ERRATUM
CHAPTER 2 – THE VALUE OF EERE'S PORTFOLIO

Last-minute changes in the budget and direction for the Weatherization and Intergovernmental Program (WIP) were not incorporated in the portfolio benefits shown in **Chapter 2**. Revised midterm benefits reflecting the changes in WIP are shown below.

	MIDTERM BENEFITS				
Metric	2010	2015	2020	2025	2030
ECONOMIC BENEFITS ("AFFORDABLE")					
Reduction in Average Delivered Natural Gas Price (Percent)	1%	1%	3%	6%	3%
Energy System Cost Savings (bil $2004) 1/	$6	$23	$39	$67	$95
Consumer Savings, Annual (bil $2004)	6	15	46	91	119
Consumer Savings, NPV (bil $2004) 2/	10	56	162	384	676
Electric Power Industry Savings, Annual (bil $2004) 3/	2	6	14	23	30
Electric Power Industry Savings, NPV (bil $2004) 2/ 3/	4	23	61	122	195
Reduction in Fraction of Household Income Spent on Energy	0.1%	0.5%	1.8%	3.5%	4.9%
Reduced Energy Intensity of Economy (Percent)	0.4%	1.8%	4.1%	6.4%	8.3%
ENVIRONMENTAL BENEFITS ("CLEAN")					
Avoided Greenhouse Gas Emissions, Annual (MMTCE/year)	8	35	105	173	233
Avoided Greenhouse Gas Emissions, Cumulative (MMTCE) 5/	16	134	503	1223	2262
Reduced Cost of Criteria Pollutant Control, NPV (bil $2004) 2/	1	2	4	10	14
SECURITY BENEFITS ("RELIABLE")					
Avoided Oil Imports, Annual (mbpd)	ns	0.2	0.6	1.3	2.1
Avoided Oil imports, Cumulative (bil barrels) 4/ 5/	ns	0.3	1.0	2.8	6.1
Security Fuel Economy Improvement (MPG of Crude Oil)	0.1	0.5	1.3	2.7	5.2
Improved Transportation Fuel Diversity (percent) 6/	ns	ns	3%	10%	22%
Reduced Oil Intensity of the Economy (percent)	ns	1.2%	2.9%	5.9%	9.2%

Table notes:
1/ 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 financial and behavioral components.
2/ NPV (net present value) calculations done using 3% real discount rate back to 2008.
3/ Electric power industry cost does not include demand-side distributed generation.
4/ Renewable generation values at output value (3412 Btu/kWh) except for biomass and geothermal where energy content is used.
5/ All cumulative values are from 2008.
6/ Diversity index change is Case minus Base (opposite of others).
7/ Midterm benefits based on NEMS-GPRA08 model.
8/ Long-term benefits based on MARKAL-GPRA08 model.
nr = not reported or calculated by model
ns = not significant relative to model error

CHAPTER 2 – THE VALUE OF EERE'S PORTFOLIO

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The Benefits of EERE's RD3 Portfolio Under a Business-As-Usual Future

Benefits analysis under the business-as usual (BAU) case reflects the effect of EERE's RD3 portfolio on a baseline case built on the *AEO2006* Reference Oil Price Case. **Table 2.1** shows the estimated economic, environmental, and security benefits of EERE's overall portfolio of investments in improved energy-efficient technologies, renewable energy technologies, and assistance to consumers in adopting these technologies. Results by five-year increments from 2010 to 2030 are shown for NEMS-GPRA08 and by five-year increments from 2035 to 2050 for MARKAL-GPRA08. The benefits reported here do not reflect last-minute changes in budget and direction for the Weatherization and Intergovernmental Program (WIP). An erratum is included at the end of this report showing revised midterm benefits estimates that reflect the changes in WIP. These revised estimates are roughly 10% higher than the estimates shown in **Table 2.1.**

Table 2.1. EERE Portfolio Benefits for FY 2008 Budget Request—Business-As-Usual Scenario

	MIDTERM BENEFITS 7/					LONG-TERM BENEFITS 8/			
Metric	2010	2015	2020	2025	2030	2035	2040	2045	2050
ECONOMIC BENEFITS ("AFFORDABLE")									
Reduction in Average Delivered Natural Gas Price (Percent)	1%	0%	3%	5%	2%	5%	10%	16%	12%
Energy System Cost Savings (bil $2004) 1/	nr	nr	nr	nr	nr	120	146	173	203
Consumer Savings, Annual (bil $2004)	4	12	43	86	110	232	322	385	381
Consumer Savings, NPV (bil $2004) 2/	6	46	148	359	632	1,518	2,088	2,707	3,278
Electric Power Industry Savings, Annual (bil $2004) 3/	1	5	13	21	26	51	63	77	69
Electric Power Industry Savings, NPV (bil $2004) 2/ 3/	2	18	54	110	174	419	536	658	766
Reduction in Fraction of Household Income Spent on Energy	0.3%	0.7%	2.0%	3.6%	4.8%	8%	9%	10%	10%
Reduced Energy Intensity of Economy (Percent)	0.3%	1.7%	3.9%	6.1%	7.8%	10%	13%	15%	17%
ENVIRONMENTAL BENEFITS ("CLEAN")									
Avoided Greenhouse Gas Emissions, Annual (MMTCE/year)	6	33	101	165	219	447	508	539	505
Avoided Greenhouse Gas Emissions, Cumulative (MMTCE) 5/	12	116	470	1158	2136	4630	7047	9680	12276
Reduced Cost of Criteria Pollutant Control, NPV (bil $2004) 2/	0	1	3	9	13	nr	nr	nr	nr
SECURITY BENEFITS ("RELIABLE")									
Avoided Oil Imports, Annual (mbpd)	ns	0.2	0.6	1.2	2.1	5.3	6.9	7.1	6.8
Avoided Oil imports, Cumulative (bil barrels) 4/ 5/	ns	0.3	1.0	2.8	6.1	17	28	41	54
Security Fuel Economy Improvement (MPG of Crude Oil)	0.1	0.5	1.3	2.8	5.3	23	38	51	64
Improved Transportation Fuel Diversity (Percent) 6/	ns	ns	4%	10%	24%	82%	86%	67%	42%
Reduced Oil Intensity of the Economy (Percent)	0.2%	1%	3%	6%	9%	26%	32%	33%	33%

Table notes:
1/ 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 financial and behavioral components.
2/ NPV (net present value) calculations done using 3% real discount rate back to 2008.
3/ Electric power industry cost does not include demand-side distributed generation.
4/ Renewable generation values at output value (3412 Btu/kWh) except for biomass and geothermal where energy content is used.
5/ All cumulative values are from 2008.
6/ Diversity index change is Case minus Base (opposite of others).
7/ Midterm benefits based on NEMS-GPRA08 model.
8/ Long-term benefits based on MARKAL-GPRA08 model.
nr = not reported or calculated by model
ns = not significant relative to model error

Economic Benefits

Figure 2.1 shows projected economic benefits associated with EERE's portfolio. The top row of charts shows net consumer cost savings, net energy system cost savings, and electric power-sector cost savings through 2050. EERE's portfolio has its greatest impact on the consumer side of the economy. Consumer savings reach $100 billion annually in 2030, and level off at almost $400 billion annually by 2045. The apparent jump in consumer savings from 2030 to 2035 is an artifact related to switching from NEMS-GPRA08 to MARKAL-GPRA08. The net present value of these savings is almost $700 billion by 2030, and more than $3 trillion by 2050.

From an economist's perspective, consumer savings do not necessarily represent the net impact of EERE's portfolio on the economy. Net annual energy system cost savings—a proxy for the consumer and producer surplus that takes into account the net gains on both the consumer and producer side of the economy—are lower than the benefits projected for consumers. Nevertheless, it doubles from $100 billion annually in 2030 to $200 billion annually in 2050. The results shown here are all based on MARKAL-GPRA08 over the entire projection because NEMS-GPRA08 cannot estimate net energy system cost.

The electric power industry—a major component of the energy producer side of the economy—shows savings that reach almost $30 billion annually by 2030, peak at almost $80 billion annually in 2045, and decline to $70 billion annually in 2050. Total electric power industry expenses were about $235 billion in 2005.[1] As with the consumer savings estimates, there is a slight discontinuity from 2030 to 2035 due to the change from NEMS-GPRA08 to MARKAL-GPRA08 models. The net present value of these savings to the electric power sector is more than $170 billion and more than $600 billion, respectively, in 2030 and 2050.

The bottom row of charts in **Figure 2.1** shows trends for other relevant economic benefits of EERE's portfolio. The relative spending of household income on energy is 5% lower in 2030 for the EERE portfolio case, with the reductions leveling off to about 10% by 2050. Reductions in energy intensity of the economy grow steadily throughout the period of 2010 through 2050, reaching 8% and 17%, respectively, in 2030 and 2050. Trends for natural gas price reductions are more volatile, showing two peaks in reductions of 5% in 2025 and 16% in 2045.

Figure 2.2 provides a historical perspective on the projected absolute trends in consumer spending on energy and the energy intensity of the U.S. economy.[2] In the absence of EERE's portfolio, consumer spending continues its historical increase through 2045. EERE's portfolio slows and ultimately reverses the historical and projected growth in consumer spending for energy. Consumer expenditures on fuel purchases are 10% lower than they would be in 2030 without EERE's portfolio, and 30% lower than projected 2050 spending without EERE's portfolio.

Energy intensity of the U.S. economy has been declining dramatically since data on this metric have been available starting in 1949. This decline is due to both structural changes in the economy—a shift from an industrial to a service-oriented economy—and to significant improvements in energy efficiency, especially since the 1970s. This historical and projected decline in energy intensity overwhelms the impact of EERE's portfolio, which provides additional 8% and 18% reductions in energy intensity in 2030 and 2050, respectively.

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[1] Revenue and expense statistics reported in *Electric Power Annual 2005*. Energy Information Administration, U.S. Department of Energy, DOE/EIA-0348(2005. Washington, D.C. November 2006.

[2] Note that the consumer spending trends presented here differ from the consumer expenditures data used to calculate the metric of net consumer savings. Projected net consumer savings includes both expenses for purchasing energy and investment costs associated with purchasing end-use energy technologies. Because EIA's historical data does not include investment costs, the trend data reported for both historical and projected consumer spending excludes consumer investment costs (and therefore overstates the EERE impact). The trends are nevertheless instructive.

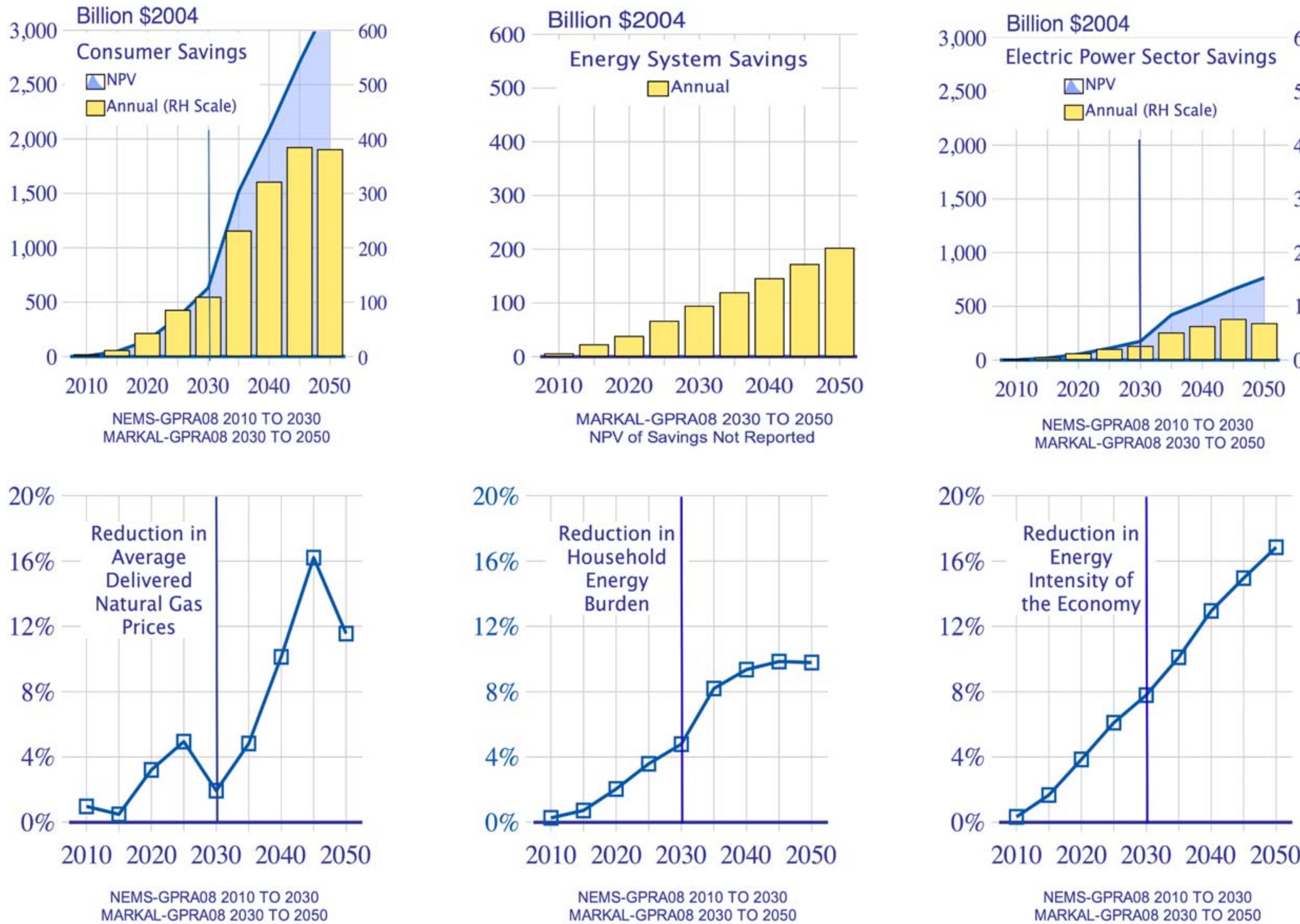
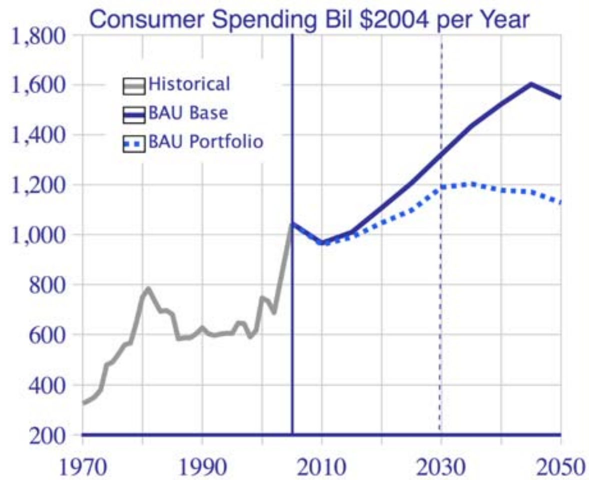
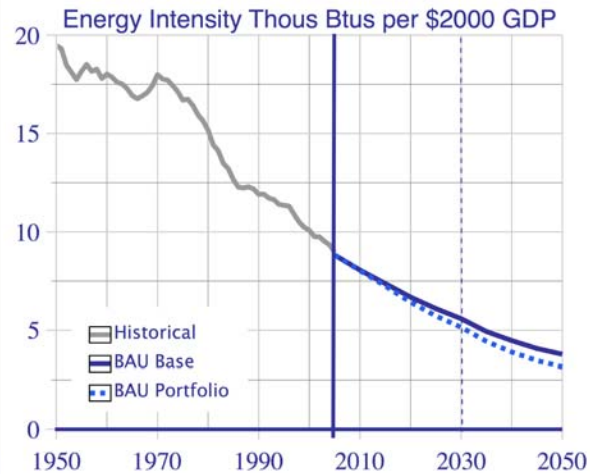


Figure 2.1. Projected Economic Benefits Metrics for EERE's RD3 Portfolio



Solid line represents historical and projected trend without future funding of the EERE portfolio. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050. Historical data to 2002 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/ EIA-0384 (2005) (Washington, D.C., July 2006) Consumer Expenditure Estimates for Energy by Source. (http:// www.eia.doe.gov/emeu/aer/contents.html)



Solid line represents historical and projected trend without future funding of the EERE portfolio. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050 Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/ EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949 -2005. (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.2. Historical and Projected Trends for Consumer Spending and Energy Intensity of the Economy under the Business-As-Usual Scenario

Environmental Metrics

Figure 2.3 shows the projected environmental benefits associated with continued funding of EERE's portfolio under the "Business-As-Usual" (BAU) scenario. Approximately 200 million metric tons of carbon per year are avoided by 2030, with savings leveling off to about 500 million metric tons per year by about 2040. The slowing in the rate of growth in carbon emissions savings in the out-years reflects assumptions about technological progress that would eventually result in many of the same outcomes as EERE's portfolio produces, but not as quickly as they can occur with continued funding of EERE's portfolio. The doubling of carbon emissions savings from 2030 to 2035 is an artifact related to the switch from NEMS-GPRA08 to MARKAL-GPRA08. Cumulative carbon savings are 2 billion and 12 billion metric tons in 2030 and 2050. The net present value of projected reduced costs of air pollution control associated with EERE's portfolio is $13 billion in 2030. These savings represent the allowance value for avoided emissions of nitrogen oxides, sulfur oxides, and mercury in the electric power sector. Pollution control cost savings are not estimated beyond 2030 because MARKAL-GPRA08 cannot estimate these savings.

Figure 2.4 provides a historical perspective on the projected absolute emissions of greenhouse gases and the greenhouse gas intensity of the U.S. economy. EERE's portfolio effectively returns emissions of greenhouse gases in 2050 to 2010 levels. Greenhouse gas emissions in a future with continued support for EERE's portfolio (measured as carbon equivalent emissions per year) are 10% and 20% lower in 2030 and 2050, respectively, than they would be without the portfolio.

As with the U.S. economy's energy intensity, greenhouse gas intensity of the U.S. economy has declined dramatically over the past half century—for structural reasons and as a result of efficiency improvements. The effect of EERE's portfolio on greenhouse gas-intensity tracks closely with the effects on energy intensity. The portfolio adds 10% and 20% more reductions in carbon intensity in 2030 and 2050, respectively.

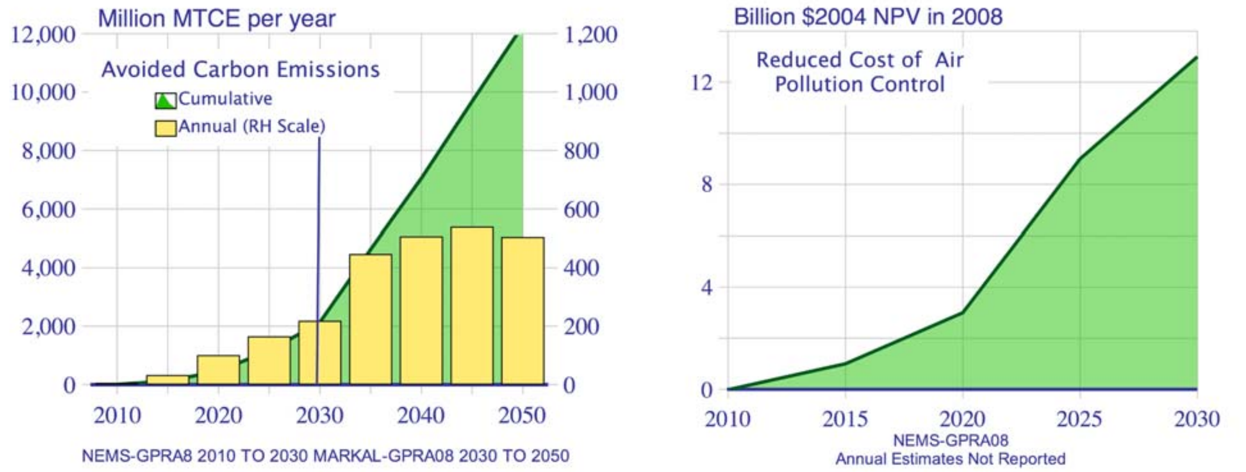
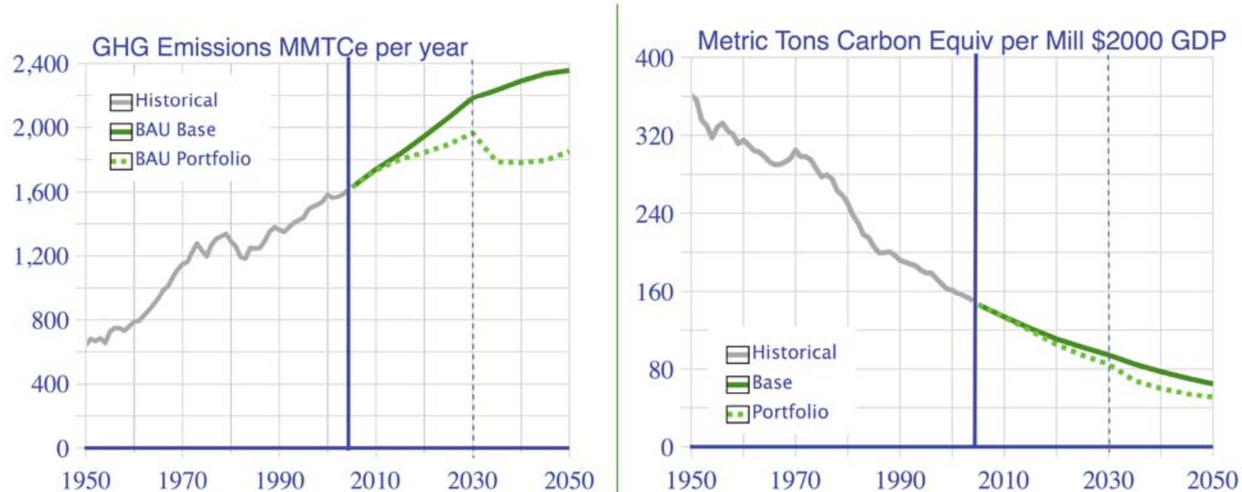


Figure 2.3. Environmental Metrics for the Business-As-Usual Scenario



Solid line represents historical and projected trend without future funding of the EERE portfolio. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2004 from U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gas Emissions in the United States 2005.* DOE/EIA-0573(2005) (Washington, D.C., July 2006) Table B3 Total Energy-Related Carbon Dioxide Emissions by End-Use Sector, and the Electric Power Sector, by Fuel Type, 1949-2004.Table available at http://www.eia.doe.gov/emeu/aer/contents.html)

Solid line represents historical and projected trend without future funding of the EERE portfolio. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical carbon emissions data to 2004 from U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gas Emissions in the United States 2005.* DOE/EIA-0573(2005) (Washington, D.C., November 2006) Table B3 Total Energy-Related Carbon Dioxide Emissions by End-Use Sector, and the Electric Power Sector, by Fuel Type, 1949-2004.Table available at http://www.eia.doe.gov/emeu/aer/contents.html). Historical GDP data from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005), (Washington, D.C., July 2006). Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949-2005. (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.4. Historical and Projected Greenhouse Gas Emissions Under the Business-As-Usual Scenario

The environmental benefits of EERE's portfolio are all the more impressive given that they occur in conjunction with real economic gains, as described in the previous section.

Security Benefits

Figure 2.5 summarizes the projected security benefits associated with EERE's portfolio of RD3 programs. The two charts in the left-hand column show overall security benefits to the U.S. economy. The two charts in the right-hand column show security benefits specific to the transportation sector.

By 2030, avoided imports of foreign oil reach 2 million barrels per day. From 2040 to 2050, avoided imports level out at about 7 million barrels per day. The apparent increase in oil import savings in 2035 is related to the switch from NEMS-GPRA08 to MARKAL-GPRA08. As with the benefits reported for the economy and the environment, the leveling off and decline in security benefits seen in the out-years is attributable to the assumption that many of the foreign oil-reducing technologies coming out of EERE's portfolio will eventually be developed in the marketplace even without the future funding of EERE's programs. The cumulative amount of avoided foreign oil reaches 6 billion barrels in 2030, climbing to 54 billion barrels by 2050.

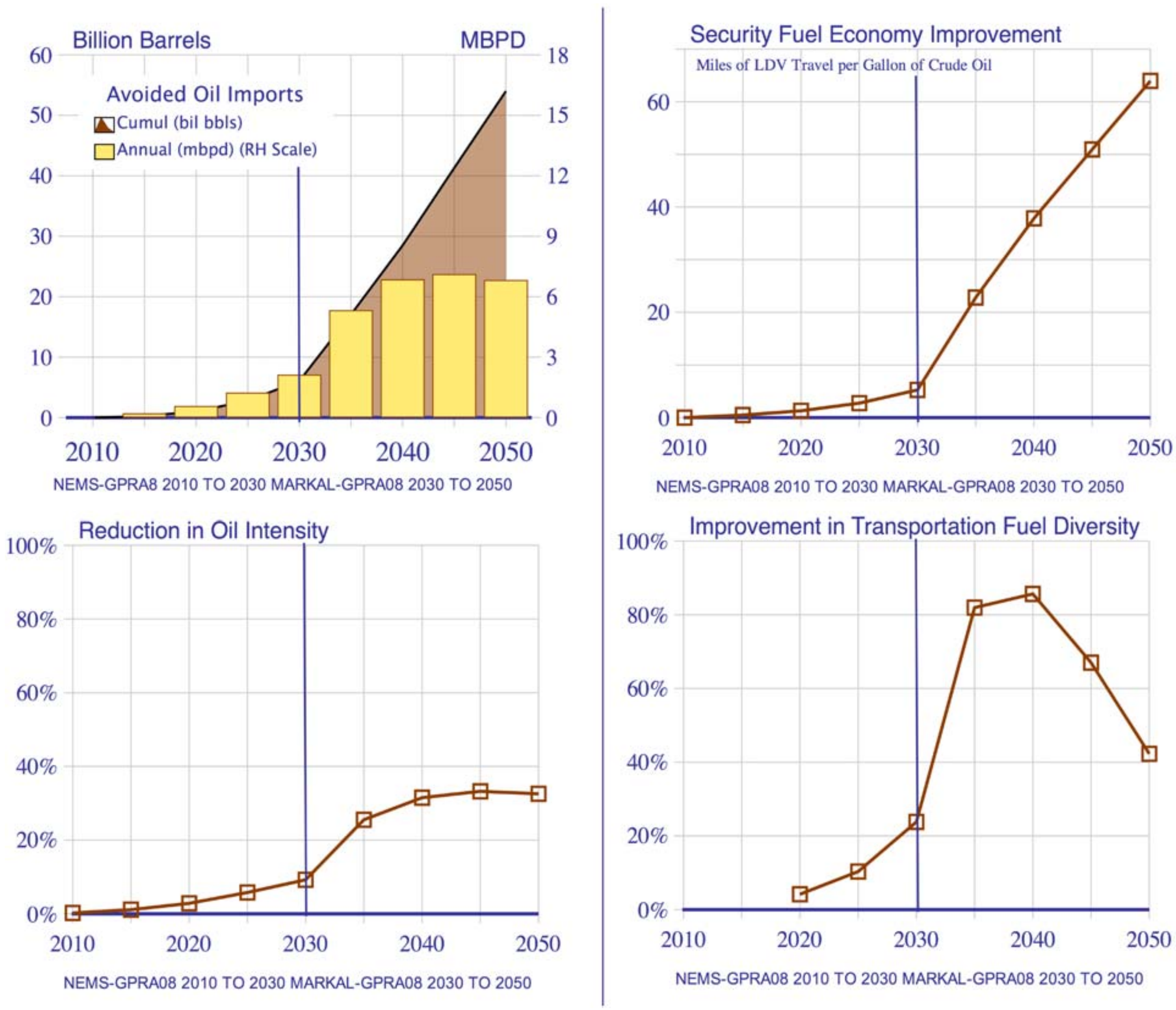
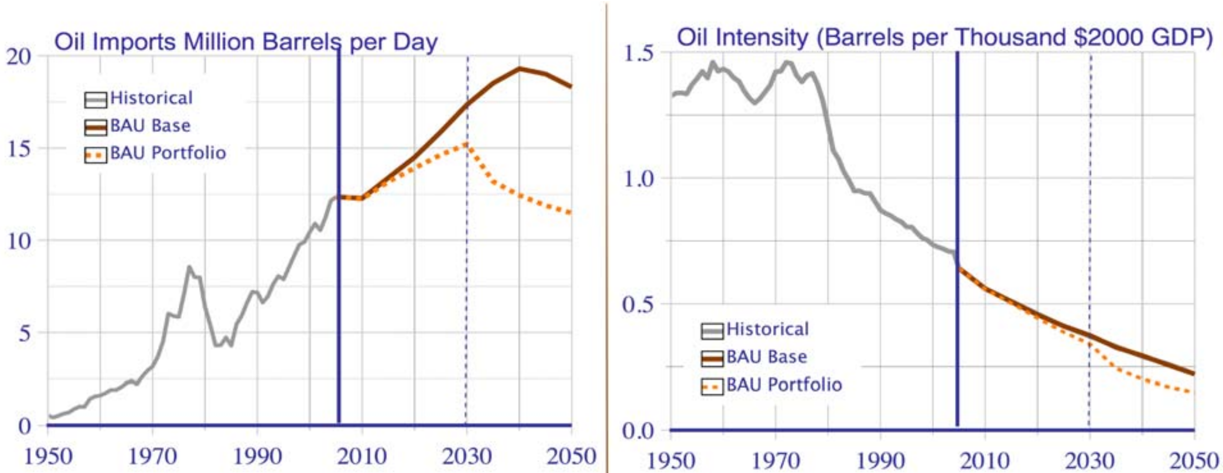


Figure 2.5. Security Metrics for EERE's Portfolio Under the Business-As-Usual Scenario

EERE’s portfolio reduces the oil intensity of the overall U.S. economy by 10% in 2030. The effect of the portfolio on oil intensity levels off at a reduction of about 35% in 2050. Again, these reductions are measured relative to the projected oil intensity of the economy in the absence of EERE’s RD3 efforts.

Figure 2.6 provides a historical perspective on oil imports and oil intensity. The late 1960s through the late 1970s saw an intense—and even exponential—growth in the U.S. demand for foreign oil. This trend was reversed briefly in the late 1970s and the first half of the 1980s in response to the oil price and supply shocks that occurred in that period. Since then, oil imports have returned to a steady rate of growth. Although the base case projection suggests that oil import growth will slow somewhat as a result of the step-change increase in oil prices experienced in recent years, demand for imported oil is expected to increase 50% from its current level—from about 12 million barrels per day up to 18 million barrels per day by 2030 in the base case—without continued support for EERE’s RD3 programs.

EERE’s portfolio stabilizes oil imports, and even leads to imports that are about 1 million barrels per day lower than today’s level. With EERE’s portfolio, oil imports peak in 2030 at 15 million barrels per day, a 12% reduction from the base case; and fall to 11 million barrels per day in 2050, a 40% reduction from the base case. A comparison of the individual program benefits results (see **Chapter 3** in this report) suggests that the largest source of savings (about two-thirds) comes from vehicle efficiency improvements, with the remaining savings coming from ethanol fuel and hydrogen fuel cells.



Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 5.1 Petroleum Overview, 1949-2005 (http://www.eia.doe.gov/emeu/aer/contents.html)

Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.5 Energy Consumption, Expenditures, and Emissions Ind icators, 1949-2005 and Table 5.1 Petroleum Overview, 1949-2005 (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.6. Historical and Projected Oil Trends for the Business-As-Usual Scenario

Oil intensity of the economy—as measured in barrels of oil per thousand $2000 of GDP—was more or less flat from 1949 through 1978; but, it has fallen steadily since then (again in response to oil supply and price shocks in the second half of the 1970s). Today, oil intensity is 0.7 barrels per thousand $2000 of GDP, roughly half of its 1978 level. Even without EERE’s RD3 programs, oil intensity is projected to continue its decline, falling to 0.4 and 0.2 barrels per thousand $2000 of GDP in 2030 and 2050, respectively. With EERE’s programs, oil intensity drops even further. By 2030, oil intensity reaches 0.3 in 2030 (9% lower than the base case) and 0.15 in 2050 (33% lower than the base case).

This year, EERE introduced two security metrics specifically related to the transportation sector—the most vulnerable part of our economy to foreign energy supply disruptions (see the charts on the right-hand side of **Figure 2.5**). The first—measured as miles traveled per gallon of crude oil consumed by light-duty vehicles—is a security-oriented variant of fuel economy for cars, sport utility vehicles (SUVs), and other small trucks. EERE's portfolio enables the U.S. light-duty vehicle fleet to gain an additional 5 miles of travel for each gallon of crude oil it consumes in 2030. By 2050, EERE's portfolio adds more than 60 miles of travel for each gallon of crude oil consumed. This improvement is due mostly to introduction of hydrogen fuel cells and improvements in vehicle efficiency.

The lack of diversity in fuel supply for transportation is another important source of vulnerability (see **Chapter 1** for more detail on how fuel diversity is calculated). As **Figure 2.5** shows, EERE's portfolio improves the diversity of the fuel supply for light-duty vehicles by more than 20% in 2030 and by more than 80% in 2040. The impact of the portfolio on fuel diversity declines rapidly after that point, as the base case market begins to catch up with the alternative fuel developments in the EERE portfolio case.

The Impact of Other Possible Futures

There is considerable uncertainty in long-term energy projections. In fact, uncertainty about future energy demand, supplies, and prices is one of the motivations for Federal investment in R&D, which can provide options for the Nation in the face of potentially adverse world energy markets. Under such circumstances, EERE's portfolio may have much greater value than under the reference or business-as-usual (BAU) projections described previously. The prospective benefits framework developed by the National Research Council (NRC) recognizes this in their recommendation of assessing benefits for several "global scenarios."[3]

EERE—in collaboration with the other DOE R&D Offices in the Office of Energy, Science, and the Environment (ESE)—has developed alternative scenarios to capture two of the key uncertainties impacting future energy: prices and climate policy. The use of alternative scenarios that project other possible futures addresses just one type of uncertainty. Modeling bias, error, and uncertainty are still embedded in all of the scenarios. Programmatic success is another major source of uncertainty that is not addressed through these scenarios.

The two alternative market scenarios that were developed for GPRA08 are a high fuel price case and a case with a constraint on national energy-related carbon emissions. Baseline cases (without EERE programs) and EERE portfolio cases have been analyzed under each of the alternative scenarios. The benefits of the portfolio are then evaluated as the difference between each pair of portfolio and base case, using a similar methodology as for the BAU GPRA08 benefits.

The differences in the benefits seen in the scenario and BAU cases can be subtle and difficult to interpret. For the high fuel price case, the alternative scenarios have different underlying macroeconomic assumptions and demands for energy services (such as light, travel, industrial steam, etc.) due to the higher energy prices. For the carbon-constrained scenario, the definition of the climate policy as a cap on energy-related carbon emissions leads to reduced emissions to the cap level in both the baseline and EERE portfolio cases. Hence, there are no carbon emission reductions attributable to the EERE portfolio of programs. The primary benefit is that the EERE programs help reach that cap at lower cost. [4]

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[3] National Research Council (2005). *Prospective Evaluation of Applied Energy Research and Development At DOE (Phase One): A First Look Forward*. The National Academies Press, Washington, D.C.

[4] One might argue that the presence of EERE technologies that allows for more rapid adoption of technologies that reduce carbon emissions might influence climate policy; however, carbon caps, including the one modeled here, usually specify a time-path for reductions. The level of emissions reductions and the timing of the reductions are thus dictated by the scenario, and not influenced by the technologies in this construct.

The off-line analyses that support the benefits analysis were revised for the alternative scenarios, although it was a challenge to do so in a comprehensive manner. For example, without multiple iterations, it is difficult to account for the impact of changes in the carbon value in the carbon scenario program cases. Thus, for programs whose inputs to the integrating models are "outcomes" (such as market penetration rates or energy savings), this potentially leads to an overstatement of benefits, especially in the carbon constraint scenario, where the value of carbon varies by case. For most programs, the baseline assumptions were not modified, except to the extent that the models will endogenously project reactions to the scenarios. In other words, the baseline technology characteristics for EERE technologies for the most part remain the same under all the scenarios.

As in the benefits analysis for the Business-As-Usual scenario, two integrated energy models were used: NEMS-GPRA08 and MARKAL-GPRA08. The former provides the midterm projections (to 2030), while the latter is used to extend them out to 2050.

The High Fuel Price Scenario Definition

The High Fuel Price (HFP) scenario is predicated on a future in which the supply of natural gas and oil, relative to demand, are more limited. As a result, significantly higher fuel prices occur (see **Figure 2.7** for comparison of oil and gas prices under the High Fuel Price and Business-As-Usual scenarios). The world oil price follows the trajectory of the AEO 2006 High Oil Price case. Oil prices start off higher than the reference case in 2006 and increase to $90 per barrel by 2030. Beyond 2030 (outside the projections in the AEO 2006 High Oil Price), oil prices increase more slowly, reaching $100 per barrel by 2050.

Natural gas supply in the High Fuel Price case was restricted in order to cause natural gas prices to increase to roughly $11 by 2030. The restrictions on gas supply included limiting the ability of new LNG terminals to be constructed, delaying the Alaska gas pipeline until after 2030, and reducing assumed Canadian resources. Coal price assumptions were not explicitly changed, but mine mouth coal prices increase by up to 8% through 2030 in NEMS-GPRA08 due to the increases in the other prices. Beyond 2030, these restrictions result in continued higher natural gas prices according to MARKAL-GPRA08, though not quite as high as the prices projected by NEMS-GPRA08 in 2030.

Carbon Constraint Scenario Definition

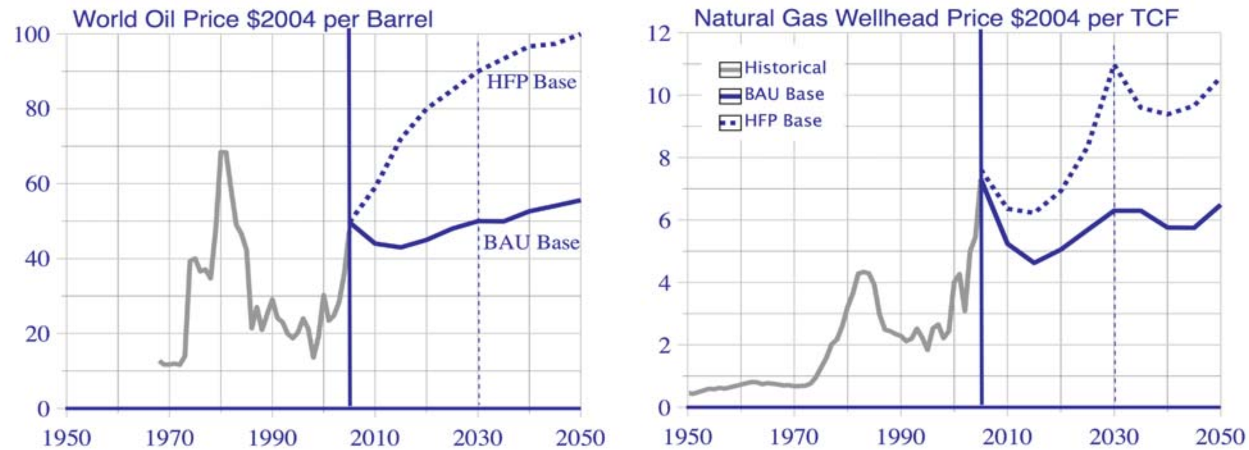
The Carbon Constraint (CC) scenario was designed to examine the implications of a cap on energy-related carbon emissions for EERE benefits. The carbon cap was set to meet the Administration's "Global Climate Change Initiative" goal of an 18% reduction in national GHG intensity (below the 2002 level) by 2012, along with assumptions for continued emission reductions through 2050.[5] **Figure 2.8** compares projected allowable emissions under this carbon cap scenario with "Business-As-Usual" baseline emissions of energy-related CO_2 emissions.

Between 2012 and 2020, the U.S. carbon cap decreases at a constant rate, reaching 1,600 MMTCE per year in 2020—representing a return to year 2000 carbon emission levels. Between 2020 and 2050, carbon emissions are constrained to decrease at a constant rate resulting in an ultimate emissions level of 1,200 MMTCE per year in 2050—representing a return to mid-1970s and early 1980s carbon emission levels. An economy-wide trading system is assumed where the lowest cost reductions will occur first.

By definition, carbon emissions are at the specified cap in the carbon cases and take place on a specified schedule, with or without EERE technologies. Therefore, no carbon emission reductions are expected that would be attributable to the EERE programs, unless the cap becomes non-binding.[6] Nevertheless, there is a significant reduction in the cost required to meet that cap when the EERE advanced technologies are

[5] Global Climate Change Policy Book. The White House, February 2002. http://www.whitehouse.gov/news/releases/2002/02/climatechange.html
[6] No banking of allowances was included in the scenario.

available. An economy-wide trading system is assumed where the lowest cost reductions will occur first. The price of the carbon allowances indicates the marginal cost of compliance.



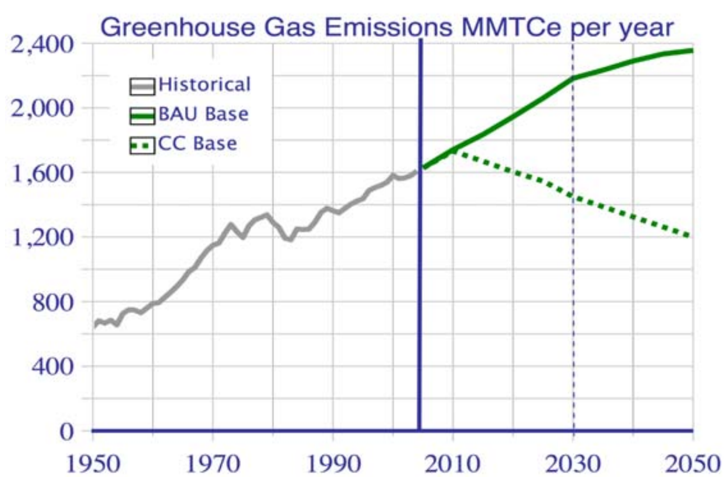
Dashed line represents world oil price under "High Fuel Price" (HFP) scenario. Solid line represents world oil price under "Business-As-Usual" (BAU) or AEO 2006 reference oil price case. NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050

Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/ EIA-0384 (2005) (Washington, D.C., July 2006) Table 5.21 Crude Oil Refiner Acquisition Costs, 1968-2005. (http:// www.eia.doe.gov/emeu/aer/contents.html)

Dashed line represents natural gas price under "High Fuel Price" (HFP) scenario. Solid line represents natural gas price under "Business-As-Usual" (BAU) or AEO 2006 reference oil price case. NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050 Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/ EIA-0384 (2005) (Washington, D.C., July 2006) Table 6.7 Natural Gas Wellhead, City Gate, and Imports Prices, 194 9-2005. (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.7. Historical and Projected Oil and Gas Prices Under Business-As-Usual and High Fuel Price Scenarios



Solid line represents energy-related CO2 emissions for the Business as Usual baseline (without EERE's portfolio). Dashed line represents allowed emissions of CO2 under a carbon cap policy. Note that EERE's portfolio has no effect on carbon emissions under a carbon cap since the allowable levels of CO2 are dictated by policy.

Historical data to 2004 from U.S. Department of Energy, Energy Information Administration. Emissions of Greenhouse Gas Emissions in the United States 2005. DOE/EIA-0573(2005) (Washington, D.C., July 2006) Table B3 Total Energy-Related Carbon Dioxide Emissions by End-Use Sector, and the Electric Power Sector, by Fuel Type, 1949-2004.Table available at http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.8. Carbon Emissions Under a Carbon Cap Policy

Figure 2.9 shows projected carbon allowance prices for the NEMS-GPRA08 and MARKAL-GPRA08 models. The two integrated energy models project very different carbon allowance prices. NEMS-GPRA08 projects a carbon allowance price in the base case that increases steadily through 2030 to about

$230 per metric ton in response to the increasingly more stringent carbon cap. The increase is less rapid in the EERE portfolio case relative to the base case, due to the development and market adoption of advanced technologies that provide opportunities for lower-cost energy efficiency or carbon-free generation. By 2030, the price increases to $165 per metric ton with the EERE portfolio.

MARKAL-GPRA08 shows a much more rapid price response to the carbon cap, with the carbon allowance price climbing to almost $250 per metric ton by 2020. Long-term allowance prices approach $300 per metric ton in the base case. The EERE portfolio reduces carbon prices significantly, eventually resulting in carbon prices that are $200 to $270 per metric ton lower than the base case—even dropping temporarily to zero in 2035.

The more aggressive response in MARKAL-GPRA08 is an example of the kinds of inherent differences in various models' structure and assumptions on consumer behavior that can lead to different extrapolations of the future. MARKAL-GPRA08 optimizes more aggressively for a future cost minimization of the energy system, resulting in more dramatic carbon price swings. In this case, MARKAL-GPRA08 achieves significant carbon savings in the transportation sector with the addition of the EERE portfolio technologies (particularly, new vehicle technologies, hydrogen fuel cells, and cellulosic ethanol), while NEMS-GPRA08 shows a much more modest response for the transportation sector.

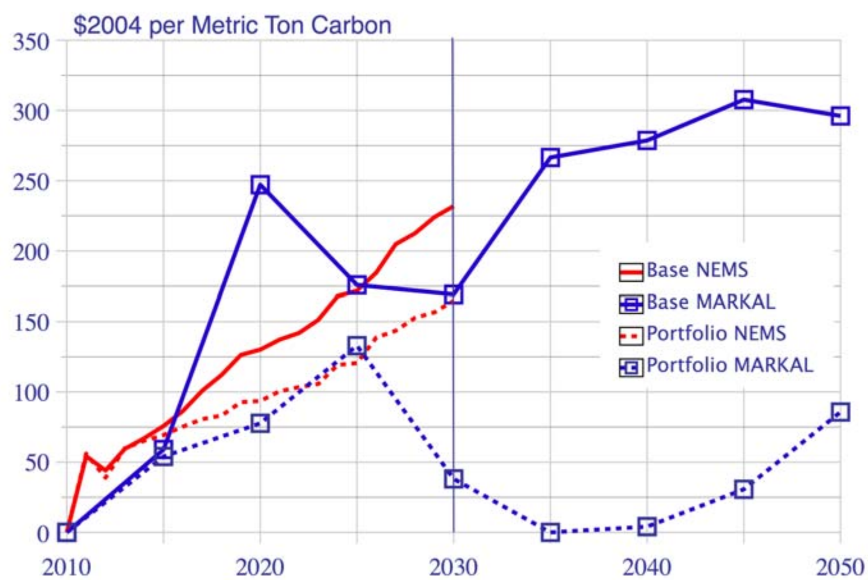


Figure 2.9. Carbon Allowance Price

Summary of Benefits Metrics Under Alternative Scenarios

Table 2.2 and **Table 2.3** summarize the benefits for EERE's RD3 portfolio under the High Fuels Price and Carbon Constraint scenarios. Subsequent sections discuss these findings in more detail.

Table 2.2. EERE Portfolio Benefits for FY 2008 Budget Request—High Fuel Price Scenario

	MIDTERM BENEFITS 7/					LONG-TERM BENEFITS 8/			
Metric	2010	2015	2020	2025	2030	2035	2040	2045	2050
ECONOMIC BENEFITS ("AFFORDABLE")									
Reduction in Average Delivered Natural Gas Price (Percent)	1%	4%	4%	8%	7%	14%	15%	22%	15%
Energy System Cost Savings (bil $2004) 1/	nr	nr	nr	nr	nr	258	303	325	341
Consumer Savings, Annual (bil $2004)	4.3	28	66	133	197	510	558	629	597
Consumer Savings, NPV (bil $2004) 2/	10	85	246	553	1012	2,681	3,758	4,794	5,703
Electric Power Industry Savings, Annual (bil $2004) 3/	2	9	14	21	25	99	103	97	73
Electric Power Industry Savings, NPV (bil $2004) 2/ 3/	5	28	68	123	185	532	735	907	1,031
Reduction in Fraction of Household Income Spent on Energy	0.21%	1.1%	2.9%	5.0%	6.7%	14%	15%	16%	14%
Reduced Energy Intensity of Economy (Percent)	0.42%	2.0%	3.8%	6.0%	7.4%	15%	18%	18%	16%
ENVIRONMENTAL BENEFITS ("CLEAN")									
Annual Avoided Greenhouse Gas Emissions (MMTCE/year)	9	46	101	148	192	606	693	597	459
Cumulative Avoided Greenhouse Gas Emissions (MMTCE) 5/	14	158	562	1,204	2,072	5,628	8,918	12,095	14,665
Reduced Cost of Criteria Pollutant Control, NPV (bil $2004) 2/	0.5	1.2	5.0	8.7	15	nr	nr	nr	nr
SECURITY BENEFITS ("RELIABLE")									
Avoided Oil Imports, Annual (mbpd)	ns	0.2	0.5	1.0	1.8	6.5	7.9	7.2	6.0
Avoided Oil imports, Cumulative (bil barrels) 4/ 5/	ns	0.2	0.8	2.2	4.8	18.5	32.0	45.7	57.5
Security Fuel Economy Improvement (MPG)	0.1	0.5	1.3	2.8	5.8	63	136	223	285
Transportation Fuel Diversity Improvement (Percent) 6/	ns	ns	6.2%	6.0%	16%	94%	91%	66%	48%
Reduced Oil Intensity (Percent)	ns	1.0%	2.8%	5.3%	9.5%	36%	43%	42%	39%

Table notes
1/ 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 financial and behavioral components.
2/ NPV (net present value) calculations done using 3% real discount rate back to 2008.
3/ Electric power industry cost does not include demand-side distributed generation.
4/ Renewable generation values at output value (3412 Btu/kWh) except for biomass and geothermal where energy content is used.
5/ All cumulative values are from 2008.
6/ Diversity index change is Case minus Base (opposite of others).
7/ Midterm benefits based on NEMS-GPRA08 model.
8/ Long-term benefits based on MARKAL-GPRA08 model.
nr = not reported or calculated by model

Table 2.3. EERE Portfolio Benefits for FY 2008 Budget Request—Carbon Constraint Scenario

	MIDTERM BENEFITS 7/					LONG-TERM BENEFITS 8/			
Metric	2010	2015	2020	2025	2030	2035	2040	2045	2050
ECONOMIC BENEFITS ("AFFORDABLE")									
Reduction in Average Delivered Natural Gas Price (Percent)	0%	1%	9%	11%	13%	40%	42%	35%	28%
Energy System Cost Savings (bil $2004) 1/	nr	nr	nr	nr	nr	177	221	247	271
Consumer Savings, Annual (bil $2004)	2.1	21	104	179	262	641	751	750	663
Consumer Savings, NPV (bil $2004) 2/	4.4	53	302	749	1,359	4,106	5,519	6,814	7,856
Electric Power Industry Savings, Annual (bil $2004) 3/	1.9	12	37	45	52	113	104	103	92
Electric Power Industry Savings, NPV (bil $2004) 2/ 3/	4.3	34	137	269	405	887	1103	1282	1425
Reduction in Fraction of Household Income Spent on Energy	0.17%	1.0%	3.8%	5.9%	8.2%	15%	16%	15%	12%
Reduced Energy Intensity of Economy (Percent)	0.20%	1.5%	2.6%	4.7%	8.0%	9.2%	13%	14%	14%
ENVIRONMENTAL BENEFITS ("CLEAN")									
Annual Avoided Greenhouse Gas Emissions (MMTCE/year)	ns	ns	ns	ns	ns	10	0	0	0
Cumulative Avoided Greenhouse Gas Emissions (MMTCE) 5/	ns	ns	ns	ns	ns	28	28	28	28
Reduced Cost of CO2 Allowances, (bil $2004)	0.0	11	59	80	97	nr	nr	nr	nr
Reduced Cost of CO2 Allowances, NPV (bil $2004) 2/	0.0	15	167	382	624	nr	nr	nr	nr
Reduced Cost of Criteria Pollutant Control, NPV (bil $2004) 2/	0.8	0	-1	-3	-4	nr	nr	nr	nr
SECURITY BENEFITS ("RELIABLE")									
Avoided Oil Imports, Annual (mbpd)	ns	0.18	0.55	1.1	1.7	7.6	8.9	8.8	7.9
Avoided Oil imports, Cumulative (bil barrels) 4/ 5/	ns	0.17	0.85	2.4	5.0	24	40	56	71
Security Fuel Economy Improvement (MPG)	0.1	0.5	1.4	2.7	4.9	41	71	106	128
Transportation Fuel Diversity Improvement (Percent) 6/	ns	ns	10%	14%	23%	191%	184%	139%	111%
Reduced Oil Intensity (Percent)	ns	0.9%	2.7%	5.3%	7.7%	35%	40%	41%	39%

Table notes
1/ 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 financial and behavioral components.
2/ NPV (net present value) calculations done using 3% real discount rate back to 2008.
3/ Electric power industry cost does not include demand-side distributed generation.
4/ Renewable generation values at output value (3412 Btu/kWh) except for biomass and geothermal where energy content is used.
5/ All cumulative values are from 2008.
6/ Diversity index change is Case minus Base (opposite of others).
7/ Midterm benefits based on NEMS-GPRA08 model.
8/ Long-term benefits based on MARKAL-GPRA08 model.
nr = not reported or calculated by model

Economic Benefits Under Alternative Scenarios

Consumer savings due to EERE's portfolio are significantly greater under the two alternative scenarios of High Fuel Prices (HFP) and Carbon Constraints (CC) than they are under the Business-As-Usual (BAU) case, as shown in **Figure 2.10**. For the High Fuel Price (HFP) scenario, annual consumer savings by 2030 are roughly double those projected under the BAU scenario. For the Carbon Constraint (CC) scenario, annual consumer savings by 2030 are 2.3 times higher than those projected under the BAU scenario. Annual consumer savings in 2030 climb to $200 billion and $260 billion, respectively, under the HFP and CC scenarios. The cumulative savings to the consumer over the period of 2008 to 2030 are $1.1 trillion and $1.4 trillion, respectively, for the HFP and CC scenarios.

In 2050, consumer savings under the HFP scenario reach $600 billion annually, 1.6 times greater than under the BAU scenario. In the carbon-constrained scenario, annual consumer savings reach $670 billion in 2050. Cumulative savings to consumers under the HFP and CC scenarios are about $6 and $8 trillion, respectively, by 2050.

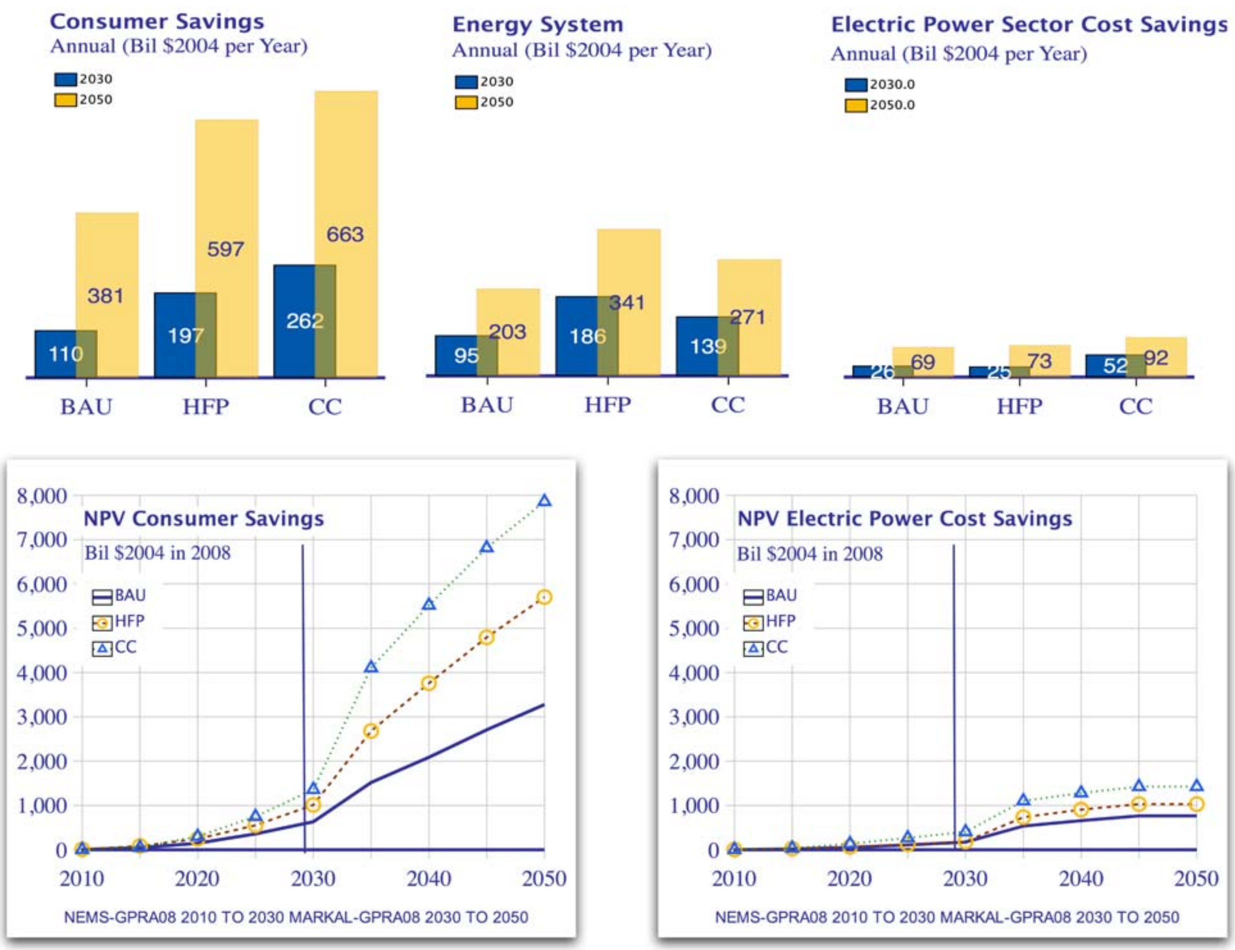


Figure 2.10. Consumer, Energy System, and Electric Power-Sector Cost Savings Under Alternative Scenarios

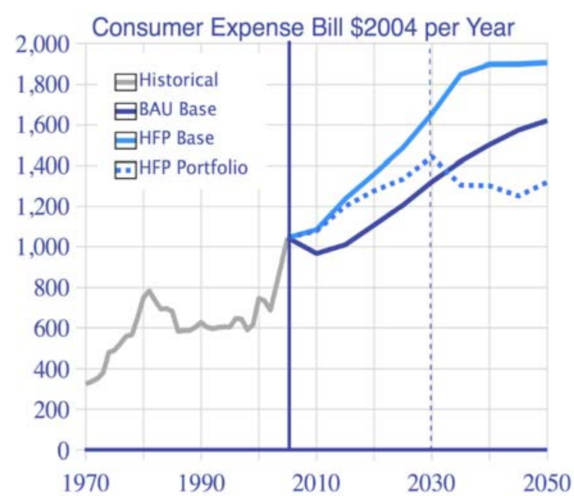
As noted in the discussion of the BAU scenario results, the estimated economic benefits of EERE's portfolio decreases as more producer-side economic impacts are considered in the calculation of savings. Thus, consumer savings are greater than estimated energy system savings, which are, in turn, greater than the producer-side cost savings seen in the electric power sector. Cost savings in the electric power sector vary significantly between the high fuel price (HFP) and the carbon constraint (CC) scenarios. Under the HFP scenario, EERE's portfolio generates relatively small additional savings over the BAU scenario. By 2025, the HFP and CC scenarios are essentially identical. This is due, in part, to the fact that the electric power sector can turn to coal as a cost-effective alternative to the high-priced oil and gas markets—making this sector less vulnerable to oil and gas prices.

The carbon constraint scenario has significant impacts on cost to the electric power sector, making EERE's renewable energy technologies more valuable. As a result, savings to the electric power sector, due to EERE's portfolio, are nearly double the savings projected under the BAU scenario in 2030. Annual savings in the electric power sector increase to almost $50 billion per year in 2030 under the carbon constraint scenario, compared to a little more than $25 billion per year under the BAU scenario. In 2050, annual electric power savings are $92 billion per year, as compared to $70 billion per year in the BAU scenario.

Historical and projected consumer spending on energy under each of the alternative scenarios is shown in **Figure 2.11**. Both base cases under the HFP and CC scenarios show significantly higher spending for energy by consumers—in both scenarios, around $300 billion per year higher in 2030 than the BAU baseline. By 2050, base case spending by consumers is $600 and $700 billion per year higher, respectively, under the HFP and CC scenarios, compared to the BAU scenario.

In the case of the HFP scenario, higher spending is directly related to higher fuel prices. In the CC scenario, higher spending is due to the added cost of carbon emissions associated with fossil fuels. A corollary to the higher cost of conventional fossil fuels under these scenarios is that the fossil fuel savings associated with EERE's portfolio is worth more, resulting in greater economic benefits to consumers and producers.

High Fuel Price Scenario

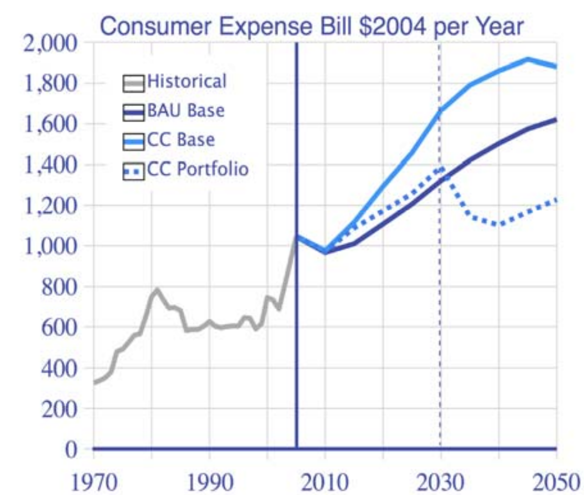


Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

HFP = High Fuel Price Scenario
BAU = Business-As-Usual

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 3.5 Consumer Expenditure Estimates for Energy by Source, 1970-2002 (http://www.eia.doe.gov/emeu/aer/contents.html)

Carbon Constraint Scenario



Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

CC = Carbon Constraint Scenario
BAU = Business-As-Usual

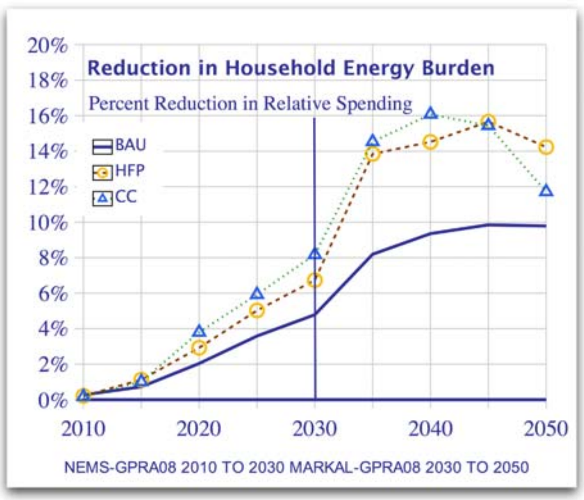
NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 3.5 Consumer Expenditure Estimates for Energy by Source, 1970-2002 (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.11. Consumer Spending for Energy Under Alternative Scenarios

The EERE portfolio eliminates 65% of the increased annual energy cost to consumers in 2030 associated with the high fuel price baseline case. In 2050, the EERE portfolio actually reduces consumer spending on energy under the HFP scenario by $300 billion per year relative to the BAU baseline. The portfolio is even more effective under the carbon constraint scenario. It eliminates 80% of the added cost to consumers in 2030 associated with the carbon constraint baseline case. In 2050, the EERE portfolio reduces consumer spending on energy by $400 billion per year, compared to the baseline case under the BAU scenario. Note that the discontinuity in projected spending trends between NEMS-GPRA08 and MARKAL-GPRA08 is more pronounced in the carbon constraint, due to the significant differences in how each model handles carbon pricing under the carbon constraint.

EERE's portfolio also reduces the impact of high fuel prices and a carbon constraint on household energy spending (see **Figure 2.10**). By 2030, relative spending of household income drops 7% and 8%, respectively, in the HFP and CC scenarios—compared to a 5% reduction in the BAU scenario. EERE's portfolio has its peak impact on household spending for energy at about 2040 to 2045 in the HFP and CC scenarios, with reductions of about 16%, compared to reductions in the BAU scenario that level off at 10%.

These results demonstrate an important element of the value of Federal funding of energy efficiency and renewable energy. Government support of high-risk technology development aimed at addressing important issues that have the potential to cause harm to society and the economy is a strategy that mitigates—in this case—possible economic hardships brought on by circumstances such as unanticipated growth in fuel prices or the need for strong measures to reduce carbon emissions.



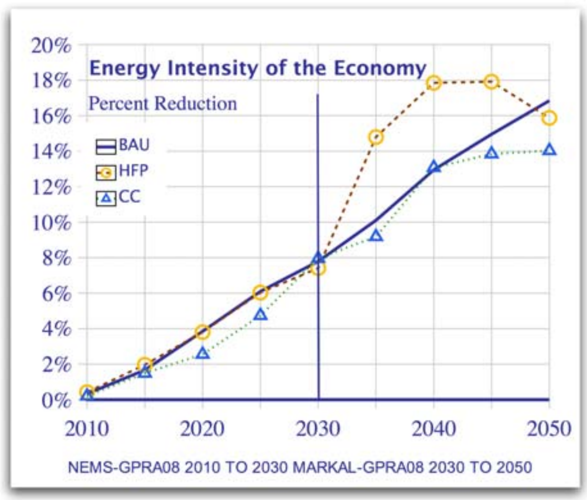
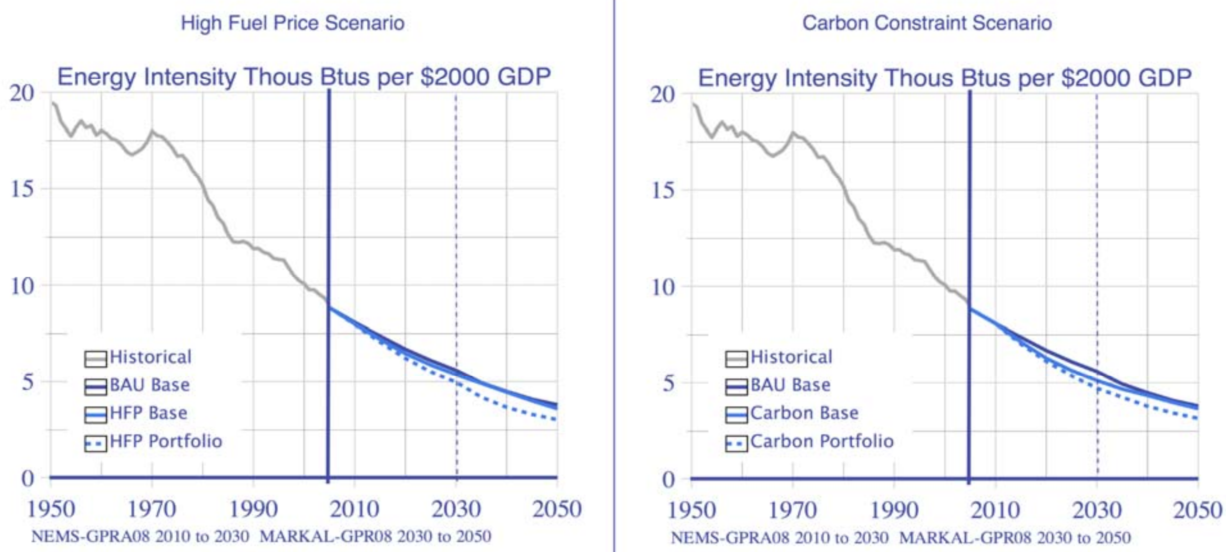


Figure 2.12. Reduction in Household Spending and Energy Intensity Under Alternative Scenarios

As **Figure 2.12** shows, energy intensity of the economy sees a reduction in all scenarios due to the introduction of technologies promoted or developed by EERE under all three scenarios (BAU, HFP, and CC). In the midterm (2010 through 2030), EERE's portfolio has slightly less impact on energy intensity under the alternative scenarios than it does under the BAU scenario. EERE's portfolio seems to peak in its impact on energy intensity around 2040 to 2045, with somewhat higher impacts seen for the HFP scenario.

Figure 2.13 shows historical and projected trends for energy intensity under all three scenarios. Long-term trends for energy intensity are only slightly impacted by changing scenarios. Energy intensity trends under the HFP Base case are almost identical to the BAU base case; while the carbon constraint base case shows somewhat lower energy intensity than the BAU scenario through 2030. The combined effect of higher fuel prices and EERE's portfolio reduces energy intensity by 11% and 20% in 2030 and 2050, respectively, compared to the BAU baseline. The combined effect of a carbon cap and EERE's portfolio reduces energy intensity by 16% compared to the BAU baseline in the midterm (2030) and long-term (2050) time frames.



Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

HFP = High Fuel Price Scenario
BAU - Business-As-Usual Scenario

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949-2005 . (http://www.eia.doe.gov/emeu/aer/contents.html)

Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

CC = Carbon Constraint Scenario
BAU = Business-As-Usual Scenario

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949-2005 . (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.13. Energy Intensity Trends Under Alternative Scenarios

Environmental Benefits of EERE's Portfolio Under Alternative Scenarios

Figure 2.14 summarizes environmental benefits of EERE's portfolio under all of the scenarios. In the midterm, carbon emission savings under the High Fuel Price scenario and under the Business-As-Usual scenario are comparable.

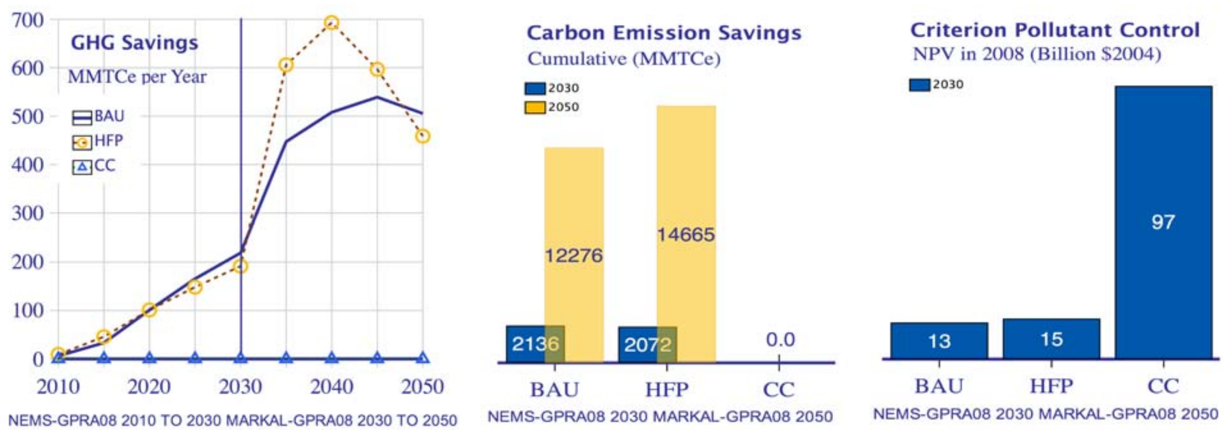


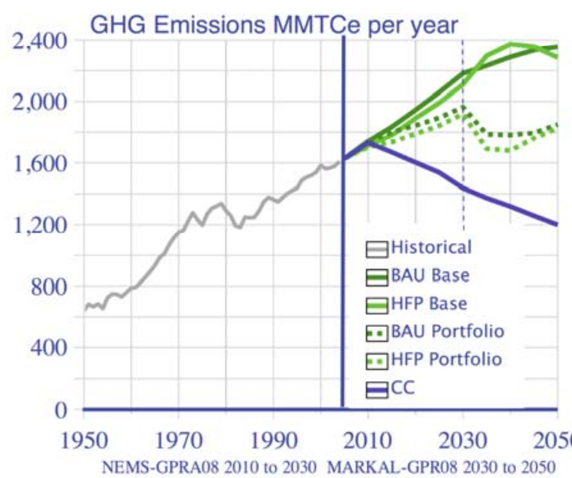
Figure 2.14. Environmental Benefits Under Alternative Scenarios

After 2020, carbon savings under the HFP are somewhat lower than under the BAU, because the electric power sector shifts more to coal use as oil and gas prices increase. GHG savings reach 180 MMTCe per year in 2030 under the HFP scenario, compared with 230 MMTCe per year under the BAU scenario. Cumulative carbon savings in 2030 are roughly the same in both scenarios—more than 2,000 MMTCe.

Long-term projections from MARKAL-GPRA08 show a peak in carbon emission savings of 700 MMTCe per year under the HFP scenario in 2040 that is significantly higher than savings under the BAU scenario. By 2050, savings due to EERE's portfolio under the HFP scenario are similar to the savings expected for the BAU scenario.

Carbon savings for the carbon constraint scenario are zero because—with or without EERE's portfolio—the carbon cap mandates the same level of carbon emission reductions.

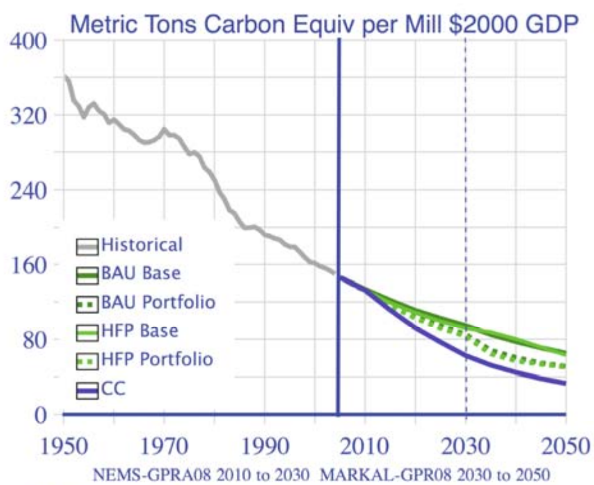
Historical and projected annual carbon emissions and carbon intensity under the BAU and HFP scenarios are shown in **Figure 2.15.** Base carbon emissions and carbon intensity are very similar under both scenarios. Likewise, the EERE portfolio cases achieve similar reductions in annual carbon emissions and carbon intensity. The carbon constraint scenario results in reductions of annual carbon emissions and carbon intensity that are twice as great as those achieved by the portfolio under either the BAU or HFP scenario.



Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

HFP = High Fuel Price Scenario
BAU = Business-As-Usual Scenario
CC = Carbon Constraint Scenario

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical data to 2004 from U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gas Emissions in the United States 2005.* DOE/EIA-0573(2005) (Washington, D.C., July 2006) Table B3 Total Energy-Related Carbon Dioxide Emissions by End-Use Sector, and the Electric Power Sector, by Fuel Type, 1949-2004.Table available at http://www.eia.doe.gov/emeu/aer/contents.html)



Solid line represents historical and projected trend without future funding of the EERE portfolo. Dashed line represents projected trend assuming continued funding of the EERE portfolio.

HFP = High Fuel Price Scenario
BAU = Business-As-Usual Scenario
CC = Carbon Constraint Scenario

NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050
Historical carbon emissions data to 2004 from U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gas Emissions in the United States 2005.* DOE/EIA-0573(2005) (Washington, D.C., November 2006) Table B3 Total Energy-Related Carbon Dioxide Emissions by End-Use Sector, and the Electric Power Sector, by Fuel Type, 1949-2004.Table available at http://www.eia.doe.gov/emeu/aer/contents.html). Historical GDP data from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005), (Washington, D.C., July 2006). Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949-2005 . (http://www.eia.doe.gov/emeu/aer/contents.html)

Figure 2.15. Carbon Emissions and Carbon Intensity Trends Under Alternative Scenarios

Reduced cost of air pollution control due to EERE's portfolio in the HFP and BAU scenarios are similar (see **Figure 2.14**). In 2030, reduced air pollution control costs $13 billion and $15 billion per year, respectively, for the HFP and BAU cases. Under the carbon constraint case, air pollution cost savings jump to almost $100 billion per year due to the inclusion of carbon allowance prices along with NO_x, SO_x, and mercury allowance prices.

Security Benefits Under Alternative Scenarios

Avoided oil imports due to EERE's portfolio are substantial under all scenarios (see **Figure 2.16**).

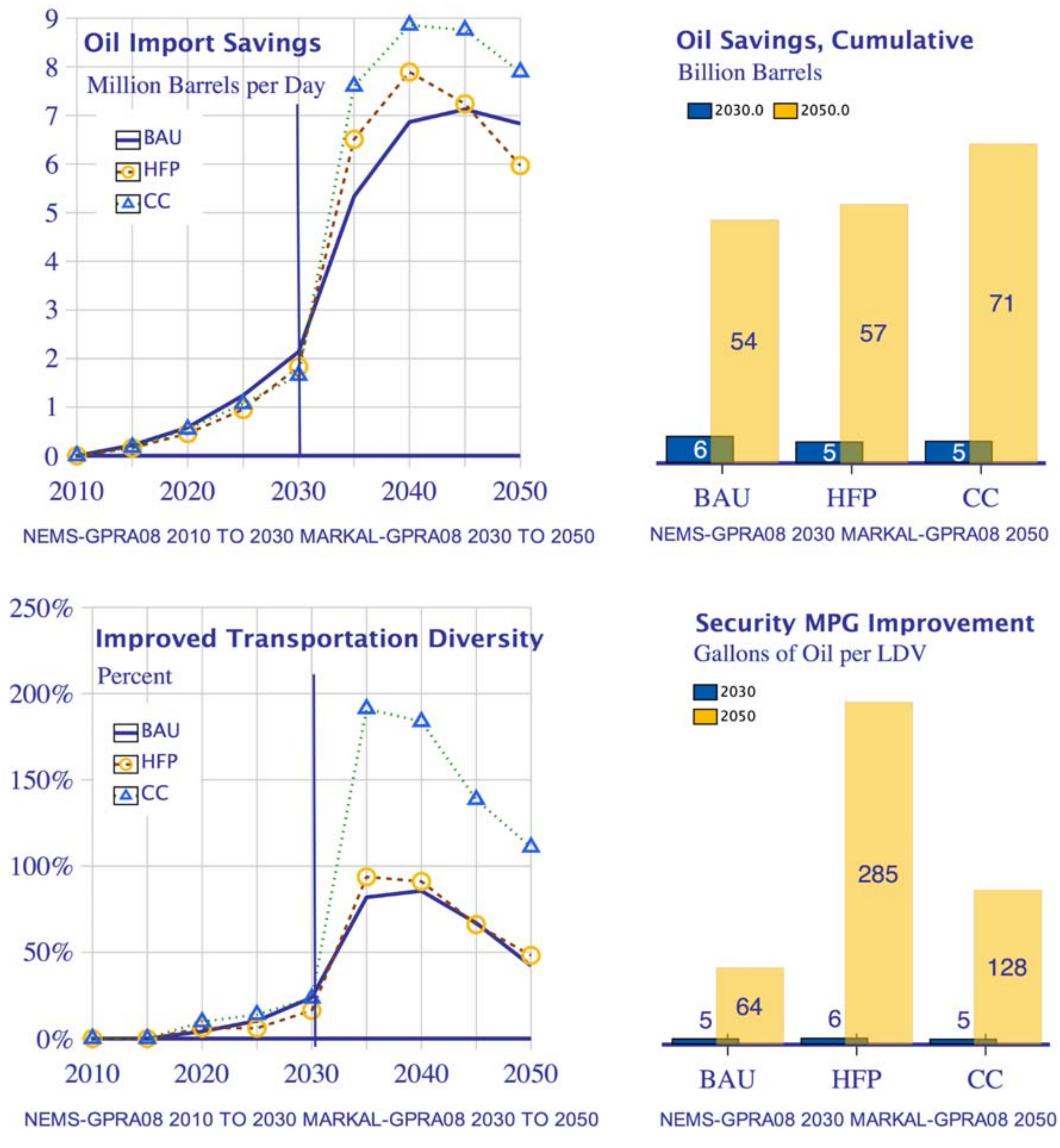
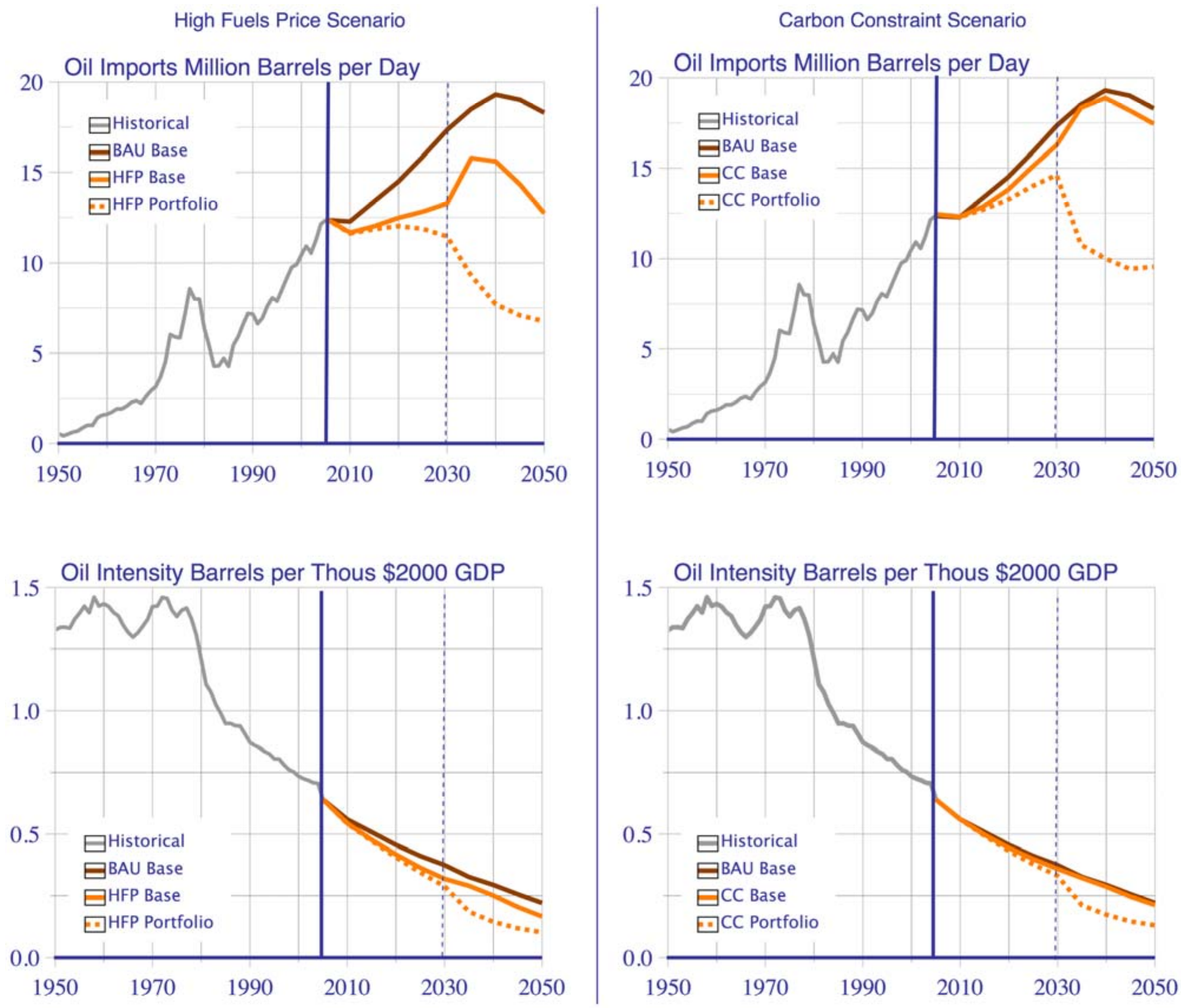


Figure 2.16. Security Benefits Under Alternative Scenarios

However, in both the HFP and the CC scenarios, the midterm impact of EERE's portfolio is somewhat less than under the BAU scenario. In 2030, EERE portfolio leads to oil import reductions of 1.8 and 1.7 million barrels per day, respectively, for the HFP and CC scenarios, compared to 2.1 mbpd under BAU conditions. Cumulative oil savings under both alternative scenarios are 5 billion barrels of oil, compared to 6 billion barrels for the BAU scenario.

In the long term (2030 through 2050), the HFP and CC scenarios see a peak in EERE's impact that occurs sooner than in the BAU scenario, reaching savings of 8 and 9 mbpd, respectively, in the HFP and CC scenarios.

Historical and projected oil import trends under all three scenarios (BAU, HFP, and CC) are shown in **Figure 2.17.**



Solid line represents historical and projected trend without future funding of the EERE portfolio. Dashed line represents projected trend assuming continued funding of the EERE portfolio. NEMS-GPRA08 2010 to 2030 MARKAL-GPRA08 2035 to 2050

Historical data to 2005 from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.5 Energy Consumption, Expenditures, and Emissions Indicators, 1949-2005 and Table 5.1 Petroleum Overview, 1949-2005 (http://www.eia.doe.gov/emeu/aer/contents.html)

HFP = High Fuel Price Scenario

CC = Carbon Constraint Scenario

BAU = Business-As-Usual Scenario

Figure 2.17. Oil Import and Oil Intensity Trends Under Alternative Scenarios

The NEMS-GPRA08 model projects a HFP baseline that has 4 million barrels per day lower import levels compared to the BAU Baseline by 2030—a 26% reduction. The combination of high oil prices and the impact of EERE's portfolio reduces projected 2030 import levels by more than 6 million barrels per day—a 34% reduction.

As the trends in **Figure 2.17** suggest, some of the differences in the midterm (2030) and long-term (2050) impacts are due to differences in the models used. In the case of oil imports, baseline imports under high fuel prices do not decline as rapidly in the MARKAL-GPRA08 projections as they do in the NEMS-GPRA08 projections. Oil imports in the EERE portfolio case under the HFP scenario, on the other hand, decline more dramatically in the MARKAL-GPRA08 projections than they do in the midterm NEMS-GPRA08 projections. By 2050, the combination of high oil prices and EERE's portfolio bring oil imports down to 7 mbpd—a level not seen in the United States since the late 1980s. This represents a reduction of 11 mbpd in oil imports over the projected baseline level in 2050—or 63%.

A carbon constraint scenario has less—but still significant—impact on oil imports. The CC baseline shows lower import levels (1 million barrels per day) compared to the BAU baseline by 2030—a 6% reduction. The combination of a carbon constraint and the impact of EERE's portfolio reduces projected 2030 import levels by 3 million barrels per day—a 16% reduction. The dramatic drop in oil imports from 2030 to 2035 reflects the more aggressive impacts of EERE's portfolio projected by MARKAL-GPRA08. The combined effect of a carbon constraint and EERE's portfolio reduces oil imports to 9.6 mbpd in 2050.

Energy security in the transportation sector improves in all scenarios, as measured by security MPG and transportation fuel diversity (see **Figure 2.16**). In the midterm (2010 through 2030), the effect of EERE's portfolio is essentially the same across all scenarios. In all three scenarios, the effect of EERE's portfolio is to improve fuel diversity in light-duty vehicles by about 25% relative to the base cases in each scenario. In the long term, EERE's portfolio has a much greater impact on transportation diversity under the carbon constraint scenario than it does under the BAU or HFP scenarios. Fuel diversity is improved by almost 200% under the HFP in the 2035 to 2040 time frame. Security MPG, meanwhile, is impacted much more by EERE's portfolio under the HFP scenario than it is under the BAU and CC scenarios. By 2050, security fuel economy increases by 285 miles of travel per gallon of crude oil consumed by light-duty vehicles under the HFP scenario, compared to 128 miles per gallon and 64 miles per gallon under the CC and BAU scenarios, respectively.

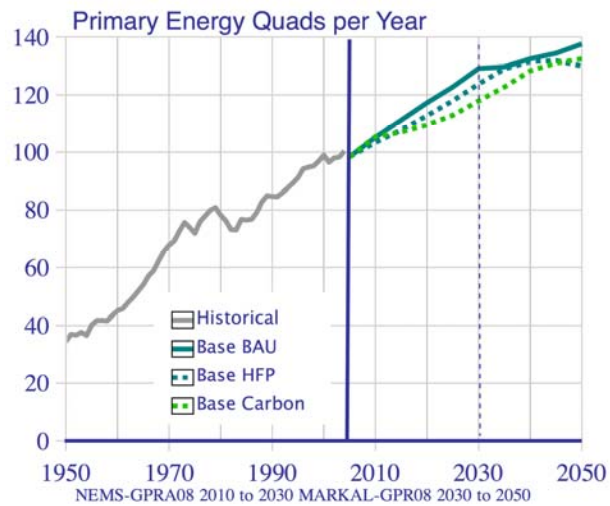
A Closer Look at the Energy Picture

Changes in Primary Energy Demand Under Alternative Scenarios

One of the key determinants of how the benefits change under the alternative scenarios is the shift in the baseline projections, given that benefits are defined as the difference between the baseline and the portfolio cases. Higher prices—seen in both the HFP and CC scenarios—shrink the demand for energy. This is due, in part, to lower demand for energy services as a result of slightly lower incomes and economic output, and behavioral responses to higher prices such as turning down thermostats and driving less. Higher energy prices also stimulate greater investment in energy efficient and renewable technologies, even in the absence of technology improvements resulting from the EERE RD3 programs.

The impacts of the alternative scenarios for high fuel prices and carbon constraints on baseline primary energy demand are shown in **Figure 2.18**. High fuel prices reduce primary energy demand by 4% in 2030—from 129 to 124 quadrillion Btus per year. The carbon constraint scenario has the strongest effect, reducing demand for primary energy by 9% in 2030—from 129 to 118 quadrillion Btus per year. By 2045, primary energy demand under the HFP and CC scenario baselines plateaus at the 2040 level of energy demand projected for the Business-as-Usual scenario baseline.

The imposition of the carbon cap has a profound impact on the energy system. Carbon emission reductions are achieved through a combination of energy service demand reductions, increased efficiency, and fuel switching to less carbon-intensive energy sources. In meeting the carbon cap, energy consumption falls in the Baseline below the level in the BAU EERE Portfolio case.



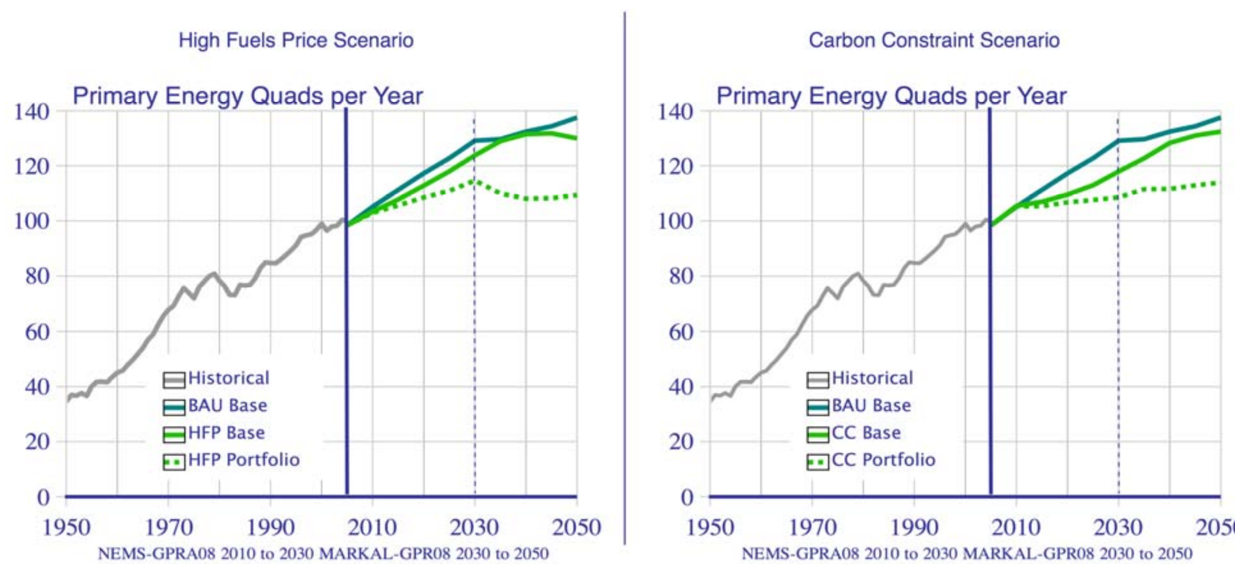
Solid lines represents total primary energy consumption (both renewable and nonrenewable) under the Business-As-Usual scenario. The dashed lines represent primary energy consumption under alternative future scenarios.

HFP = High Fuel Price Scenario
BAU = Business-As-Usual Scenario
CC = Carbon Constraint Scenario

Historical data (1949 to 2005) on primary energy use from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.1 Energy Overview, 1949-2005 (http://www.eia.doe.gov/emeu/aer/contents.html).

Figure 2.18. Primary Energy Consumption Baselines Under Alternative Scenarios

The combined effect of the alternative scenarios and EERE's portfolio leads to even greater reductions in primary energy consumption (see **Figure 2.19**).



Solid lines represents total primary energy consumption (both renewable and nonrenewable) under the baseline cases (without EERE's portfolio) scenario. The dashed lines represent primary energy consumption under alternative future scenarios. Historical data (1949 to 2005) on primary energy use from U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2005* DOE/EIA-0384 (2005) (Washington, D.C., July 2006) Table 1.1 Energy Overview, 1949-2005 (http://www.eia.doe.gov/emeu/aer/contents.html).

HFP = High Fuel Price Scenario
CC = Carbon Constraint Scenario
BAU = Business-As-Usual Scenario

Figure 2.19. Effect of EERE's Portfolio on Primary Energy Consumption Under Alternative Scenarios

By 2030, the EERE portfolio under the HFP scenario reduces primary energy consumption by 11% compared to the BAU baseline case—reducing primary energy consumption from 129 quadrillion Btus per year under the BAU baseline to 115 quadrillion Btus per year under the HFP portfolio case. The EERE portfolio under the carbon constraint scenario results in primary energy consumption that is 16% lower than the BAU baseline case in 2030—reducing primary energy consumption from 129 quadrillion Btus per year under the BAU baseline to 109 quadrillion Btus per year under the CC portfolio case. By 2050, the combined effect of high fuel prices and EERE's portfolio reduces primary energy consumption from 138 to 109 quadrillion Btus per year—a 21% reduction. The combined effect of the carbon cap and EERE's portfolio reduces primary energy consumption to 114 quadrillion Btus per year in 2050—a 17% reduction over BAU baseline of 138 quadrillion Btus per year.

The relative growth of energy demand within each of the four sectors of the U.S. energy market (transportation, residential, commercial, and industrial) is shown for two time frames—midterm (2010 to 2030) and long term (2030 to 2050)—in **Figure 2.20** and **Figure 2.21**, respectively. High fuel prices have the greatest effect, in the midterm, on transportation—reducing baseline growth in the transportation sector by about one-third and by about 20% each in the three remaining sectors. The carbon cap puts much more downward pressure on industrial- and residential-sector baseline consumption, where each sees 54% and 37% less growth in 2030. These scenario-driven reductions effectively reduce the opportunity for EERE's portfolio to impact each sector. This helps to explain why NEMS-GPRA08 shows lower oil import and carbon emission benefits in the HFP and CC scenarios, compared to the BAU scenario (see **Figure 2.14** and **Figure 2.15**).

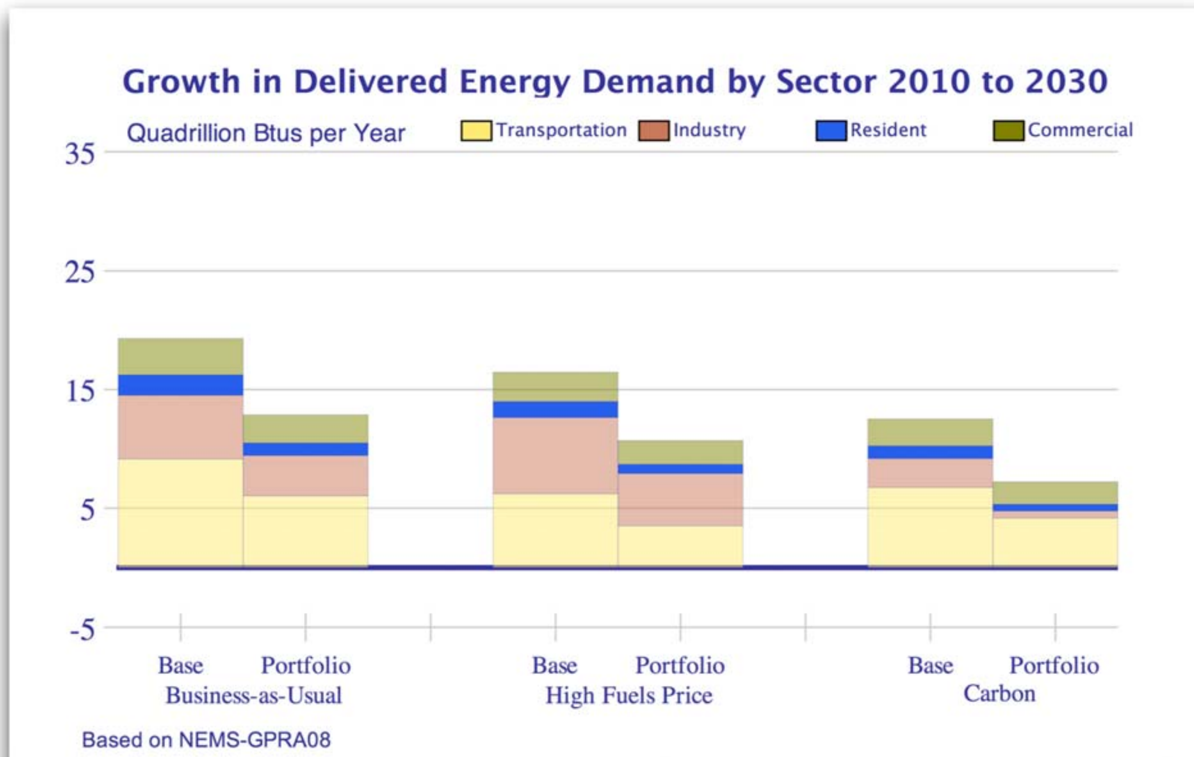


Figure 2.20. Shifts in Midterm Energy Growth by Sector Under Alternative Scenarios

The long-term picture of energy growth is shown in **Figure 2.21**. Energy growth still declines in the HFP and CC scenarios relative to the BAU scenario. In 2050, vehicle technologies have a much larger impact on energy demand overall—and on the transportation sector, in particular—in all three scenarios. Under the BAU, EERE's portfolio eliminates new growth in energy demand for the transportation sector. Under the HFP and CC scenarios, energy demand in transportation actually shrinks from 2010 to 2050.

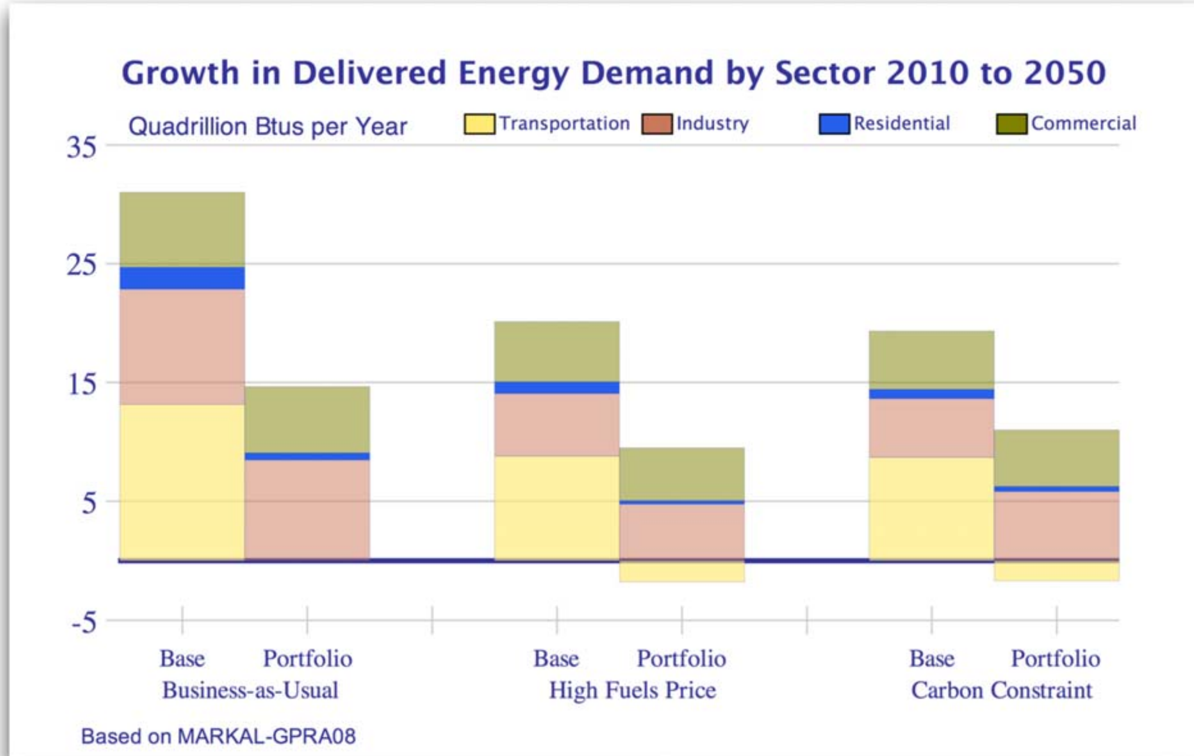


Figure 2.21. Shifts in Long-Term Energy Growth by Sector Under Alternative Scenarios

Growth in energy demand for the buildings sector is shown **Figure 2.22**. Energy growth under the alternative scenarios declines around 20% in the midterm and 25% in the long term. Relative energy savings in the buildings sector due to EERE's portfolio is somewhat lower under the alternative scenarios, compared to the BAU scenario.

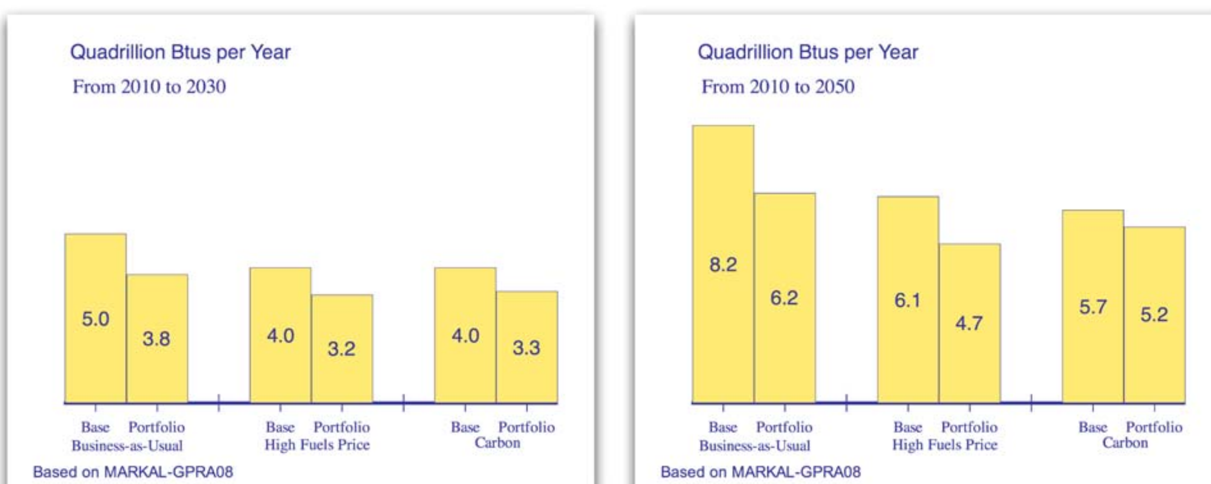


Figure 2.22. Growth in Building-Sector Energy Demand Under Alternative Scenarios

Transforming the Electric Utility Sector

Midterm shifts in electric generation capacity (based on NEMS-GPRA08) are shown in **Figure 2.23**. Baseline generation capacity in 2030 shifts away from natural gas-oriented technology (items in shades of blue in **Figure 2.23**) under the high fuels price scenario, and moves toward coal-oriented technologies (steam coal and coal-based integrated gasification combined cycle – IGCC). Renewable power generation also sees a modest increase in the HFP baseline. Under the carbon constraint scenario, baseline coal power generation capacity declines substantially, while low- and no-carbon renewable power generation and nuclear power generation capacity both grow substantially.

The EERE portfolio cases in the alternative scenarios lead to increased displacement of fossil fuel technology with renewable power generation technology, especially under the carbon constraint case, in which nearly 500 gigawatts of the 1,300 gigawatts of total installed capacity in 2030 is renewable energy-based. Note that the relative impact of the EERE portfolio on growth in renewable power generation capacity is less for the HFP and CC scenarios, because of the larger baseline levels of renewable power generation capacity that occur in these scenarios.

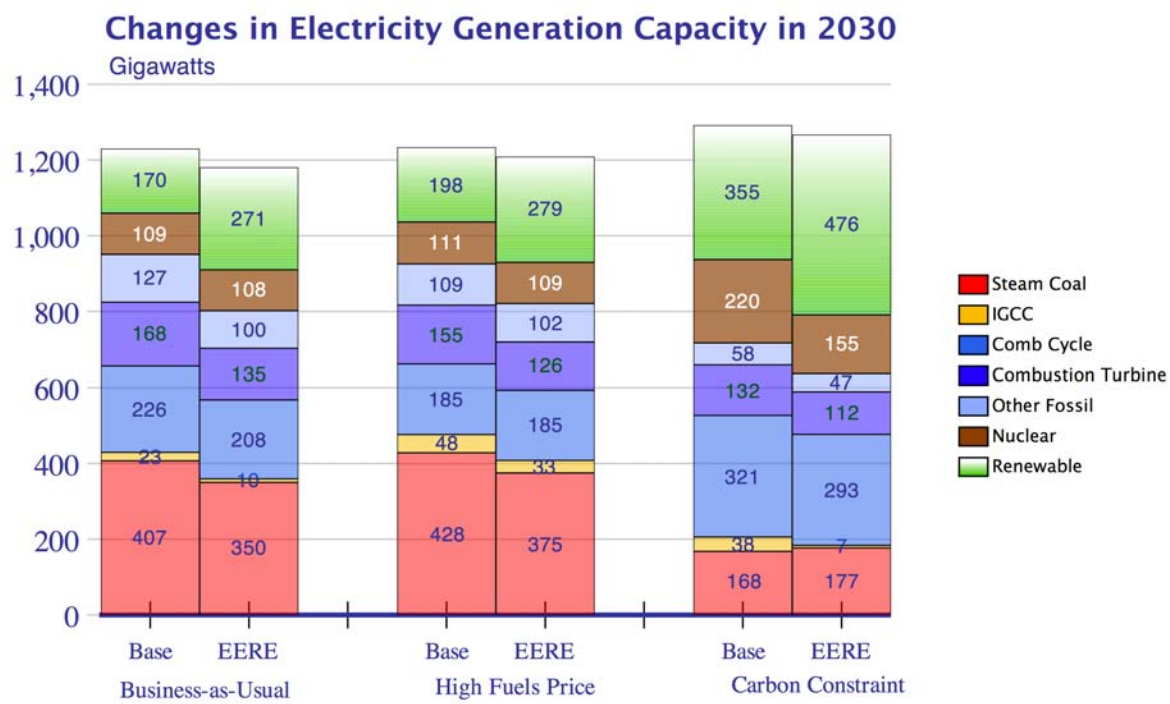


Figure 2.23. Electricity Generation Capacity in 2030 Under Alternative Scenarios

Figure 2.24 shows the relative distribution of electric power-generation capacity from 2010 to 2050 as estimated by MARKAL-GPRA08 for baseline and EERE portfolio cases under the three BAU, HFP, and CC scenarios. An inspection of distribution patterns from top to bottom in the left-hand column shows how trends in technology distribution change for the baselines as a function of scenario. The BAU baseline shows coal technologies maintaining a solid 40% of the capacity through 2050. In 2025, IGCC technology begins to displace traditional steam coal technology, growing to 50% of the total coal capacity in 2050. Natural gas technologies maintain a similarly high fraction (roughly 40%) of the total generating capacity throughout this time period. In the BAU baseline, nuclear power's share of the capacity gradually disappears. Renewable energy shows modest growth, from 11% of the total generating capacity in 1010 to 18% by 2050.

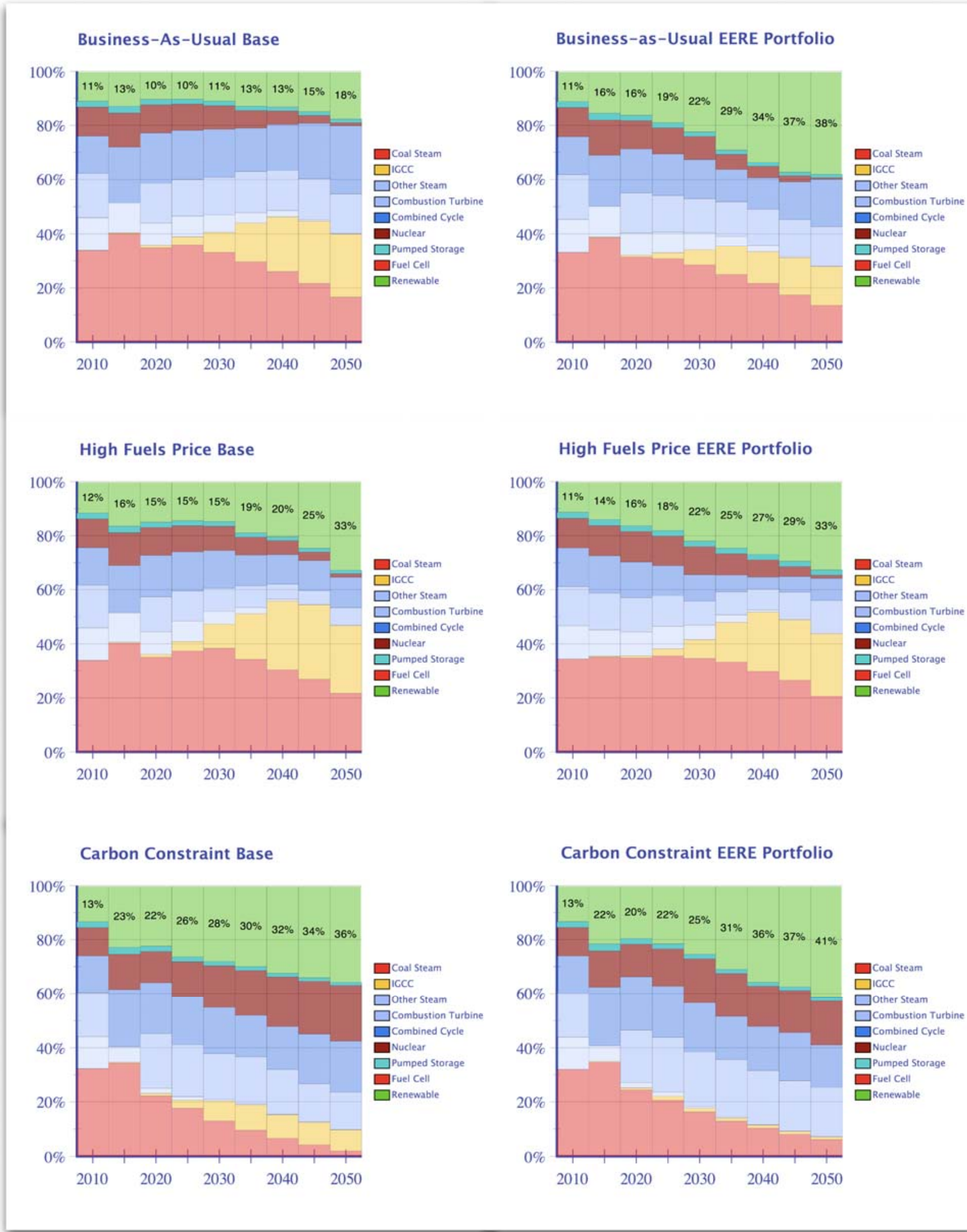


Figure 2.24. Changes in Electricity Generation Capacity Distribution Under Alternative Scenarios

High fuel prices cause a significant shift away from natural gas technologies in the base case (see the middle chart in the left column). Much of the decline in natural gas-generating capacity is made up by growth in renewable energy technologies, which represents one-third of the total capacity by 2050. Coal's share of the total generating capacity also grows under the high fuels price base case to a level of about 50% in 2050, because coal prices remain relatively low under this scenario. Under the carbon-constrained scenario, the baseline share of coal technology declines steadily, with traditional steam coal technology almost completely displaced by 2050.

The portfolio cases (charts on the right-hand side of **Figure 2.24**) vary significantly across the scenarios. EERE's renewable energy technologies have their greatest impact in the BAU scenario. The portfolio case sees nearly a doubling in the relative contribution of renewable power generation capacity over the baseline—18% versus 38% of total capacity in 2050. In the HFP and CC scenarios, the portfolio does not significantly increase renewable power generation capacity. Nevertheless, there are some impacts worth noting. In the HFP, renewable energy technology builds up earlier in the portfolio case than it does in the BAU scenario. In the carbon cap scenario, renewable energy technology seems to push out coal-based IGCC technology.

While EERE's portfolio does not necessarily influence the relative contribution of renewable energy technology capacity in the electric power sector under the HFP and CC scenarios, it does—in all scenarios—lead to significantly greater total generation of renewable electricity.[7] In 2030, the greatest amount of renewable generation occurs in the EERE portfolio case under a carbon constraint scenario (see **Figure 2.25**).

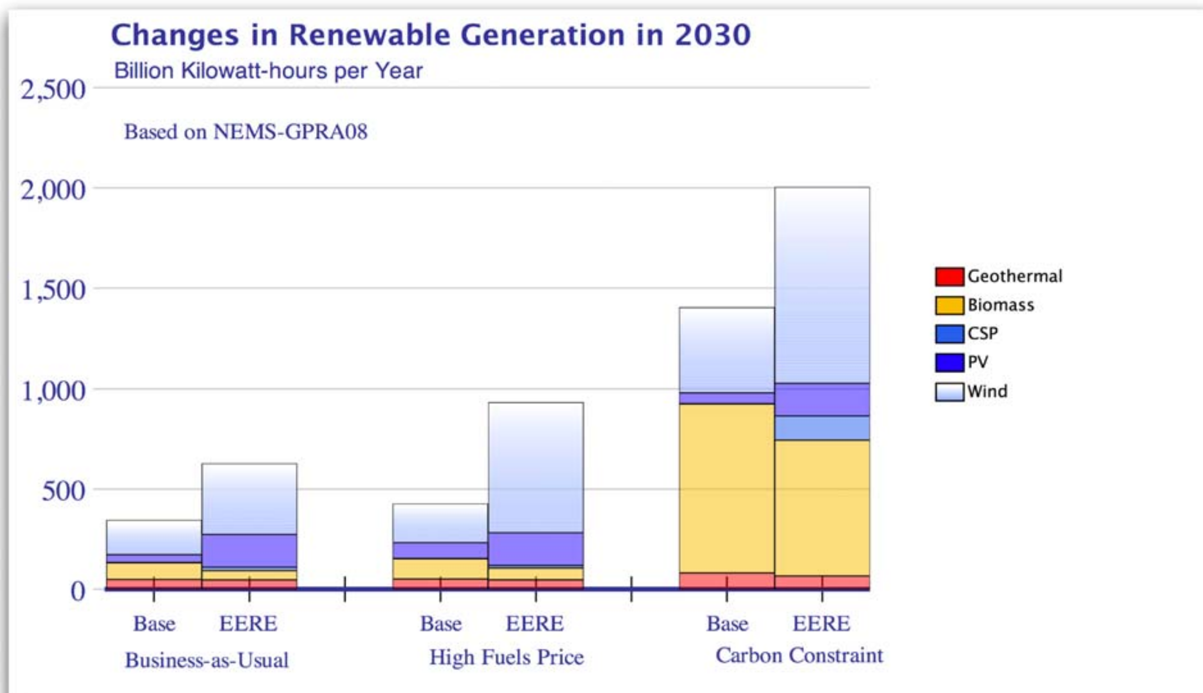


Figure 2.25. Total Renewable Electricity Generation in 2030

EERE's portfolio results in an increase from 1,300 billion to 2,000 billion kilowatt-hours per year of total generation under the carbon scenario (a 50% increase). In both the BAU and HFP scenarios, the effect of EERE's portfolio is a doubling of total renewable electricity generation—300 billion to 600 billion

[7] Note that we are referring to actual generation of electricity from renewables, not capacity for renewable generation. This is an important distinction, particularly for intermittent power sources such as wind and solar, which have lower capacity factors.

kilowatt-hours under the BAU scenario and 400 billion to 900 billion kilowatt-hours in the HFP scenario. Most of the EERE portfolio-related growth is from wind generation, which dominates both the BAU and HFP scenarios. In the carbon constraint scenario, biomass power really comes into its own, representing almost half of the renewable electricity generation in the EERE portfolio case.

In 2050, the greatest growth in renewable electricity generation occurs in the EERE portfolio case under the high fuels price scenario—reaching 2,400 billion kilowatt-hours per year. The technologies that come into play are significantly different in this time frame. By this time, solar truly comes into its own. Eighty percent of the renewable electricity generated in this case comes from equal shares of wind and solar PV. In all three scenarios, EERE's portfolio dramatically expands the contribution of wind. Under the BAU scenario, EERE's portfolio more than doubles solar's contribution, and has more modest impacts on solar generation under the HFP and CC scenarios.

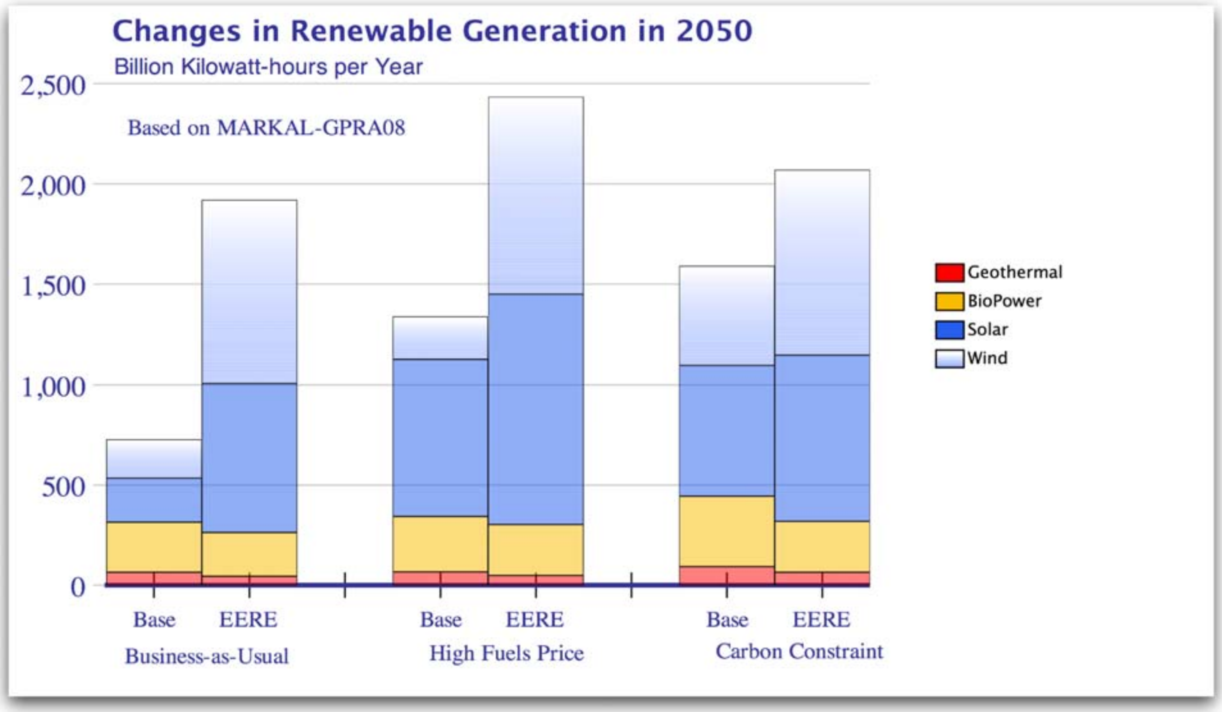
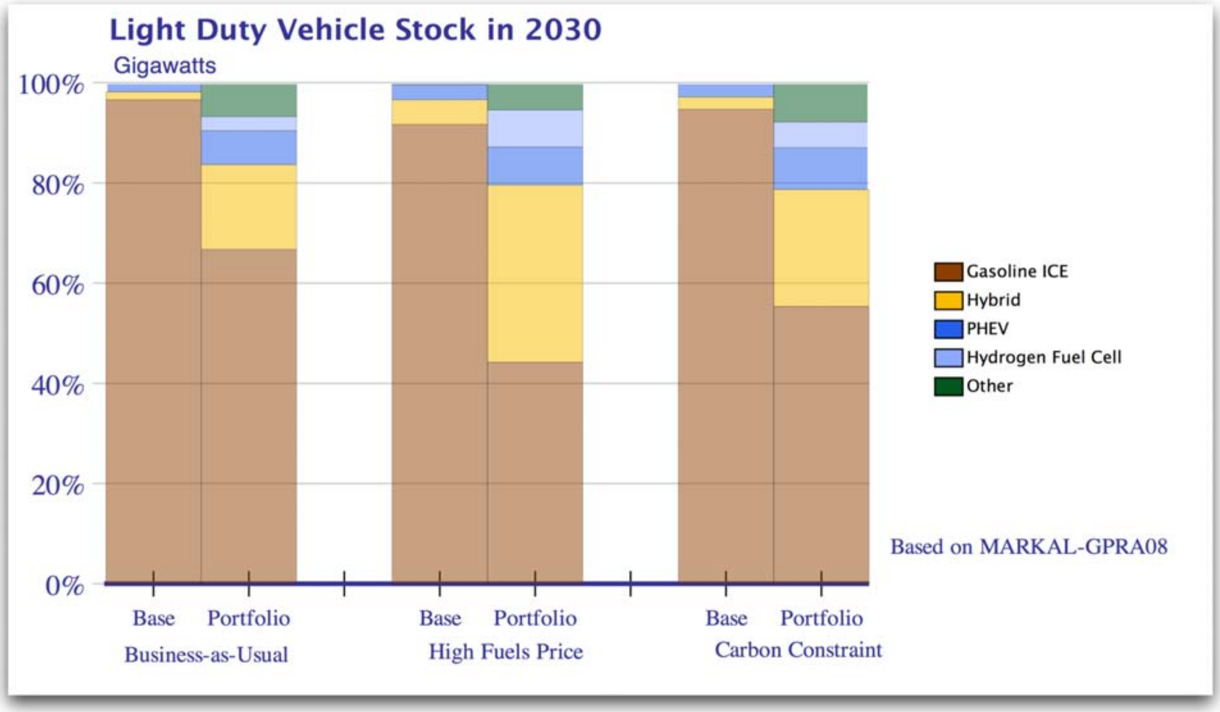


Figure 2.26. Total Renewable Electricity Generation in 2050

Transforming Transportation

The transportation sector looks very different, depending on which scenario of the future is considered. **Figure 2.27** shows the distribution of light-duty vehicle technologies in the mid- and long term, for both baseline and portfolio cases under all three scenarios. In 2030, the baseline cases under all three scenarios for light-duty vehicle fleet are dominated by gasoline internal combustion engines (ICE). This is a case where EERE's portfolio has greater impacts on the future mix of vehicle technologies under the high fuels price and carbon constraint scenarios. Under the BAU scenario, new vehicle technologies in the portfolio case displace about one-third of the gasoline fleets. The biggest impact is seen under the high fuel price scenario, where conventional gasoline vehicles drop from 92% in the base case to 44% of the total vehicle stock in the portfolio case. The largest share of the new technologies is in hybrid and plug-in hybrid vehicles.

In 2050, EERE's portfolio catalyzes a dramatic shift away from conventional gasoline vehicles to new vehicle technologies. In all scenarios, the portfolio case has 10% or less of the fleet in conventional gasoline. The baseline cases under the HFP and CC scenarios also see significant declines in conventional gasoline vehicles—with gasoline internal combustion engines (ICEs) maintaining only 34% and 46% share of the fleet in the HFP and CC scenarios, respectively.



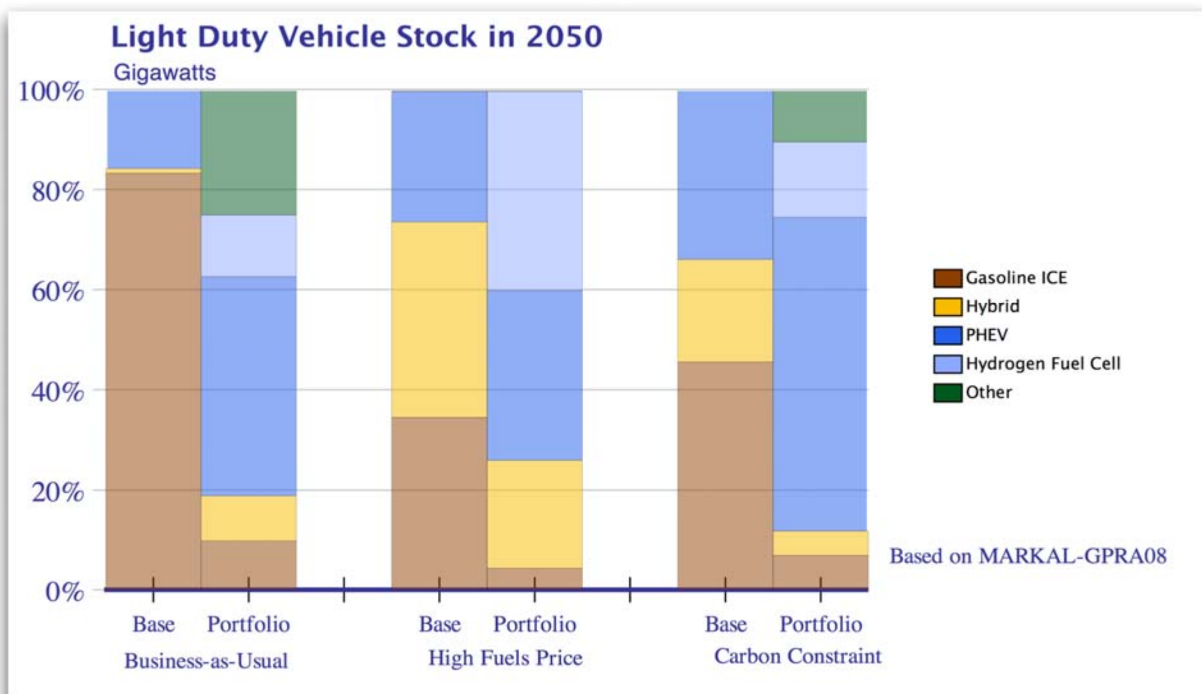
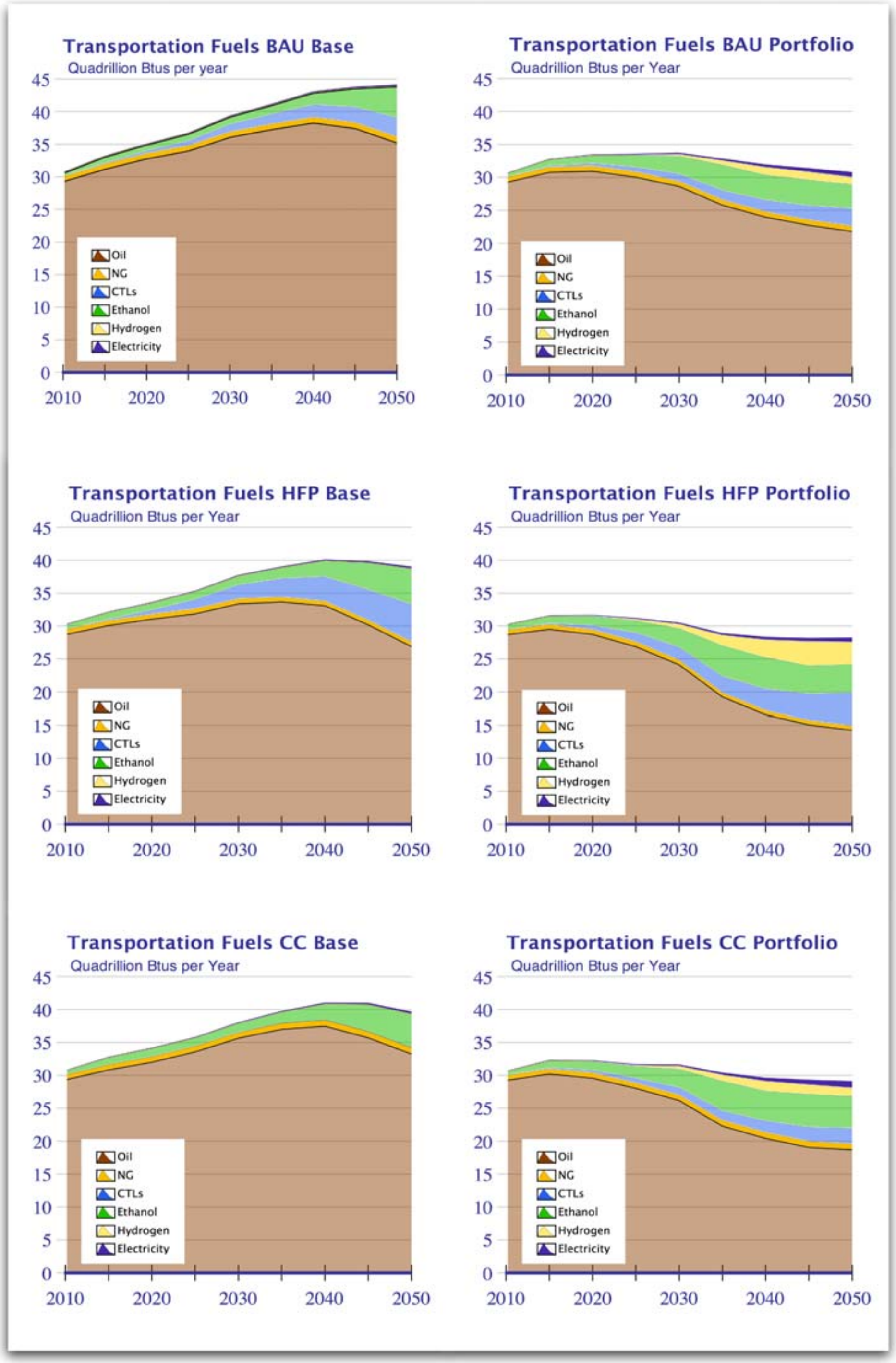


Figure 2.27. Light-Duty Vehicle Stocks in 2030 and 2050

The mix of new vehicle technologies varies among the three scenarios. The biggest difference is in the relative contribution of hydrogen fuel cell vehicles. In a high fuels price environment, hydrogen fuel cells garner 40% of the market share; while, under the BAU and carbon-constrained futures, hydrogen fuel cell vehicles capture only 12% and 15% of the fleet, respectively. This is because hydrogen fuel cells can use hydrogen made from fossil fuels as well as from renewable low- or no-carbon containing fuels.

Figure 2.28 shows the changes in fuel demand in the U.S. transportation sector for baseline and portfolio cases under all three scenarios.

The high fuels price scenario puts some downward pressure on baseline crude oil use in transportation, resulting in somewhat lower oil consumption in 2050 than in 2010. This reduced oil consumption is due primarily to introduction of ethanol and coal-to-liquids technology. Overall energy consumption in the HFP baseline is also lower, reflecting adoption of more efficient vehicle technology. Under the carbon constraint scenario, the baseline introduction of ethanol in the fuel mix is the dominant change, with some efficiency gains in vehicles as well. In all three scenarios, EERE's portfolio reduces oil consumption by roughly 50% relative to the baseline projections in 2050. The mix of fuels changes depending on the scenario, but the effect of EERE's portfolio is the same.



Based on MARKAL-GPRA08

Figure 2.28. Changes in Transportation Fuel Demand Under Alternative Scenarios

Putting the EERE Portfolio in Perspective

Figure 2.29 summarizes the overall impact of EERE's portfolio under three different futures—Business-as-Usual, High Fuel Prices and a Carbon Constraint. Each chart shows the percent improvement of selected benefits metrics for the EERE portfolio case relative to the baseline case under each scenario. The metric most impacted by EERE's portfolio is imported oil, which is reduced by 37%, 47% and 45% under the BAU, HFP, and CC scenarios. The next biggest impact is on consumer savings, which actually increases under the more adverse conditions of high fuel prices and a carbon constraint. Consumer savings are 25%, 31% and 35% higher under the BAU, HFP, and CC scenarios. EERE's portfolio reduces carbon emissions in the BAU and HFP scenarios by 20% over the respective baselines. Carbon savings under the carbon constraint scenario are, by definition, zero. But the higher results for consumer savings under the carbon constraint case suggest that EERE's portfolio mitigates the impact of the carbon constraint on consumers. Finally, energy intensity of the economy sees around 8% improvement due to EERE's portfolio in 2030. In 2050, energy intensity reductions are 17%, 16% and 14% under the BAU, HFP, and CC scenarios. Overall, the portfolio is robust in its impact across three markedly different possible futures, with the greatest gains seen for energy security.

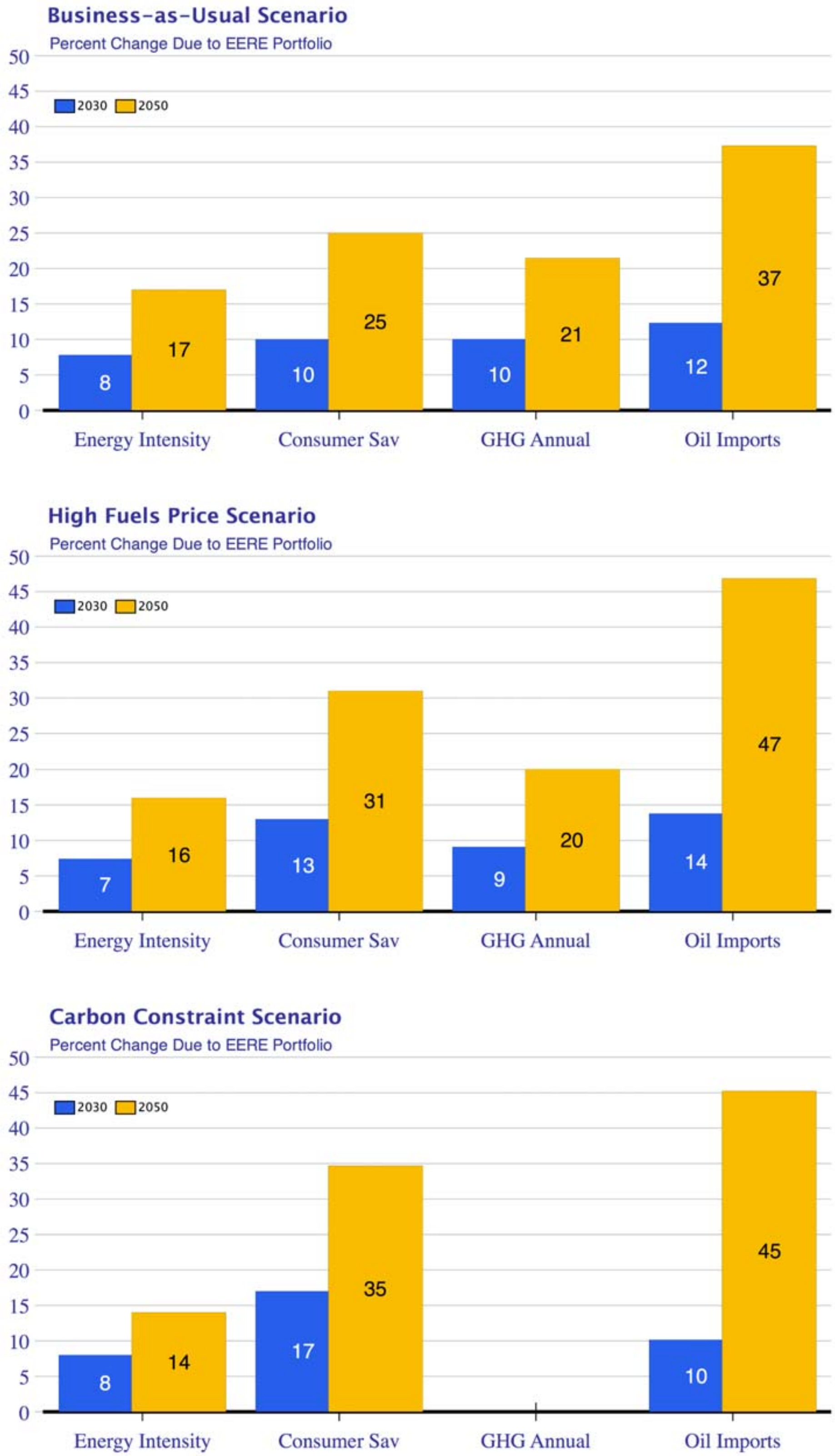


Figure 2.29. Overall Impact of EERE's Portfolio Under Alternative Scenarios