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Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals

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Energy Information Administration
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Preface and Contacts

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The model projections in this report are not statements of what will happen but of what might happen, given the assumptions and methodologies used. The reference case projections are business-as-usual trend forecasts, given known technology, technological and demographic trends, and current laws and regulations. Thus, they provide a policy-neutral starting point that can be used to analyze policy initiatives. EIA does not propose, advocate, or speculate on future legislative and regulatory changes. All laws are assumed to remain as currently enacted; however, the impacts of scheduled regulatory changes, when defined, are reflected.

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Executive Summary

This report responds to a request from Senator Ken Salazar that the Energy Information Administration (EIA) analyze the impacts of implementing alternative variants of an emissions cap-and-trade program for greenhouse gases (GHGs). The program is patterned after one recommended by the National Commission on Energy Policy (NCEP), a nongovernmental, privately-funded entity, in its December 2004 report entitled, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges.*[1] An April 2005 EIA report, *Impacts of Modeled Recommendations of the National Commission on Energy*, provided analysis of the complete NCEP program and its cap-and-trade component for GHGs alone.[2]

Senator Salazar asked EIA to re-analyze the emissions cap-and-trade component of the NCEP proposal using a range of alternative values for the emissions intensity reduction goal that defines the target emissions level and the permit price safety-valve that caps the cost of emissions permits. Generally speaking, higher intensity reduction goals lower the target emissions level, requiring more changes in the energy system to reach the target, while higher safety-valve prices raise the increase in delivered energy prices that can occur before the emissions target is implicitly relaxed to limit impacts on energy prices and the energy system.

The cases considered in this report are based on the *Annual Energy Outlook 2006* reference case (*AEO2006*), which differs significantly from the *Annual Energy Outlook 2005* used in our April 2005 report.[3,4] Key changes incorporated in the *AEO2006* include higher prices for oil, coal, and natural gas, extension of the analysis through 2030, and representation of some provisions of the Energy Policy Act of 2005 (EPACT2005). Taken together all of these factors contribute to lower energy use and lower greenhouse gas emissions in the *AEO2006* reference case compared to the *AEO2005* version. For example, in 2020, projected total consumer energy use is 4 percent lower in the *AEO2006* reference case, while total greenhouse gas emissions are 5 percent lower. The combination of lower projected baseline GHG emissions and higher fossil fuel prices in the *AEO2006* reference case tend to reduce projected GHG permit prices under a given GHG cap-and-trade program relative to the same program evaluated starting from the *AEO2005* reference case.

As in the original NCEP cap-and-trade program, the intensity reduction goals considered in this report are implemented in two stages, with faster intensity reduction rate targets beginning after 2020. The second stage intensity reduction targets range from 2.8

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[1]National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's EnergyChallenges* (Washington, DC, December 2004), web site www.energycommission.org/ewebeditpro/items/O82F4682.pdf. The National Commission on Energy Policy is a nongovernmental organization funded by the William and Flora Hewlett Foundation and its partners—The Pew Charitable Trusts, the John D. and Catherine T. MacArthur Foundation, the David and Lucile Packard Foundation, and the Energy Foundation.

[2] Energy Information Administration, *Impacts of Modeled Recommendations of the National Commission on EnergyPolicy*, SR/OIAF/2005-02 (Washington, DC, April, 2005) web site http://www.eia.doe.gov/oiaf/servicerpt/bingaman/index.html.

[3] Energy Information Administration, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, DC, February 2005), web site www.eia.doe.gov/oiaf/aeo/index.html.

[4] Energy Information Administration, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, DC, February 2006), web site www.eia.doe.gov/oiaf/aeo/index.html.

percent, as in the original NCEP proposal, to 4.0 percent. The implied 2030 GHG emissions targets in the cases examined vary from 4 percent below to 14 percent above the 2004 emissions level, well below the 39-percent increase in GHG emissions projected in the reference case. The safety-valve prices in 2010, expressed in 2004 dollars per metric ton of carbon dioxide-equivalent (CO_2 equivalent) range from $6, as in the original NCEP proposal to $31. Safety-valve prices in 2030, also in 2004 dollars, range from $10 to $49.

The emissions cap and safety-valve combinations in all the cases examined lead to reductions in GHG emissions relative to the reference case. However, the GHG intensity reduction goals are not fully achieved in cases where the safety-valves are triggered at some point in the projection period. Relative to the reference case, total GHG emissions are reduced by 5.2 percent to 13.6 percent in 2020 and by 8.7 percent to 27.9 percent in 2030 (Figure ES1). In all cases except the most stringent one, GHG emissions continue to increase over the entire 2004 through 2030 period. In the most stringent case, GHG emissions increase slowly through 2018 and then fall until they are only 0.5 percent above the 2004 emission level in 2030. The GHG permit prices range from $8 to $24 (2004 dollars) per metric ton CO_2 equivalent in 2020 and from $10 to $49 per metric ton CO_2 equivalent in 2030 (Figure ES 2).

Reductions in both energy-related carbon dioxide (CO_2) emissions and other greenhouse gas emissions in all sectors play a role in the lower GHG emissions. Reductions in other greenhouse gas emissions are important in all cases, particularly in the less stringent cases where they account for a large share of the overall GHG emissions reductions. If the market response in the industries that produce these gases is not as large as represented in the engineering-based abatement curves supplied by the Environmental Protection Agency (EPA) that are used in this analysis, more pressure will be put on energy markets to reduce their emissions raising the GHG permit prices, unless permit prices are constrained by the safety-valve mechanism.

Because the cost of GHG permits under the cap-and-trade program raises the cost of using fossil fuels, all sectors of the energy economy respond with lower overall energy use and a shift away from fossil fuels where economical. Because of coal's relatively high CO_2 content per unit of energy content and its relatively low price in the reference case, GHG permit prices have a larger impact on the cost of using coal than they do on the other fossil fuels. For example, delivered coal prices – including the costs of holding GHG emission permits – are between 51.9 percent and 156.8 percent higher in 2020 and between 57.4 percent and 305.6 percent higher in 2030. Motor gasoline prices are $0.06 per gallon to $0.19 per gallon (3.0 percent to 9.3 percent) higher in 2020 and $0.08 per gallon to $0.41 per gallon (3.7 percent to 18.9 percent) higher in 2030.

By far, the largest changes in GHG emissions and fuel use are projected in the power sector, which accounts for over 90 percent of reference case coal use and can switch to technologies that can generate electricity using a variety of other energy sources. Relative to the reference case, coal generation is projected to be between 4.8 percent and 27.2 percent lower in 2020 and between 15.8 percent and 64.5 percent lower in 2030. In the two less stringent program cases, coal generation still grows between 2004 and 2030, though at a slower rate than in the reference case. In the two most stringent program cases, coal generation in 2030 is expected to be between 9.5 and 39.2 percent below the 2004 level. New coal plants with carbon capture and sequestration equipment are added in these two cases, but their generation is not large enough to offset the impacts of coal plant retirements and lower generation from the remaining coal plants.

In contrast to coal, the power sector is projected to increase its use of nuclear and renewable fuels in the cap-and-trade cases. While 6 gigawatts (GW) of new nuclear plants are added between 2004 and 2030 in the reference case, between 25 and 123 GW are added in the program cases. The 2030 share of generation accounted for by nuclear plants falls to 14.7 percent in the reference case, but ranges from 17.6 percent to 31.8 percent in the program cases. Renewable fuels, particularly wind and biomass, also account for a larger share of generation in the program cases. In the reference case, the share of generation accounted for by nonhydroelectric renewable generation grows from 2.2 percent to 4.3 percent, while in the program cases it increases to between 7.3 percent and 20.6 percent. Wind capacity grows from 7 GW to 20 GW in the reference case, but grows to between 27 and 86 GW in the program cases. Similarly, biomass capacity grows from 6 GW to 12 GW in the reference case, but grows to between 30 and 101 GW in the program cases.

In the residential sector, relative to the reference case, delivered energy consumption is between 0.6 percent and 1.7 percent lower in 2020 and between 0.9 percent and 3.5 percent lower in 2030. Similarly in the commercial sector, delivered energy consumption is between 1.3 percent and 3.0 percent lower in 2020 and between 1.8 percent and 5.8 percent lower in 2030. Despite the reductions in energy consumption, higher delivered energy prices lead to higher energy bills for consumers. Relative to the reference case, annual per household energy expenditures (excluding motor fuels costs) are $61 to $169 (3.8 to 10.5 percent) higher in 2020 and $91 to $336 (5.4 percent to 20.0 percent) higher in 2030.

Similar responses are projected in the industrial and transportation sectors. Relative to the reference case, delivered industrial energy consumption is between 2.0 percent and 3.2 percent lower in 2020 and between 4.5 percent and 7.9 percent lower in 2030. In the transportation sector, energy consumption is between 0.7 percent and 2.2 percent lower in 2020 and between 1.2 percent and 4.9 percent lower in 2030, when compared to the reference case.

In the transportation sector, the higher energy prices in the program cases lead to reduced travel and slightly higher penetration of hybrid and diesel cars. However, the increase in gasoline prices, at most $0.41 per gallon higher than in the reference case, is not enough to cause a large shift in the mix of vehicles purchased. Because of lower projected coal use in the power sector, relative to the reference case, rail transportation in the program cases is much lower.

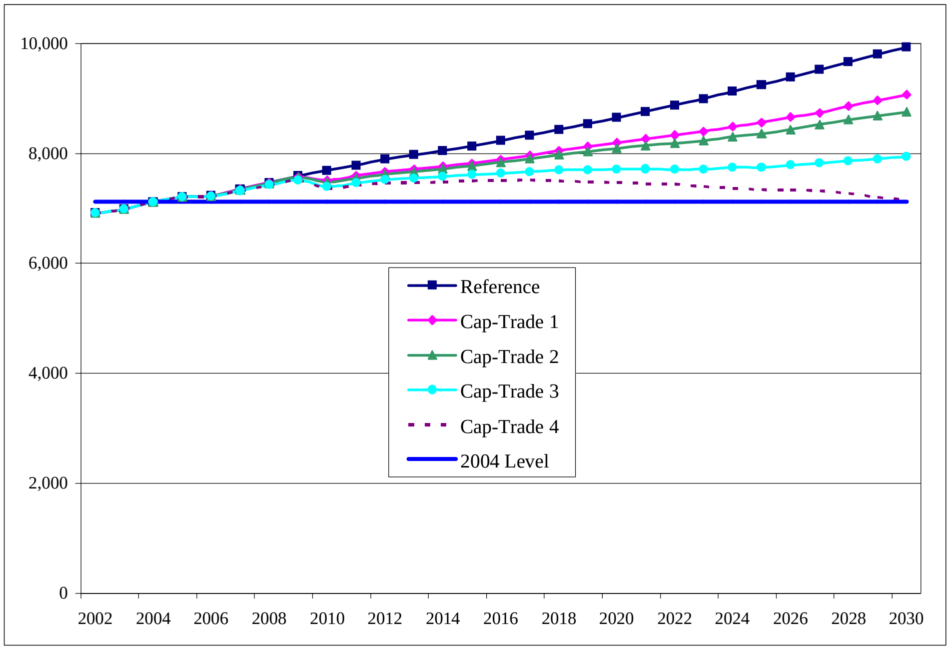
Higher delivered energy prices lower real income to households. This reduces energy consumption and indirectly reduces real spending (due to lower purchasing power) for other goods and services. Relative to the reference case, discounted total real gross domestic product (GDP) over the 2010 to 2030 time period ranges from $244 billion to $800 billion (0.10 to 0.32 percent) lower, while discounted real consumer spending is between $248 billion and $772 billion (0.15 to 0.46 percent) lower in the program cases.

Table ES-1 summarizes the key parameters that define the program cases considered in this report. Tables ES-2a and ES-2b summarize key results for 2020 and 2030 respectively. As with all analyses that look forward more than a few years, there is considerable uncertainty in these projections. It is particularly difficult to foresee how existing technologies might evolve or what new technologies might emerge as market conditions change, particularly when those changes are fairly dramatic. This analysis suggests that to comply with increasingly stringent GHG emissions limits, all energy providers, particularly electricity producers, will rely increasingly on technologies, such as nuclear power, wind, and biomass, that play a relatively small role today or have not been built in the U.S. for many years.

If the development of these technologies is limited for one reason or another, power providers will have two choices. First, they can turn to other low-GHG or non-GHG technologies, such as new fossil generators with carbon capture and sequestration equipment. Such technologies also face cost and development challenges. Second, they can purchase a larger number of permits at the safety-valve price to allow for continued reliance on current fossil-fired generation to a greater extent than projected in the program cases. To the extent this occurs, projected reductions in GHGs would be reduced. One way or another, significantly reducing energy-related GHG emissions would require a shift away from fossil energy sources that currently account for 86 percent of US energy consumption. The costs of such a shift are inherently very uncertain.

Figure ES 1: Total Greenhouse Gas Emissions in Alternative Cases, 2002-2030

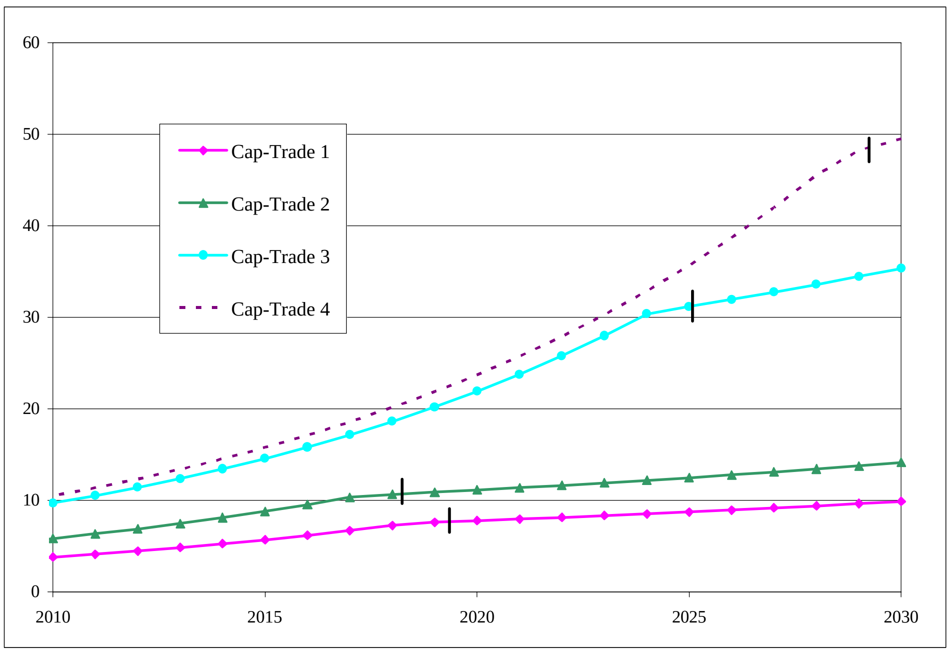
(Million Metric Tons Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Figure ES 2: Greenhouse Gas Permit Prices in Cap and Trade Cases, 2010-2030

(2004 Dollars per Metric Ton Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Table ES 1: Analysis Cases

Case Name	GHG Intensity Reduction Goal (percent per year)		Safety-valve Price (2004 dollars per metric ton CO_2 equivalent)		Other
	2010-2019	2020-2030	2010	2030	
Cap-Trade 1	2.4	2.8	$ 6.16	$ 9.86	Greenhouse gas cap-and-trade system with safety-valve.
Cap-Trade 2	2.6	3.0	$ 8.83	$14.13	
Cap-Trade 3	2.8	3.5	$22.09	$35.34	
Cap-Trade 4	3.0	4.0	$30.92	$49.47	
Cap-Trade 3 Low Other	2.8	3.5	$22.09	$35.34	Cap-Trade 3 with 50 percent reduction in "other" than energy-related CO_2 GHG abatement supply.
Cap-Trade 3 Low Safety	2.8	3.5	$ 8.83	$14.13	Cap-Trade 3 with lower assumed safety-valve price.
Cap-Trade 3 High Tech	2.8	3.5	$22.09	$35.34	Cap-Trade 3 with more optimistic technology assumptions.

Table ES 2a: Summary Results from the Reference and Program Cases in 2020

	2004	Reference	Cap-Trade 1	Cap-Trade 2	Cap-Trade 3	Cap-Trade 3 High Tech	Cap-Trade 3 Low Other	Cap-Trade 3 Low Safety	Cap-Trade 4
Emissions of greenhouse gases (million metric tons CO_2 equivalent)									
Covered Emissions Goal	NA	NA	6,964	6,808	6,635	6,635	6,635	6,635	6,467
Total covered emissions	6,159	7,571	7,121	7,014	6,635	6,536	6,711	6,986	6,396
Energy-related carbon dioxide	5,900	7,119	6,927	6,843	6,497	6,378	6,417	6,816	6,259
Other covered emissions	259	452	194	171	138	158	295	171	137
Non-covered emissions	963	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077
Total greenhouse gases	7,122	8,649	8,198	8,091	7,712	7,613	7,788	8,063	7,473
Permit price (2004 dollars per metric ton CO_2 equivalent)	NA	NA	7.8	11.1	21.9	13.2	25.4	11.1	23.7
Delivered energy prices, including permit costs (2004 dollars per physical unit, as indicated)									
Motor gasoline (per gallon)	1.90	2.08	2.14	2.17	2.26	2.15	2.28	2.17	2.27
Jet fuel (per gallon)	1.22	1.42	1.51	1.54	1.63	1.51	1.66	1.54	1.65
Distillate (per gallon)	1.74	1.93	2.03	2.07	2.18	2.05	2.21	2.07	2.19
Natural Gas (per thousand cubic feet), all users	7.74	7.14	7.57	7.74	8.21	7.73	8.41	7.68	8.20
Residential	10.72	10.48	10.90	11.08	11.57	11.10	11.79	11.03	11.54
Electric power	6.07	5.53	5.99	6.16	6.61	6.05	6.81	6.10	6.50
Coal (per short ton)	28.81	28.55	43.32	49.55	69.32	52.80	76.00	49.59	73.21
Electricity (cents per kwh)	7.57	7.25	7.68	7.89	8.34	7.71	8.51	7.88	8.33
Fossil energy consumption (quadrillion Btu)									
Petroleum	40.1	48.1	47.2	47.0	46.5	44.4	46.4	47.0	46.5
Natural Gas	23.1	27.7	27.4	27.3	26.9	25.8	27.0	27.4	26.2
Coal	22.5	27.6	26.5	25.7	22.6	23.4	21.8	25.4	20.5
Electric power sector generation (billion kilowatthours)									
Total	3,799	4,835	4,785	4,758	4,701	4,541	4,680	4,756	4,703
Petroleum	115	92	34	34	28	27	26	34	26
Natural Gas	619	968	1,032	1,022	1,005	1,003	1,026	1,027	909
Coal	1,954	2,435	2,353	2,281	1,990	2,065	1,919	2,256	1,801
Nuclear	789	871	871	885	926	892	923	906	945
Renewable	323	469	496	536	753	554	785	534	1,023
Real Gross Domestic Product (billion 2000 dollars)	10,756	17,541	17,528	17,522	17,500	17,543	17,493	17,527	17,503

Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

Table ES 2b: Summary Results from the Reference and Program Cases in 2030

	2004	Reference	Cap-Trade 1	Cap-Trade 2	Cap-Trade 3	Cap-Trade 3 High Tech	Cap-Trade 3 Low Other	Cap-Trade 3 Low Safety	Cap-Trade 4
Emissions of greenhouse gases (million metric tons CO_2 equivalent)									
Covered Emissions Goal	NA	NA	6,907	6,615	6,123	6,123	6,123	6,123	5,665
Total covered emissions	6,159	8,742	7,878	7,568	6,752	6,594	6,950	7,440	5,971
Energy-related carbon dioxide	5,900	8,114	7,604	7,333	6,546	6,384	6,534	7,204	5,790
Other covered emissions	259	627	274	235	206	210	416	235	181
Non-covered emissions	963	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189
Total greenhouse gases	7,122	9,930	9,067	8,757	7,941	7,783	8,139	8,629	7,160
Permit price (2004 dollars per metric ton CO_2 equivalent)	NA	NA	9.9	14.1	35.3	29.8	35.3	14.1	49.5
Delivered energy prices, including permit costs (2004 dollars per physical unit, as indicated)									
Motor gasoline (per gallon)	1.90	2.19	2.27	2.31	2.48	2.43	2.48	2.31	2.60
Jet fuel (per gallon)	1.22	1.56	1.66	1.69	1.90	1.83	1.89	1.69	2.03
Distillate (per gallon)	1.74	2.06	2.21	2.25	2.47	2.48	2.47	2.26	2.62
Natural Gas (per thousand cubic feet), all users	7.74	8.22	8.77	9.04	10.00	9.63	10.04	8.94	10.70
Residential	10.72	11.67	12.25	12.53	13.52	13.24	13.58	12.41	14.24
Electric power	6.07	6.41	7.01	7.31	8.24	7.92	8.26	7.16	8.89
Coal (per short ton)	28.81	30.30	47.71	54.18	93.88	83.17	93.94	53.69	122.94
Electricity (cents per kwh)	7.57	7.51	8.18	8.48	9.40	8.85	9.44	8.38	9.74
Fossil energy consumption (quadrillion Btu)									
Petroleum	40.1	53.6	52.3	52.0	50.9	47.5	50.8	52.0	50.3
Natural Gas	23.1	27.7	27.7	27.8	27.0	26.4	27.2	27.5	26.7
Coal	22.5	34.5	30.0	27.2	20.1	20.9	20.0	26.0	13.6
Electric power sector generation (billion kilowatthours)									
Total	3,799	5,503	5,461	5,421	5,272	5,043	5,265	5,425	5,211
Petroleum	115	101	35	35	27	25	25	33	22
Natural Gas	619	822	942	956	870	1,052	892	906	851
Coal	1,954	3,205	2,792	2,437	1,766	1,849	1,760	2,293	1,178
Nuclear	789	871	1,020	1,166	1,418	1,288	1,393	1,460	1,762
Renewable	323	504	672	827	1,191	829	1,195	734	1,398
Real Gross Domestic Product (billion 2000 dollars)	10,756	23,112	23,085	23,077	23,042	23,045	23,045	23,075	22,984

Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

1. Background and Scope of the Analysis

This service report was prepared by the Energy Information Administration (EIA), in response to an October 20, 2005, request from Senator Ken Salazar (see Appendix A). Senator Salazar requested that EIA assess the impacts of alternative greenhouse gas intensity[5] reduction goals and permit safety-valve prices. He requested that the analysis build on an earlier EIA Report that analyzed the policies recommended by the National Commission on Energy Policy (NCEP), a nongovernmental, privately-funded entity, in its December 2004 report entitled, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges.*[6,7]

Among the policies recommended by the NCEP was a greenhouse gas (GHG) reduction program with a goal to reduce GHG intensity in two phases beginning in 2010. The NCEP recommended a GHG intensity reduction goal of 2.4 percent per year in the first phase between 2010 and 2019, and a goal of 2.8 percent per year in the second phase beginning in 2020. The NCEP proposed meeting the reduction targets with an emission cap-and-trade program with a safety-valve[8] permit price of $7 per metric ton of carbon dioxide equivalent in 2010 (nominal dollars rising at 5 percent per year).

This report examines the impacts of alternative GHG intensity reduction goals on greenhouse gas emissions, energy demand, supply and prices, together with the economic impacts using the National Energy Modeling System (NEMS).[9] Specifically, Senator Salazar requested "analysis of additional intensity-improvement/safety-valve combinations with intensity improvements ranging from 2.6 to 4.0 percent per year and safety-valve values ranging from $10 to $35 (in 2010 nominal dollars, rising five percent per year)."

Pursuant to Senator Salazar's request, this report considers variations in the greenhouse gas intensity reduction program originally recommended by the NCEP. It does not evaluate the impacts of other programs suggested by the NCEP. The impacts of the GHG intensity reduction goals analyzed are compared with the reference case results published by EIA in the *Annual Energy Outlook 2006* (*AEO2006*) in February 2006.[10] Since the

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5 Greenhouse gas intensity is defined as the emissions of greenhouse gases from covered sources per real dollar of GDP (in 2000 dollars). Greenhouse gases are measured in metric tons of carbon dioxide (CO_2) equivalent. The gases covered in the proposed reduction program include energy-related carbon dioxide, methane from coal mining, nitrous oxide from nitric acid and adipic acid production, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

6 National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's EnergyChallenges* (Washington, DC, December 2004), web site www.energycommission.org/ewebeditpro/items/O82F4682.pdf. The National Commission on Energy Policy is a nongovernmental organization funded by the William and Flora Hewlett Foundation and its partners—The Pew Charitable Trusts, the John D. and Catherine T. MacArthur Foundation, the David and Lucile Packard Foundation, and the Energy Foundation.

7 Energy Information Administration, *Impacts of Modeled Recommendations of the National Commission on EnergyPolicy*, SR/OIAF/2005-02 (Washington, DC, April, 2005) web site http://www.eia.doe.gov/oiaf/servicerpt/bingaman/index.html

8 The safety-valve is an agreement by the government to sell emission permits at a given price so as to limit the potential permit cost to a maximum. The government is assumed to sell permits sufficient to make up the difference between covered emissions and the emissions goal. As a result, the government begins to accrue additional permit revenue once the safety-valve price is reached.

9 Energy Information Administration, *The National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003) (Washington, DC, March, 2003), web site www.eia.doe.gov/oiaf/aeo/overview/index.html.

10 Energy Information Administration, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, DC, February 2006), web site www.eia.doe.gov/oiaf/aeo/index.html.

earlier report was based on the *AEO2005*, a brief discussion is provided of the key differences between the *AEO2005* and *AEO2006* that impact greenhouse gas emissions.

This report, like other EIA analyses of energy and environmental policy proposals, focuses on the impacts of those proposals on energy choices made by consumers in all sectors and the implications of those decisions for the economy. This focus is consistent with EIA's statutory mission and expertise. The study does not account for any possible health or environmental benefits that might be associated with curtailing GHG emissions.

Greenhouse Gas Intensity Reduction Cases

Table 1 summarizes the greenhouse gas intensity improvement rates and permit safety-valve prices for the analysis cases in this report. The Cap-Trade 1 through Cap-Trade 4 cases, which incorporate progressively larger rates of targeted intensity improvements and progressively higher safety-valve prices, are the main focus of this report. The GHG intensity reduction goals used in these cases were chosen to span the ranges in the analysis request. In addition, permit safety-valve prices for each case were selected from the range of safety-valves requested by Senator Salazar. The permit safety-valve prices shown in Table 1 are in 2004 dollars while the requested $10 to $35 range was given in 2010 dollars. In 2010 dollars, the $8.83 value shown would be $10 while the $30.92 value would be $35. As requested, the safety-valves are assumed to increase 5 percent annually in nominal dollars from 2010 through 2030.

The report also discusses three additional cases based on the intensity reduction goals in the Cap-Trade 3 case, but with alternative assumptions about the permit safety-valve price, the abatement opportunities for other greenhouse gases, and the rate of technological change. The Cap-Trade 3 Low Safety case is the same as the Cap-Trade 3 case, except that it uses a lower GHG permit safety-valve price to illustrate how the safety-valve can impact the results actually achieved. The Cap-Trade 3 High Tech case examines the impacts of alternative technology improvement assumptions. It includes the same greenhouse gas targets and safety-valves as the Cap-Trade 3 case, but incorporates the technology assumptions from the High Integrated Technology case in the *AEO2006*.[11] The Cap-Trade 3 Low Other case addresses uncertainty about the emissions reductions that might occur in non-energy-related greenhouse gases. NEMS does not explicitly represent consumer and producer behavior with respect to the non-energy-related greenhouse gases. Instead, engineering-based emissions abatement curves for these other gases were derived from work done by the Environmental Protection Agency (EPA) and were used to represent how consumers and producers might

[11] The *AEO2006* high technology case assumes earlier introduction, lower costs, and higher efficiencies for energy technologies in the end-use sectors, as well as improved costs and efficiencies for advanced fossil-fired, nuclear, and renewable generating technologies in the electric power sector.

Table 1: Analysis Cases

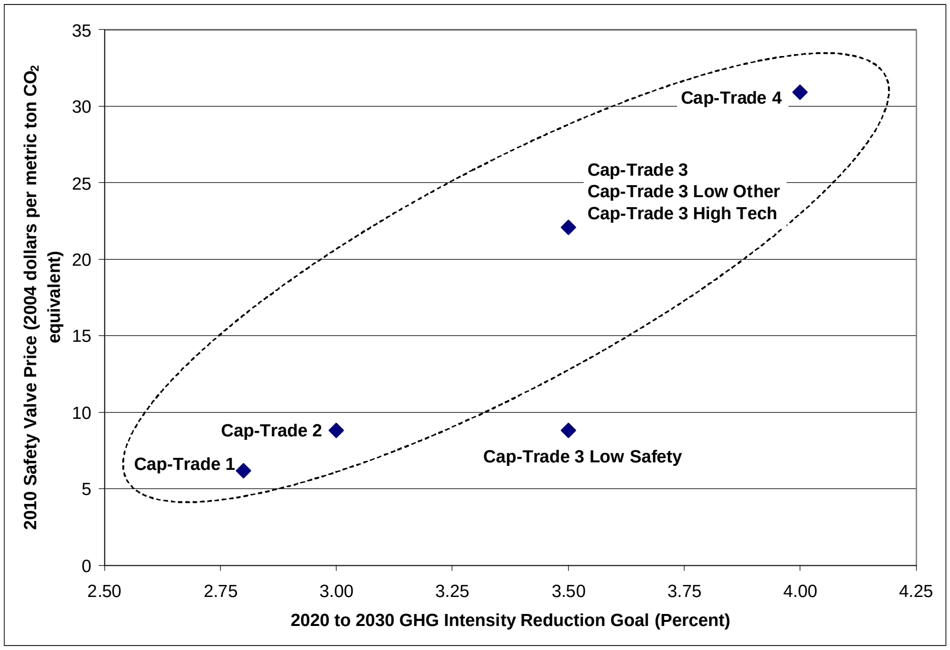
Case Name	GHG Intensity Reduction Goal (percent per year)		Safety-valve Price (2004 dollars per metric ton CO_2 equivalent)		Other
	2010-2019	2020-2030	2010	2030	
Cap-Trade 1	2.4	2.8	$ 6.16	$ 9.86	Greenhouse gas cap-and-trade system with safety-valve.
Cap-Trade 2	2.6	3.0	$ 8.83	$14.13	
Cap-Trade 3	2.8	3.5	$22.09	$35.34	
Cap-Trade 4	3.0	4.0	$30.92	$49.47	
Cap-Trade 3 Low Other	2.8	3.5	$22.09	$35.34	Cap-Trade 3 with 50 percent reduction in other GHG abatement supply.
Cap-Trade 3 Low Safety	2.8	3.5	$ 8.83	$14.13	Cap-Trade 3 with lower assumed safety-valves.
Cap-Trade 3 High Tech	2.8	3.5	$22.09	$35.34	Cap-Trade 3 with more optimistic technology assumptions.

respond to a GHG cap and trade program. However, markets often do not respond as rapidly as some engineering-based analyses would suggest, so the Cap-Trade 3 Low Other case assumes a 50-percent reduction in the quantity available on the other greenhouse gas abatement curves

Figure 1 illustrates the GHG intensity reduction goal and safety-valve price combinations examined. The Cap-Trade 1 case represents the program recommended by the NCEP. Starting from this case, the Cap-Trade 2, Cap-Trade 3 and Cap-Trade 4 cases (throughout the rest of this report referred to as the “Cap-Trade” cases) pair increasingly stringent GHG intensity reduction goals with increasing permit safety-valve prices, defining the dotted ellipse in Figure 1. Combinations of intensity rate reduction targets and safety-valve prices below and to the right of the dotted ellipse in Figure 1 pair relatively stringent intensity rate reduction goals with relatively low safety-valve prices. These combinations, such as the Cap-Trade 3 Low Safety case, tend to produce energy model results similar to those for combinations within the dotted ellipse with less stringent intensity goals and the same safety-valve, as shown in the next chapter.

Combinations of relatively modest intensity rate reduction goals with relatively high safety-valve prices, above and to the left of the dotted ellipse in Figure 1, are not explicitly addressed in this report. However, once the safety-valve price is set at a level where the safety-valve is not triggered, further increases in the safety-valve price have no impact on the energy model or economic model results. Model results for combinations in the region above and to the left of the dotted ellipse in Figure 1 are generally close to those that would result from policies that set intensity rate reduction targets without a safety-valve price mechanism. However, even a non-binding safety-valve price would continue to provide some degree of economic and energy system protection in a situation where the cost of emissions abatement proves to be significantly higher than technologies and behavior as modeled in NEMS for energy-related CO_2 or by EPA for other greenhouse gases would suggest. Such an outcome could occur if technologies that penetrate the market significantly in the modeled program cases, for example new nuclear power plants, run into unanticipated technical or siting problems.

Figure 1: GHG Intensity Reduction Goals and Safety-valve Combinations Examined



Methodology

The analysis of energy sector and energy-related economic impacts of the various GHG emission reduction proposals in this report is based on NEMS results. NEMS projects emissions of energy-related CO_2 emissions resulting from the combustion of fossil fuels, representing about 84 percent of total GHG emissions today. For this analysis, the *AEO2006* reference case emissions for energy-related CO_2 were augmented with baseline emissions projections for other covered GHGs to create a baseline for total covered GHG emissions. Projections of non-CO_2 GHG emissions, including the covered non-CO_2 gases, are derived from an unpublished Environmental Protection Agency (EPA) "no-measures" case, a recent update to the "business-as-usual" case cited in the White House Greenhouse Gas Policy Book Addendum[12] released with the Climate Change Initiative. The projections from the Policy Book were based on several EPA-sponsored studies conducted in preparation of the U.S. Department of State's Climate Action Report

[12] See "Addendum" in the "Global Change Policy Book" at http://www.whitehouse.gov/news/releases/2002/02/climatechange.html. The business-as-usual (BAU) projections cited in the addendum are somewhat higher than a "Policies and Measures" case EPA developed for the *U.S. Climate Action Report 2002*.

2002.[13] The no-measures case was developed by EPA in preparation for a planned 2006 "National Communication" to the United Nations in which a "with-measures" policy case is to be published.[14]

Simulations of the emissions cap-and-trade policy in NEMS were used to estimate the price of GHG permits over time and resulting changes in the energy system. First, starting from the projected level of energy-related CO_2 emissions in 2010 from the *AEO2006* reference case and the EPA projection for emissions of other GHGs in 2010, the GHG intensity rate reduction targets for each of the analysis cases were translated into annual emissions targets for the 2011 to 2030 period.

NEMS endogenously calculates changes in energy-related CO_2 emissions in the analysis cases. The cost of using each fossil fuel includes the costs associated with the GHG permits needed to cover the emissions produced when they are used. These adjustments influence energy demand and energy-related CO_2 emissions. The GHG permit price also determines the reductions in the emissions of other GHGs based on the abatement cost relationships supplied by EPA, as discussed above. With emission permit banking, NEMS solves for the time path of permit prices such that cumulative emissions match the cumulative target, provided the permit price remains below the safety-valve permit price. Once the safety-valve permit price is attained and the previously-banked permits are exhausted, actual GHG emissions can exceed the calculated annual emissions target, as fossil fuel users and other GHG emitters can purchase an unlimited number of emissions permits from the government at the safety-valve price.

NEMS, like all models, is a simplified representation of reality. Projections are dependent on the data, methodologies, model structure, and assumptions used to develop them. Since many of the events that shape energy markets are random and cannot be anticipated (including severe weather, technological breakthroughs, and geopolitical developments), energy markets are subject to uncertainty. Moreover, future developments in technologies, demographics, and resources cannot be foreseen with certainty. Nevertheless, well-formulated models are useful in analyzing complex policies, because they ensure consistency in accounting and represent key interrelationships, albeit imperfectly, to provide insights.

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[13] U.S. Department of State, *U.S. Climate Action Report 2002* (Washington, DC, May 2002), Chapter 5, "Projected Greenhouse Gas Emissions," pp. 70-80, web site: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsUSClimateActionReport.html .

[14] Personal communication from Casey Delhotal, of the Environmental Protection Agency, to Dan Skelly of the Energy Information Administration, on July 7, 2005. EIA adjusted the EPA no-measures case projections to extrapolate from the most recent 2002-to-2004 data on these gases as published by EIA, as well as to estimate the intervening years of the projections, since the projections were only provided for every five years beginning in 2005 and ending in 2020. In addition, EIA extrapolated the projection to 2030 for this analysis based on the average annual growth rates of individual emissions sources from 2015 to 2020.

EIA's projections are not statements of what will happen, but what might happen, given technological and demographic trends and current policies and regulations. EIA's reference case is based on current laws and regulations. Thus, it provides a policy-neutral starting point that can be used to analyze energy policy initiatives. EIA does not propose, advocate, or speculate on future legislative or regulatory changes within its reference case. Laws and regulations are generally assumed to remain as currently enacted or in force (including sunset or expiration provisions); however, the impacts of scheduled regulatory changes, when clearly defined, are reflected.

2. Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals

As discussed in Chapter 1, this analysis focuses on the four Cap-Trade cases with alternative GHG intensity reduction targets and permit price safety-valves, and several additional cases that explore the impacts of alternative assumptions. These cases reflect the cap-and-trade mechanism recommended by the NCEP and were designed to span the set of alternative parameters identified by Senator Salazar. Discussion of the additional cases is provided where necessary to highlight important findings or illustrate the sensitivity of the analysis findings to key assumptions.

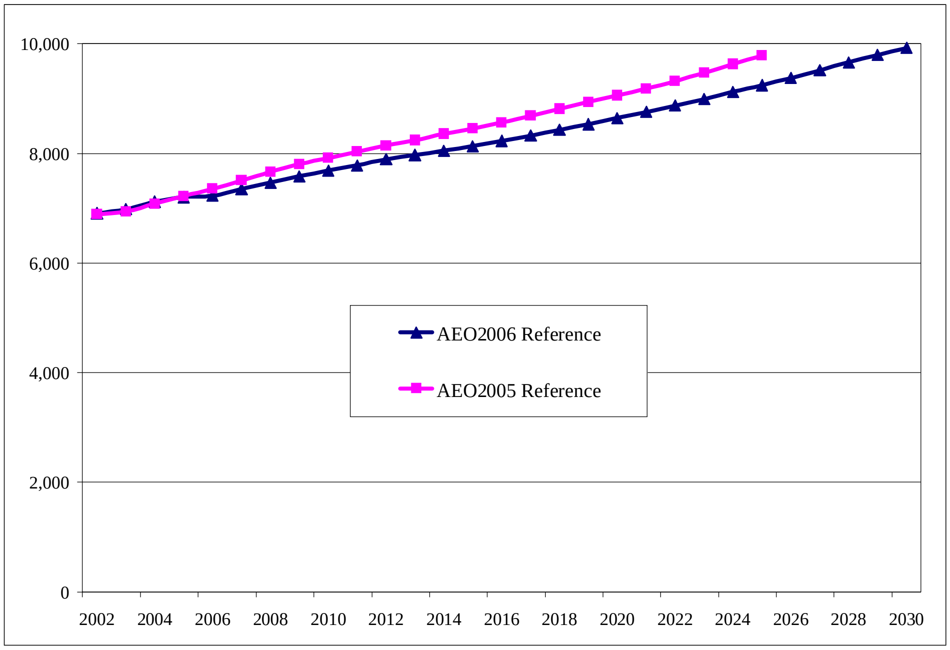
Updating to *AEO2006*

The main analysis cases in this report are based on the reference case from the *AEO2006*. EIA's earlier analysis of the NCEP recommendations was based on the reference case from the *AEO2005*. The update to the *AEO2006* impacts the analysis because of important changes in the *AEO2006* projections. The key changes include significantly higher prices for oil, coal, and natural gas, extension of the analysis through 2030, and representation of some key provisions of the Energy Policy Act of 2005 (EPACT2005), the Clean Air Interstate Rule (CAIR), and the Clean Air Mercury Rule (CAMR). For this analysis, EIA also updated the assumed baseline for non-CO_2 GHGs based on the most recent historical data on these gases as well as updated projections from a "no-measures" case provided by the EPA in July 2005.

Compared to the *AEO2005* reference case, world oil prices, natural gas wellhead prices, and coal minemouth prices are 55, 6, and 15 percent higher, respectively, in 2020 in the *AEO2006* reference case. These higher fossil fuel prices together with new energy efficiency standards and various technology incentives called for in EPACT2005, and slower expected growth in non-energy-related GHG emissions, contribute to lower overall energy use and lower GHG emissions. In 2010, projected total energy use is 5.6 percent lower in the *AEO2006* reference case, while total greenhouse gas emissions are 2.5 percent lower. As a result, relative to EIA's April 2005 analysis based on *AEO2005*, the emissions target implied by any GHG intensity reduction goal using the *AEO2006* reference case as a starting point is lower. Over the 2010 to 2025 time period, the difference in targets generally ranges between 200 and 300 million metric tons CO_2 equivalent, or 2.5 to 3.5 percent.

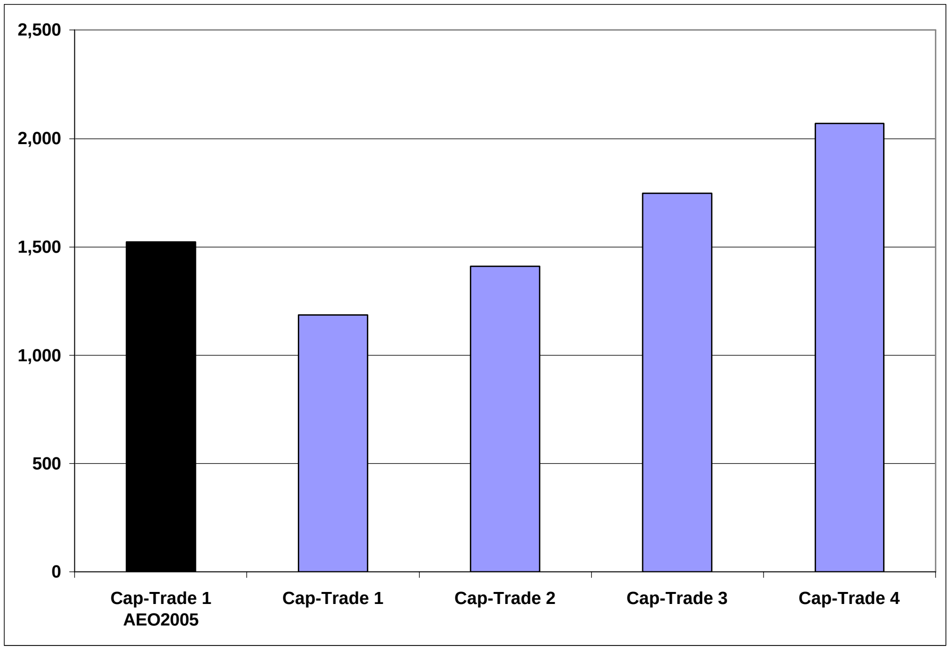
However, notwithstanding the lower emissions targets, the required emissions reduction to reach those targets is smaller in this analysis than in the April 2005 version, as the reduction in projected outyear emissions between the *AEO2006* and *AEO2005* reference cases (Figure 2) is greater than the reduction in implied emissions targets. For example, in the earlier analysis, total greenhouse gas emissions in 2025 had to be reduced by 1,522 million metric tons from the reference case level. Using the *AEO2006* reference case as a starting point, the required reduction from the 2025 projected level is much smaller, only 1,187 million metric tons. Figure 3 presents the level of the targeted emissions reduction in 2025 for the Cap-Trade 1 (NCEP) program parameters for both the *AEO2005* and

Figure 2: Greenhouse Gas Emissions in Alternative Reference Cases, 2002-2030
(Million Metric Tons Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, AEO2005.D102004A, and BING_CAP.d021005A.

Figure 3: Targeted Reduction in Covered Greenhouse Gas Emissions in 2025
(Million Metric Tons Carbon Dioxide Equivalent)



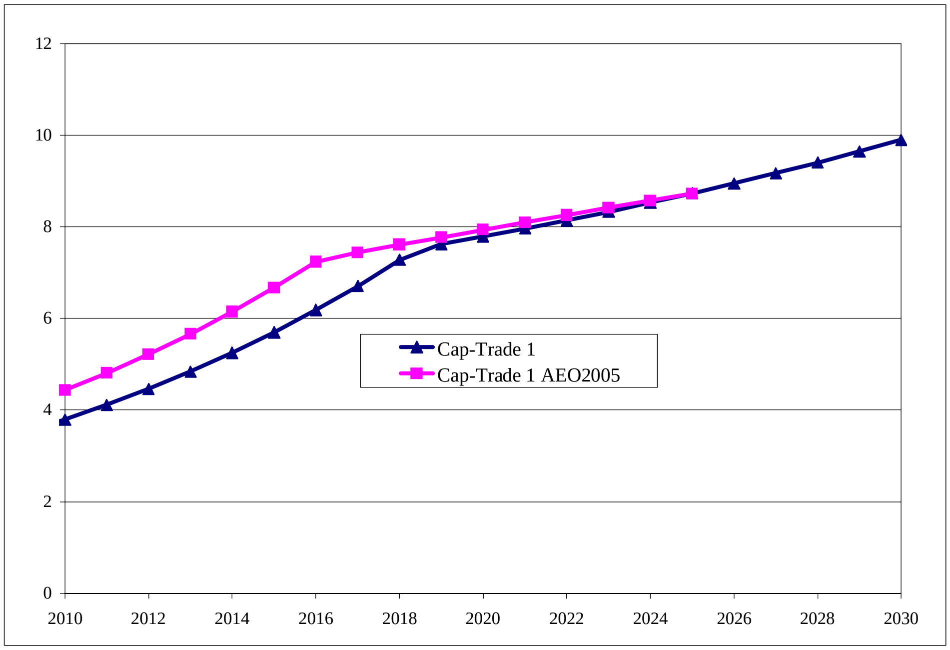
Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, AEO2005.D102004A, and BING_CAP.d021005A.

AEO2006 baselines, as well as the targeted emission reductions for the Cap-Trade 2 though Cap-Trade 4 cases using the current (*AEO2006*) baseline only.

The smaller emissions reduction requirement and the higher fossil fuel prices in the *AEO2006* reference case tend to reduce the projected GHG permit prices. The higher fossil fuel prices make non-fossil alternatives relatively more attractive and a lower GHG permit price is needed to encourage GHG emissions reductions. However, when the safety-valve prices recommended by the NCEP are incorporated, as in the Cap-Trade 1 case, the projected permit prices are the same after 2018 whether the analysis is carried out using the *AEO2006* or *AEO2005* reference case as the baseline, because the safety-valve is triggered in both cases. Without the safety-valve, permit prices in both cases would be substantially higher (Figure 4).

Figure 4: Greenhouse Gas Permit Prices, 2010-2030

(2004 Dollars per Metric Ton Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, AEO2005.D102004A, and BING_CAP.d021005A.

Greenhouse Gas Emissions and Permit Prices

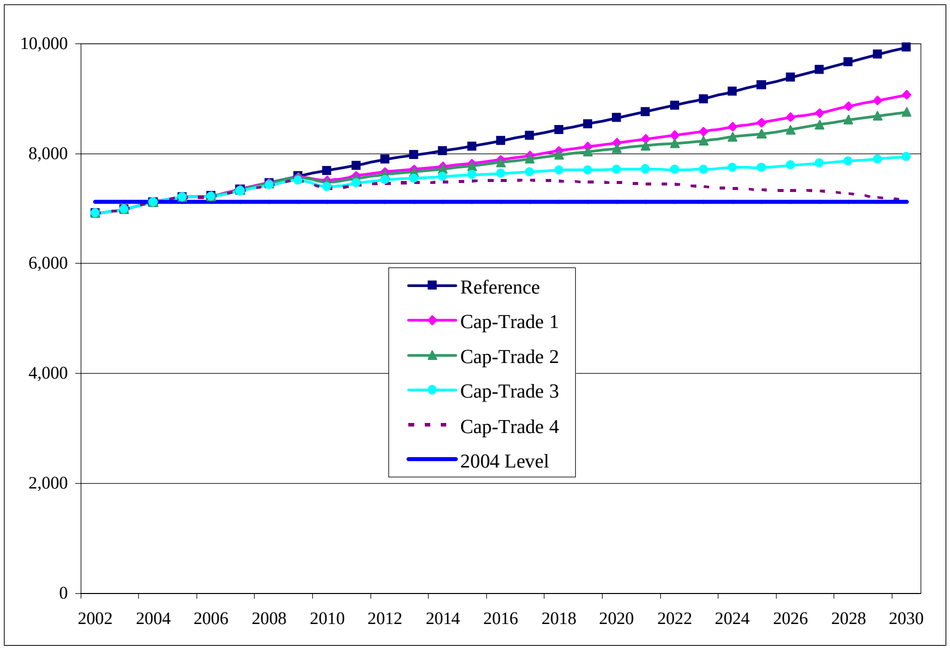
Relative to the reference case, complying with the alternative GHG intensity reduction goals and permit safety-valve prices in the Cap-Trade cases will lead to significant reductions in total GHG emissions (Figure 5). However, because the GHG permit safety-valve is triggered in each of these cases, total covered emissions exceed the covered emissions goals. In 2020 total GHG emissions range from 5 to 14 percent lower across the Cap-Trade cases (Tables 2a and 2b). This change grows even larger by 2030, ranging from 9 to 28 percent lower GHG emissions than in the reference case. Except for the

Cap-Trade 4 case, total GHG emissions are generally projected to increase over time following an initial dip in 2010, albeit more slowly than in the reference case. By 2030, total GHG emissions in the Cap-Trade 4 case are projected to be just slightly above the 2004 emissions level.

The impact of the permit safety-valve price on GHG emissions can be seen by comparing variants of the Cap-Trade 3 case with the same GHG intensity reduction goal, but alternative permit safety-valve prices, to the Cap-Trade 2 case, which has a less stringent intensity reduction goal but the same safety-valve prices as the Cap-Trade 3 Low Safety case (Figure 6). As a result of the different GHG permit safety-valve prices, GHG emissions in the two Cap-Trade 3 variants range between 7 percent and 11 percent below the reference case level in 2020 and between 13 percent and 20 percent lower in 2030. The Cap-Trade 3 Low Safety and the Cap-Trade 2 cases, which have identical safety-valves, have very similar emissions profiles in Figure 6, and nearly identical energy market impacts (Tables 2a and 2b) once the safety-valve takes effect. One continuing difference between the Cap-Trade 2 and Cap-Trade 3 Low Safety cases is in the amount of permits purchased through the safety-valve mechanism, and in government revenues from sales of such permits, since fewer permits are given to emitters under the more stringent emissions intensity reduction goals of the Cap-Trade 3 Low Safety case than under the Cap-Trade 2 case.

Figure 5: Total Greenhouse Gas Emissions in Alternative Cases, 2002-2030

(Million Metric Tons Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Table 2a: Summary Results from the Reference and Program Cases in 2020

	2004	Reference	Cap-Trade 1	Cap-Trade 2	Cap-Trade 3	Cap-Trade 3 High Tech	Cap-Trade 3 Low Other	Cap-Trade 3 Low Safety	Cap-Trade 4
Emissions of greenhouse gases (million metric tons CO_2 equivalent)									
Covered Emissions Goal	NA	NA	6,964	6,808	6,635	6,635	6,635	6,635	6,467
Total covered emissions	6,159	7,571	7,121	7,014	6,635	6,536	6,711	6,986	6,396
Energy-related carbon dioxide	5,900	7,119	6,927	6,843	6,497	6,378	6,417	6,816	6,259
Other covered emissions	259	452	194	171	138	158	295	171	137
Non-covered emissions	963	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077
Total greenhouse gases	7,122	8,649	8,198	8,091	7,712	7,613	7,788	8,063	7,473
Permit price (2004 dollars per metric ton CO_2 equivalent)	NA	NA	7.8	11.1	21.9	13.2	25.4	11.1	23.7
Delivered energy prices, including permit costs (2004 dollars per physical unit, as indicated)									
Motor gasoline (per gallon)	1.90	2.08	2.14	2.17	2.26	2.15	2.28	2.17	2.27
Jet fuel (per gallon)	1.22	1.42	1.51	1.54	1.63	1.51	1.66	1.54	1.65
Distillate (per gallon)	1.74	1.93	2.03	2.07	2.18	2.05	2.21	2.07	2.19
Natural Gas (per thousand cubic feet), all users	7.74	7.14	7.57	7.74	8.21	7.73	8.41	7.68	8.20
Residential	10.72	10.48	10.90	11.08	11.57	11.10	11.79	11.03	11.54
Electric power	6.07	5.53	5.99	6.16	6.61	6.05	6.81	6.10	6.50
Coal (per short ton)	28.81	28.55	43.32	49.55	69.32	52.80	76.00	49.59	73.21
Electricity (cents per kwh)	7.57	7.25	7.68	7.89	8.34	7.71	8.51	7.88	8.33
Fossil energy consumption (quadrillion Btu)									
Petroleum	40.1	48.1	47.2	47.0	46.5	44.4	46.4	47.0	46.5
Natural Gas	23.1	27.7	27.4	27.3	26.9	25.8	27.0	27.4	26.2
Coal	22.5	27.6	26.5	25.7	22.6	23.4	21.8	25.4	20.5
Electric power sector generation (billion kilowatthours)									
Total	3,799	4,835	4,785	4,758	4,701	4,541	4,680	4,756	4,703
Petroleum	115	92	34	34	28	27	26	34	26
Natural Gas	619	968	1,032	1,022	1,005	1,003	1,026	1,027	909
Coal	1,954	2,435	2,353	2,281	1,990	2,065	1,919	2,256	1,801
Nuclear	789	871	871	885	926	892	923	906	945
Renewable	323	469	496	536	753	554	785	534	1,023
Real Gross Domestic Product (billion 2000 dollars)	10,756	17,541	17,528	17,522	17,500	17,543	17,493	17,527	17,503

Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

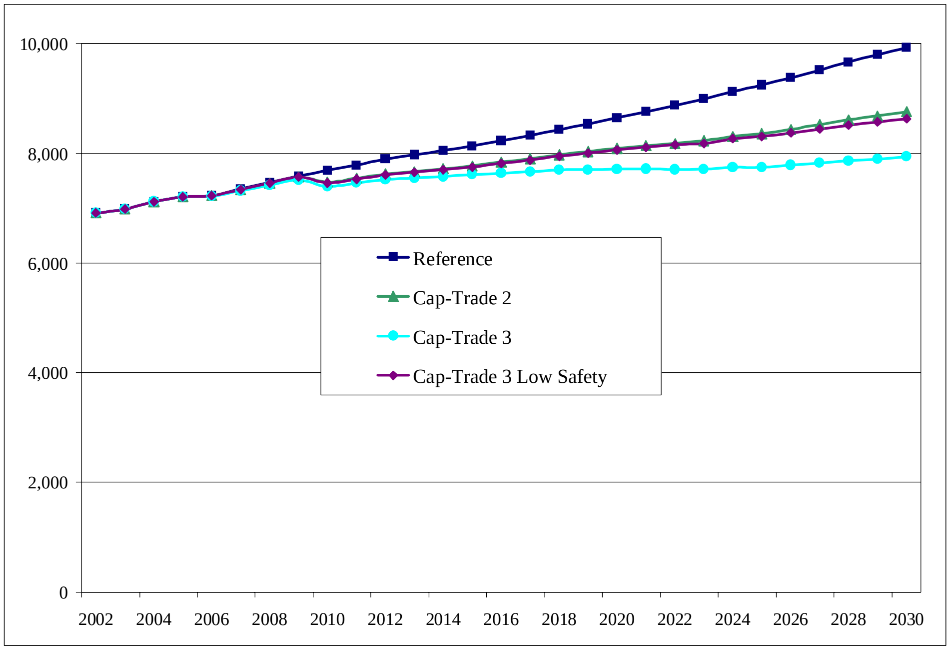
Table 2b: Summary Results from the Reference and Program Cases in 2030

	2004	Reference	Cap-Trade 1	Cap-Trade 2	Cap-Trade 3	Cap-Trade 3 High Tech	Cap-Trade 3 Low Other	Cap-Trade 3 Low Safety	Cap-Trade 4
Emissions of greenhouse gases (million metric tons CO_2 equivalent)									
Covered Emissions Goal	NA	NA	6,907	6,615	6,123	6,123	6,123	6,123	5,665
Total covered emissions	6,159	8,742	7,878	7,568	6,752	6,594	6,950	7,440	5,971
Energy-related carbon dioxide	5,900	8,114	7,604	7,333	6,546	6,384	6,534	7,204	5,790
Other covered emissions	259	627	274	235	206	210	416	235	181
Non-covered emissions	963	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189
Total greenhouse gases	7,122	9,930	9,067	8,757	7,941	7,783	8,139	8,629	7,160
Permit price (2004 dollars per metric ton CO_2 equivalent)	NA	NA	9.9	14.1	35.3	29.8	35.3	14.1	49.5
Delivered energy prices, including permit costs (2004 dollars per physical unit, as indicated)									
Motor gasoline (per gallon)	1.90	2.19	2.27	2.31	2.48	2.43	2.48	2.31	2.60
Jet fuel (per gallon)	1.22	1.56	1.66	1.69	1.90	1.83	1.89	1.69	2.03
Distillate (per gallon)	1.74	2.06	2.21	2.25	2.47	2.48	2.47	2.26	2.62
Natural Gas (per thousand cubic feet), all users	7.74	8.22	8.77	9.04	10.00	9.63	10.04	8.94	10.70
Residential	10.72	11.67	12.25	12.53	13.52	13.24	13.58	12.41	14.24
Electric power	6.07	6.41	7.01	7.31	8.24	7.92	8.26	7.16	8.89
Coal (per short ton)	28.81	30.30	47.71	54.18	93.88	83.17	93.94	53.69	122.94
Electricity (cents per kwh)	7.57	7.51	8.18	8.48	9.40	8.85	9.44	8.38	9.74
Fossil energy consumption (quadrillion Btu)									
Petroleum	40.1	53.6	52.3	52.0	50.9	47.5	50.8	52.0	50.3
Natural Gas	23.1	27.7	27.7	27.8	27.0	26.4	27.2	27.5	26.7
Coal	22.5	34.5	30.0	27.2	20.1	20.9	20.0	26.0	13.6
Electric power sector generation (billion kilowatthours)									
Total	3,799	5,503	5,461	5,421	5,272	5,043	5,265	5,425	5,211
Petroleum	115	101	35	35	27	25	25	33	22
Natural Gas	619	822	942	956	870	1,052	892	906	851
Coal	1,954	3,205	2,792	2,437	1,766	1,849	1,760	2,293	1,178
Nuclear	789	871	1,020	1,166	1,418	1,288	1,393	1,460	1,762
Renewable	323	504	672	827	1,191	829	1,195	734	1,398
Real Gross Domestic Product (billion 2000 dollars)	10,756	23,112	23,085	23,077	23,042	23,045	23,045	23,075	22,984

Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

Figure 6: Impact of Alternative GHG Permit Safety-valve Prices on Greenhouse Gas Emissions, 2002-2030

(Million Metric Tons Carbon Dioxide Equivalent)

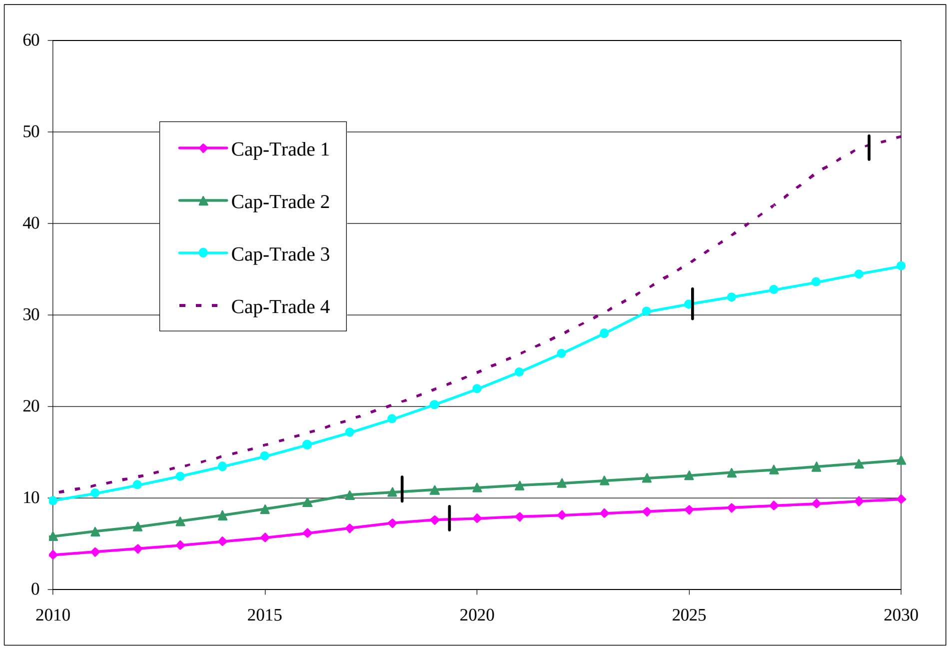


Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP35S10.D012306a.

The greenhouse gas permit price varies significantly across cases depending on the stringency of the GHG intensity reduction goal and the permit safety-valve price (Figure 7). In 2020, the permit prices range from $8 per metric ton CO_2 equivalent in the Cap-Trade 1 case to $24 per metric ton CO_2 equivalent in the Cap-Trade 4 case. This range widens to $10 to $49 per metric ton CO_2 equivalent in 2030.

In each of the Cap-Trade cases the GHG permit price increases steadily until its growth is slowed by each case's permit safety-valve. The year where the permit safety-valve becomes limiting in each case is shown in Figure 7 by a vertical hash mark on each line. For example, the GHG permit safety-valve price becomes limiting in 2028 in the Cap-Trade 4 case, 2025 in the Cap-Trade 3 case, 2018 in the Cap-Trade 2 case and 2019 in the Cap-Trade 1 case. Without the safety-valves the GHG permit prices would continue to rise in each of the cases until the GHG intensity reduction targets were reached. However, the annual emissions targets implied by the intensity rate reduction goals would not necessarily be complied with in each year because of year-to-year emissions banking and trading.

Figure 7: Greenhouse Gas Permit Prices in Cap and Trade Cases, 2010-2030
(2004 Dollars per Metric Ton Carbon Dioxide Equivalent)



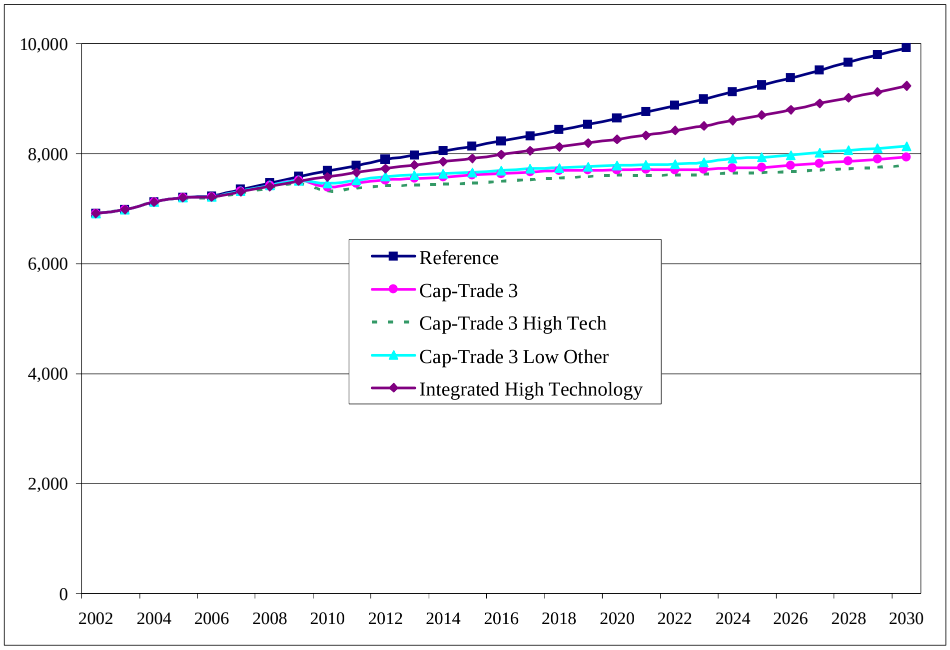
Source: National Energy Modeling System runs SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

The market responses to a GHG intensity reduction program are sensitive to assumptions about technological improvements and the potential for emissions reductions in non-CO_2 GHGs. More rapid technological improvements, such as those incorporated in the *AEO2006* integrated high technology case, could lead to lower GHG emissions when an intensity reduction program is introduced (Figure 8). Relative to the reference case, the technology assumptions in the integrated high technology case lead to 4 percent lower GHG emissions in 2020 and 7 percent lower GHG emissions in 2030. When the Cap-Trade 3 GHG intensity reduction program is introduced under these assumptions, as in the Cap-Trade 3 High Tech case, the required emissions reductions are projected to be achieved without triggering the GHG permit safety-valve (Figure 9).

On the other hand, if the emissions reduction opportunities for non-CO_2 GHGs are less than indicated by engineering-based marginal abatement curves prepared by the EPA that are used in this analysis, the safety-valve will be triggered earlier than under reference case assumptions, and higher GHG emissions could result. In 2020, the GHG permit prices among the cases shown in Figure 9 range from $13 per metric ton carbon equivalent to $25 per metric ton carbon dioxide equivalent.

Figure 8: Greenhouse Gas Emissions in Alternative Cap-Trade 3 Cases

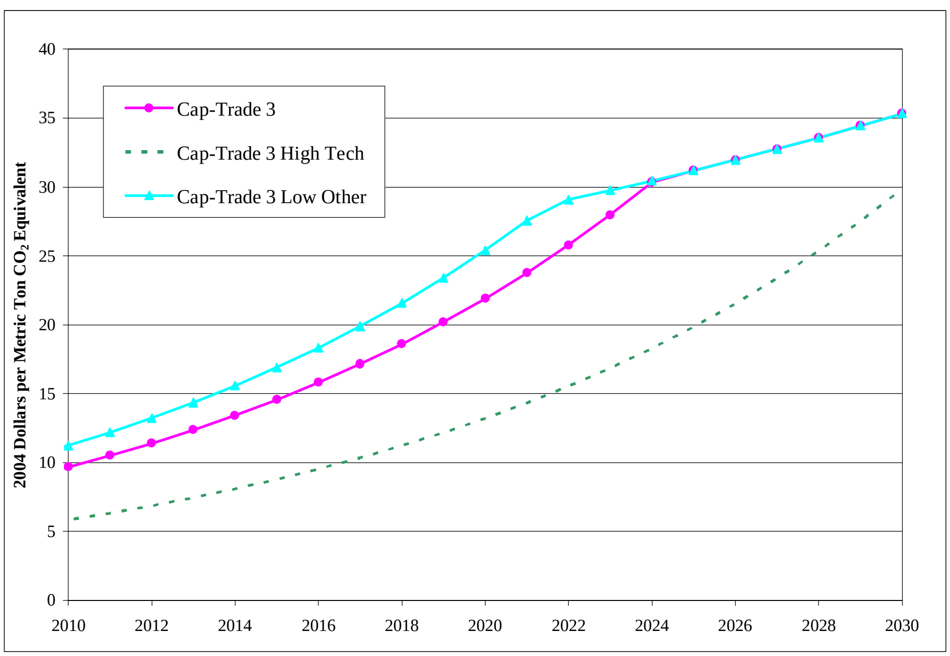
(Million Metric Tons CO_2 Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, HTRKITEN.D121905A, SALACAP35.D012306A, SALACAP35HI.D012306A, and SALACAP35LOTH.D012506A.

Figure 9: Greenhouse Gas Permit Prices in Alternative Cap and Trade 3 Cases

(2004 Dollars per Metric Ton CO_2 Equivalent)

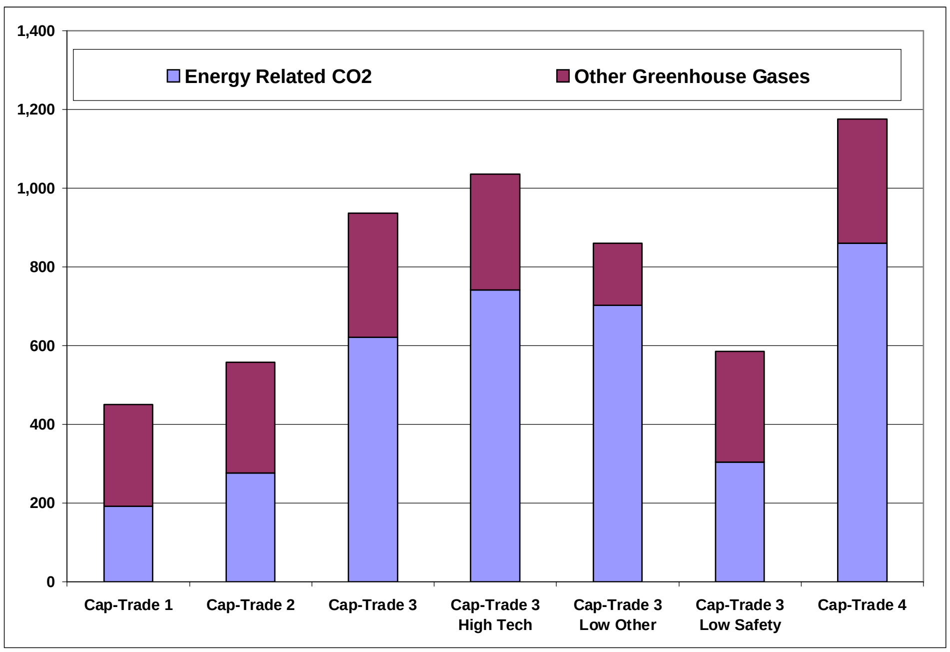


Source: National Energy Modeling System runs: SALACAP35.D012306A, SALACAP35HI.D012306A, and SALACAP35LOTH.D012506A.

Emissions reductions in the alternative cap-and-trade cases considered in this analysis are projected to occur in all of the GHGs (Figures 10 and 11). Reductions in GHG emissions other than energy-related CO_2, particularly the high global warming potential gases, are most important in the earlier years and the less stringent cases. The abatement curves, taken from EPA analyses, suggest that there are numerous opportunities to reduce the emissions of these gases, and they play a particularly important role in the least stringent cases, such as the Cap-Trade 1 case, where they account for 57.8 percent of the reductions in 2020 and 40.9 percent of the reductions in 2030. In the more stringent Cap-Trade 4 case, they account for 26.8 percent of the reductions in 2020 and 16.1 percent of the reductions in 2030.

Figure 10: Greenhouse Gas Emissions Reductions in Alternative Cases in 2020

(Million Metric Tons Carbon Dioxide Equivalent)

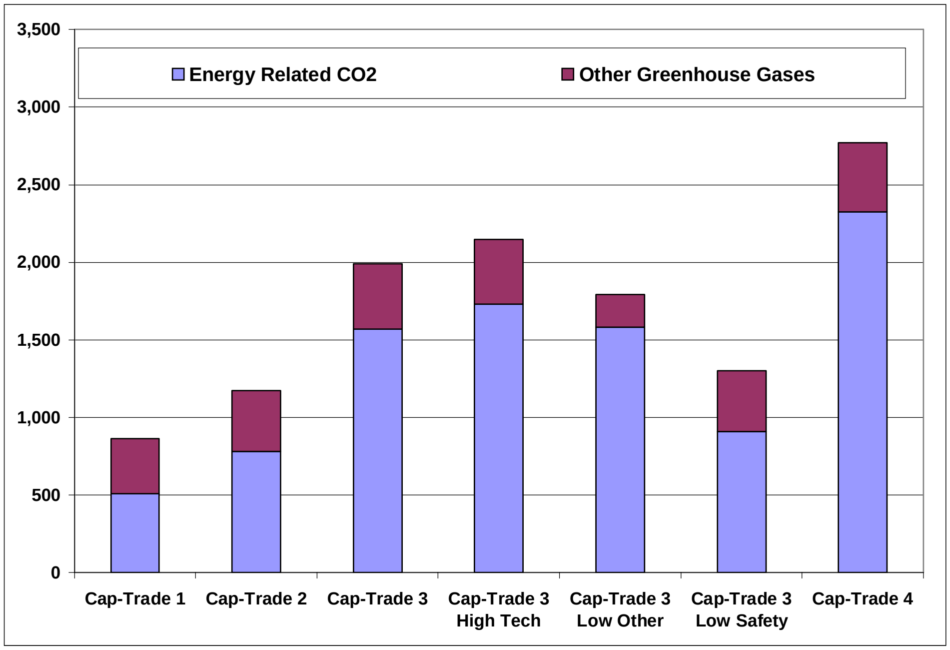


Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

Energy-related CO_2 emissions reductions play a large role in each of the Cap-Trade cases, but their contribution to the total GHG emissions reductions increases over time and with the stringency of the reduction requirement. In the Cap-Trade 1 case, they account for 42.6 percent of the GHG emissions reductions in 2020 and 59.1 percent in 2030. In the Cap-Trade 4 case, they account for 73.2 percent of the GHG emissions reductions in 2020 and 83.9 percent in 2030.

Under alternative assumptions about technological improvement and the availability of emissions reductions from the other GHGs, the level and mix of reductions could vary. For example, with more optimistic assumptions about technology improvements, as in the Cap-Trade 3 High Tech case, larger reductions in energy-related CO_2 emissions

Figure 11: Greenhouse Gas Emissions Reductions in Alternative Cases in 2030
(Million Metric Tons Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

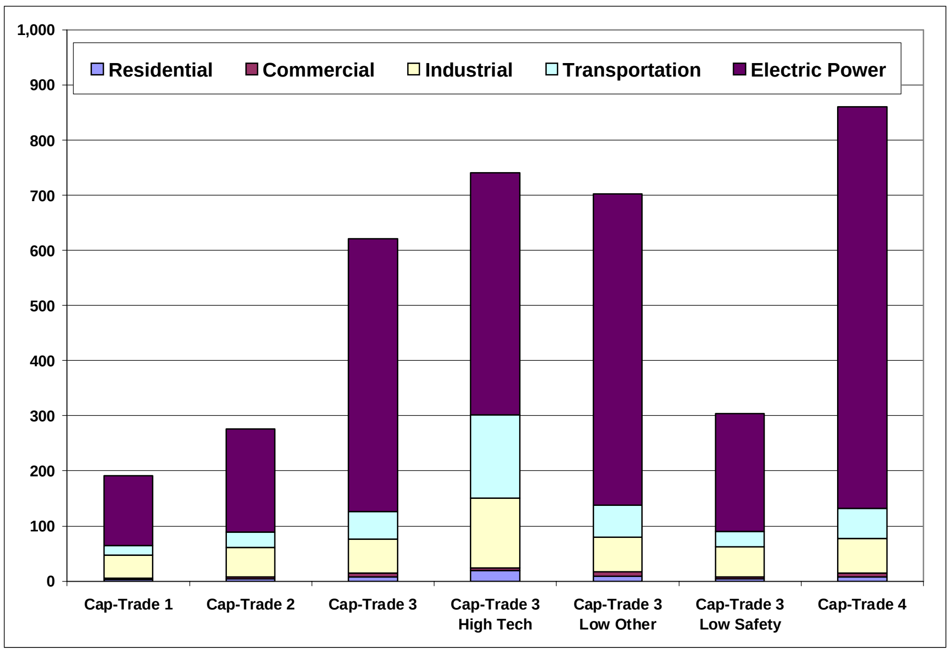
occur. In 2020 and 2030, energy-related CO_2 emissions reductions are 19.2 percent and 10.4 percent higher, respectively, in the Cap-Trade 3 High Tech case than they are in the Cap-Trade 3 case. The larger reduction in energy-related CO_2 emissions expected in the Cap-Trade 3 High Tech case allows the greenhouse intensity reduction goal to be achieved without triggering the permit safety-valve. In 2020, energy-related CO_2 emissions are also higher in the Cap-Trade 3 Low Other case than they are in the Cap-Trade 3 case. This occurs because lower reductions in other greenhouse gases lead to a higher GHG permit price which stimulates greater reductions in energy-related CO_2 emissions. By 2030, the reductions in energy-related CO_2 emissions in the Cap-Trade 3 Low Other and Cap-Trade 3 cases are less than 1 percent different because the permit safety-valve has been triggered in both cases. In the Cap-Trade 3 Low Other case, the safety-valve is triggered earlier than it is in the Cap-Trade 3 case, limiting the pressure to further reduce energy-related CO_2 emissions to offset the impact of lower reductions in other greenhouse gases.

Relative to the Cap-Trade 3 case, emissions reductions in both energy-related CO_2 emissions and other GHGs are much lower in the Cap-Trade 3 Low Safety case. In fact, the emissions reductions projected in the Cap-Trade 3 Low Safety case are almost the same as those projected in the Cap-Trade 2 case. This occurs primarily because the cases share the same assumed permit safety-valve prices. If a relatively stringent GHG intensity reduction goal is paired with a relatively low permit safety-valve, the government will end up selling larger numbers of permits at the safety-valve price, implicitly relaxing the targeted intensity reduction goal.

The reductions in energy-related CO_2 emissions are projected to come from all sectors of the economy, but the electric power sector, with its diverse fuel mix, accounts for the majority of these reductions in all cases (Figures 12 and 13). Across the Cap-Trade cases, the electric power sector accounts for between 65.9 percent and 84.6 percent of the total energy-related CO_2 emissions reductions in 2020 and between 67.6 percent and 84.5 percent of the total energy-related CO_2 emissions reductions in 2030. The share of reductions accounted for by the electricity sector grows over time as new non-fossil generating plants are built in the Cap-Trade cases because of the increase in fossil fuel prices. The share of energy-related CO_2 emissions reductions accounted for by the other sectors is fairly small in all cases except for the Cap-Trade 3 High Tech case. In that case, more optimistic technology assumptions in the industrial and transportation sectors increase their contribution to the energy-related CO_2 emissions reductions.

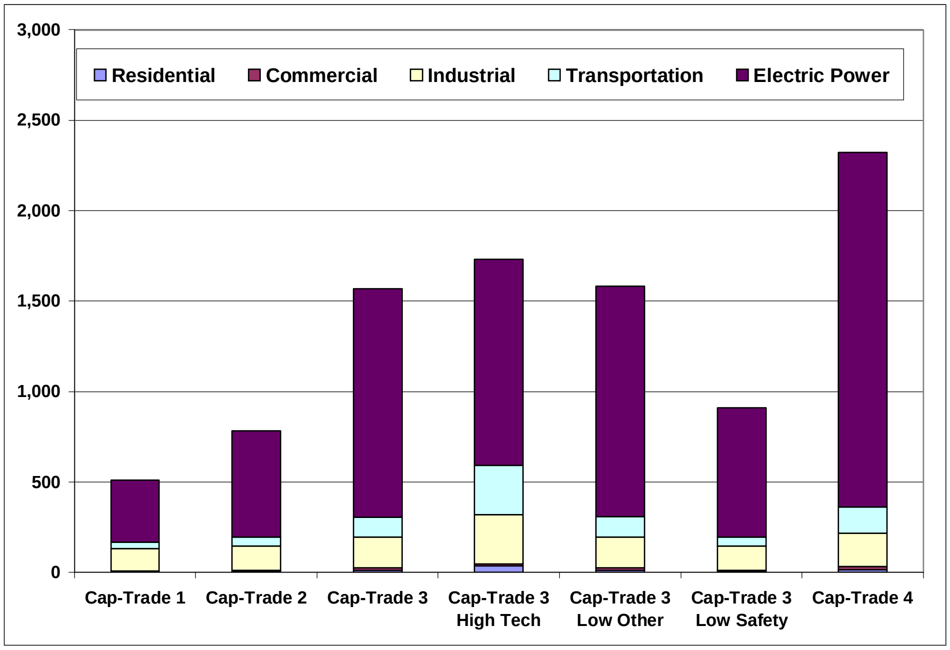
Figure 12: Energy-related CO_2 Emissions Reductions by Sector in 2020

(Million Metric Tons Carbon Dioxide Equivalent)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

Figure 13: Energy-related CO_2 Emissions Reductions by Sector in 2030
(Million Metric Tons Carbon Dioxide Equivalent)



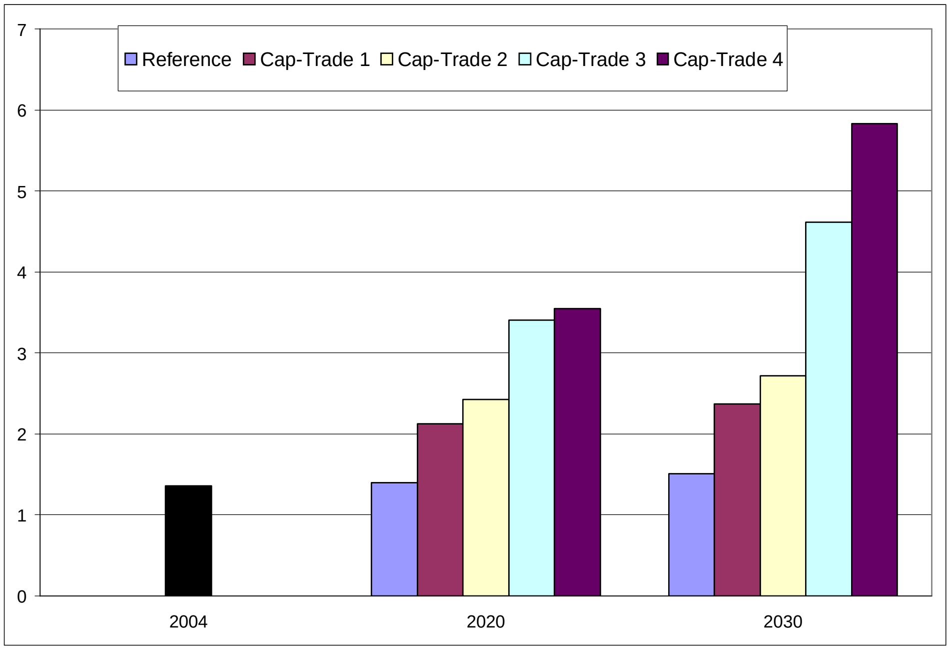
Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, SALACAP35HI.D012306A, SALACAP35LOTH.D012506A, SALACAP35S.D012306A and SALACAP40.D012006a.

The costs of GHG emission permits lead to much higher delivered fossil fuel prices in the Cap-Trade cases. Relative to the reference case, average coal minemouth prices are actually lower in the Cap-Trade cases than in the reference case. However, when the costs of holding permits to cover the emissions are included, delivered coal prices are much higher (Figure 14). For example, in the reference case, coal delivered to the power sector is projected to cost $1.39 per million Btu in 2020, while in the Cap-Trade cases it costs between $2.12 per million Btu and $3.55 per million Btu. As the GHG permit price continues to rise over time, the cost of using coal also increases. By 2030, the cost of coal in the Cap-Trade cases ranges from $2.37 per million Btu to $5.84 per million Btu, from just over one and half to almost four times the reference case price. Relative to the reference case, average delivered coal prices in 2020 are between 52.2 percent and 154.6 percent higher in the Cap-Trade cases. By 2030, this difference grows to between 57.0 percent 286.6 percent higher than in the reference case.

For natural gas and motor gasoline the story is similar. Relative to the reference case, average wellhead prices in the Cap-Trade cases are lower in most years. However, when GHG permit costs are included, delivered natural gas prices are much higher in the Cap-Trade cases (Figure 15). Relative to the reference case, average delivered natural gas prices in 2020 are between 6.1 percent and 15.1 percent higher in the Cap-Trade cases. By 2030, this difference grows to between 6.7 percent and 30.2 percent higher than in the reference case. Motor gasoline prices are between $0.06 per gallon and $0.19 per gallon

Figure 14: Delivered Coal Prices to the Power Sector

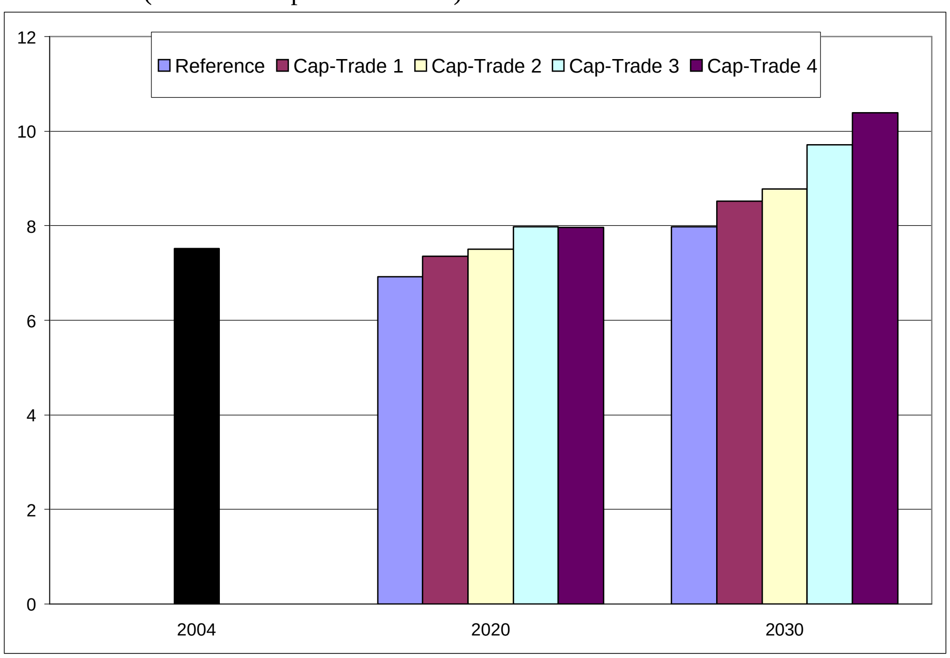
(2004 dollars per million Btu)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Figure 15: Average Delivered Natural Gas Prices

(2004 dollars per million Btu)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

(3.0 to 9.3 percent) higher in 2020 in the Cap-Trade cases than in the reference case. By 2030 this difference grows to $0.08 per gallon to $0.41 per gallon (3.7 to 18.9 percent).

Electricity Sector Emissions, Generation and Prices

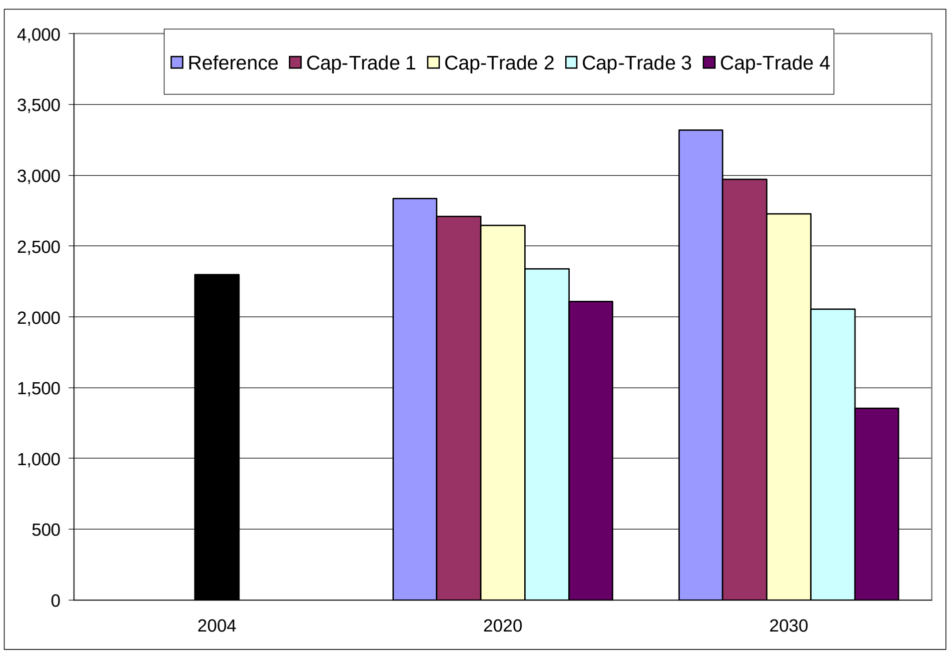
Implementing a GHG intensity reduction program could have significant impacts on power sector CO_2 emissions, generation by fuel, generating technology selection, electricity sales, and electricity prices. In the Cap-Trade cases the power sector shifts away from its long-term reliance on coal-fired generation, towards increasing reliance on nuclear and non-hydroelectric renewable generation. These changes lead to lower emissions. However, together with the cost of holding emissions permits for remaining fossil-fired generation, they also increase electricity prices.

CO_2 Emissions

In the reference case, total power sector CO_2 emissions are projected to increase 44.3 percent between 2004 and 2030 as the industry increases its use of fossil fuels, particularly coal (Figure 16). In the Cap-Trade cases, power sector CO_2 emissions are expected to be 4.5 percent to 25.7 percent below the reference case level in 2020 and 10.4 percent to 59.2 percent below the reference case level in 2030. In the most stringent cases, the Cap-Trade 3 and Cap-Trade 4 cases, power sector CO_2 emissions in 2030 are projected to be 10.6 percent to 41.1 percent below the 2004 emissions.

Figure 16: Power Sector CO2 Emissions

(Million Metric Tons CO_2)

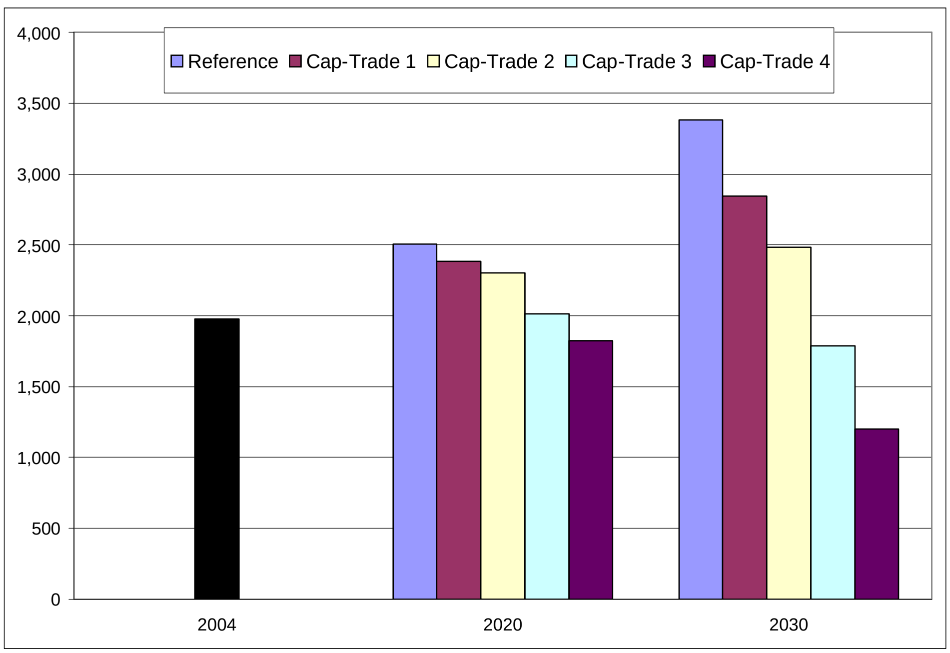


Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Generation by Fuel

To reduce its CO_2 emissions, the power industry, including generators in the industrial and commercial sectors, is expected to shift away from its historical reliance on coal generation (Figure 17). Total coal generation in 2020 is projected to be between 120 billion kilowatthours and 681 billion kilowatthours (4.8 to 27.2 percent) below the reference case level in the Cap-Trade cases. By 2030, the reduction in coal generation relative to the reference case grows larger, ranging from 536 billion kilowatthours and 2,180 billion kilowatthours (15.8 to 64.5 percent) in the Cap-Trade cases. These reductions are so large that in the more stringent cases, the Cap-Trade 3 and Cap-Trade 4 cases, projected coal generation in 2030 is below coal generation in 2004. In the reference case, coal accounts for 57.1 percent of total generation in 2030, but its share falls to between 21.7 percent and 49.1 percent in the Cap-Trade cases.

Figure 17: Coal Generation
(Billion Kilowatthours)



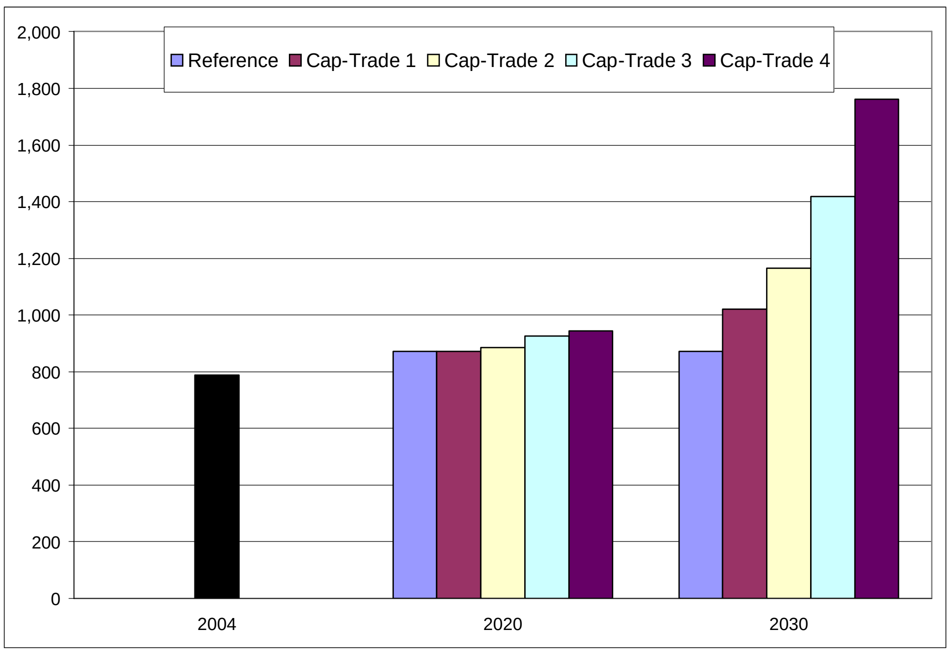
Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

The higher coal costs in the Cap-Trade cases significantly reduce the demand for new coal plants, particularly in the two most stringent cases. In the reference case, 174 gigawatts of new coal capacity is projected to be added between 2005 and 2030. The amount added over the same period ranges between 10 gigawatts and 96 gigawatts in the Cap-Trade cases. In the two most stringent cases, the only coal plants added other than those already under construction, are plants with carbon capture and sequestration equipment. By 2030, 17 gigawatts of coal capacity with carbon capture and sequestration equipment are added in the Cap-Trade 4 case.

In contrast to the situation for coal generation, nuclear generation is projected to increase significantly in the Cap-Trade cases (Figure 18). In the reference case, nuclear generation is projected to increase from 789 billion kilowatthours in 2004 to 871 billion kilowatthours in 2030, as existing plants are upgraded and 6 gigawatts of new capacity, stimulated by incentives in the EPACT2005, are added. The amount of new nuclear capacity added in the Cap-Trade cases varies from 25 gigawatts to 123 gigawatts. As a result of the additions, the share of generation accounted for by nuclear plants in 2030 increases from 14.7 percent in the reference case to between 17.6 percent and 31.8 percent in the Cap-Trade cases.

Figure 18: Nuclear Generation

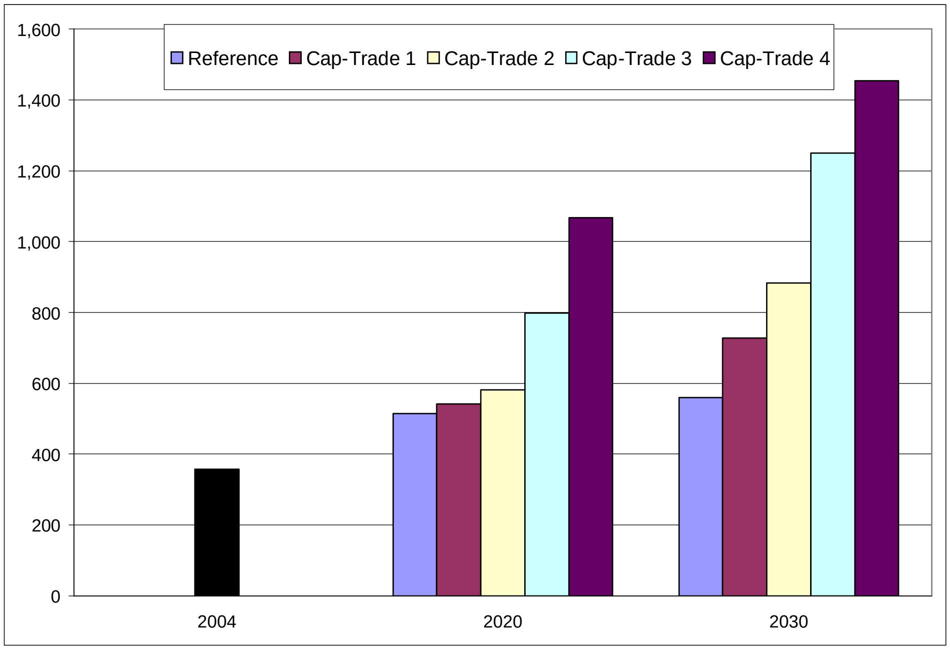
(Billion Kilowatthours)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

As for nuclear generation, renewable generation is also expected to see significant growth in the Cap-Trade cases (Figure 19). In the reference case, renewable generation is

Figure 19: Renewable Generation
(Billion Kilowatthours)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

projected to increase from 358 billion kilowatthours in 2004 to 559 billion kilowatthours in 2030. Part of this growth is stimulated by tax incentives for certain renewable technologies in EPACT2005. In the Cap-Trade cases, renewable generation is projected to grow to between 542 billion kilowatthours and 1,068 billion kilowatthours in 2020 and between 728 billion kilowatthours and 1,455 billion kilowatthours in 2030. Most of the increase in renewable generation is expected to be from non-hydroelectric renewable generators, mainly wind and biomass. As a result, the non-hydroelectric renewable share of generation, currently 2.2 percent, increases significantly in the Cap-Trade cases. By 2030, the share ranges from 4.3 percent in the reference case to between 7.3 percent and 20.6 percent in the Cap-Trade cases.

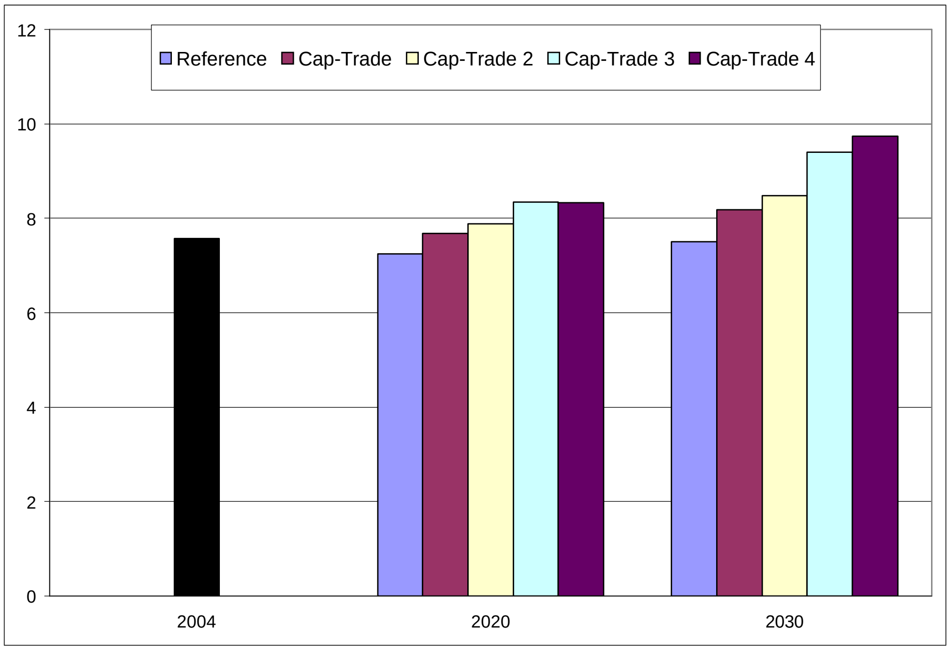
Oil and natural gas generation are also impacted by efforts to reduce power sector GHG emissions, but to lesser degrees than coal, nuclear, and renewables. Oil generation, already a very small part of electricity market, falls even further in the Cap-Trade cases. Relative to the reference case, natural gas generation in 2030 is between 9 percent and 17 percent higher in the Cap-Trade cases.

Electricity Prices

The shift away from coal to increased use of nuclear and renewable fuels, together with the costs of holding emissions permits, affects electricity prices (Figure 20). In the reference case, electricity prices fall from 7.6 cents per kilowatthour in 2004, to 7.2 cents per kilowatthour in 2020, and then increase slowly to 7.5 cents per kilowatthour in 2030 as fuel prices rise. In the Cap-Trade cases,2020 electricity prices range from 7.7 cents per kilowatthour to 8.3 cents per kilowatthour, an increase of 6.0 percent to 15.0 percent over the reference case level. As the GHG permit price continues to rise between 2020 and 2030 in the Cap-Trade cases, the cost of using fossil fuels also continues to grow, and electricity prices grow with them. By 2030, electricity prices in the Cap-Trade cases range from 8.2 cents per kilowatthour to 9.7 cents per kilowatthour, which is between 8.0 percent and 28.6 percent above the reference case level. Consumers' total electricity bill in 2020 in the Cap-Trade cases is between $16 billion and $40 billion (4.7 to 11.8 percent) higher than in the reference case. By 2030, the increase in consumer bills above the reference case level in the Cap-Trade cases grows to between $28 billion and $91 billion (7.0 to 22.8 percent).

Figure 20: Electricity Prices

(2004 Cents per kilowatthour)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

End-Use Energy Consumption

In response to higher delivered fossil fuel and electricity prices in the Cap-Trade cases, consumers and businesses in all sectors of the economy are projected to reduce their energy consumption and, where possible, shift their consumption away from fossil fuels. These changes reduce overall energy consumption, but raise consumers' energy bills.

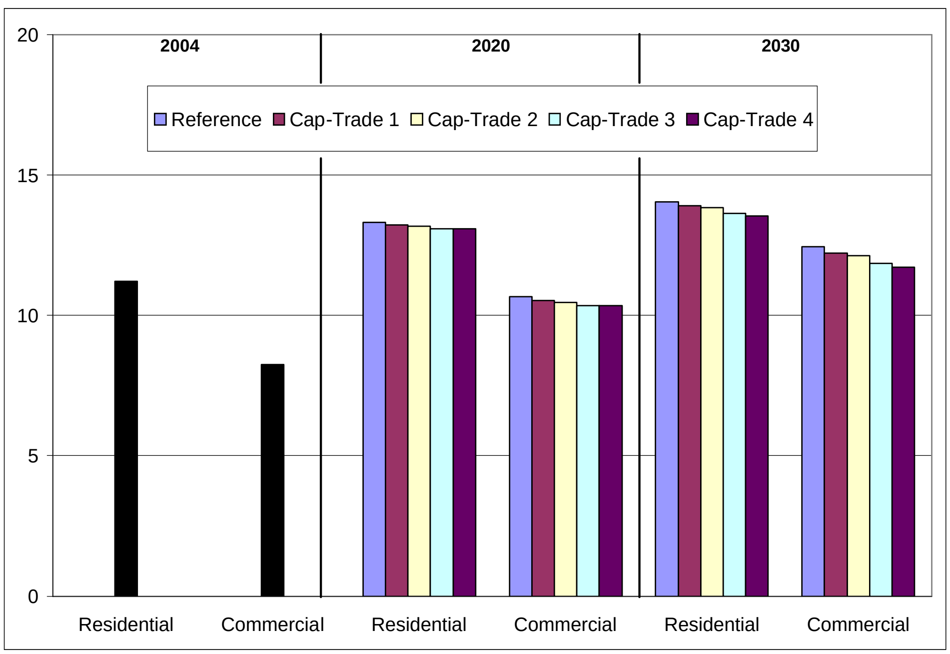
Residential and Commercial

Residential and commercial consumers are expected to use less energy if a GHG cap and trade program is implemented. Relative to the reference case, total delivered residential energy consumption in the Cap-Trade cases is between 0.6 percent and 1.7 percent lower in 2020, and between 0.9 percent and 3.5 percent lower in 2030 (Figure 21). Similarly, for the commercial sector, total delivered energy consumption in the Cap-Trade cases is between 1.3 percent and 3.0 percent lower in 2020 and between 1.8 percent and 5.8 percent lower in 2030.

These changes result from consumer responses to higher costs for all fossil fuels and electricity in the Cap-Trade cases. These costs include the purchase price of the fuels together with the costs of permits needed to cover the GHG emissions associated with their use. For example, relative to the reference case, the average delivered price of

Figure 21: Delivered Residential and Commercial Energy Consumption in Alternative Cases

(Quadrillion Btu)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

natural gas is between $0.44 per thousand cubic feet and $1.08 per thousand cubic feet (6.1 and 15.1 percent) higher in 2020 in the Cap-Trade cases. By 2030, this difference grows to between $0.55 per thousand cubic feet and $2.49 per thousand cubic feet (6.7 and 30.2 percent). For distillate fuel oil and electricity the projected percentage changes in average prices are similar to those for natural gas.

Even with lower energy consumption, households are projected to see higher energy bills. Relative to the reference case, annual per household energy expenditures in 2020 are 3.8 to 10.5 percent ($61 to $169) higher in the Cap-Trade cases. By 2030, the difference increases, with annual per household energy expenditures ranging from 5.4 percent to 20.0 percent ($91 to $336) higher in the four cases.

Where possible, homeowners will increase their use of non-fossil energy. For example, relative to the reference case, the number of homes with solar photovoltaic (PV) systems increases between 17.4 percent and 78.2 percent across the four cases by 2030. However, even with large percentage changes, the stock of homes with PV systems remains small. The 78.2 percent increase, results in about 0.1 percent of the homes having PV systems by 2030.

As in the residential sector, the impact of higher energy prices outweighs the impact of reductions in commercial energy consumption, resulting in an $8 billion to $20 billion (4.6 to 11.5 percent) increase in commercial energy expenditures in the Cap-Trade cases in 2020, relative to the reference case. The increase in expenditures is greater by 2030, ranging from $14 billion to $47 billion (6.6 to 21.8 percent) higher than commercial sector energy expenditures in the reference case.

Also, as in the residential sector, commercial consumers are expected to increase their use of non-fossil fuels in response to a GHG cap and trade program. Across the Cap-Trade cases, total commercial sector PV capacity is from 3 percent to 12 percent higher in 2020 than in the reference case. By 2030, commercial sector PV capacity in the Cap-Trade cases ranges from 30 to 164 percent higher than in the reference case.

The GHG cap and trade program also stimulates commercial users to increase their investments in natural gas-fired combined heat and power plants (CHP). These facilities can be very efficient and higher fossil fuel prices make investments in them more attractive. Overall, commercial natural gas-fired CHP capacity is from 2 percent to 3 percent higher in 2020 in the Cap-Trade cases, when compared to the reference case. By 2030, the increase relative to the reference case increases to between 11 percent and 37 percent.

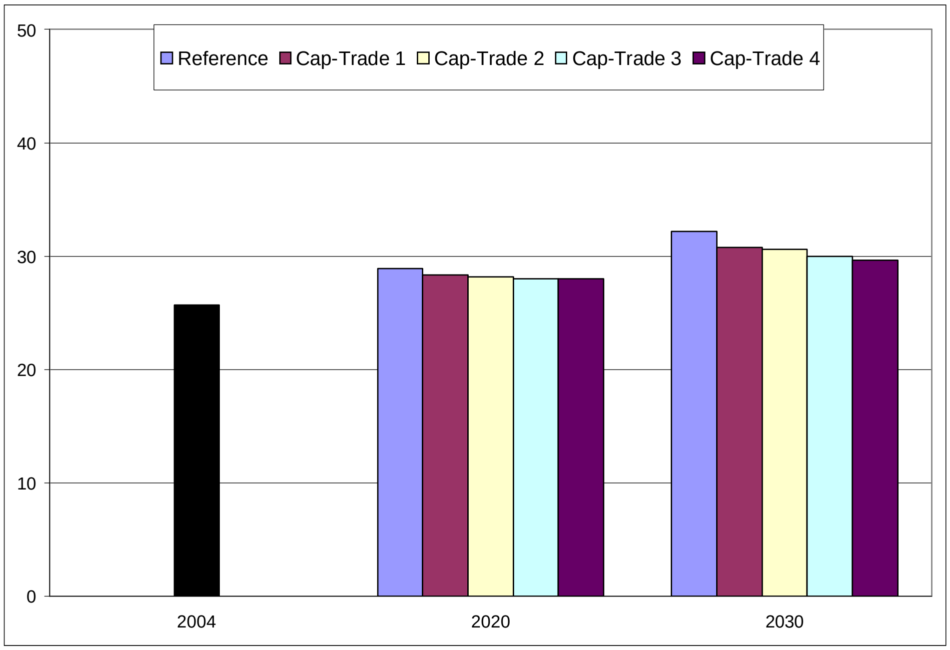
Industrial

Industrial consumers also reduce their energy consumption in response to higher energy prices, particularly their consumption of coal. Relative to the reference case, delivered industrial energy consumption in the Cap-Trade cases is between 2.0 percent and 3.2 percent lower in 2020, and between 4.5 percent and 7.9 percent lower in 2030 (Figure 22). The largest percentage reductions occur in industrial coal and purchased electricity. Relative to the reference case, both metallurgical and general industrial coal use fall by between 1.2 percent and 4.5 percent in 2020 in the Cap-Trade cases. This change grows to a decline of 1.4 percent to 8.1 percent by 2030. Total industrial coal consumption, which includes coal used in CTL production, decreases even more in the Cap-Trade cases. Relative to the reference case, total industrial coal use is between 16.8 percent and

22.9 percent lower in the Cap-Trade cases in 2020 and between 36.3 percent and 48.5 percent lower in 2030. The use of coal in CTL plants, 19 gigawatts of which are added in the reference case, is eliminated in the two most stringent Cap-Trade cases. Purchased electricity consumption in the industrial sector is between 1.6 percent and 3.6 percent lower in 2020 in the Cap-Trade cases and the difference widens to between 2.5 percent and 7.4 percent lower in 2030.

Figure 22: Industrial Energy Consumption in Alternative Cases

(Quadrillion Btu)



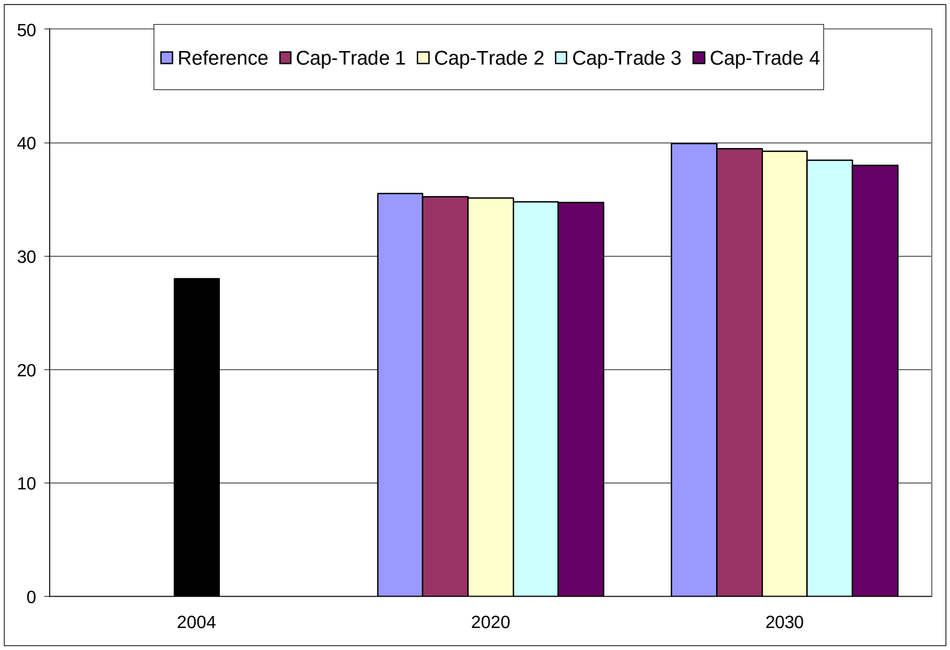
Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

While energy consumption falls in the industrial sector in the Cap-Trade cases, total industrial energy expenditures rise. Relative to the reference case, industrial energy expenditures increase by between $10 billion (5.4 percent) and $26 billion (14.5 percent) in 2020 and by between $16 billion (7.2 percent) and $47 billion (28.0 percent) in 2030 in the Cap-Trade cases. Industrial output, measured in year 2000 dollars, is also reduced relative to the reference case by $56 billion (0.6 percent) to $237 billion (2.5 percent) in 2030 in the Cap-Trade cases.

Transportation

Responding to higher gasoline, diesel, and jet fuel prices, transportation consumers also reduce their energy consumption (Figure 23). Relative to the reference case, these higher prices lead to 0.7 percent to 2.2 percent lower transportation sector energy consumption in 2020 and 1.2 percent to 4.9 percent lower transportation sector energy consumption in the Cap-Trade cases.

Figure 23: Transportation Sector Energy Consumption in Alternative Cases
(Quadrillion Btu)



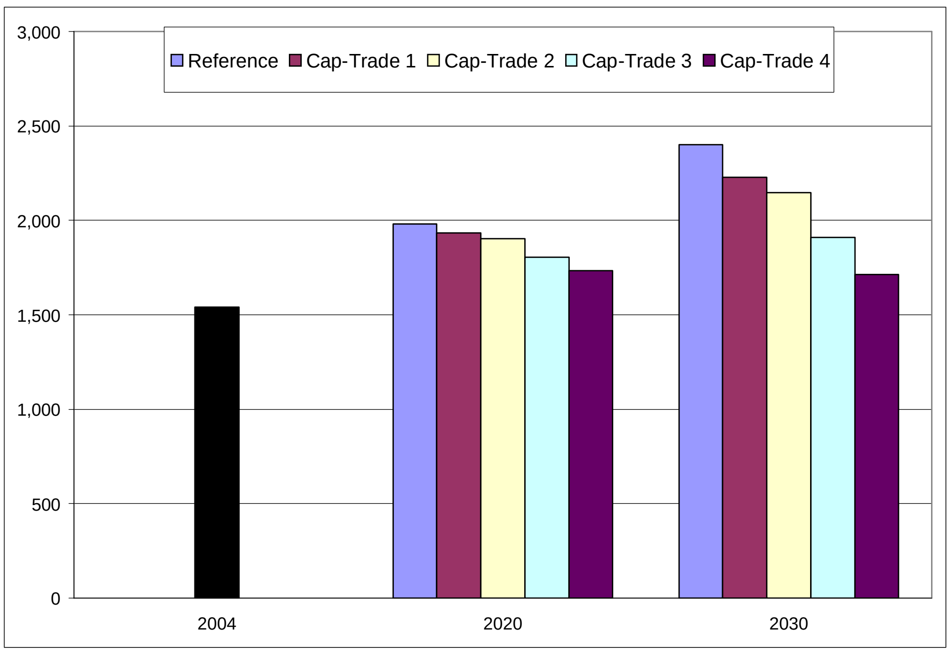
Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

The lower transportation energy consumption results from a combination of reduced travel and increased purchases of more efficient vehicles. In 2020, the reduction in light duty vehicle miles traveled from the reference case level ranges from 23 billion miles to 60 billion miles (0.6 to 1.7 percent) in the Cap-Trade cases. By 2030 this difference grows to between 32 billion miles to 146 billion miles (0.7 to 3.4 percent). Freight truck travel is also slightly lower in the Cap-Trade cases because of lower industrial output.

Though accounting for a much smaller share of the change in transportation energy usage, railroad usage is expected to be significantly lower in the Cap-Trade cases, because of large reductions in coal use (Figure 24). Relative to the reference case, 2020 rail-ton miles traveled are 50 billion ton miles to 247 billion ton miles (2.5 to 12.4 percent) lower in the Cap-Trade cases. As the usage of coal continues to slow relative to the reference case, 2030 rail ton miles are 175 billion ton miles to 690 billion ton miles (7.3 to 28.7 percent) lower in the Cap-Trade cases than in the reference case. Because of the lower coal use, in the Cap-Trade 4 case, total railroad usage is only 11.3 percent above the 2004 level in 2030, an average annual growth rate of just over 0.4 percent per year. This compares to the 1.7 percent annual growth projected between 2004 and 2030 in the reference case.

Improved fuel economy also contributes to the lower transportation sector energy consumption. The higher fuel prices in the Cap-Trade cases stimulate consumers to shift away from light trucks and purchase more hybrid and diesel vehicles. However, even the largest increase in gasoline prices in 2030, $0.41 per gallon, is not enough to stimulate a dramatic shift in the mix of vehicles purchased. The changes that do occur are gradual, but by 2030, the percent of new light vehicle sales that are cars increases from 42.6 percent in the reference case to between 44.0 percent and 48.0 percent the Cap-Trade cases. Sales of hybrid vehicles in 2030 grow from 11.5 percent of new light vehicle sales in the reference case to between 11.7 percent and 12.5 percent of new light vehicle sales in the Cap-Trade cases. In the Cap-Trade 4 case, hybrid and diesel vehicle sales are both about 100,000 vehicles higher than in the reference case in 2030. Because of the shift in vehicle purchases in the Cap-Trade cases, new light duty vehicle fuel economy is between 0.3 miles per gallon (mpg) to 1.3 mpg (0.9 to 4.4 percent) higher in 2030 than in the reference case.

Figure 24: Railroad Travel in Alternative Cases
(Billion Ton Miles Traveled)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Fuel Supply

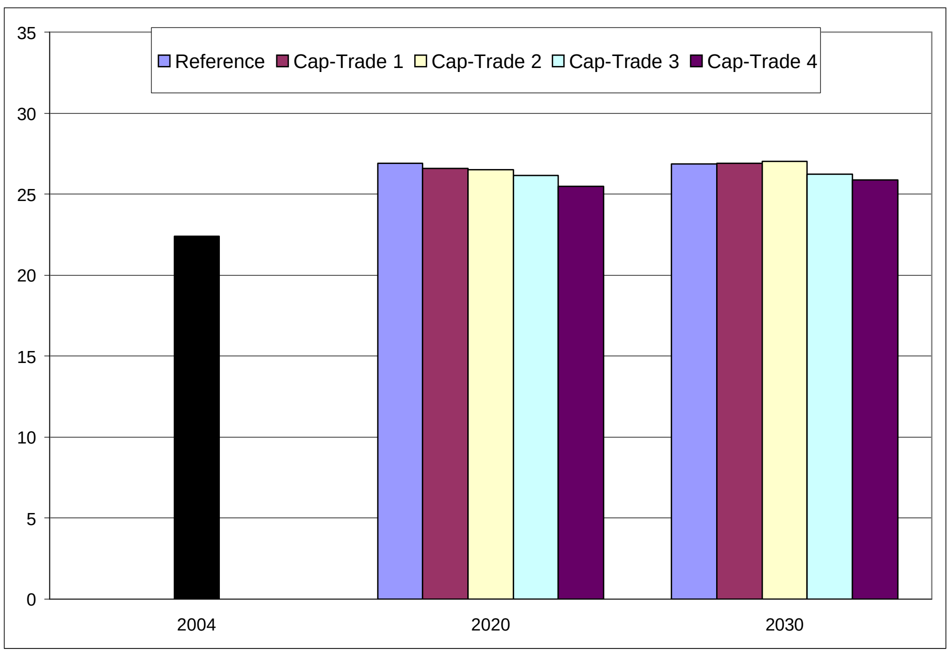
Natural Gas

In general, relative to the reference case, total natural gas consumption is lower in the Cap-Trade cases, but the differences are very small, 5 percent or less (Figure 25). The change in consumption occurs mainly in the electric power sector, but most other sectors show similar small changes. The one exception is the industrial sector which shows a slight increase in natural gas consumption in the Cap-Trade cases as increased investments in CHP plants offset reductions in natural gas use in other industrial areas.

The supply response comes from a combination of lower domestic gas production and lower net imports, with a slightly greater share of the reduction coming from domestic production when the GHG intensity reduction goal is less stringent, and from imports when the GHG intensity reduction goal is more stringent. Cumulatively from 2005 through 2030, gas production is reduced by between 2.7 and 10.4 trillion cubic feet relative to the reference case in the Cap-Trade cases. Over the same time period, relative to the reference case, net natural gas imports are reduced by between 2.2 and 12.5 trillion cubic feet. The two supply sources most affected by a greenhouse gas intensity reduction program are unconventional natural gas supplies and liquefied natural gas. Domestic unconventional sources (tight gas sands, gas shales, and coalbeds), show the largest changes, with cumulative reductions between 2.4 and 7.6 trillion cubic feet

Figure 25: Natural Gas Consumption

(Trillion Cubic Feet)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

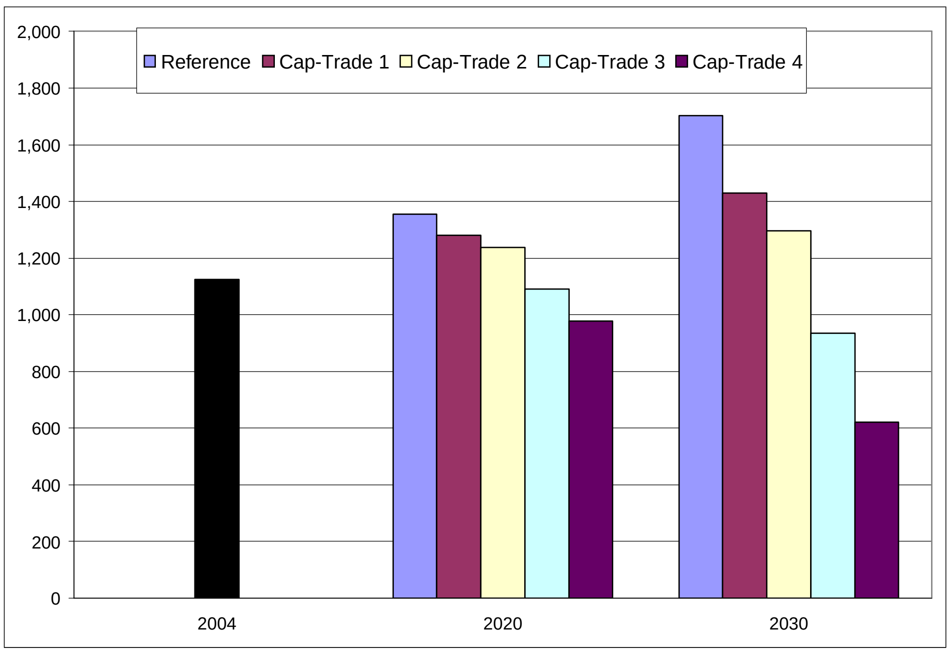
in the Cap-Trade cases. Seventy-five percent or more of the cumulative reduction in net imports is attributable to lower liquefied natural gas imports.

Coal

Because of large reductions in coal use in the electric power sector, coal production is much lower in the Cap-Trade cases (Figure 26). Relative to the reference case, total coal production is between 74 million tons and 379 million tons (5.4 and 27.9 percent) lower in 2020 and between 274 million tons and 1,081 million tons (16.1 and 63.5 percent) lower in 2030 in the Cap-Trade cases. In the Cap-Trade 3 and Cap-Trade 4 cases, coal production in 2020 and 2030 is actually below 2004 coal production. Both eastern and western coal production are lower in the Cap-Trade cases, but the impact is larger in the west because that is where coal production is projected to grow in the reference case.

Figure 26: Coal Production

(Million short tons)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Petroleum

Relative to the reference case, the consumption of petroleum products is lower in the Cap-Trade cases, as consumers respond to the higher delivered petroleum product prices that result when the costs of GHG permits are included. Petroleum consumption in 2020 is projected to be between 0.4 million barrels per day and 0.8 million barrels per day (1.8 to 3.3 percent) lower in the Cap-Trade cases than in the reference case. By 2030 the difference grows to between 0.6 million barrels per day and 1.6 million barrels per day (2.2 to 5.9 percent) lower in the Cap-Trade cases than in the reference case. However, domestic crude oil production is relatively unaffected because the world crude oil prices are unchanged. The reduction in petroleum supply in the Cap-Trade cases comes from reductions in imported oil and reductions in domestic CTL production. In the Cap-Trade cases in 2020, CTL production is 0.2 million barrels per day (80 to 100 percent) lower than in the reference case. By 2030, the change is between 0.6 million barrels per day to 0.8 million barrel per day (81 to 100 percent) lower than in the reference case. The GHG permit cost increases the cost of using coal, making CTL production uncompetitive with imported oil.

In 2020, total oil imports in the Cap-Trade cases are between 0.27 and 0.53 million barrels per day (1.9 to 3.7 percent) lower than in the reference case. By 2030, the difference ranges from 0.05 to 0.76 million barrels per day (0.3 to 4.4 percent) lower than in the reference case, with about two thirds of the reduction coming from product imports and the remainder from crude oil imports.

Ethanol production and E85 consumption are relatively unaffected by the greenhouse gas permit price. Although the price difference between E85 and gasoline on a per gallon basis increases by as much as about $0.25 per gallon in 2030 in the most stringent case, E85 remains uneconomical on an energy content basis. That is, the price of E85 in the reference case is 25 percent higher than the gasoline price in 2030. In the Cap-Trade 4 case, the price of E85 still remains over 20 percent higher than the gasoline price – closer, but still uneconomical on a national level.

Economic Impacts

Implementing a GHG emissions cap and trade program based on a targeted rate of reduction in emissions intensity in which some emissions permits will be auctioned[15] and others will be sold if the safety-valve is triggered will impact the economy through two mechanisms. First, efforts to reduce GHG emissions and the requirement to hold permits for all remaining GHG emissions will raise energy prices, particularly those for fossil fuels. Second, the auctioning of permits and the sale of additional permits if the safety-valve is triggered will increase revenues to the government. In turn, higher energy prices and increased government revenues will impact aggregate economic growth.

Prices

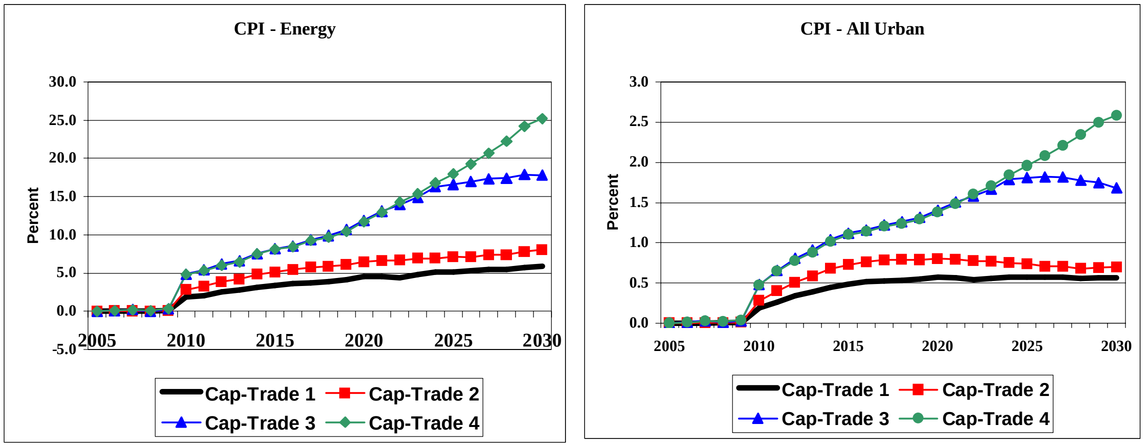
Relative to the reference case, the consumer price index for energy (CPI-Energy) in 2020 ranges from 4.6 percent to 11.7 higher in the Cap-Trade cases (Figure 27). By 2030, this difference grows to between 5.9 percent and 25.2 percent higher than in the reference case. These higher energy prices in the Cap-Trade cases contribute to increases in the All-Urban Consumer Price Index (CPI), a measure of aggregate consumer prices in the

[15] The NCEP report recommended that most emission permits (95 percent initially, declining to 90 percent between 2013 and 2022) would be allocated to emission sources at no cost primarily on the basis of past emissions.

economy. In the Cap-Trade cases, the CPI is between 0.6 percent and 2.6 percent higher than in the reference case in 2030.

Figure 27: Impacts on the Consumer Price Index (CPI) for Energy and the All Urban CPI

(Percent Change from Reference Case)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

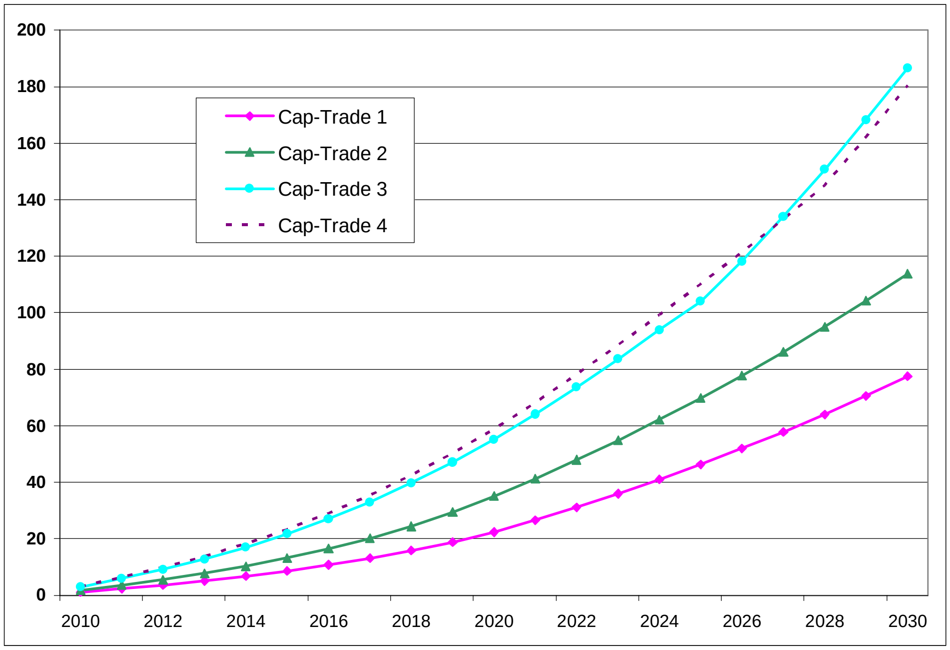
Government Revenues

The projected government revenues collected each year in the Cap-Trade cases is a function of the GHG permit price, the number of permits auctioned, and the number of permits (if any) sold at the safety-valve price. In 2030, the projected government revenue collected ranges from $15 billion to $40 billion (2000 dollars) in the Cap-Trade cases. The discounted value in 2010, using a 4 percent discount rate, of the cumulative revenue collected between 2010 and 2030 in the Cap-Trade cases ranges from $78 billion to $187 billion (2000 dollars) (Figure 28).

Alternative assumptions about the availability of abatement opportunities for GHGs other than energy-related CO_2 and alternative settings for the permit safety-valve price affect the amount of revenue that the government might collect. For example, in the Cap-Trade 3 case the cumulative discounted revenue collected is projected to reach $187 billion. However, in the Cap-Trade 3 Low Other case, this value increases to $235 billion. In the Cap-Trade 3 Low Other case, the reduced availability of other greenhouse gas abatement opportunities leads to an earlier triggering of the permit safety-valve causing the government to sell more permits. Conversely, in the Cap-Trade 3 Low Safety case, the total cumulative government permit revenue is only $135 billion, much lower than the level expected in the Cap-Trade case. The lower revenue collection occurs because of the government sells permits at the lower safety-valve price in the Cap-Trade 3 Low Safety case. The revenue collected in the this case is much closer to $114 billion collected in the Cap-Trade 2 case that uses the same safety-valve prices and also has very similar energy market impacts.

Figure 28: Cumulative Sum of Discounted Forecast Revenue, 2010-2030

(Billion discounted 2000 dollars)

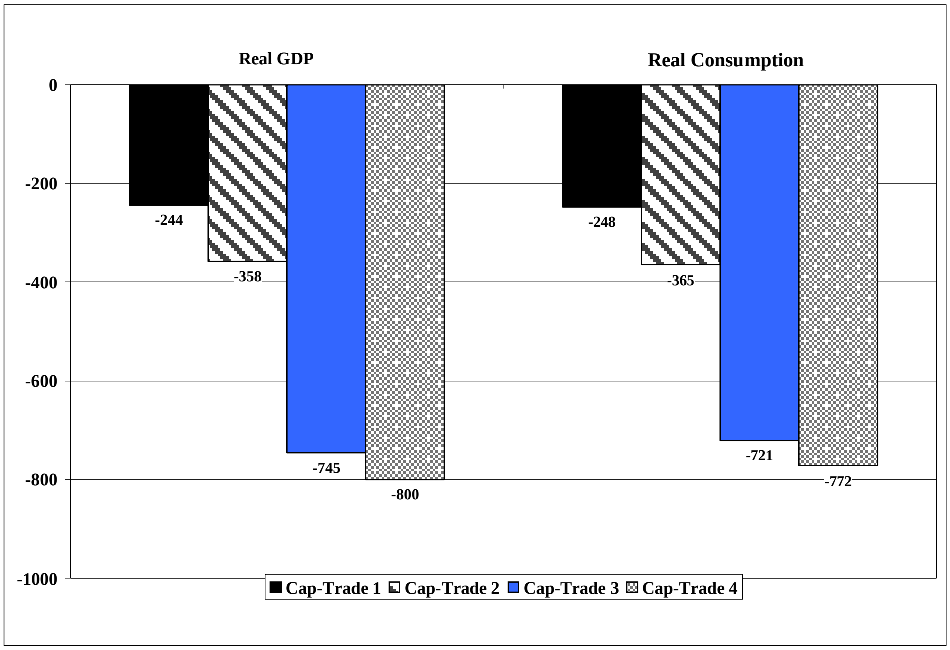


Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Real GDP and Consumption

The higher delivered energy prices in the Cap-Trade cases lowers real output for the economy. They reduce energy consumption, but also indirectly reduce real consumer spending (due to lower purchasing power) for other goods and services. The lower aggregate demand for goods and services in the Cap-Trade cases results in lower real GDP relative to the reference case (Figure 29). Relative to the reference case, total discounted real GDP over the 2010 to 2030 time period ranges from $244 billion to $800 billion (0.10 to 0.32 percent) lower in the Cap-Trade cases. Over the same time period, discounted real consumer spending is between $248 billion and $772 billion (0.15 to 0.46 percent) lower than in the reference case in the Cap-Trade cases.

Figure 29: Sum of Discounted Impacts on Real GDP and Real Consumption, 2010-2030
(Billion 2000 dollars)



Source: National Energy Modeling System runs AEO2006.D111905A, SALACAP.D012006a, SALACAP30.D012306a, SALACAP35.D012306a, and SALACAP40.D012006a.

Uncertainty

All long-term projections engender considerable uncertainty. It is particularly difficult to foresee how existing technologies might evolve or what new technologies might emerge as market conditions change, particularly when those changes are fairly dramatic. This analysis suggests that to comply with increasingly stringent GHG emissions limits all energy providers, particularly electricity producers, will increasingly rely on technologies that play a relatively small role today or have not been built in the United States in many years.

Non-hydroelectric renewable generators currently provide 2.2 percent of the electricity generated. In the reference case, their share is expected to grow to 4.3 percent in 2030. In the Cap-Trade cases their share grows to between 7.3 percent and 20.6 percent of generation by 2030. To supply the amount of non-hydroelectric renewable generation projected in the most stringent case, the capacity of wind and biomass plants would have to grow to 13 and 16 times, respectively, the amount of capacity existing in 2004. While this level of growth is certainly possible, it comes with a lot of uncertainty. It is possible that such growth might lead to significant reductions in the costs of these technologies. On the other hand it is also possible that costly hurdles such as siting resistance, higher than expected transmission interconnection costs or fuel supply limits could arise that limit their development.

Similarly, this analysis suggests that the power sector would significantly increase its reliance on nuclear power in order to reduce GHG emissions. However, the last nuclear order in the United States was placed in 1978 and the last nuclear plant to enter service began operating in 1996. In the reference case, nuclear capacity is projected to increase by 9 gigawatts, including 3 gigawatts of uprates at existing plants and 6 gigawatts of new nuclear plants, about 4 to 6 new plants. In the Cap-Trade cases, nuclear capacity is projected to grow by between 28 gigawatts and 125 gigawatts. In the most stringent case, nuclear capacity would have to more than double from the 2004 level. As for wind and biomass, it is possible that such growth in nuclear power might lead to significant cost reductions. On the other hand, costly hurdles, such as unexpectedly high construction costs, public resistance to the siting of facilities, or waste disposal concerns could arise to limit their development.

If the development of these technologies is limited for one reason or another, power providers will have two choices. First, they can turn to other low-GHG or non-GHG technologies, such as new fossil generators with carbon capture and sequestration equipment, that play a fairly small role in today's market. Second, they can purchase a larger number of permits at the safety-valve price to permit continued reliance on current fossil-fired generation to a greater extent than projected in the program cases. To the extent this occurs, projected reductions in GHGs would be reduced. One way or another, significantly reducing energy-related GHG emissions would require a shift away from fossil energy sources that accounted for 86 percent of U.S. energy consumption in 2004. The costs of such a shift, particularly a large one, are inherently uncertain.

Appendix A. Analysis Request Letter

KEN SALAZAR
COLORADO

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20 October 2005

Mr. Guy F. Caruso
Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Caruso:

On September 20, 2005, the Senate Committee on Energy and Natural Resources received testimony regarding the economic aspects of strategies to manage climate change, including testimony from Dr. Howard Gruenspecht of your staff. During that hearing, I expressed interest in further analysis of variations on the National Commission on Energy Policy (NCEP) proposal that was the focus of the hearing. Per discussions between our staff members, this letter outlines my request for that analysis.

In April 2005, the Energy Information Administration (EIA) released a report analyzing the policy recommendations contained within the 2004 National Commission on Energy Policy (NCEP) report entitled, "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges." Since this analysis was published, the U.S. Senate has passed a "Sense of the Senate" resolution calling for mandatory limits and incentives to slow, stop, and reverse the growth of greenhouse gas emissions in a manner and at a pace that will encourage comparable actions by other countries while not significantly harming our economy.

One element of the NCEP policy package considered in EIA's report is a greenhouse gas (GHG) emissions intensity reduction program to achieve a GHG intensity improvement of 2.4 percent per year between 2010 and 2019 and 2.8 percent per year between 2020 and 2025. The program also entailed a safety-valve permit price starting at $7 per metric ton CO_2 equivalent in 2010 nominal dollars that would increase by 5 percent annually up to $14.55 in 2025. I would like EIA to build on its analysis to date by running a number of additional intensity target and safety valve scenarios.

I am particularly interested in an analysis of additional intensity-improvement/safety-valve combinations with intensity improvements ranging from 2.6 to 4.0 percent per year and safety valve values ranging from $10 to $35 (in 2010 nominal dollars, rising five percent per year). This analysis should also consider the impact of base case and high technology assumptions.

This report should include estimates of the same environmental and economic indicators from the previous report, including but not limited to supply estimates (by fuel), GHG emissions, GDP and employment.

The purpose of this analysis would be to draw out the relative effects of alternative policies. By running different combinations, this product should allow policy makers to evaluate the impact of changing the safety valve price through this range given the base case intensity improvement (2.4 percent through 2020 and 2.8 percent thereafter), and to evaluate the impact of increasing the intensity improvement through this range in combination with various safety valve prices.

I understand that EIA is now updating its energy model in preparation for the release of the 2006 Annual Energy Outlook and that the reference case for the new Outlook is scheduled to be released this November. Please use the updated model and the new reference case when performing the additional analysis. I recognize that I should not expect the results of this study to be delivered until February 2006.

Thank you for your assistance with this report. Should you have any questions please do not hesitate to contact Dr. John Plumb in my office at 202-224-5852.

Sincerely,

Ken Salazar

Ken Salazar