PROJECTED BENEFITS OF FEDERAL ENERGY EFFICIENCY AND RENEWABLE ENERGY PROGRAMS (FY 2007-FY 2050)

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PREFACE

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 Research, Development, Demonstration, and Deployment (RD3) technology and market improvements funded by its fiscal year (FY) 2007 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

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

Shortly after GPRA was enacted, EERE initiated a corporate approach to benefits analysis that examined the energy, economic, and environmental impacts of program efforts. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions. Although the benefits analysis has changed since it was initiated 12 years ago, the amount of energy saved or displaced continues to be a key measure of the EERE program impact. Other key metrics include measurement of economic and environmental benefits, as well as increasingly important security and dependency metrics, such as oil and natural gas saved.

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

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[1] See http://www.eere.energy.gov/office_eere/budget.html.
[2] See the Government Performance and Results Act (GPRA) of 1993 at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html and http://www.whitehouse.gov/omb/circulars/a11/02toc.html
[3] Our integrating energy model for calculating midterm benefits (through 2025), NEMS-GPRA07, and our integrating energy model for calculating long-term benefits (through 2050), MARKAL-GPRA07, report different economic measures. NEMS-GPRA07 estimates consumer-expenditure savings, which are the gross savings from avoiding purchased energy. They do not include all incremental investment required to achieve these savings. MARKAL-GPRA07 estimates energy-system cost savings, which includes both the savings from avoiding purchased energy and the incremental investment required for the advanced energy technology. In future GPRA reports, it is intended that both models will report the same economic metric.
[4] Achieving program goals is generally not dependent on a single technical pathway, but instead encompasses a number of alternative approaches, of which some may fall short without jeopardizing realization of the final goal. The pursuit of multiple pathways can increase the likelihood of achieving program goals, thereby reducing the risk of the program. Risk is being addressed in a separate EERE effort to develop a standard approach to risk assessment.

- Programs will be funded at levels consistent with DOE's FY 2007 Budget Request.
- Funding levels will remain constant in inflation-adjusted dollars or increase to accommodate key initiatives in particular cases, as indicated.
- Funding is assumed to be in place until goals are achieved.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model[5] as the foundation for managing its portfolio of efficiency and renewable investments, and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, a logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities. The logic model employed by EERE (**Figure P.1**) provides an integrated approach that explicitly links requested budget levels to performance goals and estimated benefits—and helps ensure that estimated benefits reflect the funding levels requested. The elements of the logic model, which are specified in GPRA, are included in the annual budget request.

Multiyear Program Plans (MYPPs), developed by each of EERE's nine 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 the RD3 effort.[6] Inputs may include cost-shared or leveraged funds, as well as EERE program dollars—and may also include advances by others on which the program builds. Performance milestones capture intermediate points of discernable progress toward outputs and are used by program managers, DOE, OMB, and others to track program progress toward their outputs. Outputs, often referred to as "program goals" or "program performance goals,"[7] are the resulting products or achievements of an overall area of activity. EERE's R&D programs typically specify their outputs in terms of technology advances (e.g., reduced costs, improved efficiency), while deployment programs develop outputs related to their immediate market impacts (e.g., number of homes weatherized). Outputs evolve over time as the program pursues increasing levels of technology performance or market penetration.[8]

This benefits analysis links these program outputs to their market impacts or outcomes. EERE's programs have discernable effects on energy markets, both by reducing the level of energy demand (through efficiency improvements) and by changing the mix of our energy supplies (through increased renewable and distributed energy production). The program goals or outputs

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

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

[7] Some programs derive their outputs through technology-cost simulation models to develop the specific requirements to meet overall program cost and performance goals. Specific details of the representation of the program outputs in NEMS-GPRA07, MARKAL-GPRA07, and the underlying program analysis and documentation are found in Chapters 2 and 3 of this report and Appendices B through J.

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

are therefore often used as input to the integrating energy models. Further, the changed energy mix has environmental and economic implications. EERE incorporates these effects in its *outcomes*—the displacement of conventional energy demand, the avoidance of carbon emissions, and the energy expenditure or net cost savings.

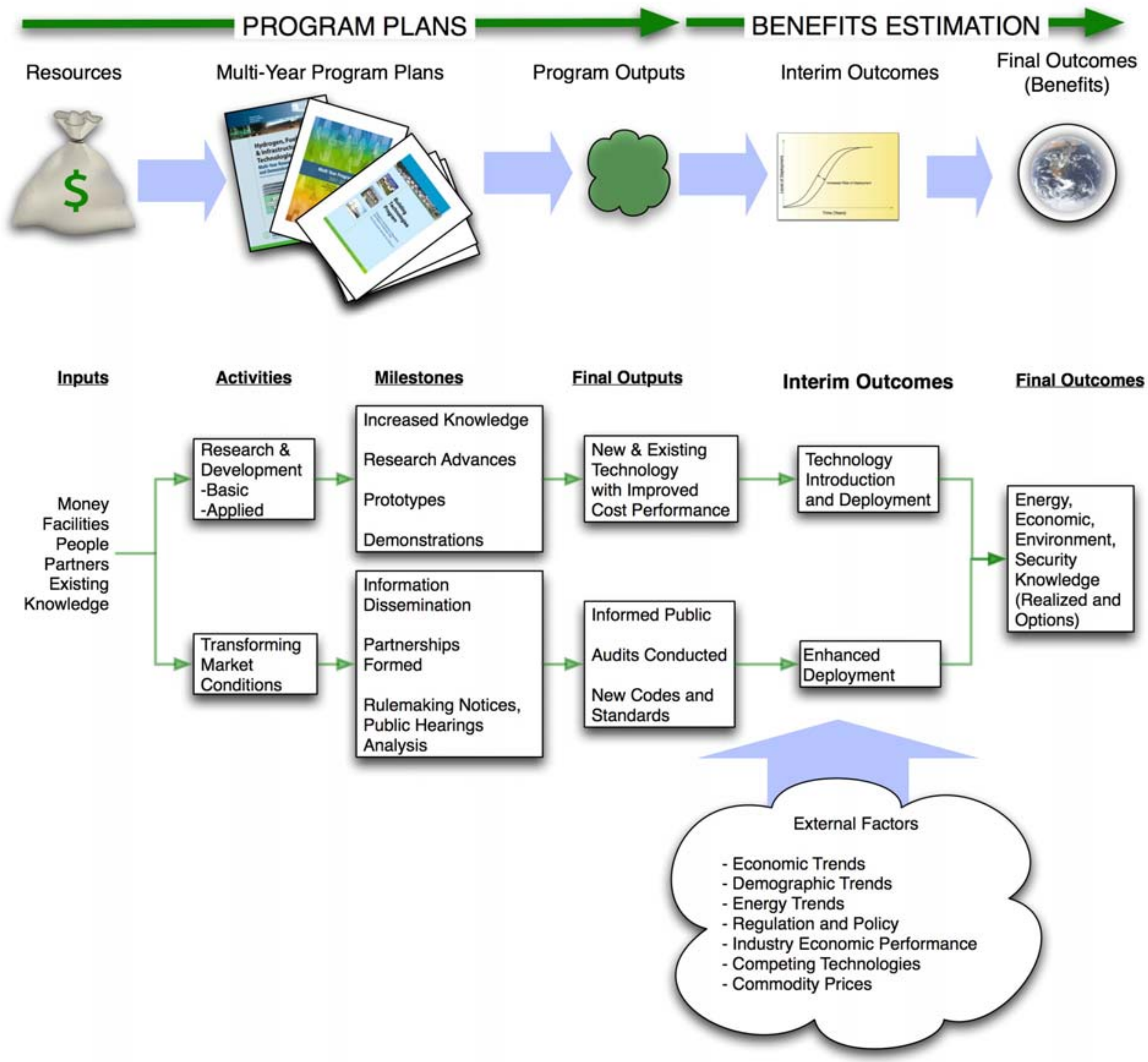

Figure P.1. Generalized EERE Logic Model

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

While the logic model discussed here shows the linkage between resources and benefits for each program, it does not show the full scope of how benefits analysis fits in the overall process of performance management. **Figure P.2** shows a more holistic perspective on the role of benefits analysis in performance management. When used appropriately, benefits analysis serves as an important feedback loop at two levels: 1) individual program planning, and 2) EERE management assessment of its technology development and deployment portfolio. In the first case, this analysis can help individual program managers make better choices about the suite of activities and technology options that will maximize their program's benefits to the Nation. Looking at the benefits available from the entire suite of EERE programs in an integrated portfolio can help decision-makers maximize the overall return on government investment in energy efficiency and renewable energy technologies. Results of benefits analyses represent just one of many important criteria that must be weighed in prioritizing spending across the portfolio.

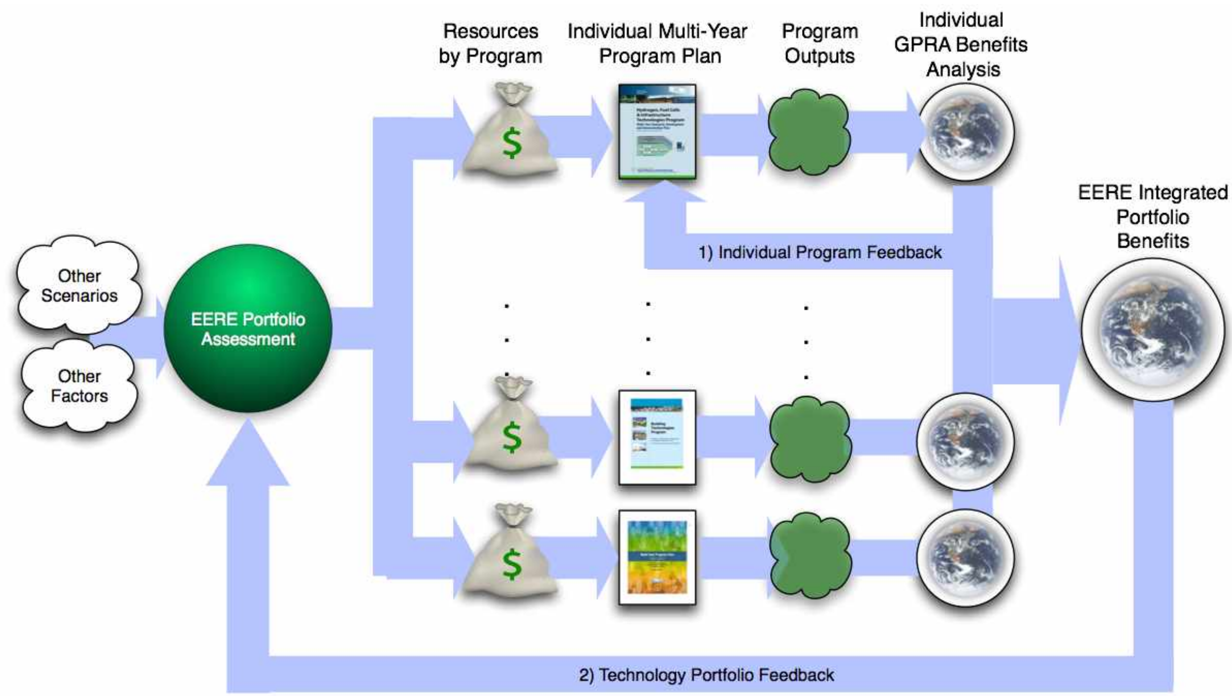

Figure P.2. Holistic View of the Role of Benefits Analysis in EERE Performance Management

Benefits Framework

The EERE Benefits Framework addresses the link between program outputs and their resulting outcomes—and, hence, benefits. EERE uses these R&D outputs to estimate its outcomes (benefits) by comparing the future U.S. energy system and its associated costs and environmental impacts with and without the contributions of its program outputs. The market impacts of each of the nine programs are first assessed separately and then combined to assess the benefits of EERE's overall portfolio.[9] The integrated portfolio benefits are not simply the sum of the individual program benefits, because the portfolio benefits reflect the interaction and interplay among the various programs.

EERE—along with the offices of Fossil Energy (FE), Nuclear Energy (NE), Electricity Delivery

[9] EERE's benefits analysis, which measures final outcomes due to EERE programs and a host of other external factors as shown in Figure P.1, is distinct from impacts analysis, which determines the portion of outcomes having a causal relationship with EERE's actions.

and Energy Reliability (OE), and Science (Sc)—is in the process of adopting a common framework, building on work initially developed by the National Research Council (NRC) to assess the benefits associated with past DOE research efforts.[10] EERE's annual estimates of prospective benefits have been incorporated into an integrated framework addressing the benefits of both existing and future program activities. The framework can be represented by a matrix, in which the rows distinguish among four types of benefits, and the columns represent different elements of time and uncertainty.

This report addresses the three shaded cells of the matrix, reflecting benefits under a business-as-usual energy future (**Figure P.3**). EERE, FE, NE, OE, and Sc currently are developing methods for assessing the value to the country of developing technologies that prepare the Nation for unexpected energy needs. DOE and EERE metrics are still evolving, especially with regard to how knowledge benefits and real options[11] benefits are represented.

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

Figure P.3. FY 2007 Benefits Metrics Reported

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

- **Standard baseline(s) and methodological approaches.** EERE uses the Energy Information Administration's (EIA) *Annual Energy Outlook 2005* (*AEO2005*) Reference Case as a consistent starting point for analysis of all of its programs.[12] A standard set of methodological approaches (guidance) is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE

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

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

[12] See *The Annual Energy Outlook 2005 with Projections to 2025*, February 2005, DOE/EIA-0383 (2005), available at http://www.eia.doe.gov/oiaf/archive/aeo05/index.html. The timing of the release of the *Annual Energy Outlook* reports is such that we are always working with the prior year's outlook. Thus, in 2006, we developed benefits estimates for the proposed FY 2007 budget using AEO2005. In most years, this lag in the availability of the energy forecast poses little problem, because the changes in the energy outlook from year to year are relatively small. This year, however, the recently released AEO2006 reference case shows a dramatic increase in oil and gas prices relative to the AEO2005 forecast. When the new, higher, oil prices of AEO2006 are used next year, benefits estimates for the EERE programs will be substantially different. This year, we have added two new scenarios beyond the reference case to look at the impacts of higher oil prices and of possible constraints on carbon emissions.

program goals (outputs). This guidance is 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 midterm (5-20 years) and long-term (20-50 years) time frames.

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

Benefits Analysis Process

EERE's benefits-analysis process involves three major steps (**Figure P.4**). In **Step 1,** EERE's Office of Planning, Budget, and Analysis (PBA) develops a standard baseline and methodological approach (guidance) to help ensure consistency in estimates across programs. In **Step 2,** EERE's programs develop specific technology and market information, which is necessary to understanding the potential roles of each program in its target markets. In **Step 3**, PBA uses this program and market information to assess the impacts of each EERE program (as well as the overall EERE portfolio) on energy markets in the United States using integrated energy-economic models.

The process by which the FY04 benefits estimates were developed largely reflects EERE's prior organization, although a few changes in net benefits estimation were adopted in the FY04 analysis, including an initial reflection of the benefits framework recommendations of the National Academy of Sciences (NAS).

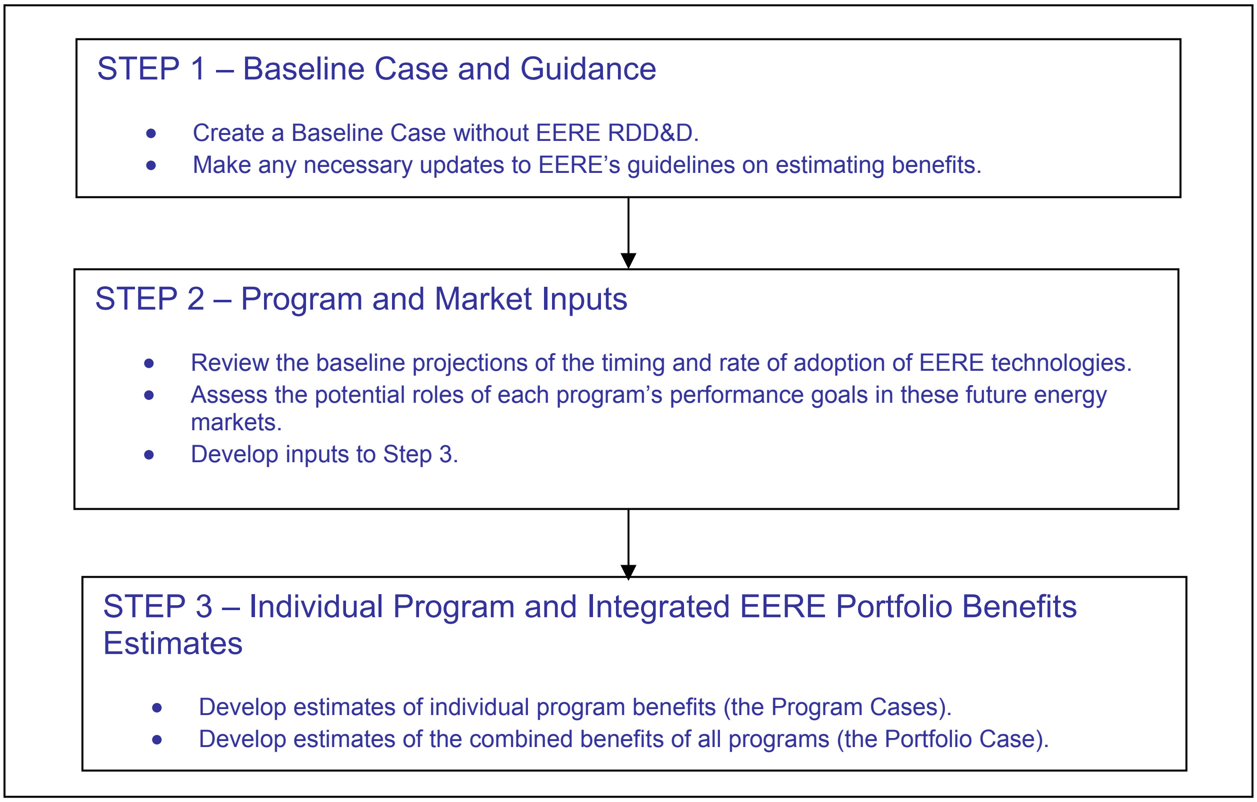

Figure P.4. EERE Program and Portfolio Benefits-Analysis Process

Step 1: Baseline Case

Baseline Case

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

The most recent[13] *Annual Energy Outlook* Reference Case is used as the starting point for developing the Baseline Case. The Energy Information Administration (EIA) *Annual Energy Outlook* (*AEO*) Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy (e.g., to reflect the availability of new appliances), technology improvements that might improve the efficiency of energy use, and changes in energy resource production costs, including renewable energy. Current energy market policies, such as state renewable portfolio standards (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. Neither the EIA Reference Case nor the EERE Baseline Case includes any changes in future energy policies.[14]

In establishing its Baseline Case, EERE makes a number of modifications to the *AEO2005* Reference Case (see **Table P.1**)[15]. Modifications are made to the same model—the National Energy Modeling System (NEMS)—used by EIA in developing the *AEO2005*. To distinguish it from EIA's version, the model is referred to as NEMS-GPRA07. The *AEO2005* Reference Case is also the starting point for the long-term (to 2050) benefits modeling using MARKAL-GPRA07. The Baseline Cases for both NEMS-GPRA07 and MARKAL-GPRA07 are aligned as closely as possible, but the two models are different in their internal design.[16]

[13] Benefits analysis for the proposed FY 2007 budget began in January 2006. The most recent outlook available at the time was *AEO2005.* Final benefits estimates are submitted to OMB as part of the FY 2007 Budget Request in January 2007, before the new AEO2006 reference case was available. See *Annual Energy Outlook 2005* with projections to 2025, February 2005, DOE/EIA-0383 (2005) for Reference Case projections. Available at http://www.eia.doe.gov/oiaf/archive/aeo04/pdf/0383(2004).pdf.

[14] At the publication date of the *AEO2005*, the Energy Policy Act of 2005 (as well as the extension of the production tax credit) had not yet been affected. Because our GPRA benefits analysis is built off of *AEO2005*, our estimates are not reflective of these policies. While other changes are made to AEO's baseline case, a change of this magnitude was not within the scope of our analysis, given the available time.

[15] More detail on baseline construction may be found in Appendix A.

[16] See Box 2.1 in Chapter 2 for an overview of NEMS and Box 3.1 in Chapter 3 for an overview of MARKAL.

Table P.1. Summary of Baseline Changes from the AEO2005

	AEO2005	GPRA07 Baseline Case
Removal of EERE Programs		
Million Solar Roofs	0.3 GW installed 2007 to 2025	Removed
Photovoltaic system costs	Significant improvement	Slower rate of improvement
Residential high efficiency shell packages	Small penetration	Removed
Cellulosic ethanol production	Commercially available by 2015	Not commercially available by 2025
Greater Technology Improvement in Base		
Solid-state lighting	Very small improvement	Much greater improvement
Onshore wind performance	33% to 44% capacity factors, depending on wind class and year	35% to 53% capacity factors, depending on wind class and year
Onshore wind capital costs	1% reduction over 20 years	12% to 15% reduction (depending on wind class) over 20 years
Conventional corn ethanol production	Yield of 2.65 gallons per bushel	Yield of 2.80 gallons per bushel
Corn ethanol production with residual starch	Not included	Available in 2011
Hybrid Electric Vehicles	Sales share at 6% by 2025	Sales share at 11% by 2025
Energy Market Updates		
PV system size	2 kW residential, 25 kW commercial	4 kW residential, 100 kW commercial
PV maximum market share	30% for both residential and commercial	60% for residential and 55% for commercial
California PV subsidy	Not included	Included for residential systems
Solar water heat	Maximum 20% replacement market	New and up to 50% replacement market
Corn ethanol maximum production	5.7 billion gallons	10.0 billion gallons
Structural Changes		
Offshore wind	No offshore wind technology	Offshore wind
Commercial shell efficiency	Index	Technology representation
Commercial DG algorithms		Market share and stock accounting modified

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, depending on the form in which programs specify their output or performance goals and how NEMS-GPRA07 and MARKAL-GPRA07 utilize this information. It ranges from the compilation of technology goals to detailed market analyses that produce technology-penetration rates—and, in some cases, delivered energy savings.

NEMS-GPRA07 and MARKAL-GPRA07 contain detailed technology representations of electricity markets, most residential and commercial end uses, and vehicle choice—but use trends to represent industrial efficiency improvements and existing residential shell retrofits. For programs that address these markets, this step simply requires (1) confirming the adequacy of the target-market representation in the Baseline Case and (2) providing the program goals in a format consistent with the model. Any updated market-characteristic information is used to adjust NEMS-GPRA07 and MARKAL-GPRA07 for both the Baseline Case and the Program Case to avoid ascribing external factors as benefits. Analysts use the program goal information to adjust the commercialization date, technology characteristics, or market-penetration rate for the Program Case. The comparison of market technology introduction and market-penetration rates, with and without the program goal—and the calculation of the energy displaced—occur within NEMS-GPRA07 and MARKAL-GPRA07.

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 for assessing technology or market features that cannot be adequately represented in a broad energy-economic model, or to translate program goals into the variables used in the modeling. In general, analysts perform the most detailed off-line analyses for the Industrial Technologies Program , Weatherization and Intergovernmental Program (WIP), Federal Energy Management Program (FEMP), and portions of the Building Technologies Program. Analysts tailor these off-line analytical approaches to the characteristics of the program and target market being analyzed; but, in all cases, they are conducted within the overall guidance provided through the GPRA benefits-estimation process.

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

Where NEMS-GPRA07 and MARKAL-GPRA07 do not include technology-by-technology information (e.g., cost, date of availability), or specific market-penetration rates, it is often necessary to translate program goals into the more general rates of technology improvement used by the models. This is true for the Industrial Technologies Program and some elements of the

Building Technologies Program, where numerous specific technology advances or market-deployment efforts will accelerate overall efficiency improvements in buildings or factories specified in the Baseline Case.

Off-line analysis also can be required for targeted submarkets that are simply not included in NEMS-GPRA07 or MARKAL-GPRA07—or for which the resulting technology use is not fully market-driven. Examples include the Federal sector (addressed by FEMP) and the Low-Income Weatherization Assistance Program, in which the Federal Government directly purchases home efficiency improvements.

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

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

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

Market Penetration. Over time, new technologies typically make their way into markets—and, therefore, affect energy use—gaining their share of new sales as consumers learn about the availability of the product. Manufacturing capacity then grows, and product prices fall with economies of scale and learning.[17] 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 (a niche market) before they are generally cost-effective. Price, or cost-effectiveness, is often not the only aspect of the new technology or deployment program that shapes its rate of market uptake. Many non-price or cost factors affect consumer behavior.

[17] 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).

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

Through the use of specialized spreadsheets or other models,[18] program analysts produce estimates of market penetration and direct energy savings associated with these market sales. However, these "off-line" estimates of direct energy savings are not benefits estimates, because they do not account for market interactions. Analysts integrate these off-line estimates within the NEMS-GPRA07 and MARKAL-GPRA07 models as the final part (**Step 3**) of the process.

Step 3: Individual Program and Integrated EERE Portfolio Benefits Estimates

The final step for estimating the impacts of EERE's FY 2007 Budget Request is to analyze all of EERE's programs in a consistent economic framework and to account for the interactive effects among the various programs. Estimates of individual EERE program energy savings cannot be simply summed to create a value for all of EERE, because there are feedback and interactive effects resulting from (1) changes in energy prices resulting from lower energy consumption and (2) the interaction among programs affecting the mix of generation sources and those affecting the demand for electricity.

The process begins by modeling each EERE program individually within NEMS-GPRA07 and MARKAL-GPRA07. In each NEMS-GPRA07 and MARKAL-GPRA07 Program Case, only the modeling assumptions related to the outputs of the program being analyzed are changed. The modeling assumptions related to the other EERE programs remain as they were in the EERE Baseline Case. Analysts model each program separately to derive estimated energy savings without the interaction of the other programs. They then compare the results from the NEMS-GPRA07 and MARKAL-GPRA07 Program Cases to the Baseline Case to measure the individual benefits of the EERE program being analyzed. This process, while explicitly ignoring the potential market interactions of one EERE technology or program with all others, does provide a useful data point. Specifically, the Program Case represents neither the technical potential of a program (absent all market interactions) nor the full economic potential (with all market interactions), but somewhere in between those two points. It is admittedly unrealistic to assume that one program would meet its goals while all other programs fail to meet theirs. Nevertheless, the "Program Cases" allow the programs, analysts, and readers to examine the total potential benefits of each technology suite alone.

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

For programs modeled using NEMS-GPRA07 and MARKAL-GPRA07 directly, analysts compute the Individual Program Goal Case by changing the assumptions representing the program outputs; i.e. the goals or performance targets of the program, such as reducing low wind-speed turbine costs and improving their performance. The R&D programs are represented in NEMS-GPRA07 and MARKAL-GPRA07 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 are modeled through changes in consumer hurdle rates or other appropriate market-penetration parameters, with the goal of representing the market share targeted by the program.

In cases where program goals cannot be easily modeled using NEMS-GPRA07 and MARKAL-GPRA07, analysts estimate benefits using a variety of off-line tools, as described in **Step 2**. These supporting analyses typically provide either estimates of market penetration and per-unit energy savings, or total site energy savings, which are then used as inputs to NEMS-GPRA07 and MARKAL-GPRA07. In cases where the off-line analyses produce a direct estimate of site energy savings, analysts adjust this information by an "integration factor" and incorporate it in NEMS-GPRA07 and MARKAL-GPRA07, in order to calculate primary energy savings. The amount of the integration factor is based on how much program overlap or "integration" was captured by the off-line tools. The revision is based on the expert judgment of the benefits analysis team. See **Chapters 2 and 3** for discussion of program-by-program benefit estimates, including such reductions.

Once each of the programs (or group of programs) is represented individually within NEMS-GPRA07 and MARKAL-GPRA07, the benefits of EERE's portfolio are estimated by combining all of the program goals into one EERE Portfolio Case. The portfolio case is not equal to the sum of the individual program cases, because the former accounts for various market interactions. Some of EERE's technologies and programs complement each other; others are competitive substitutes. The program cases do not capture the complementarity and substitutability inherent in the portfolio case. Detailed projections from the EERE Baseline and Portfolio Benefits Case are presented in **Chapters 1, 2 and 3.**

Scenario Analysis

In prior years, benefits estimates were reported for a single future energy scenario. Because of the uncertainties of energy and economic projections, this view of our energy future has limited value, especially in assessing the benefits of the full suite of technologies in the EERE portfolio. Assessing only one possible future may be particularly misleading for programs in which a significant part of the worth of the program may lie as a hedge against less likely, but possible, futures. Evaluating EERE's portfolio for a variety of possible futures offers insight about the robustness[19] of the portfolio.

[19] One measure of a portfolio's "robustness" is the degree to which its composite parts become more or less important under a given future. In other words, the portfolio as a whole may be said to be robust, if it is resilient against a range of futures, even if the individual parts (or programs, in our case) may play differing roles. Note that portfolio robustness may be measured in a variety of ways, including how much redundancy there is in the portfolio – if contingency planning is valued; the degree to which the portfolio is subject to various risks; the expected performance of the portfolio alignment versus other possible alignments, etc.

This year, we have taken the first step toward introducing scenario analysis for the EERE portfolio. Two scenarios were evaluated: 1) a high oil-price case, and 2) a carbon-constrained future. Because this is EERE's first foray into scenario analysis for GPRA benefits, we report the results as an appendix to this report (see **Appendix K**). Given the recent and sustained increases in crude oil and natural gas prices, the high fuels-price case is particularly relevant in understanding the value of EERE's portfolio in what is likely to be the base case in future years. Similarly, understanding the impact of these programs under different carbon emissions scenarios is an increasingly important topic. We will evaluate our methodology for scenario analysis this year; and we expect that scenario analysis will be a part of the main benefits report for the FY 2008 budget request.

Future GPRA Benefits Development

As part of DOE's continuing efforts to implement the President's Management Agenda—and to be responsive to the advice offered by the National Academy of Sciences/National Research Council—DOE is in the process of integrating its GPRA benefits analyses across the offices of Energy, Science, and Environment (ESE). This integration process is expected to be fully completed for the FY 2010 budget request, but significant and important steps and progress will be evident along the way. The GPRA benefits analysis for the FY08 budget request will show a DOE-wide portfolio case, in which all offices' RD3 programs are combined. Further, EERE technologies' benefits will be evaluated relative to an ESE-wide baseline (as opposed to a baseline in which only EERE advanced technologies are removed from the AEO reference). Moreover, the inputs to the integrating models will be developed using common methodologies across all ESE offices. The result will be a much clearer picture of the benefits of the full DOE portfolio than has been represented to date.

Another major development afoot in DOE's benefits analysis is the treatment of risk and uncertainty. As in prior years, the benefits in this report are shown for Programs and the Portfolio assuming that RD3 goals are achieved and that they are achieved on time. It is also assumed that RD3 funding is continued as required. These assumptions represent a considerable simplification in a number of ways. First, for R&D there is considerable technical risk in what the actual output of the program activities might be. In fact, the output in a given year could be greater or less than the specified goal, or alternatively a specified goal may be achieved earlier or later than scheduled. Moreover, for a given output, the outcome is not known with certainty, because it will be affected by market risk considerations.

EERE and DOE, in coordination with NRC, are in the process of integrating the treatment of risk into the benefit process as part of a multiyear activity. This work will include the explicit treatment of technical risk and improved treatment market risk to lead to better estimates of both program outputs and outcomes. These refinements will also address the potential use of discount rates.

Report Organization

In addition to the Executive Summary and this Preface, this report contains three chapters. **Chapter 1** presents the overall results of the benefits and savings estimates from both the individual programs and the overall EERE portfolio. **Chapter 2** describes, in detail, the estimated midterm benefits (to 2025) of each program area using NEMS-GPRA07. **Chapter 3** describes, in detail, the estimated long-term benefits (to 2050) of each program area using MARKAL-GPRA07.

Eleven appendices are included. **Appendix A** provides the Baseline Cases and their implementation in NEMS-GPRA07 and MARKAL-GPRA07. **Appendices B through J** provide program-analysis team inputs for EERE's programs. **Appendix K** describes the results of new scenario analyses conducted this year to look at the effect of high fuel prices and a carbon constraint.