APPENDIX A – GPRA08 BENEFITS ESTIMATES: NEMS AND MARKAL MODEL BASELINE CASES

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The NEMS-GPRA08 Baseline Case Assumptions and Projections

Overview

The Office of Energy Efficiency and Renewable Energy (EERE) programs use integrated energy models to analyze the benefits expected from successful implementation of individual programs and the EERE portfolio as a whole. The use of integrated models provides a consistent economic framework and incorporates the interactive effects among the various programs. Feedback and interactive effects result from (1) changes in energy prices resulting from lower energy consumption, (2) the interaction between supply programs affecting the mix of generation sources and the end-use sector programs affecting the demand for electricity, and (3) additional savings from reduced energy production and delivery.

A modified version of the National Energy Modeling System (NEMS)[1] was one of the models used for this benefits analysis. NEMS is an integrated energy model of the U.S. energy system that was developed by the Energy Information Administration (EIA) for forecasting and policy analysis purposes. NEMS provides projection capability to the year 2030, so it is used for the midterm benefits analysis. The latest version of NEMS available at the time of the benefits analysis was used as the starting point. This is a slightly updated version from the *Annual Energy Outlook 2006* (*AEO2006*) that was set up by EIA at the request of the DOE R&D offices for use in GPRA scenarios.[2] Several modifications were subsequently made to the model by EERE to enhance its ability to represent the EERE programs. The modified version of the model is referred to as NEMS-GPRA08.

Changes in Assumptions for GPRA08 Baseline

The first step in the benefits analysis process is to establish an appropriate Baseline Case. The EERE Baseline Case is a projection intended to represent the future U.S. energy system without the effect of EERE programs. This Baseline Case ensures that program benefits are estimated based on the same initial forecasts for economic growth, energy prices, and levels of energy demand. It also ensures that these initial assumptions are consistent with each other; e.g., that the level of electricity demand expected under the economic growth assumptions could be met at the electricity price assumed. It provides a basis for assessing how well renewable and efficiency technologies might be able to compete against future, rather than current, conventional energy technologies (e.g., more efficient central power generation). Finally, it helps ensure that underlying improvements in efficiency and renewable energy are not counted as part of the benefits of the EERE programs. This year, for GPRA08, a coordinated Baseline was constructed by all the Energy, Science, and Environment (ESE) offices that represent a projection without any of the DOE RD3 programs.

The most recent Annual Energy Outlook Reference Case is used as the starting point for developing the base case.[3] The Energy Information Administration (EIA) *Annual Energy*

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[1] *The National Energy Modeling System: An Overview 2003*, March 2003, DOE/EIA-0581(2003).
[2] The request for the slightly modified base case was made under an initiative to coordinate and integrate the GPRA analyses undertaken by the various offices within DOE's Office of Energy, Science, and Environment. Formally, the request was transmitted to EIA through the Office of Fossil Energy and the National Energy Technology Laboratory's NEMS modelers.
[3] The updated NEMS produces similar reference case projections as the *Annual Energy Outlook 2006 with Projections to 2030*, February 2006, DOE/EIA-0383 (2006). See http://www.eia.doe.gov/oiaf/archive/aeo06/pdf/0383(2006).pdf.

Outlook (AEO) Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy (e.g., to reflect the availability of new appliances), technology improvements that might improve the efficiency of energy use, and changes in energy resource production costs, including renewable energy. Current energy market policies, such as state renewable portfolio standards (RPS) and tax policies, which facilitate the development and adoption of these technologies, are included in the Base Case. This approach ensures that EERE's benefits estimates do not include expected impacts of such policies. Neither the EIA Reference Case nor the EERE Base Case includes any changes in future energy policies.

Removal of EERE programs. Several adjustments are made to remove EERE programs from the EIA Reference Case. For example, the most efficient shell improvement packages for new residential buildings were removed, although the impact was minimal because they received small market share in the AEO. Cellulosic ethanol production was assumed to not become available until 2030 without EERE's R&D efforts, although with improved characteristics compared to the *AEO2006.*

Table 1. Summary of Baseline Changes from the *AEO2006*

	AEO2006	GPRA08 Baseline Case
Removal of EERE Programs		
Residential highest efficiency shell packages	Small penetration	Removed
Cellulosic ethanol production	Commercially available by 2015	Not commercially available until 2030
Greater Technology Improvement in Base		
Photovoltaic system costs	Some improvement	Slightly more improvement for commercial systems after 2020
Solid-state lighting	Small improvement	Much greater improvement
Onshore wind performance	35 to 44 percent capacity factors depending on wind class and year (2010 to 2030)	40 to 49 percent capacity factors depending on wind class and year (2010 to 2030)
Onshore wind capital costs	0.3 percent reduction from 2010 to 2030	6 to 8 percent reduction (depending on wind class) from 2010 to 2030
Conventional corn ethanol production	Constant costs (excluding fuel and feedstocks)	Improving costs over time, based on 7-year lag from program goals
Cellulosic ethanol production	Constant costs (excluding feedstocks)	Improving costs over time, based on 15-year lag from program goals
Hybrid-electric vehicles	Stock share at 6 percent by 2030	Stock share at 11 percent by 2030
Energy Market Updates		
PV system size	2 to 4 kW residential, 25 to 45 kW commercial	4 kW residential, 100 to 200 kW commercial
PV maximum market share	30 percent for both residential and commercial	60 percent for residential and 55 percent for commercial
California PV subsidy	Not included	Included for residential systems
Biomass supply		Updated supply curves
Cellulosic maximum production	50 to 280 million gallons per year growth limit	200 million gallons per year increasing to 20% to 25% of previous year
Structural Changes		
Offshore wind capacity	Not included	Included
Commercial DG algorithms		Market share and stock accounting modified; growth limit imposed for solar PV
Plug-in hybrid vehicles	Not included	Included
Light-duty vehicle attributes		Ability to specify attributes over time

Greater Technology Improvement in Base. There are a few EERE technologies that are either not represented in the *AEO2006,* or their improvement is less than anticipated by the program in the absence of EERE programs. These technology assumptions were also modified for the GPRA08 Baseline.

- The improvement in distributed photovoltaic system costs was modified with slightly greater improvement in the commercial systems

- In commercial lighting, solid-state lighting characteristics were assumed to improve significantly more than the very minimal improvement in the *AEO2006.*

- Offshore wind technology characteristics were added, and the onshore wind characteristics were modified. The onshore capital costs were assumed to decline more rapidly over time. In addition, the capacity factors for each wind class were assumed to be higher than in the *AEO2006*, although lower than the program goals. Both of these changes for onshore wind increase the projected market penetration of wind in the Baseline and shrink the benefits attributed to the EERE R&D.

- The representation of hybrid-electric vehicles was modified by gradually increasing the consumer preference for hybrids, leading to greater adoption of hybrids in the base.

- Corn ethanol production costs, excluding fuel and feedstock costs, were assumed to start somewhat lower and improve over time based on a seven-year lag of the program goals. When commercialized in 2030, cellulosic ethanol production costs are lower than the *AEO2006* costs.

Energy Market Updates. A few other modifications were made to reflect EERE program assumptions or updated information about energy markets. These changes affect both the Baseline and the Benefits Cases.

- The size of typical PV systems was increased to 4 kW in residential buildings, and 100 kW increasing to 200 kW in commercial buildings to reflect recent PV installation experience and trends.

- The maximum market for PV systems was increased from 30% to 55% in the commercial sector and to 60% for residential PVs.

- California PV credits were incorporated in the Pacific region.

- The biomass supply curves were updated based on data from researchers at the University of Tennessee (UT). The new curves have generally less biomass available at low cost, but significantly more total resources at higher-cost levels.

- Because the technology is very new, cellulosic production capacity is assumed to be able to expand only at a rate of 500 million gallons per year initially, and then by 25% per year through 2025 and 20% thereafter. This has no impact on the Baseline, but affects the Program goal case.

Structural Changes. In a few cases, we made structural changes to improve the model's representation of markets important to EERE technologies.

- Offshore wind was added as another technology option with resources available in the coastal regions and the regions around the Great Lakes.

- Alterations to the distributed generation algorithm in the building modules were made to reflect market adoption data gathered by Lawrence Berkeley National Laboratory,[4] to account for buildings that have already installed a DG technology in prior years, and to allow greater than an annual 0.5% adoption rate in existing buildings. In addition, a limit on the expansion rate of PV installations was imposed to reflect time needed to expand manufacturing capability.

- In the light-duty vehicle module, plug-in hybrid vehicles were added as an additional technology. Also, the input data file was modified to allow the direct modification of vehicle attributes.

A summary of these modifications is provided in **Table 1**. Greater detail can be found in the individual program appendices.

GPRA08 Baseline Projections

In the Baseline projections, oil prices are projected to fall after 2006 and then gradually increase again after 2015, as shown in **Figure A-1**. Natural gas prices follow a similar pattern. Electricity prices also drop from a near-term high then stay relatively constant. Coal prices, on the other hand, are projected to be relatively constant in real terms for the entire period.

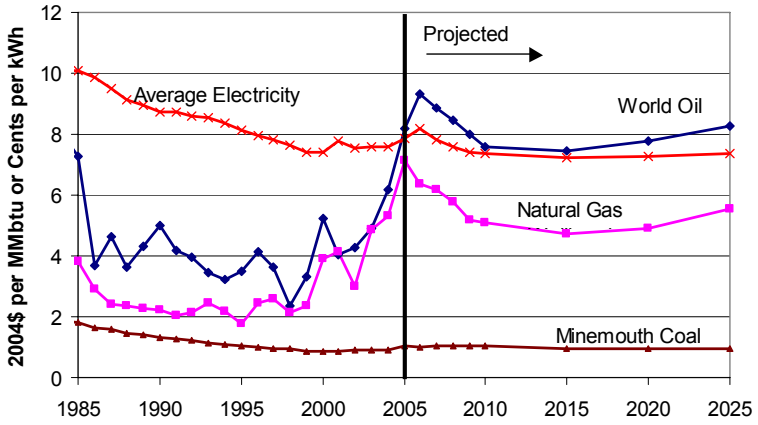

Figure A-1. Projected Energy Prices

The resulting Baseline Case projects a 22% increase in conventional energy demand from 2010 to 2030.[5] Energy efficiency and renewable energy improvements, however, contribute toward a

[4] See modeling methodology section for more detail.
[5] Very similar to the *AEO2006.*

31% reduction in conventional energy intensity (energy used per dollar of GDP produced) during the same period (**Figure A-2**).[6] Between 2010 and 2025, renewable energy technology improvements result in increases in renewable electric generation in central and distributed applications of roughly 240 billion of kWh, which is an almost 50% increase in non-hydroelectric generation.

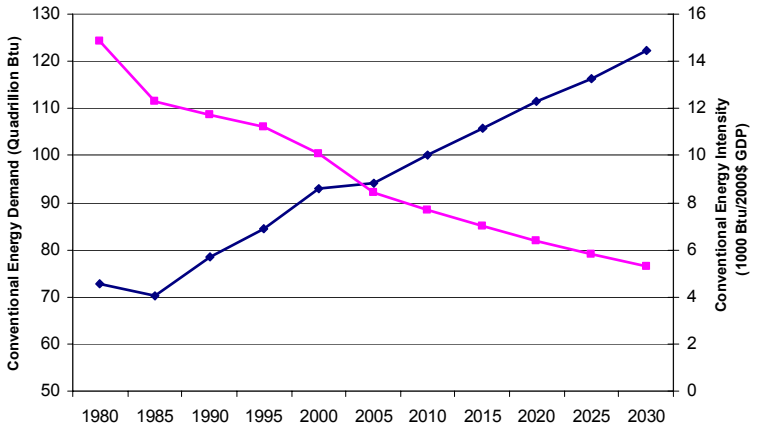

Figure A-2. Projected Conventional Energy Demand and Energy Intensity

The following tables (**A-1 through A-6**) are a few of the key output tables generated by NEMS-GPRA08.

[6] Energy intensity changes result from a mix of structural changes in the economy (e.g., growing service sector) and efficiency improvements. Two recent EERE-sponsored studies provide additional background on understanding the sources of changes to our energy intensity: Ortiz and Sollinger, *Shaping Our Future by Reducing Energy Intensity in the U.S. Economy; Volume 1: Proceedings of the Conference* (2003, Rand Corporation); and Bernstein, Fonkych, Loeb, and Loughran, "State-Level Changes in Energy Intensity and their National Implications" (2003, Rand Corporation).

Table A-1. Total Energy Supply and Disposition Summary
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2010	2015	2020	2025	2030
Production					
Crude Oil & Lease Condensate	12.69	12.24	11.79	10.64	9.81
Natural Gas Plant Liquids	2.36	2.49	2.54	2.44	2.36
Dry Natural Gas	18.90	20.27	20.87	20.11	19.52
Coal	25.97	26.02	27.77	30.85	33.45
Nuclear Power	8.44	8.66	9.09	9.09	9.09
Renewable Energy 1/	6.87	7.51	8.34	9.35	9.98
Other 2/	2.15	2.82	3.12	3.39	3.69
Total	77.38	80.01	83.53	85.86	87.89
Imports					
Crude Oil 3/	21.93	23.11	24.70	27.14	29.78
Petroleum Products 4/	6.30	7.42	8.08	8.64	9.29
Natural Gas	5.18	6.09	6.14	6.72	7.94
Other Imports 5/	0.45	0.74	1.56	2.00	2.21
Total	33.86	37.35	40.47	44.50	49.23
Exports					
Petroleum 6/	2.15	2.18	2.24	2.27	2.33
Natural Gas	0.55	0.57	0.66	0.83	0.94
Coal	1.03	0.54	0.46	0.48	0.39
Total	3.74	3.29	3.37	3.58	3.66
Discrepancy 7/	-0.32	-0.12	-0.11	-0.08	0.00
Consumption					
Petroleum Products 8/	43.20	45.79	48.30	50.83	53.83
Natural Gas	23.96	26.21	26.78	26.43	26.95
Coal	25.28	25.94	28.19	31.11	33.57
Nuclear Power	8.44	8.66	9.09	9.09	9.09
Renewable Energy 1/	6.87	7.51	8.34	9.35	9.98
Other 9/	0.08	0.08	0.05	0.05	0.05
Total	107.82	114.19	120.74	126.85	133.46
Net Imports - Petroleum	26.07	28.35	30.54	33.51	36.74
Prices (2004 dollars per unit)					
World Oil Price ($ per bbl) 10/	43.99	43.00	44.99	47.99	49.99
Gas Wellhead Price ($ / Mcf) 11/	5.24	4.62	5.05	5.68	6.30
Coal Minemouth Price ($ / ton)	22.13	20.37	20.07	20.50	21.20
Electricity (cents / Kwh)	7.37	7.14	7.26	7.35	7.54

1/ Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy. See Table A18 for selected nonmarketed residential and commercial renewable energy.

2/ Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.

3/ Includes imports of crude oil for the Strategic Petroleum Reserve.

4/ Includes imports of finished petroleum products, unfinished oils, alcohols, ethers, and blending components.

5/ Includes coal, coal coke (net), and electricity (net).

6/ Includes crude oil and petroleum products.

7/ Balancing item. Includes unaccounted for supply, losses, gains, net storage withdrawals, heat loss when natural gas is converted to liquid fuel, and heat loss when coal is converted to liquid fuel.

8/ Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum-based liquids for blending, such as ethanol.

9/ Includes net electricity imports, methanol, and liquid hydrogen.

10/ Average refiner acquisition cost for imported crude oil.

11/ Represents lower 48 onshore and offshore supplies.

Table A-2. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

Energy Consumption	2010	2015	2020	2025	2030
Residential					
Distillate Fuel	0.83	0.78	0.72	0.65	0.59
Kerosene	0.09	0.09	0.08	0.07	0.07
Liquefied Petroleum Gas	0.56	0.58	0.61	0.63	0.64
Petroleum Subtotal	1.48	1.45	1.41	1.35	1.30
Natural Gas	5.33	5.52	5.67	5.73	5.79
Coal	0.01	0.01	0.01	0.01	0.01
Renewable Energy 1/	0.44	0.43	0.43	0.42	0.41
Electricity	4.98	5.38	5.76	6.07	6.43
Delivered Energy	12.23	12.79	13.29	13.58	13.95
Electricity Related Losses	10.74	11.30	11.96	12.40	12.81
Total	22.98	24.09	25.25	25.98	26.76
Commercial					
Distillate Fuel	0.48	0.49	0.50	0.50	0.51
Residual Fuel	0.12	0.12	0.12	0.12	0.12
Kerosene	0.02	0.02	0.02	0.03	0.03
Liquefied Petroleum Gas	0.10	0.10	0.10	0.10	0.10
Motor Gasoline 2/	0.05	0.05	0.05	0.05	0.05
Petroleum Subtotal	0.77	0.78	0.79	0.80	0.81
Natural Gas	3.17	3.45	3.67	3.86	4.08
Coal	0.09	0.09	0.09	0.09	0.09
Renewable Energy 3/	0.09	0.09	0.09	0.09	0.09
Electricity	4.88	5.42	5.91	6.45	7.00
Delivered Energy	8.98	9.82	10.55	11.28	12.06
Electricity Related Losses	10.51	11.39	12.28	13.18	13.95
Total	19.49	21.22	22.83	24.46	26.01
Industrial 4/					
Distillate Fuel	1.20	1.20	1.23	1.26	1.33
Liquefied Petroleum Gas	2.21	2.27	2.35	2.44	2.51
Petrochemical Feedstocks	1.48	1.49	1.51	1.52	1.55
Residual Fuel	0.20	0.19	0.20	0.21	0.22
Motor Gasoline 2/	0.32	0.32	0.32	0.33	0.34
Other Petroleum 5/	4.62	4.85	5.07	5.37	5.73
Petroleum Subtotal	10.04	10.32	10.68	11.13	11.68
Natural Gas	8.03	8.27	8.43	8.63	8.89
Lease and Plant Fuel 6/	1.12	1.20	1.25	1.18	1.14
Natural Gas Subtotal	9.15	9.47	9.68	9.82	10.03
Metallurgical Coal	0.62	0.61	0.59	0.58	0.58
Other Industrial Coal	1.43	1.43	1.43	1.44	1.45
Coal-to-Liquids Heat and Power	0.00	0.17	0.62	1.22	1.68
Net Coal Coke Imports	0.02	0.02	0.02	0.01	0.02
Coal Subtotal	2.07	2.22	2.65	3.25	3.72
Renewable Energy 7/	1.79	1.90	2.01	2.14	2.29
Electricity	3.61	3.75	3.91	4.08	4.30
Delivered Energy	26.65	27.66	28.94	30.42	32.02
Electricity Related Losses	7.78	7.89	8.12	8.34	8.58
Total	34.43	35.55	37.05	38.76	40.60

1/ Includes wood used for residential heating.
2/ Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
3/ Includes commercial sector consumption of wood and wood waste, landfill gas, municipal solid waste, and other biomass for combined heat and power.
4/ Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Represents natural gas used in the field gathering and processing plant machinery.
7/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass.

Table A-3. Energy Prices by Sector and Source
(2004 Dollars per Million Btu, Unless Otherwise Noted)

	2010	2015	2020	2025	2030
Residential	17.15	16.74	17.30	17.96	18.75
Primary Energy 1/	11.45	10.92	11.48	12.25	12.97
Petroleum Products 2/	14.75	14.79	16.06	17.34	18.57
Distillate Fuel	12.78	12.78	13.59	14.26	14.56
Liquefied Petroleum Gas	18.19	17.98	19.53	21.17	22.91
Natural Gas	10.56	9.92	10.36	11.06	11.72
Electricity	24.94	24.30	24.48	24.64	25.14
Commercial	16.45	15.87	16.36	16.92	17.62
Primary Energy 1/	9.12	8.53	8.89	9.44	9.97
Petroleum Products 2/	10.54	10.66	11.26	11.86	12.29
Distillate Fuel	10.11	10.40	10.92	11.44	11.74
Residual Fuel	6.14	6.04	6.29	6.67	6.93
Natural Gas	8.97	8.21	8.53	9.10	9.68
Electricity	22.50	21.71	22.10	22.44	23.05
Industrial 3/	8.56	8.20	8.53	8.92	9.44
Primary Energy	7.26	6.98	7.31	7.74	8.27
Petroleum Products 2/	9.45	9.46	10.00	10.67	11.46
Distillate Fuel	10.71	11.40	11.86	12.48	12.89
Liquefied Petroleum Gas	12.06	11.88	13.13	14.11	15.42
Residual Fuel	6.32	6.31	6.62	7.01	7.39
Natural Gas 4/	5.87	5.25	5.63	6.22	6.83
Metallurgical Coal	2.36	2.19	2.23	2.28	2.28
Steam Coal	1.86	1.80	1.81	1.85	1.90
Electricity	0.00	0.86	1.12	1.22	1.26
	15.80	14.99	15.36	15.57	16.06
Transportation					
Primary Energy	14.83	14.83	15.38	15.89	16.28
Petroleum Products 2/	14.81	14.81	15.36	15.88	16.27
Distillate Fuel 5/	14.82	14.82	15.38	15.89	16.28
Jet Fuel 6/	14.27	14.54	14.82	15.30	15.62
Motor Gasoline 7/	9.62	9.89	10.49	10.93	11.50
Residual Fuel	16.53	16.35	17.01	17.51	17.87
Liquefied Petroleum Gas 8/	6.40	6.32	6.55	7.05	7.66
Natural Gas 9/	16.72	16.47	16.97	18.34	19.43
Ethanol (E85) 10/	11.59	10.81	11.06	11.62	12.13
Electricity	21.30	20.52	21.30	21.73	22.11

1/ Weighted average price includes fuels below as well as coal.
2/ This quantity is the weighted average for all petroleum products, not just those listed below.
3/ Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.
4/ Excludes use for lease and plant fuel.
5/ Diesel fuel containing 500 parts per million (ppm) or 15 ppm sulfur. Price includes Federal and State taxes while excluding county and local taxes.
6/ Kerosene-type jet fuel. Price includes Federal and State taxes while excluding county and local taxes.
7/ Sales weighted-average price for all grades. Includes Federal, State, and local taxes.
8/ Includes Federal and State taxes while excluding county and local taxes.
9/ Compressed natural gas used as a vehicle fuel. Price includes estimated motor vehicle fuel taxes.
10/ E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol actually varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

Table A-4. Electricity Supply, Disposition, Prices, and Emissions
(Billion Kilowatthours, Unless Otherwise Noted)

	2010	2015	2020	2025	2030
Generation by Fuel Type					
Electric Power Sector 1/					
Power Only 2/					
Coal	2181	2235	2442	2721	2980
Petroleum	92	92	90	99	104
Natural Gas 3/	528	703	707	636	652
Nuclear Power	809	829	871	871	871
Pumped Storage/Other	-9	-9	-9	-9	-9
Renewable Sources 4/	414	452	500	568	604
Distributed Generation (Natural Gas)	0	0	1	1	2
Total	4015	4303	4601	4889	5203
Combined Heat and Power 5/					
Coal	31	31	30	29	28
Petroleum	2	2	2	2	2
Natural Gas	140	155	149	131	124
Renewable Sources	4	4	4	4	4
Other (remove for AEO tables)	0	0	0	0	0
Total	177	192	185	166	158
Total Net Generation	4192	4495	4786	5054	5361
Less Direct Use	28	28	28	28	28
Net Available to the Grid	4164	4467	4758	5026	5333
Commercial and Industrial Generation 6/					
Coal	23	39	81	138	182
Petroleum	12	13	14	13	13
Natural Gas	101	115	132	146	158
Other Gaseous Fuels 7/	4	5	5	5	5
Renewable Sources 4/	40	43	46	54	90
Other 8/	12	12	12	12	12
Total	192	226	289	368	460
Less Direct Use	149	164	190	226	278
Total Sales to the Grid	43	62	100	143	183
Total Electricity Generation	4385	4721	5076	5423	5821
Total Net Generation to the Grid	4207	4529	4858	5169	5516

1/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

2/ Includes plants that only produce electricity.

3/ Includes electricity generation from fuel cells.

4/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other biomass, solar, and wind power.

5/ Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report NAICS code 22).

6/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

7/ Other gaseous fuels include refinery and still gas.

8/ Other includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Table A-4. Electricity Supply, Disposition, Prices, and Emissions
(Billion Kilowatthours, Unless Otherwise Noted)

	2010	2015	2020	2025	2030
Generation by Fuel Type					
Electric Power Sector 1/					
Power Only 2/					
Coal	2181	2235	2442	2721	2980
Petroleum	92	92	90	99	104
Natural Gas 3/	528	703	707	636	652
Nuclear Power	809	829	871	871	871
Pumped Storage/Other	-9	-9	-9	-9	-9
Renewable Sources 4/	414	452	500	568	604
Distributed Generation (Natural Gas)	0	0	1	1	2
Total	4015	4303	4601	4889	5203
Combined Heat and Power 5/					
Coal	31	31	30	29	28
Petroleum	2	2	2	2	2
Natural Gas	140	155	149	131	124
Renewable Sources	4	4	4	4	4
Other (remove for AEO tables)	0	0	0	0	0
Total	177	192	185	166	158
Total Net Generation	4192	4495	4786	5054	5361
Less Direct Use	28	28	28	28	28
Net Available to the Grid	4164	4467	4758	5026	5333
Commercial and Industrial Generation 6/					
Coal	23	39	81	138	182
Petroleum	12	13	14	13	13
Natural Gas	101	115	132	146	158
Other Gaseous Fuels 7/	4	5	5	5	5
Renewable Sources 4/	40	43	46	54	90
Other 8/	12	12	12	12	12
Total	192	226	289	368	460
Less Direct Use	149	164	190	226	278
Total Sales to the Grid	43	62	100	143	183
Total Electricity Generation	4385	4721	5076	5423	5821
Total Net Generation to the Grid	4207	4529	4858	5169	5516

1/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.
2/ Includes plants that only produce electricity.
3/ Includes electricity generation from fuel cells.
4/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other biomass, solar, and wind power.
5/ Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report NAICS code 22).
6/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.
7/ Other gaseous fuels include refinery and still gas.
8/ Other includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Table A-5. Electricity Generating Capacity
(Gigawatts)

	2010	2015	2020	2025	2030
Electric Power Sector 2/					
Power Only 3/					
Coal Steam	313.3	310.3	316.2	332.4	355.3
Other Fossil Steam 4/	121.8	74.5	62.6	53.2	43.5
Combined Cycle	151.5	153.8	162.3	168.0	175.9
Combustion Turbine/Diesel	136.2	130.0	129.6	128.6	132.0
Nuclear Power 5/	100.9	101.0	108.0	108.0	108.0
Pumped Storage	20.8	20.8	20.8	20.8	20.8
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources 6/	102.7	113.3	144.8	167.3	186.1
Distributed Generation (Natural Gas) 7/	0.2	0.3	0.5	0.6	1.1
Total	947.4	904.2	944.6	979.0	1022.9
Combined Heat and Power 8/	0.0	0.0	0.0	0.0	0.0
Coal Steam	4.9	4.3	4.3	4.3	4.3
Other Fossil Steam 4/	0.5	0.5	0.5	0.5	0.5
Combined Cycle	32.3	32.3	32.3	32.3	32.3
Combustion Turbine/Diesel	2.9	2.9	2.9	2.9	2.9
Renewable Sources 6/	0.4	0.4	0.4	0.4	0.4
Total	41.0	40.5	40.5	40.5	40.5
Cumulative Planned Additions 9/					
Coal Steam	8.3	9.3	9.3	9.3	9.3
Other Fossil Steam 4/	0.1	0.1	0.1	0.1	0.1
Combined Cycle	25.7	25.7	25.7	25.7	25.7
Combustion Turbine/Diesel	5.3	5.3	5.3	5.3	5.3
Nuclear Power	0.0	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources 6/	10.3	11.6	11.9	12.1	12.2
Distributed Generation 7/	0.0	0.0	0.0	0.0	0.0
Total	49.8	52.0	52.3	52.5	52.6
Cumulative Unplanned Additions 9/					
Coal Steam	3.0	3.0	8.9	25.1	48.0
Other Fossil Steam 4/	0.0	0.0	0.0	0.0	0.0
Combined Cycle	0.0	2.4	10.8	16.5	24.4
Combustion Turbine/Diesel	4.8	8.6	10.4	10.5	13.9
Nuclear Power	0.0	0.0	6.0	6.0	6.0
Pumped Storage	0.0	0.0	0.0	0.0	0.1
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources 6/	0.4	9.9	41.0	63.4	82.1
Distributed Generation 7/	0.2	0.3	0.5	0.6	1.1
Total	8.4	24.2	77.6	122.2	175.7
Cumulative Electric Power Sector Additions	58.2	76.2	129.9	174.6	228.3

Table A-5. Electricity Generating Capacity (Continued)

	2010	2015	2020	2025	2030
Cumulative Retirements 10/					
Coal Steam	3.0	5.9	5.9	5.9	6.0
Other Fossil Steam 4/	2.0	43.9	50.6	56.0	56.2
Combined Cycle	0.6	0.6	0.6	0.6	0.6
Combustion Turbine/Diesel	1.4	8.3	8.4	8.4	8.5
Nuclear Power	0.0	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources 6/	0.1	0.1	0.1	0.1	0.1
Total	7.1	58.8	65.6	71.0	71.3
Total Electric Power Sector Capacity	988.4	965.5	1027.6	1102.0	1171.0
Commercial and Industrial Generators 11/					
Coal	4.2	6.3	11.6	19.6	24.4
Petroleum	1.8	1.8	1.9	1.9	1.9
Natural Gas	17.7	19.6	21.8	23.7	25.3
Other Gaseous Fuels	1.5	1.5	1.5	1.6	1.6
Renewable Sources 6/	6.6	7.1	7.6	10.5	26.6
Other	0.7	0.7	0.7	0.7	0.7
Total	32.5	37.0	45.3	57.9	80.6
Cumulative Capacity Additions 9/	3.2	7.7	15.9	28.6	51.2

1/ Net summer capacity is the steady hourly output that generating equipment is expected to supply to system load (exclusive of auxiliary power), as demonstrated by tests during summer peak demand.

2/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

3/ Includes plants that only produce electricity. Includes capacity increases (uprates) at existing units.

4/ Includes oil-, gas-, and dual-fired capacity.

5/ Nuclear capacity reflects operating capacity of existing units, including 3.9 gigawatts of uprates through 2025.

6/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other biomass, solar and wind power. Facilities co-firing biomass and coal are classified as coal.

7/ Primarily peak-load capacity fueled by natural gas.

8/ Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report NAICS code 22).

9/ Cumulative additions after December 31, 2004.

10/ Cumulative retirements after December 31, 2004.

11/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

Table A-6. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2010	2015	2020	2025	2030
Residential					
Petroleum	28	27	26	25	24
Natural Gas	77	80	82	82	83
Coal	0	0	0	0	0
Electricity	256	267	284	299	316
Total	360	374	392	407	423
Commercial					
Petroleum	15	15	16	16	16
Natural Gas	46	50	53	56	59
Coal	2	2	2	2	2
Electricity	250	270	291	318	344
Total	313	337	362	392	420
Industrial 1/					
Petroleum	121	125	130	136	143
Natural Gas 2/	130	134	137	139	142
Coal	53	56	68	83	95
Electricity	185	187	193	201	211
Total	488	503	528	560	592
Transportation					
Petroleum 3/	564	605	646	684	729
Natural Gas 4/	10	11	12	12	12
Electricity	5	5	5	5	5
Total	579	621	663	701	747
Electric Power Sector 5/					
Petroleum	21	21	20	22	24
Natural Gas	81	100	99	89	89
Coal	591	604	650	709	759
Other 6/	4	4	4	4	4
Total	696	729	773	824	876
Total by Primary Fuel 7/					
Petroleum 3/	749	793	838	883	936
Natural Gas	343	375	383	378	386
Coal	646	663	720	794	857
Other 6/	4	4	4	4	4
Total	1741	1835	1945	2060	2183

1/ Fuel consumption includes energy for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public.

2/ Includes lease and plant fuel.

3/ This includes international bunker fuel, which by convention are excluded from the international accounting of carbon dioxide emissions. In the years from 1990 through 2002, international bunker fuels accounted for 82 to 100 million metric tons carbon dioxide equivalent of carbon dioxide annually.

4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.

5/ Includes electricity-only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

6/ Includes emissions from geothermal power and nonbiogenic emissions from municipal solid waste.

7/ Emissions from the electric power sector are distributed to the primary fuels.

The MARKAL-GPRA08 Baseline Assumptions and Projections

Economic and Demographic Assumptions

The Baseline Case used to evaluate the impact of the EERE portfolio was benchmarked to EIA's *Annual Energy Outlook 2006* (*AEO2006*) for the period between 2006 and 2030. To the extent possible, the same input data and assumptions were used in MARKAL-GPRA08 as were used to generate the *AEO2006* Reference Case. For example, the macroeconomic projections for gross domestic product (GDP), housing stock, commercial square footage, industrial output, and vehicle miles traveled were taken from the *AEO2006.* At the sector level, both supply-side and demand-side technologies were characterized to reflect the *AEO2006* assumptions where the representation of technologies is similar between MARKAL (MARKet ALlocation) and the National Energy Modeling System (NEMS).

The resulting projections track closely with the *AEO2006* at the aggregate level, although they do not match exactly at the end-use level. For the period after 2030, various sources were used to compile a set of economic and technical assumptions. For instance, the primary economic drivers of GDP and population were based on the real GDP growth rate from the *Congressional Budget Office's Long-Term Budget Outlook* and population growth rates from the Social Security Administration's *2005 Annual Report to the Board of Trustees* low-cost assumptions.[7]

In the reference case, GDP is projected to increase at an average annual rate of 3% from 2005 to 2025, and then slow to an average annual rate of 2.4% from 2025 to 2050. The population growth rate is projected to decline from an average annual rate of 0.8% between 2005 and 2025 to 0.5% from 2025 to 2050. The Reference Case macroeconomic assumptions are shown in **Table 2**.

Table 2. Reference Case Macroeconomic and Demographic Assumptions

											Annual Growth Rates		
	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'05-'25	25-'50	'05-'50
GDP (Bill. 2001$)	$11,414	$13,356	$15,444	$17,962	$20,606	$23,666	$26,907	$30,295	$33,777	$37,220	3.0%	2.4%	2.7%
Population (Million)	296.8	310.1	323.5	337.0	350.6	364.8	375.6	384.1	390.0	395.4	0.8%	0.5%	0.6%
Total Households (Million)	115.4	122.9	130.1	137.2	143.5	149.8	150.2	153.6	156.0	158.2	1.1%	0.4%	0.7%
Commercial Floorspace (Bill. sq ft)	76.2	82.3	88.9	96.0	103.7	112.0	119.7	127.3	134.7	141.6	1.6%	1.3%	1.4%
Industrial Production (2000=100)	101	111	123	136	150	167	188	210	232	254	2.0%	2.1%	2.1%
Light Duty Vehicle Miles Traveled (Bill. VMT)	2,619	2,890	3,171	3,474	3,791	4,132	4,418	4,653	4,820	4,978	1.9%	1.1%	1.4%

Assumptions on Energy Prices

Table 2 shows projected energy prices for the reference case. Real natural gas prices are projected to drop between 2005 and 2015, and then increase at nearly 1.8% per year from 2015 to 2025 before increasing amounts of arctic gas and LNG imports limit the average annual increase to 0.8% from 2025 to 2050. Real crude oil prices are also projected to drop between 2005 and 2015, and increase at average annual rates of 1.4% between 2010 and 2025, and 1.0% per year thereafter.

Average real mine mouth coal prices are projected to continue to decline by about 0.3% a year between 2005 and 2020, due to increasing productivity gains and a continued shift to less labor-

[7] "The Long-Term Budget Outlook," Congressional Budget Office, December 2003. *The 2005 Annual Report of the Board of Trustees of the Federal Old Age and Survivors Insurance and the Federal Disability Insurance Trust Funds*, March 2005.

intensive Western coal production. However, coal prices are projected to increase at an average rate of 1.2% per year after 2020, due to increased demands, gradually increasing mine depths, and a saturation of labor productivity gains.

Table 3. Reference Case Energy Prices

											Annual Growth Rates		
2001 $s	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'05-'25	25-'50	'05-'50
World Oil Price ($/bbl)	$47.10	$41.19	$39.68	$42.57	$45.52	$48.60	$50.62	$52.63	$54.08	$55.58	-0.2%	0.8%	0.4%
Natural Gas Wellhead Price ($/Mcf)	$7.67	$4.76	$4.01	$4.35	$4.78	$5.42	$5.76	$5.75	$6.49	$6.41	-2.3%	1.2%	-0.4%
Coal Minemouth Price ($/short ton)	$19.90	$20.84	$19.00	$18.92	$19.44	$20.48	$22.41	$23.70	$25.83	$27.44	-0.1%	1.4%	0.7%

Primary Energy Consumption

As a result of slightly increasing energy prices relative to technology improvements and shifts within the economy, energy demand is projected to increase more slowly than GDP. As shown in **Table 4**, total primary energy use is projected to increase at a rate of 1.0% per year from 2005 to 2025, and at an average annual rate of 0.5% between 2025 and 2050. By 2050, total primary energy consumption is projected to reach approximately 138 quadrillion Btus (quads). Overall, the energy consumption to GDP ratio is projected to decline by 1.9% per year from 2005 to 2050, while total carbon emissions increase by 0.8% per year during the same period.

Table 4. Primary Energy Consumption, Energy Intensity, and Carbon Emissions

											Annual Growth Rates		
	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'05-'25	25-'50	'05-'50
Petroleum	39.8	40.4	42.8	44.3	45.5	46.8	48.8	49.7	50.4	49.0	46.5	0.7%	0.0%	0.3%
Natural Gas	22.0	23.4	25.9	28.1	29.1	29.3	29.6	30.1	31.0	31.8	32.5	1.1%	0.4%	0.7%
Coal	22.4	22.3	23.0	24.6	27.0	30.4	33.2	34.9	36.0	38.4	40.5	1.6%	1.2%	1.3%
Nuclear	8.1	8.4	8.4	8.7	9.1	9.1	9.1	7.1	5.9	3.6	1.5	0.4%	-7.1%	-3.8%
Renewables	6.5	4.6	5.1	5.9	6.2	6.2	6.8	7.9	9.1	11.7	16.6	1.4%	4.0%	2.9%
Total Primary Energy	**98.8**	**99.1**	**105.1**	**111.6**	**116.9**	**121.8**	**127.5**	**129.7**	**132.5**	**134.4**	**137.6**	1.0%	0.5%	0.7%
Energy/GDP (Thos. Btu/ '01$ GDP)	10.5	8.7	7.9	7.2	6.5	5.9	5.4	4.8	4.4	4.0	3.7	-1.9%	-1.9%	-1.9%
Carbon Emissions (MMT)	1,594	1,627	1,725	1,834	1,934	2,052	2,167	2,234	2,290	2,334	2,356	1.2%	0.6%	0.8%

Petroleum's share of total energy consumption is projected to decline from 41% in 2005 to about 34% in 2050. The natural gas share is projected to remain relatively constant at about 24%. Coal generation is projected to increase from a 22% share in 2005 to nearly 29% in 2050. Almost all existing nuclear generation capacity is assumed to retire between 2025 and 2050.[8] However, 19 GW of new nuclear capacity is projected to be added between 2025 and 2050. The share of renewable energy is also projected to increase from 7% and 9% throughout the projection period.

End-Use Energy Demand

The sectoral breakout of energy use, shown in **Figure 3,** demonstrates that transportation energy demand is projected to increase by 1.0% per year, while commercial building and industrial energy demand both grow at an average of about 0.8% annually between 2005 and 2050. Residential energy consumption increases by about 0.9%, on average, between 2005 and 2025; but this trend reverses as demand contracts in the later years bring net change in the primary energy requirement to zero for this sector. The growth rates in energy consumption are a function

[8] The nuclear generation retirement schedule was derived by examining reactor license expiration dates and applying one 20-year extension where applicable.

of the opposing trends of increasing end-use energy-service demand and improvements in the efficiency of technologies that satisfy this demand, as well as macroeconomic shifts toward less energy-intensive industries. This phenomenon is best illustrated by examining the energy intensity of the economy. **Figure 4** shows the relative energy intensity for different end-use and conversion sectors and the economy as a whole.

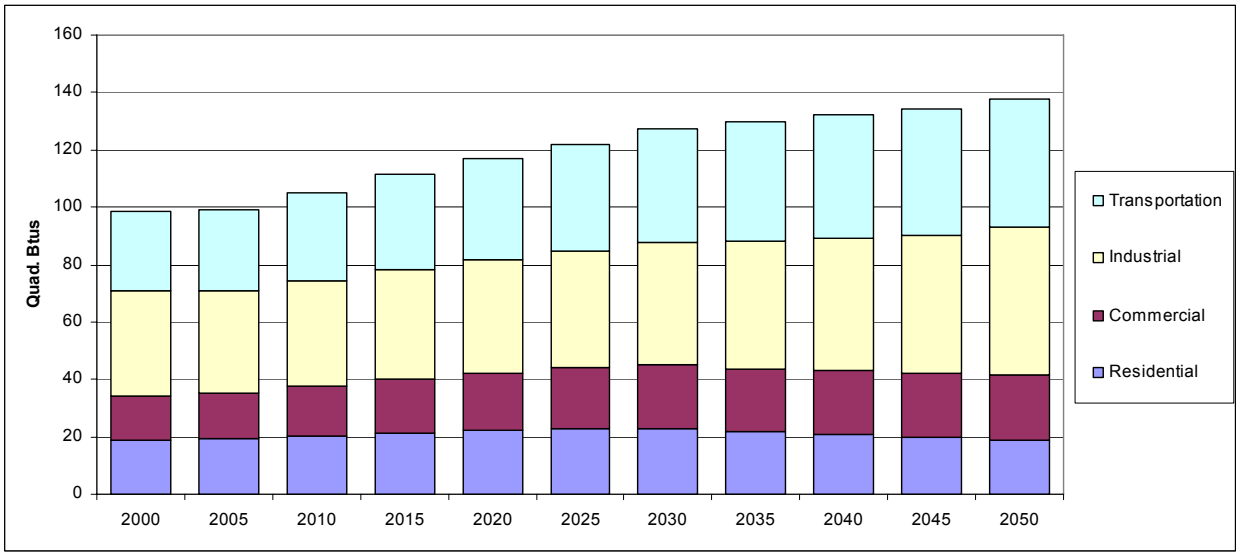

Figure 3. Energy Consumption by Sector

Note: Consumption totals include electric generation and distribution losses.

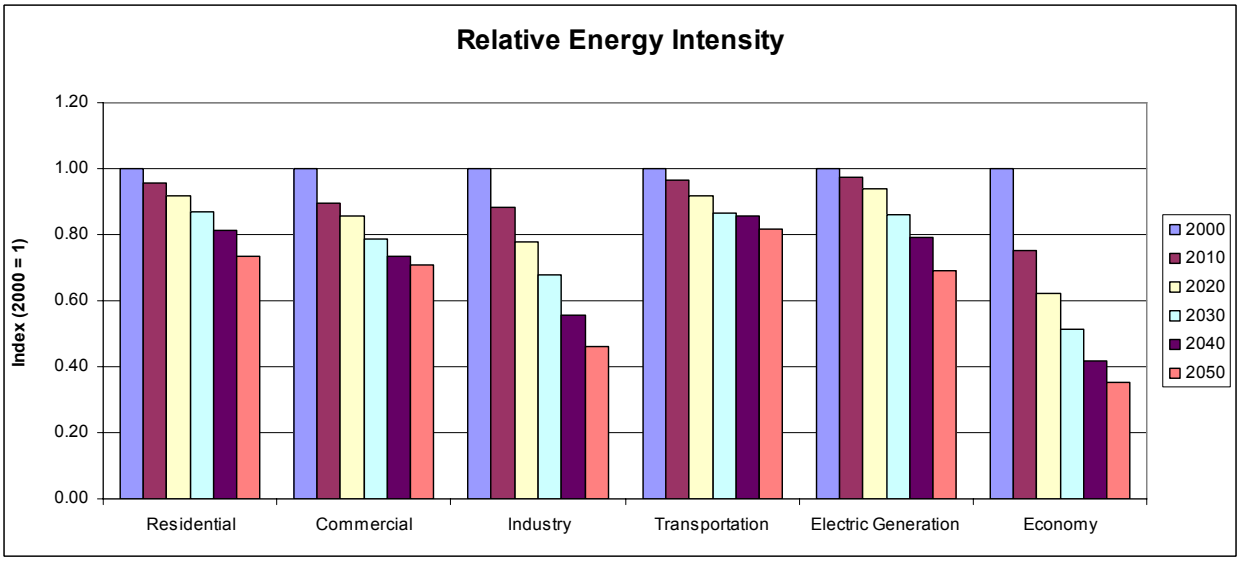

Figure 4. Relative Energy Intensity by Sector

Note: Residential index is primary energy excluding miscellaneous use per household. Commercial index is primary energy use excluding office equipment and miscellaneous appliances per square foot. Industrial index is total primary energy per unit output. Transportation index is light-duty vehicle primary energy per mile traveled. Electricity index is non-renewable average heat rate. Economy index is total primary energy per unit GDP.

As shown in **Figure 4**, our Reference Case projection indicates that the energy intensity of the economy (which we've defined as total primary energy consumption per $ of GDP) is projected to fall by almost two-thirds by 2050. This decrease reflects both a continued shift toward a service-based economy, as well as increases in energy technology efficiency. End-use efficiencies are projected to increase throughout the economy over the projection period as new, more efficient capital stocks are purchased to replace existing equipment and to meet new demand. The Reference Case technology database includes technologies that are expected to become available in the future, as well as those that are currently on the market. For example, more efficient electric heat pumps and light-duty vehicles are assumed to become available throughout the projection period. The technical and economic data associated with these technologies are derived from a variety of sources, but rely most heavily on the NEMS database.

The residential energy intensity index shows significant improvements in energy use per household. However, the residential index excludes "miscellaneous demands," the fastest growing segment of residential energy demand. The miscellaneous demand category includes electric devices such as home computers, TVs, microwave ovens, as well as devices such as gas lamps and swimming pool heaters. Because these service demands are growing faster than the sector as a whole, their energy use per household actually increases over time. Thus, the inclusion of miscellaneous demands in the calculation of residential energy intensity would obscure the efficiency gains being made in other residential service demands. While these miscellaneous demands are excluded from the chart, they are modeled within MARKAL.

The commercial energy intensity index shows significant improvements in energy use per square foot. However, as with the residential sector, this calculation excludes the fastest-growing demand categories: office equipment and miscellaneous commercial appliances. The inclusion of these demand categories would result in relatively constant commercial energy demand per square foot.

The industrial-sector efficiency index shows dramatic declines in energy intensity due to a shift from energy-intensive industries to nonenergy-intensive manufacturing, as well as improvements in process efficiency. Between 2005 and 2050, nonenergy-intensive manufacturing output is expected to grow at twice the rate as energy-intensive industrial output. This shift in output exaggerates the decline in energy intensity. However, in the transportation sector, consumer preferences for more powerful engines and a continued shift from passenger cars to sport utility vehicles (SUVs), limit gains in overall efficiency.

In the power-generation sector, the efficiency of nonrenewable generation is expected to increase as older, less efficient fossil steam units retire and new high efficiency gas combined-cycle and IGCC capacity is built. Electric generation by type is shown in **Figure 5**; natural gas-fired generation is projected to increase its share of total generation from about 20% to 26% over the projection period. Coal-fired generation remains the largest source of electricity at 50% to 57% of total generation. Due to significant retirements of existing nuclear capacity, the share of nuclear generation falls from 21% to 2% of generation in the projection period. Renewable generation increases from 10% to 15% of total generation.

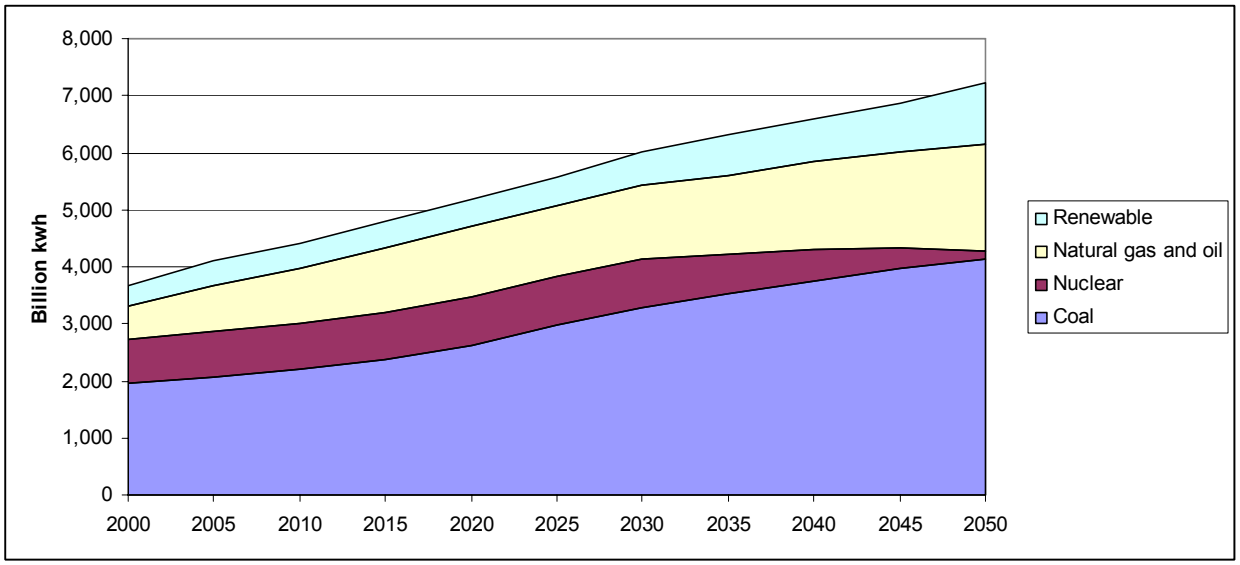

Figure 5. Electricity Generation by Type

While both natural gas and coal-fired generation show increased efficiency, fossil fuel use for electric generation increases by 56% during the projection period. Such an increase in coal and natural gas demand for power generation is dependent on the availability of these resources. However, potential reduction in supply (such as changes in the outlook in natural gas supply) would necessitate a significant change in fuels used for electric generation.