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.

---

[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.

---

[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.

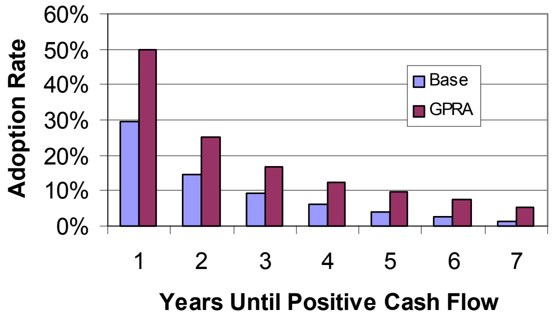
The analysis is performed for each of 11 commercial building types in nine regions. Even so, this is a fairly high level of aggregation; and, therefore, the model may not capture some of the niche markets that DER may fill. The DEER Program facilitates the development of the DER market by improving the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

---

[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

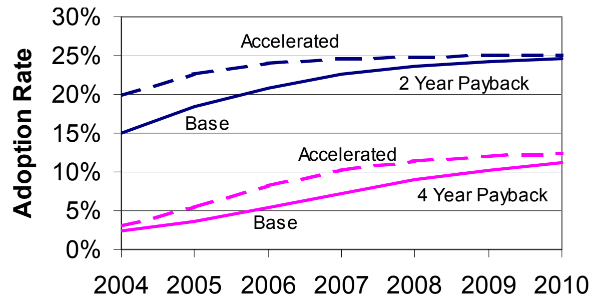
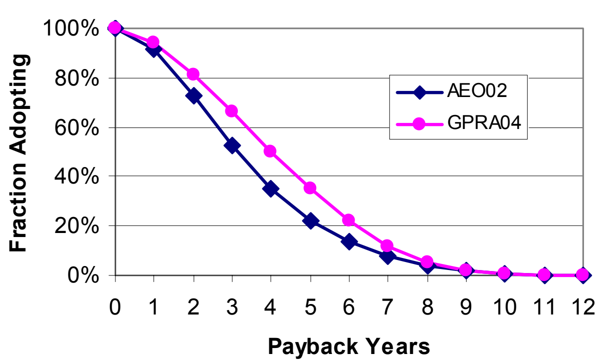


Figure 4.2. DER Market Share Over Time in New Commercial Buildings

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**.

[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).

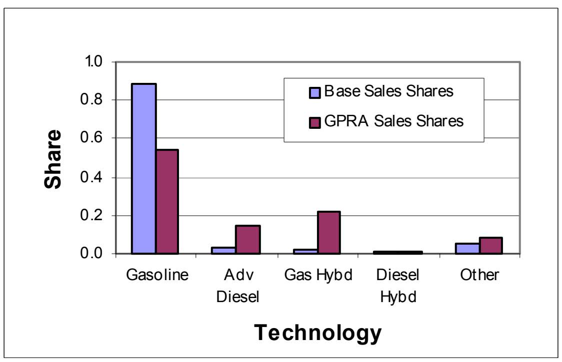


Figure 4.4. Vehicle Sales Shares in 2010

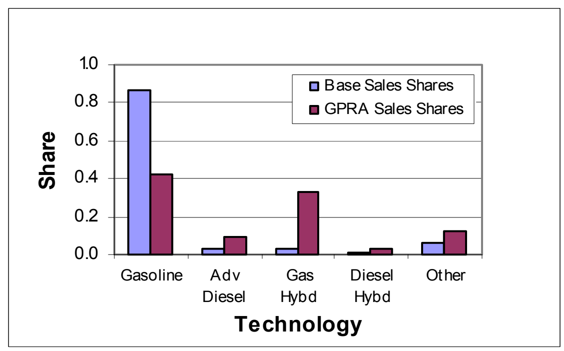
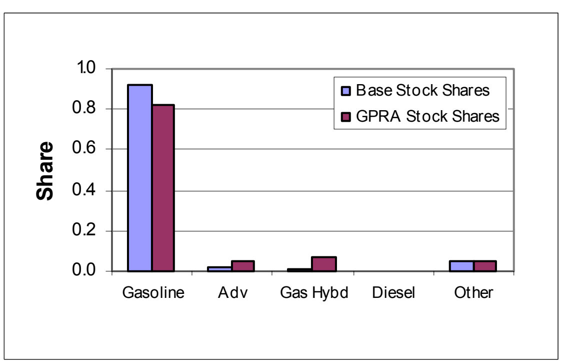


Figure 4.5. Vehicle Sales Shares in 2020



Source: NEMS-GPRA04 outputs

Figure 4.6. Vehicle Stock Shares in 2010

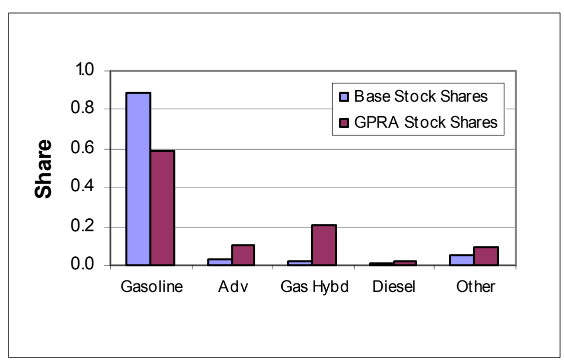


Figure 4.7. Vehicle Stock Shares in 2020

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.

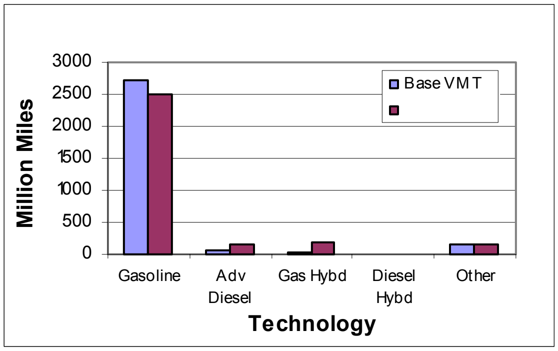
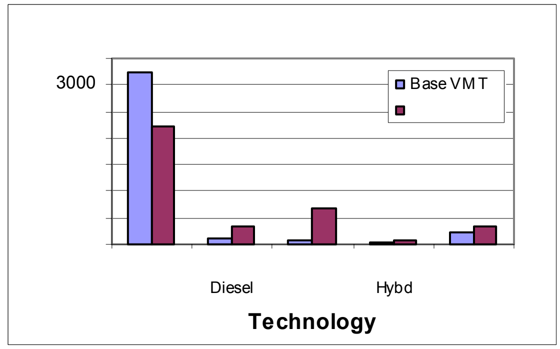


Figure 4.8. Vehicle Miles Traveled in 2010



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.

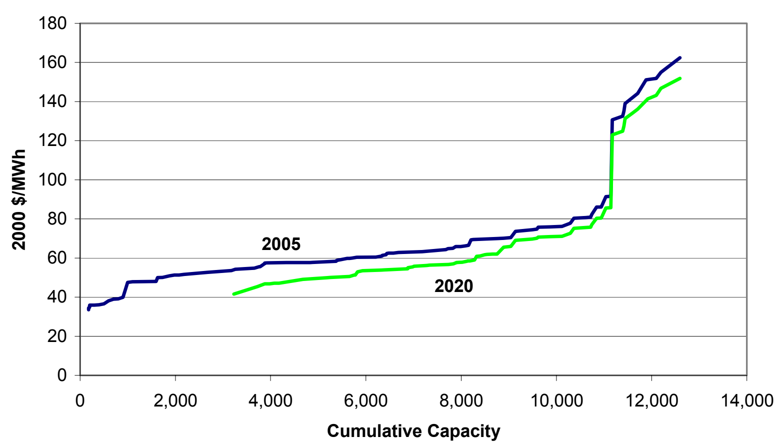
The logit function inherently represents the distribution of consumer preference, and no single vehicle type receives 100 percent of the market share within a size range and region. As shown previously, the gasoline hybrid sales share in 2020 is 33 percent averaged across all regions and size classes,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

[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.