintenance Cost	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		
Top Speed	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Luggage Space	0.75	0.90				0.85	0.90				0.90	1.00			0.90	1.00				1.00	1.00		
Fuel Economy	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Hybrid (A) - Diesel	**2011**	**2015**	**2025**			**2010**	**2015**	**2025**			**2011**	**2015**	**2025**		**2010**	**2015**	**2025**			**2012**	**2015**	**2025**	
Vehicle Price	1.18	1.12	1.05			1.20	1.15	1.05			1.20	1.15	1.05		1.20	1.15	1.05			1.20	1.15	1.05	
Range	1.00	1.00	1.00			1.00	1.00	1.00			1.00	1.00	1.00		0.90	0.95	0.95			0.90	0.90	0.95	
Maintenance Cost	1.03	1.05	0.98			1.05	1.05	1.00			1.09	1.05	1.00		1.05	1.05	1.00			1.05	1.05	1.00	
Acceleration	0.90	0.90	0.90			1.00	1.00	1.00			0.90	0.90	0.90		0.90	0.90	0.90			1.00	1.00	1.00	
Top Speed	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	
Luggage Space	0.95	0.95	0.95			0.95	0.95	0.95			0.90	0.90	1.00		0.90	0.90	0.90			0.80	0.90	0.90	
Fuel Economy	1.50	1.75	2.00			1.50	1.75	2.00			1.50	1.75	2.00		1.50	1.75	2.00			1.50	1.75	2.00	
Hybrid (B)	**2004**	**2010**	**2015**	**2020**	**2030**	**2004**	**2010**	**2015**	**2020**	**2030**	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**	**2030**	**2006**	**2010**	**2015**	**2020**
Vehicle Price	1.10	1.05	1.03	1.01	1.01	1.10	1.08	1.03	1.01	1.01	1.10	1.08	1.03	1.01	1.10	1.08	1.03	1.01	1.01	1.10	1.08	1.03	1.01
Range	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	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maintenance Cost	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	0.93
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	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	0.75	0.90	0.90	0.90	0.90	0.75	0.90	0.90	0.90	0.80	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	0.85	0.95	0.95	0.95	0.95	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.95	0.95	1.00
Fuel Economy	1.25	1.35	1.45	1.50	1.50	1.25	1.35	1.40	1.50	1.50	1.25	1.35	1.45	1.50	1.25	1.35	1.40	1.50	1.50	1.25	1.35	1.45	1.50
Fuel Cell (hydrogen)	**2018**	**2020**	**2025**	**2030**		**2016**	**2020**	**2025**	**2030**		**2014**	**2020**	**2025**	**2030**	**2012**	**2016**	**2020**	**2025**	**2030**	**2012**	**2020**	**2025**	**2030**
Vehicle Price	1.35	1.30	1.15	1.15		1.40	1.25	1.15	1.15		1.35	1.25	1.15	1.15	1.40	1.35	1.25	1.15	1.15	1.35	1.25	1.15	1.15
Range	0.75	0.75	0.75	0.75		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	0.90
Maintenance Cost	1.05	1.05	0.93	0.90		1.05	1.05	0.93	0.90		1.10	1.10	0.95	0.90	1.05	1.05	1.05	0.93	0.90	1.05	1.05	0.93	0.90
Acceleration	1.10	1.10	1.10	1.10		1.00	1.00	1.00	1.00		1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.00	1.00	1.00	1.00
Top Speed	0.90	0.90	0.90	0.90		0.72	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
Luggage Space	0.90	0.90	0.90	0.90		0.80	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.80	0.80	0.85	0.85
Fuel Economy	2.50	2.70	3.00	3.00		2.20	2.50	3.00	3.00		2.00	2.50	3.00	3.00	2.00	2.30	2.50	3.00	3.00	2.00	2.50	3.00	3.00
Fuel Cell (gasoline)						**2010**	**2020**	**2025**	**2030**		**2010**	**2020**	**2030**		**2010**	**2020**	**2030**						
Vehicle Price						1.40	1.35	1.20			1.35	1.30			1.40	1.35							
Range						1.00	1.00	1.00			1.00	1.00			1.00	1.00							
Maintenance Cost						1.05	1.00	0.93	OUT		1.05	1.00	OUT		1.05	1.00	OUT						
Acceleration						1.00	1.00	1.00	OF		1.00	1.00	OF		1.00	1.00	OF						
Top Speed						1.00	1.00	1.00	MARKET		1.00	1.00	MARKET		1.00	1.00	MARKET						
Luggage Space						0.90	0.90	0.90			0.90	0.90			0.90	0.90							
Fuel Economy						1.50	1.80	2.00			1.40	1.80			1.40	1.80							