CHAPTER 1 – ESTIMATING PROSPECTIVE BENEFITS OF EERE'S PORTFOLIO

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The Office of Energy Efficiency and Renewable Energy (EERE) estimates expected benefits for its overall portfolio and for each of its nine Research, Development, Demonstration, and Deployment (RD3) programs. Benefits for the FY 2008 budget request[1] are estimated for the midterm (2008-2030) and long term (2030-2050). Two separate models suited to these periods are employed—NEMS-GPRA08 for the midterm and MARKAL-GPRA08 for the long term. [The first is a modified version of the National Energy Modeling System (NEMS) for the Government Performance and Results Act (GPRA); and the second is a modified version of the MARKet ALlocation (MARKAL) model for GPRA.] Estimated benefits reflect the value of program activities from 2008 forward. They do not include the impacts of past program success, nor technology development or deployment efforts outside EERE's programs.

Focusing on Fundamental Benefits to the Nation

The direct outcome of EERE's energy efficiency improvements and renewable energy technology developments is a reduction in the use of traditional energy resources such as coal, oil, and natural gas. For this reason, EERE has, in the past, relied on projections of nonrenewable energy displacement as a key indicator of both RD3 progress and value to the Nation. While reducing the use of nonrenewable energy may result in benefits to the Nation, it is not an intrinsically valuable benefit. For example, reducing coal use can reduce greenhouse gas emissions from the burning of coal for heat and power—something of potential value to the Nation. But it is not the only means of reducing greenhouse gas emissions from coal. Clean coal technology can both improve the efficiency of converting coal to energy and reduce greenhouse gas emissions via carbon sequestration.

This distinction became very clear when EERE joined the broader effort this year among all of the DOE offices of Energy, Science, and Environment (ESE) to understand the value of DOE's entire RD3 energy portfolio. ESE's RD3 portfolio includes projects within the Office of Fossil Energy (FE), Nuclear Energy (NE), Electricity Delivery and Energy Reliability (OE), and Science (Sc). A more rigorous valuation of the programs involves—an ESE-wide working group has concluded—metrics that reflect intrinsic or fundamental benefits to the Nation. As a result, this year's assessment of the EERE portfolio is based on a new set of metrics.

The choice of metrics has been influenced not only by the collaborative effort within ESE, but also by collaborative efforts with the National Research Council (NRC) during the past few years.

> "DOE funding of energy R&D is not," the NRC concluded in a 2001 analysis of the value of DOE's energy efficiency and fossil energy research programs, "necessarily associated with the most obviously attractive advances. Rather, as basic economic principles suggest, DOE research should also, and even mostly, be associated with public policy objectives."[2]

In that 2001 study, the NRC proposed a matrix for evaluating the benefits of DOE's research, as shown in **Figure 1.1**. The public good identified by NRC fell into the three categories of economic, environmental, and security benefits. The emphasis of the NRC assessment was retrospective in nature. NRC focused on three areas of public good from DOE research, which were purposely aligned with the strategic goals of the DOE. Within the context of the three classes of public good they saw from DOE energy research, NRC identified benefits associated with DOE outcomes that ranged from technology "ready to go" to technology that was very high risk or that had even "failed."

[1]EERE budget-request materials may be accessed at http://www1.eere.energy.gov/ba/pba/budget_formulation.html
[2]Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, National Research Council. *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000.* ISBN: 0-309-07448-7 (2001). Free PDF available at http://www.nap.edu/catalog/10165.html

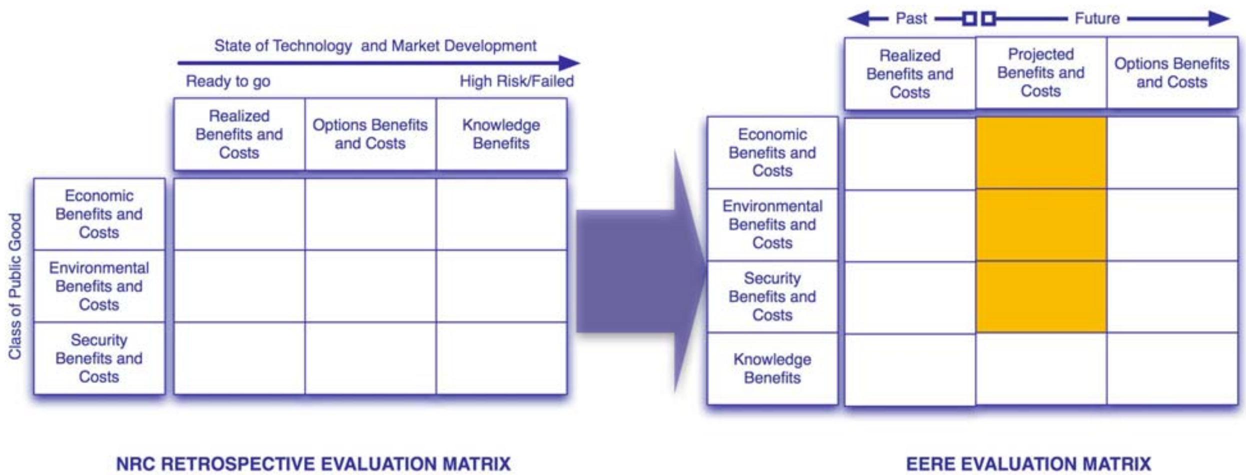

Figure 1.1. Evolution of an Evaluation Matrix – DOE RD3 Programs

Technologies from DOE programs that were fully developed in markets that were ready to accept them had "realized" benefits and costs. Technologies that were still in the development stage offered "options benefits." Technologies that remained very high risk or had experienced market failure were seen as still offering "knowledge benefits."

In 2003, DOE's ESE offices brought together experts to discuss how to extend the NRC framework to the kind of prospective benefits analysis reported here.[3] DOE's RD3 activities fit into all three categories of public good and all three categories of risk reflected in the NRC's original retrospective framework. The modified evaluation matrix that came out of the 2003 discussions is also shown in **Figure 1.1.** Note that knowledge benefits in this scheme are now a class of public good (i.e., a row in the matrix rather than a column). This is a logical extension of the NRC's original view that knowledge benefits exist regardless of the commercial failure or success of the technology being developed. EERE is working with DOE's Office of Science and other offices within ESE to develop indicators that reflect the value of "knowledge."

The matrix elements highlighted in yellow represent benefits categories for which EERE has adopted specific indicators. This year (as in prior years), EERE's prospective benefits are—effectively—built on an assumption of 100% probability of success, falling under the category of "projected benefits"—perhaps better described as "projected realized benefits." As part of the FY 2009 budget process, EERE will expand the projections to reflect differences in relative risk among the RD3 activities, allowing for estimation of "options" benefits for technologies that face some risk of failure.

DOE has recently revised its strategic plan.[4] The new plan is organized along five themes, two of which are particularly relevant to understanding the value of EERE's results. **Box 1.1** shows the themes and goals that are relevant to benefits analysis for RD3 programs.

[3] Lee, R. et al. *Estimating the Benefits of Government-Sponsored Energy R&D: Synthesis of Conference Discussions.* Oak Ridge National Laboratory, Oak Ridge, Tennessee (2003)
[4] U.S. DOE Office of the Chief Financial Officer. *U.S. Department of Energy Strategic Plan 2006.* DOE/CF-0010, Washington, D.C. (2006). Available at www.energy.gov.

Box 1.1. DOE's Strategic Goals

Theme 1: Energy Security—Promoting America's energy security through reliable, clean, and affordable energy.

Goal 1.1 Energy Diversity: ***Increase our energy options and reduce dependence on unstable foreign fuel supplies****, thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs.*

Goal 1.2 Environmental Impacts of Energy: ***Reduce greenhouse gas emissions*** *and* ***other environmental impacts*** *(water use, land use, criteria pollutants) from our energy production and use.*

Goal 1.3 Energy Infrastructure: Create a more ***flexible, secure, reliable, and higher capacity*** *U.S. energy infrastructure by improving energy services throughout the economy,* ***enabling use of diverse sources, and improving robustness against, as well as recovery from, disruptions****.*

Goal 1.4 Energy Use: ***Cost effectively*** *improve the* ***energy efficiency of the U.S. economy***

Theme 3: Scientific Discovery and Innovation—Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology.

Goal 3.1 Scientific Discovery: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Goal 3.2 Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

Goal 3.3 Research Integration: Integrate basic and applied research to accelerate innovation and to create transformational solutions for U.S. energy needs.

Economic Benefits

The economic metrics used in this report are summarized in **Table 1.1**. These metrics are aligned with the modified NRC categories described in **Figure 1.1** as well as with DOE's recently revised strategic goals described in **Box 1.1.** In its deliberation on how to assess the economic benefits of DOE's RD3 programs, the NRC strongly recommended the adoption of "consumer and producer surplus" as a rigorous measure of net benefit to the economy. The energy system cost as measured in MARKAL-GPRA08 (see metric No. 2 in **Table 1.1**) can be used as an approximate measure of the change in consumer and producer surplus. In NEMS-GPRA08, there is currently no simple way to measure energy system cost or consumer and producer surplus.

While consumer and producer surplus may represent a more comprehensive method of measuring economic benefit, it is a metric that is both difficult to quantify and difficult for many people to understand. For that reason, this year's benefits analysis includes a variety of different metrics or indicators that shed light on different elements of the economic impacts of EERE's RD3 activities—

including impacts on natural gas prices (a particularly acute issue in the past few years), consumer and household spending on energy, electric-sector costs, and energy intensity of the economy. Detailed descriptions of these metrics are provided in **Table 1.1**. Where net present values are computed, a 3% discount rate is used following NRC guidance as well as guidance from the White House Office of Management and Budget (OMB).

Environmental Metrics

The environmental metrics used in this report are summarized in **Table 1.2**. These metrics are aligned with the modified NRC categories described in **Figure 1.1**, as well as with DOE's recently revised strategic goals. Defining environmental metrics for EERE's RD3 programs is difficult. In the past, the only environmental metric that has been tracked is reductions in greenhouse gas emissions—because it is both measurable and directly attributable to energy impacts. The problem of attribution for other regulated emissions is that EERE's programs cannot take credit for emission reductions that are required by policies or regulations that exist independent of the emissions savings of the technologies being developed by EERE.

This year, a new metric has been introduced that estimates the reduced cost of meeting existing and known future regulations for air emissions. The concept is that, given a level of reduction or control mandated by policy, EERE's technologies that lead to lower generation rates of regulated air pollutants will lower costs for air pollution control. This savings is measured as reduction in emissions of NO_x and $SO_{x,}$ times the value of the allowance permit for these pollutants. In future years, we anticipate developing metrics that more comprehensively address the broad range of air-, water-, and land-related environmental impacts related to energy production and use.

Energy Security Metrics

The energy security metrics used in this report are summarized in **Table 1.3**. These metrics are aligned with the modified NRC categories described in **Figure 1.1,** as well as with DOE's recently revised strategic goals. Defining energy security metrics for EERE's RD3 programs is even more difficult than for economic or environmental benefits. The obvious focus for energy security is the Nation's dependence on oil and the increasing levels of foreign imports. Thus, four out of the five metrics reported here are oil-related—including year-to-year and cumulative estimates of avoided foreign oil imports and oil intensity of the economy.

Because U.S. transportation demand for energy is almost exclusively reliant on petroleum, two of the energy security metrics are specific to transportation. One is a twist on the commonly recognized measure of fuel economy reported by the Environmental Protection Agency (EPA) in miles per gallon. This new metric is referred to as a "security fuel economy" measured as miles per gallon of crude oil consumed. The details of how this metric is calculated are in **Table 1.3**.

The second transportation-related metric—the transportation fuel diversity index—requires a little more explanation. As DOE goals 1.1 and 1.3 suggest (see **Box 1.1**), diversifying the Nation's sources of energy is seen as an important strategy for improving the reliability of energy supply. Diversification is a common-sense notion applied by many individuals as a means of reducing risk and vulnerability in financial investment decisions and in many other situations. Diversity indices have been used to measure the "health" of market, ecosystems, and other systems.

Table 1.1. EERE Metrics for the NRC Category of Economic Benefits

DOE Theme Key Word:	"Affordable"
Relevant DOE Goal	Goal 1.4 Energy Use
DOE Key Phrases	"Cost Effective," "Energy Efficiency of the U.S. Economy"

1. **Reduction in Average Delivered Natural Gas Price (Percent).** The percent change in the average natural gas prices measured in constant 2004 dollars. Average natural gas price in NEMS mid-term benefits projections is a rolling three-year average. Average natural gas price in MARKAL long-term benefits projections is the value reported for each five-year increment.
2. **Energy System Cost Savings, Annual Billion $2004**. Energy system costs include the annualized capital costs for all capital stock (residual and new), as well as O&M and fuel costs. Annualized capital costs are calculated using MARKAL hurdle rates, which include both a financial and behavioral components.
3. **Consumer Savings, Annual Billion $2004.** Total energy expenditures for all consumers (residential, commercial, industry, and transportation energy prices times energy quantities, same as reported in the *Annual Energy Outlook* (*AEO2006*[5]) plus consumer capital expenditures (post-processor computed for selected end-use energy-using equipment investments expressed in annuities calculated using a 3% discount rate and the average lifetime of the equipment).
4. **Consumer Savings, NPV, Billion $2004**. Net present value (NPV) of annual net consumer expenditures beginning in year 2008, discounted at 3%.
5. **Electric Power Industry Savings, Annual Billion $2004**. Total annual expenses and capital payments (fuel, O&M, and capital for retrofits, new generation capacity, and transmission upgrades). Capital costs are levelized using a 3% discount rate over 30 years. Currently, distribution costs and existing transmission costs are not included. In addition, only the power industry costs are included, not distributed generation installed by consumers.
6. **Electric Power Industry Savings, NPV Billion $2004**. Net present value of electric power industry costs beginning in year 2008, discounted at 3%.
7. **Reduction in Fraction of Household Income Spent on Energy**. Fraction of household income spent is defined as residential fuel bill expenditures, plus light-duty vehicle (LDV) fuel bill expenditures, plus capital investments for residential end uses and LDVs divided by real disposable personal income.
8. **Reduced Energy Intensity of Economy (Percent)**. Primary energy is computed with renewable generation counted as 3,412 Btu/kWh except for biomass or other energy sources where Btus are consumed. This is computed as the sum of 1) all primary nonrenewable energy consumption, plus 2) non-biomass generation times 3,412, plus biomass, plus 3) other nonelectric renewable fuels divided by the chain-weighted $2000 value for gross domestic product (GDP), as reported in the *AEO2006*).

[5] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006: With Projections to 2030.* Washington, D.C. February 2007. See http://www.eia.doe.gov/oiaf/aeo/index.html

Table 1.2. EERE Metrics for the NRC Category of Environmental Benefits

DOE Theme Key Word	"Clean"
Relevant DOE Goal	Goal 1.2 Environmental Impacts of Energy
DOE Key Phrases	"Reduce greenhouse gas emissions and other environmental impacts"

1. **Avoided Greenhouse Gas Emissions, Annual (MMTCE/year).** Total million metric tons of carbon equivalent per year from all energy sectors (same as reported in the *AEO2006*, but as carbon instead of carbon dioxide).
2. **Avoided Greenhouse Gas Emissions, Cumulative (MMTCE).** Total cumulative carbon emissions beginning in 2008, in million metric tons of carbon equivalent.
3. **Reduced Cost of Criteria Pollutant Control, NPV (bil $2004).** Net present value in 2008 of allowance permits for NO_x, SO_x, and mercury in billions of $2004, discounted at 3%.

Table 1.3. EERE Metrics for the NRC Category of Security Benefits

DOE Theme Key Word	"Reliable"
Relevant DOE Goals	Goal 1.1 Energy Diversity Goal 1.3 Energy Infrastructure
DOE Key Phrases	"Flexibility," "Reduced Foreign Oil"

1. **Avoided Oil Imports, Annual (mbpd).** Net crude oil imports and petroleum product savings each year, measured in millions of barrels per day.
2. **Avoided Oil imports, Cumulative (bil barrels).** Cumulative oil import savings beginning in 2008.
3. **Security Fuel Economy Improvement (MPG of Crude Oil).** Light-duty vehicle miles traveled divided by light-duty vehicle oil (gasoline, diesel, and LPG) consumption converted to gallons.
4. **Transportation Fuel Diversity Improvement (percent).** Percent change in the Shannon-Wiener diversity index for the transportation sector, calculated based on estimates of the *pro rata* share of primary energy sources contributing to U.S. energy supply. (See detailed discussion in the text of this chapter).[6]
5. **Oil Intensity Reduction (percent)**. Measured as percent change in annual oil consumption per GDP. Oil intensity is billion barrels of oil consumed per dollar of annual GDP.

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[6] In ecology, a diversity index is a statistic that measures the biodiversity of an ecosystem. The Shannon index (also called the Shannon–Wiener index), H', is one of several diversity indices used to measure biodiversity. It is estimated as follows:

$$H' = \sum_{i=1}^{S} p_i \ln p_i$$

where p_i is the fraction of each proportion of individuals in a given species "*i*" relative to the total population, and S is the total number of species. This index takes into account both the number of species and the "evenness" of distribution of the species. In fact, H' always has a maximum value when all species are present in equal numbers. When few species exist or when a small number of species dominate, the value of H' is lower. We apply this index to transportation energy diversity by substituting types of primary energy sources for species.

Meeting Congressional and Presidential Demand for Accountability

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.[7] The analyses reported here support these GPRA requirements by providing a quantitative assessment of the benefits that may accrue to the Nation if the performance goals of EERE's programs are realized.

The analysis summarized in this report also supports the President's Management Agenda by linking funding and performance goals to real benefits to the Nation. EERE's programs develop these goals based on the following key assumptions:[8]

- Programs will be funded at levels consistent with DOE's FY 2008 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[9] 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 the relationship between budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities. The logic model employed by EERE (**Figure 1.2**) 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, identify available *inputs*, the *activities* that will be undertaken with their budget, the performance *milestones* they expect to achieve as they pursue these activities, and the resulting products or *outputs* of the RD3 effort.[10] 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, the White House OMB, and others to track program progress toward their outputs. Outputs, often referred to as "program goals" or "program performance goals,"[11] are the resulting products or achievements of an overall area of

[7] 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

[8] 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.

[9] The logic model is a fundamental program planning-and-evaluation tool. For more 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.

[10] Appendices B through J provide more information on each program's multiyear program plan and the inputs, activities, milestones, and outputs that are included.

[11] 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-GPRA08, MARKAL-GPRA08, and the underlying program analysis and documentation are found in Chapters 2 and 3 of this report and Appendices B through J.

activity. EERE's RD3 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.[12]

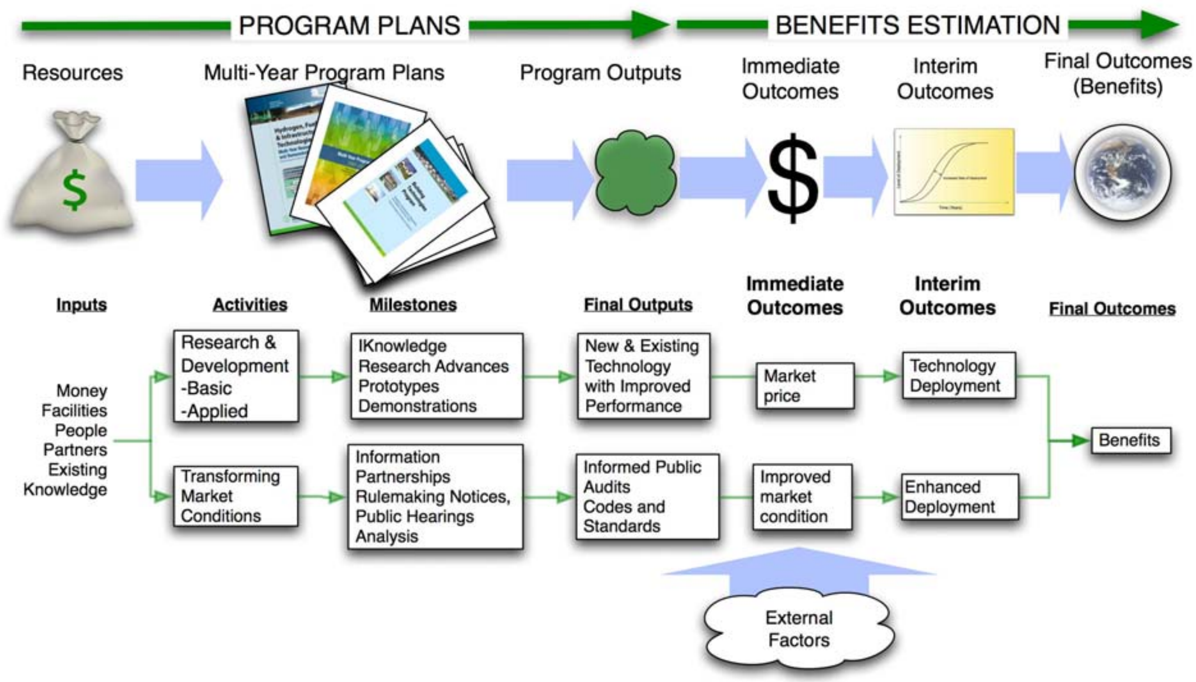

Figure 1.2. Generalized EERE Logic Model

This benefits analysis links these program outputs to their market impacts or outcomes using integrated energy market models. 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).

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 1.3** 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

[12] 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.

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.

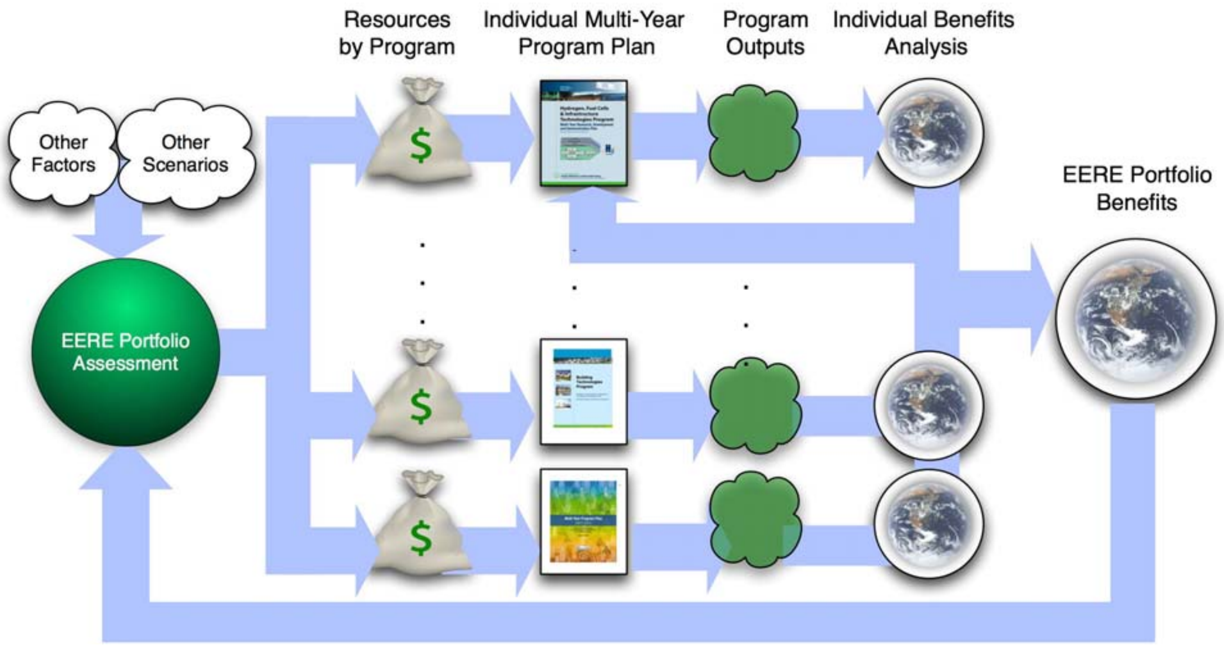

Figure 1.3. Holistic View of the Role of Benefits Analysis in EERE Performance Management

Benefits Analysis Process

EERE's benefits analysis process involves three major steps. 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 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 and other DOE RD3 energy, science, and environment (ESE) 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* (*AEO2006*) Reference Case provides an independent representation of the likely evolution of energy markets. Neither the EIA Reference Case nor the EERE Baseline Case includes any changes in future energy policies.

In establishing its Baseline Case, EERE makes a number of modifications to the *AEO2006* Reference Case. Modifications are made to the same model—the National Energy Modeling System (NEMS)—used by EIA in developing the *Annual Energy Outlook*. To distinguish it from EIA's version, the model is referred to as NEMS-GPRA08. The *AEO2006* Reference Case is also the starting point for the long-term

[13] See http://www.eia.doe.gov/oiaf/aeo/index.html

(to 2050) benefits modeling using MARKAL-GPRA08. The Baseline Cases for both NEMS-GPRA08 and MARKAL-GPRA08 are aligned as closely as possible, but the two models are different in their internal design.

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-GPRA08 and MARKAL-GPRA08 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.

For much of EERE's portfolio, "off-line" analyses are needed to translate information about program technology and market characteristics into usable modeling inputs. 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.