

Definition of GPRA08 Benefits Metrics

The choice of metrics has been influenced not only by a collaborative effort within DOE, but also by collaborative efforts with the National Research Council (NRC) over 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.”¹

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.”

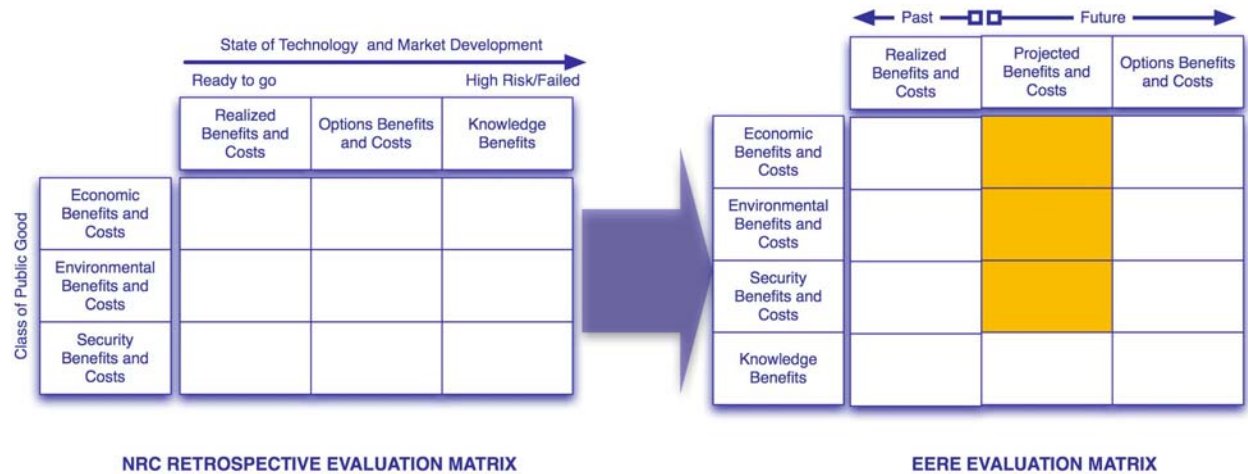


Figure 1.1. Evolution of an Evaluation Matrix DOE RD3 Programs

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 program offices brought together experts to discuss how to extend the NRC framework to the kind of prospective benefits analysis reported here.² 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

¹Committee 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>

² 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)

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.

The matrix elements highlighted in yellow represent benefits categories for which DOE has adopted specific indicators. This year (as in prior years), DOE'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, DOE will expand these 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.

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. 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 #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 DOE 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 percent 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 DOE 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 DOE 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 DOE.

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, DOE 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 DOE 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 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 detail of how this metric is calculated are provided in [Table 1.3](#).

The second transportation-related metric—the transportation fuel diversity index—requires a little more explanation. As DOE goals suggest, diversifying the Nation’s sources of energy is seen as an important strategy for improving the reliability of energy supply. Diversification is a commonsense 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 financial markets, ecosystems and other systems. A Shannon–Wiener diversity index, typically used to measure biodiversity, has been applied to transportation energy diversity by substituting types of primary energy sources for biological species.

Calculating Program Benefits

Program benefits are calculated by comparing the output of energy systems models for the parameters of interest for each metric for two separate cases. The two cases employed are:

- A. A world where there is no federal funding available to advance technology.
- B. A world where federal funding is used to achieve the goals of the DOE programs.

The benefits of the DOE portfolio of research are determined by taking the difference between the results of these two cases for the parameters associated with each metric.

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

DOE Theme Key Word: Relevant DOE Goal DOE Key Phrases	"Affordable" Goal 1.4 Energy Use "Cost Effective", "Energy Efficiency of the U.S. Economy"
<ol style="list-style-type: none"> 1. <i>Reduction in Average Delivered Natural Gas Price (Percent)</i>. The percent change in the average natural gas prices measured in constant 2004 dollars. 2. <i>Energy System Cost Savings, Annual Billion \$2004</i>. 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. <i>Consumer Savings, Annual Billion \$2004</i>. Total energy expenditures for all consumers (residential, commercial, industry, and transportation energy prices times energy quantities, same as reported in the AEO) 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. <i>Consumer Savings, NPV, Billion \$2004</i>. Net present value of annual net consumer expenditures beginning in year 2008, discounted at 3%. 5. <i>Electric Power Industry Savings, Annual Billion \$2004</i>. 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. <i>Electric Power Industry Savings, NPV Billion \$2004</i>. Net present value of electric power industry costs beginning in year 2008, discounted at 3%. 7. <i>Reduction in Fraction of Household Income Spent on Energy</i>. 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. <i>Reduced Energy Intensity of Economy (Percent)</i>. Primary energy is computed with renewable generation counted as 3412 Btu/kWh except for biomass or other energy sources where Btus are consumed. This is computed as the sum of 1) all primary non-renewable energy consumption plus 2) non-biomass generation times 3412 plus biomass plus 3) other non-electric renewable fuels divided by the chain weighted 2000\$ value for GDP (as reported in the AEO). 	

Table 1.2. DOE 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”
<ol style="list-style-type: none"> 1. <i>Avoided Greenhouse Gas Emissions, Annual (MMTCE/year)</i>. Total million metric tons of carbon equivalent per year from all energy sectors (same as reported in the AEO, but as carbon instead of carbon dioxide). 2. <i>Avoided Greenhouse Gas Emissions, Cumulative (MMTCE)</i>. Total cumulative carbon emissions beginning in the year 2008 in million metric tons of carbon equivalent. 3. <i>Reduced Cost of Criteria Pollutant Control, NPV (bil 2004\$)</i>. 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. DOE 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”
<ol style="list-style-type: none"> 1. <i>Avoided Oil Imports, Annual (mbpd)</i>. Net crude oil imports and petroleum product savings each year measured in millions of barrels per day. 2. <i>Avoided Oil imports, Cumulative (bil barrels)</i>. Cumulative oil import savings beginning in the year 2008 3. <i>Security Fuel Economy Improvement (MPG of Crude Oil)</i>. Light duty vehicle miles traveled divided by light duty vehicle oil (gasoline, diesel and LPG) consumption converted to gallons. 4. <i>Transportation Fuel Diversity Improvement (percent)</i>. Percent change in the Shannon-Wiener diversity index for the transportation sector calculated based on estimates of the <i>pro rata</i> share of primary energy sources contributing to U.S. energy supply. (See detailed discussion in the text of this chapter).³ 5. <i>Oil Intensity Reduction (percent)</i>. Measured as percent change in annual oil consumption per GDP. Oil intensity is billion barrels of oil consumed per dollar of annual GDP. 	

³ 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.