SR/OIAF/2007-04

Energy Market and Economic Impacts of S. 280, the Climate Stewardship and Innovation Act of 2007

July 2007

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Office of Integrated Analysis and Forecasting
U.S. Department of Energy
Washington, DC 20585

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Background

This report responds to a request from Senators Joseph Lieberman and John McCain for an estimate of the economic impacts of S. 280, the Climate Stewardship and Innovation Act of 2007. S. 280 would establish a series of caps on greenhouse gas emissions starting in 2012 followed by increasingly stringent caps beginning in 2020, 2030 and 2050. It provides estimates of the effects of S. 280 on energy markets and the economy through 2030, the current time horizon of projections in the Energy Information Administration's (EIA) *Annual Energy Outlook (AEO2007)*.

The gases regulated under S. 280 are carbon dioxide, methane, nitrous oxide, and three classes of fluorinated gases—hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Covered entities include those in the commercial, industrial, and electric power sectors with annual emissions at any single facility in excess of 10,000 metric tons carbon dioxide equivalent; refiners and importers of petroleum products sold for transportation; and producers and importers of fluorinated gases. EIA estimates that about 78 percent of the total greenhouse gas emissions in 2005 would be covered under the allowance program. The specific S. 280 allowance caps for each time period are:

2012 to 2019. . . . . . . 2004 emissions level
2020 to 2029. . . . . . . 1990 emissions level
2030 to 2049. . . . . . . 22 percent below 1990 emissions level
2050 and beyond . . . .60 percent below 1990 emissions level

Under S. 280, covered entities would be required to report their greenhouse gas emissions annually and submit a matching number of government-issued allowances. Some tradable allowances would be distributed for free and the remainder would be auctioned to raise funds for supporting programs. These include programs to encourage innovative emissions reduction technologies and to mitigate adverse economic impacts on consumers and communities. Allowances in excess of compliance needs can be banked for future use. Entities would also be able to meet up to 30 percent of their allowance obligation with offsets for emissions reductions from non-covered entities and foreign sources.

Results

Analysis Cases

This section discusses the projected impacts of S. 280 relative to a reference case based on the *Annual Energy Outlook 2007 (AEO2007)*.[1] The estimates are sensitive to several assumptions about program implementation that would be made following enactment of S.280. As suggested

[1] Energy Information Administration, *Annual Energy Outlook 2007*, DOE/EIA-0383(2007) (Washington, DC, February 2007), web site: www.eia.doe.gov/oiaf/aeo/index.html.

by Senate staff, the share of allowances auctioned is assumed to grow from 30 percent in 2012 to 90 percent in 2030. Furthermore, although S.280 includes the commercial sector in its coverage list, it is considered exempt for purposes of this analysis because the vast majority of buildings are not large enough to emit 10,000 metric tons of greenhouse gases per year.

The **S.280 Core** case is the focus of this report. However, because the potential availability and cost of offsets is a significant source of uncertainty in the analysis, the report includes sensitivity cases using a range of alternative assumptions regarding the availability of offsets. The **Fixed 30 Percent Offsets** case assumes a sufficient supply of economical international offsets is available to allow covered entities to take full advantage of the 30-percent offset option in all years. In contrast, the **No International** case limits the supply of offsets to domestic sources.

Emissions Impacts and Cap Compliance

Compliance with the caps on covered emissions is achieved through a combination of domestic emissions reductions, increases in domestic biogenic sequestration, purchases of international offsets and the accumulation (crediting) and use (debiting) of banked allowances.

Compared to the reference case, total U.S. greenhouse gas emissions in the S280 Core case are 1,024 million metric tons (13 percent) lower in 2020 and 2,685 million metric tons (28 percent) lower in 2030 (Table ES-1; Figure ES-1).

Emission reductions from energy-related CO_2 account for less than half of the total compliance response in the initial phase of the program, when the use of offsets and non-CO_2 abatement opportunities predominate. In 2020, the reduction in energy-related CO_2 emissions in the S280 Core case, relative to the reference case, accounts for one third of the compliance response. The energy-related CO_2 share of the overall compliance response increases over time as the caps (and also the limits on the use of offsets that are directly linked to the cap) are cut, allowance prices rise, and the impacts of investments in new energy related capital accumulate. By 2030, the reduction in energy-related CO_2 emissions in the S280 Core case accounts for about half of the total compliance response.

When international offsets are assumed to be more readily available, as in the Fixed 30 Percent Offsets case, covered entities accumulate more allowances in the first phase of S.280 and use those banked allowances to lower the need to reduce emissions through 2030. In contrast, when international offsets are not readily available, as in the No International case, covered entities build a smaller allowance bank and compliance relies more heavily on domestic emissions reductions.

The electric power sector is expected to account for the vast majority of the reductions in energy-related CO_2 emissions. For example, in the S280 Core case, about 89 percent of the energy-related CO_2 emissions reductions in 2030 relative to the reference case are associated with electricity, where substitution away from coal is a relatively cost-effective way to reduce emissions. The remaining reductions in energy-related CO_2 are split in roughly equal measure between the industrial and transportation sectors.

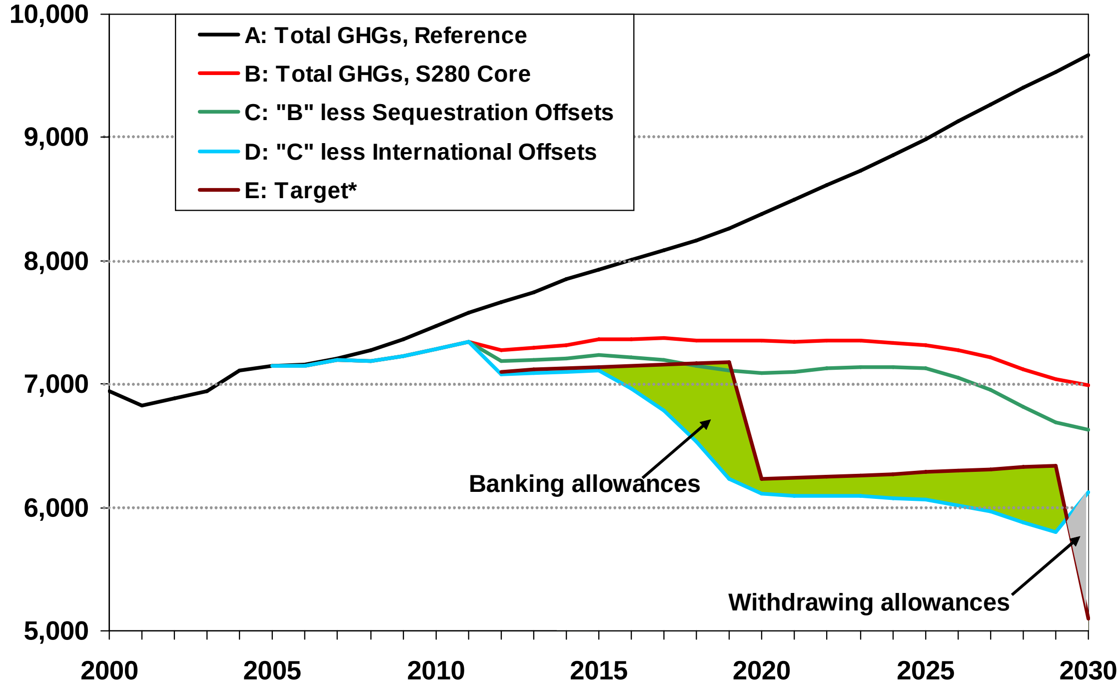
Table ES-1: Summary of Emissions and Energy Market Results

(Emissions in million metric tons CO_2 equivalent; other results in indicated units)

	1990	2005	2020		2030	
			Refer-ence	S.280 Core	Refer-ence	S.280 Core
Greenhouse gas emissions						
Energy-related carbon dioxide	4979	5945	6879	6116	7888	5520
Nonenergy carbon dioxide	6	63	76	72	84	76
Methane	702	612	694	542	772	573
Nitrous oxide	333	367	388	355	410	375
Fluorinated gases	87	160	340	268	518	443
Total	6107	7147	8377	7353	9672	6987
Covered energy-related carbon dioxide	4422	5242	6090	5333	7064	4702
Other covered emissions	237	323	524	390	719	567
Total covered emissions	4659	5565	6614	5722	7783	5269
Offsets						
Noncovered emission reductions	0	0	0	94	0	99
Biogenic carbon sequestration	0	0	0	260	0	360
International sources	0	0	0	984	0	505
Total offsets	0	0	0	1338	0	964
Compliance Summary				6185		5027
Allowances issued (cap)	NA	NA	NA	4461	NA	3209
Covered emissions, less offsets	4659	5565	6614	4385	7783	4305
Net allowance bank change	NA	NA	NA	76	NA	-1096
Allowance price (2005 dollars per metric ton CO2 equivalent)	NA	NA	NA	22.2	NA	47.9
Offset Price (2005 dollars per metric ton CO2 equivalent)	NA	NA	NA	20.9	NA	19.5
Delivered energy prices (2005 dollars per unit indicated)(includes allowance cost)						
Motor gasoline, transport (per gallon)	1.64	2.32	1.97	2.14	2.21	2.56
Jet fuel (per gallon)	1.09	1.77	1.40	1.60	1.64	2.04
Diesel (per gallon)	1.61	2.41	2.10	2.30	2.34	2.78
Natural gas (per thousand cubic feet)						
Residential	7.97	12.80	10.83	10.62	11.66	11.33
Electric power	3.27	8.41	5.91	6.73	6.42	8.38
Coal, electric power sector (per million Btu)	2.01	1.53	1.57	3.59	1.70	5.85
Electricity (cents per kilowatthour)	9.03	8.10	7.91	8.72	8.05	9.75
Primary energy use (quadrillion Btu)						
Liquid fuels	33.6	40.7	46.5	45.2	52.1	49.3
Natural gas	19.6	22.7	27.1	26.3	26.9	25.0
Coal	19.2	22.9	27.1	20.4	34.1	12.1
Nuclear power	6.1	8.1	9.2	10.4	9.1	19.9
Renewable	6.2	5.9	8.5	11.9	9.0	17.0
Other	0.0	0.1	0.0	0.1	0.0	0.2
Total	84.7	100.3	118.4	114.3	131.1	123.5
Purchased electricity	9.3	12.5	15.5	14.7	17.6	16.2

Note: For simplicity the “delivered” prices of coal and natural gas to the electric power sector represent the effective delivered cost, including the cost of emissions allowances.
Sources: National Energy Model System runs S280BASE.D060107a, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

Figure ES-1: Greenhouse Gas Emissions and Compliance in the S.280 Core Case, 1990-2030
(million metric tons CO_2 equivalent)



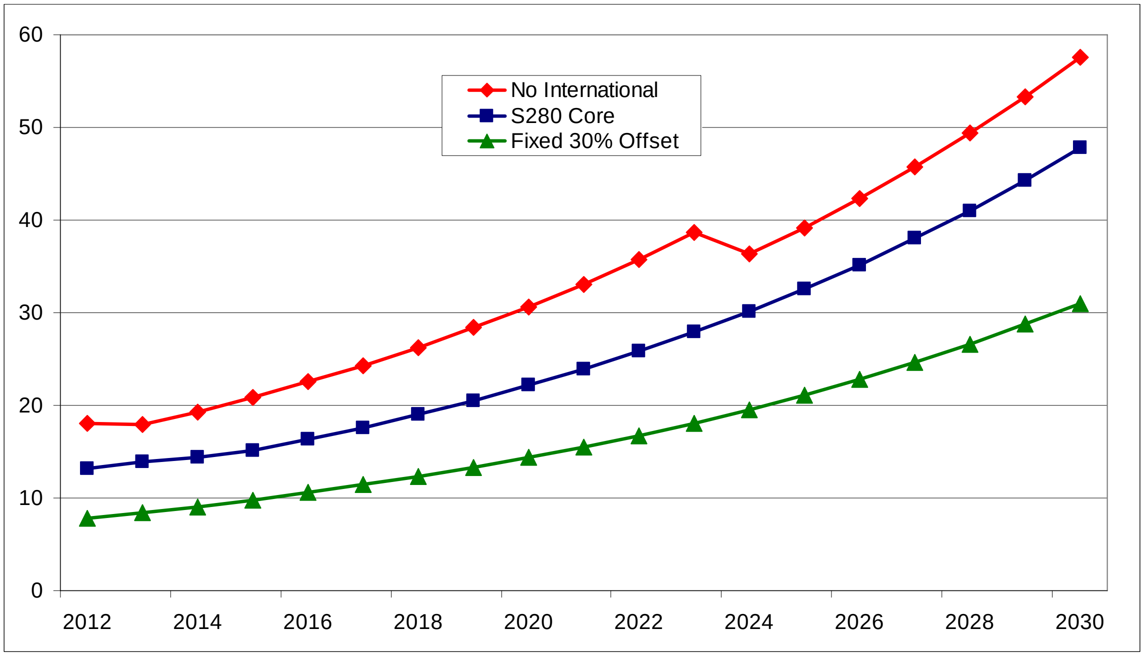
* "Target" reflects the cap on covered emissions after exemptions, combined with the noncovered and exempt emissions in the reference case.
Sources: National Energy Model System runs S280BASE.D060107a, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

Allowance Prices

Allowances prices (in 2005 dollars per metric ton carbon dioxide equivalent) range from $14 to $31 in 2020 and from $31 to $58 in 2030 in the main S280 cases (Figure ES-2). Allowance prices in the No International case are higher than in the S280 Core case because emissions goals must be met from domestic sources.[2] Lower allowance prices in the Fixed 30 Percent Offsets case reflect the more optimistic assumptions regarding the availability of international offsets.

[2] A temporary drop in the 2024 allowance price in the No International case occurs during a short interval when allowance banking is not economical. Prices fluctuate over such intervals and may even decline if the cap becomes less costly, such as when new carbon-neutral electricity plants come on line.

Figure ES-2: Projected Allowance Prices, 2012-2030
(2005 dollars per million metric ton CO_2 equivalent)



Sources: National Energy Model System runs S280BASE.D060107a, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

Energy Price Impacts[3]

Under S. 280, the value of allowances will generally be reflected in delivered fossil fuel and electricity prices. Higher prices will lead to a reduction in the use of fossil fuels and, where possible, a shift to emission-free or lower-emission energy sources.

Coal prices are most significantly impacted, in both absolute and percentage terms, because coal has the highest carbon content among the fossil fuels and is lowest priced of the fossil fuels. The price of coal to the electric power sector in the S280 Core case is 129 percent above the reference case level in 2020 and 245 percent above it in 2030. Industrial coal users experience similar price impacts.

Natural gas price impacts are much smaller than those for coal. For example the cost of natural gas to the electric power sector in the S280 Core case is 15 percent above the reference case in 2020 and 31 percent above it in 2030.   Covered industrial entities that use natural gas face similar impacts. However, natural gas users not covered by the program, including residential and agricultural consumers, benefit from a small decline in their delivered natural gas prices as demand is reduced in covered sectors. The projected natural gas price impacts reflect a massive shift to emission-free technologies for baseload generation, such as nuclear and renewables. If

[3] Energy prices are from Table ES1 and are reported in 2005 dollars.

such a transition cannot be made, and conventional coal generation is instead substantially replaced by generation using natural gas, impacts on natural gas prices could increase dramatically.

Average electricity prices in the S.280 Core case are 10 percent higher than the reference case level in 2020 and 21 percent higher in 2030. The percentage change in electricity prices varies across regions, and is closely tied to the share of coal-fired power in the reference case generation mix.

Price increases for petroleum-based transportation fuels in the S280 Core case, relative to the reference case, range from 8 percent to 14 percent in 2020 and from 16 percent to 25 percent in 2030, with jet fuel towards the high end of the ranges and highway fuels towards the low end. Highway fuel prices are less affected in percentage terms because taxes and distribution costs, which are not impacted by allowance costs, account for a larger share of their delivered prices. The increase in the price of gasoline in 2030 is 34 cents per gallon in the S280 Core case.

Energy Use Impacts

When compared to the reference case, the consumption of coal, liquid fuels (mainly petroleum), and natural gas are all lower in the S. 280 cases, while the use of nuclear power and renewable energy are substantially higher.

Total primary energy consumption in 2030 in the S280 Core case is 3 percent lower than in the reference case in 2020 and 6 percent lower in 2030, as conservation and improvements in energy efficiency are stimulated by the higher energy prices and the technology support programs in S. 280. Projected petroleum and natural gas consumption in 2030 in the S280 Core case are higher than present levels, and petroleum use continues to grow throughout the projection.

In contrast, coal use in the S. 280 cases is much lower than in the reference case in all years and lower than current consumption in 2030. To reduce its CO_2 emissions, the power industry is expected to shift away from its historical reliance on coal generation. In the reference case, coal accounts for 58 percent of total generation in 2030,[4] but its share falls to between 11 percent and 35 percent in the main S. 280 cases. Coal generation in the S280 Core case is 26 percent below the reference case level in 2020 and 69 percent lower in 2030. Relative to the 2005 level, coal generation in the S280 Core case is 48 percent lower in 2030.

An estimated 145 gigawatts of new nuclear capacity is added in the S280 Core case, increasing nuclear generation to 1,909 billion kilowatthours in 2030, 120 percent above the reference case level in 2030. Across the three main S. 280 cases, nuclear generation in 2030 provides from 22 percent to 42 percent of total electricity generation, compared to 15 percent in the reference case.

The renewable share of power sector generation in 2030 is 9 percent in the reference case, and grows to between 22 percent and 28 percent across the main S. 280 cases. In the reference case, biomass generation grows from 38 billion kilowatthours in 2005 to 111 billion kilowatthours in

[4] The generation numbers cited include end-use sector generation.

2020 and 131 billion kilowatthours in 2030. In the S280 Core case, biomass generation in 2020 is over three times that of the reference case, and by 2030 is almost 8 times greater than the reference level. Wind generation grows from 15 billion kilowatthours in 2005 to 51 billion kilowatthours in 2020 and remains at that level through 2030 in the reference case. In the S280 Core case, wind generation in 2020 is nearly double that of the reference case, and by 2030 is 2.5 times greater than the reference level.

The adoption of carbon capture and storage (CCS) technology for electric power plants is not expected to be cost-competitive with nuclear and biomass for base load generation at the allowance prices in the S280 Core case. In the No International case, with higher allowance prices, coal plants with CCS begin to penetrate in the last few years of the projection, and 11 gigawatts of capacity with CCS are added by 2030. In a sensitivity case where nuclear capacity is held to its reference case level, CCS plays a larger role by 2030. However, CCS technology also faces significant potential hurdles, and its availability for commercial deployment on a large scale prior to 2030 is uncertain.

In transportation, the energy price increases under S. 280 reduce the projected energy consumption by influencing vehicle purchase and travel decisions. By 2030, transportation use of motor gasoline declines by 4 percent in the S. 280 Core case relative to the reference case. With a shift in the vehicle mix, including increased sales of hybrid and diesel vehicles, and the adoption of more advanced technologies, new light vehicle fuel economy improves by 2 to 3 percent by 2030 (0.6 to 1.0 miles per gallon) in the main S. 280 cases, compared to the reference case.

In the industrial sector, total delivered energy is lower by 2 percent in the S280 Core case in 2020 compared to the reference, and 6 percent lower in 2030, partly due to slower growth in output of energy-intensive industries as a result of higher energy costs. Among these industries with large percentage reductions in energy use relative to the reference in 2030 are aluminum (10 percent), steel (10 percent), and glass (8 percent).

Specific industries could be more heavily impacted than the overall industrial sector. For example, in the reference case, an emerging coal-to-liquids (CTL) industry is projected to supply 434 thousand barrels of oil per day by 2030. Under S. 280, the CTL is not expected to be viable in the 2030 time frame, eliminating this domestic source of petroleum supply, and reducing projected industrial coal consumption for CTL heat and power by 0.9 quadrillion Btu.

Economic Impacts

S. 280 increases the cost of using energy, which reduces real economic output, reduces purchasing power, and lowers aggregate demand for goods and services. The result is that projected real Gross Domestic Produce (GDP) falls relative to the reference case. The impacts generally increase over time, as the cap-and-trade program requires larger changes in the energy system. Relative to the reference case, real GDP in 2030 is between 0.3 percent and 0.5 percent lower in 2030 in the main S. 280 policy cases. Impacts on real consumption, a more direct indicator of the economic welfare of American consumers, are similar, averaging 0.4 percent lower in the main S.280 policy cases.

Total discounted GDP over the 2009 to 2030 time period is $533 billion (-0.22 percent) lower in the S280 Core case and ranges from $471 billion (-0.19 percent) lower in the Fixed 30 Percent Offsets case to $572 billion (-0.23 percent) lower in the No International case.

The combined value of the auctioned and distributed allowances, or allowance revenue, tends to grow over time as the allowance price rises. By 2029, the total revenue in the S280 Core case rises to $287 billion, before falling to $233 billion in 2030 when the number of allowances issued drops. Economic impacts are sensitive to the specific assumptions made regarding the recycling of allowance revenues.

Uncertainty

The prospect for substantial reductions in the role of conventional coal-fired generation by 2030 and the potential role of international offsets are among the most important uncertainties affecting the analysis.

This analysis suggests that increasing the use of nuclear and renewable power is an economical compliance strategy, with nuclear generating capacity more than doubling over the next 25 years. However, concerns about siting, waste disposal, and project risk could deter nuclear development. The **No Nuclear case** holds nuclear capacity to the reference case level, driving allowance prices 6 percent higher than those in the S280 Core case by 2030. Similarly, there are questions about the potential development of a large scale bio-power industry. For example, the analysis does not assume enactment of a significant new mandate for the use of biofuels in the transportation sector, which would tend to reduce the availability of biomass for electricity generation. The costs of integrating large quantities of wind into the power grid are another issue. If nuclear and renewable generation cannot grow rapidly, the deployment of CCS technology would be more likely. However, the industry would again be relying on a technology about which there is considerable uncertainty.

The effects uncertainty regarding the potential role of international offsets is illustrated by the range of allowance prices, an indicator of marginal compliance costs, across cases with different assumptions about offset availability. Relative to the S.280 Core case, allowance prices in 2030 are 20 percent higher in the No International case and 35 percent lower in the Fixed 30 Percent Offsets case.

While the report includes some sensitivity analysis of individual uncertainties, projected allowance prices and economic impacts could increase well beyond the estimates provided if issues arise simultaneously in several key areas. Moreover, the likelihood of such a scenario may not be independent of policy design choices that influence the behavior of stakeholders. For example, a stakeholder with a primary focus on GHG emissions reduction and a secondary interest in minimizing reliance on nuclear power and offsets would likely be less inclined to actively oppose both nuclear power and offsets if the policy design included a mechanism to relieve compliance pressure that was tied to the level of compliance costs or other measures of economic impact.

The analysis of S. 280 is subject to a number of additional limitations that deserve emphasis. S. 280 calls for a reduction in the emission caps in 2030 and 2050, but the modeled time horizon in this study extends through 2030. While EIA has attempted to take into account investor behavior anticipating the post-2030 regulations, such as advanced allowance banking, the economic implications of S.280 on the economy after 2030 have not been evaluated. Our analysis suggests that large reductions in carbon dioxide emissions in the electric power sector will be necessary to achieve the emissions caps through 2030. Meeting the 2050 caps would likely require a nearly carbon-free electric power supply and a substitution of petroleum-based fuels in transportation, a potentially costly transition from current trends.

The reference case used as the baseline for this analysis is only one of many possible paths representing future economic and energy markets trends under current laws and policies. The *Annual Energy Outlook 2007* presents a range of cases reflecting alternative growth and price paths. All else equal, higher growth in the U.S. economy raises baseline emissions and increases the total amount of reductions required to comply with a cap linked to historical emissions, while lower growth has the opposite effect. Assuming fixed emissions objectives for other countries, higher growth abroad would increase their internal requirement for emissions reductions and reduce the availability of international offsets to U.S. entities covered under S.280, while lower growth has the opposite effect. A baseline with higher conventional energy prices tends to increase both energy efficiency and the penetration of alternative energy sources, reducing the burden of compliance with a cap linked to historical emissions, while lower prices have the opposite effect.

The report also includes sensitivity cases that highlight the effect of varying other key assumptions. The **S280 High Tech** case uses the more optimistic technology development assumptions from the *AEO2007* Integrated High Technology case, rather than assumptions from the *AEO2007* reference case.[5] Projected allowance prices in 2030 in the S280 High Tech case are $40 per metric ton of CO_2 equivalent, compared to $48 per metric ton in the S280 Core case. The **High Auction** case assumes an initial auction share of 70 percent, rather than 30 percent, with a steady increase to 90 percent by 2030, the same end point used in the main S. 280 cases. With more allowance revenue allocated to consumers and the government and less to businesses, the short term (2012 to 2016) impact of S.280 on GDP is slightly lower than under the S280 Core case, and the long term (2021 to 2030) impact is somewhat higher. The **Unlimited Offsets** case assigns no limit on using offsets, in contrast to the 30 percent limit in the main S. 280 cases. With greater use of domestic and international offsets in the Unlimited Offsets case, energy-related CO_2 impacts are less than half of that of the S280 Core case. Projected allowance prices in 2030 in the Unlimited Offset case are $25 per metric ton of CO_2 equivalent, compared to $48 per metric ton in the S280 Core case.

[5] The *AEO2007* 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.

1. Background and Scope of the Analysis

This service report was prepared by the Energy Information Administration (EIA) in response to a February 5, 2007, request from Senators Lieberman and McCain for an estimate of the economic impacts of S. 280, the Climate Stewardship and Innovation act of 2007 (Appendix A). In a follow-up letter the Senator's staff provided additional guidance on the analysis request, describing the key scenarios they wished examined and specifying that the *Annual Energy Outlook 2007*[6] *(AEO2007)* reference case serve as a starting point (Appendix B).

Overview of the Climate Stewardship and Innovation Act of 2007

S. 280 establishes a long-term program to reduce greenhouse gas emissions (GHG) through an emissions cap-and-trade system and various supporting policies, including:

- a mandatory emissions reporting system for covered entities,
- a national greenhouse gas database and registry of emissions reductions,
- a program to encourage innovative emissions reduction technologies,
- a program to facilitate financing for climate technology projects, and
- provisions to mitigate adverse economic impacts of the bill on consumers and communities and to fund climate change adaptation programs.

The cap-and-trade program applies to most greenhouse gas emissions sources, the exceptions being those in the uncovered residential and agriculture sectors and emissions sources in the covered sectors where exemptions apply. The specific provisions include:

- Covered Sectors are the commercial, industrial, electric power, and transportation sectors.
- Covered Entities are those owning or controlling a source of emissions in the commercial, industrial, and electricity sectors that emit, from any single facility,[7] greenhouse gas emissions from stationary sources greater than 10,000 metric tons carbon dioxide (CO_2) equivalent.
- Transportation emissions from petroleum are regulated upstream through the refiners and importers that supply petroleum products for transportation use.
- Fluorinated Gases: Producers and importers of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride would be required to submit allowances for emissions associated with their products, subject to the 10,000-metric-ton minimum.
- Exemptions: The Environmental Protection Agency (EPA) may exempt emission sources where their measurement or estimation is impractical, such as many sources of nitrous oxide and methane emissions.

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[6] Energy Information Administration, *Annual Energy Outlook 2007*, DOE/EIA-0383(2007) (Washington, DC, February 2007), web site: www.eia.doe.gov/oiaf/aeo/index.html.

[7] The bill requires that all of a covered entity's emissions are subject to allowance requirements—not just the emissions of the facilities with emissions in excess of the threshold.

To cap greenhouse gas emissions, a fixed number of tradable emission allowances would be issued each year, with an unspecified share auctioned and the rest distributed for free. Each emission allowance provides the right to emit one ton of greenhouse gases, measured in CO_2 equivalent units based on the 100-year global warming potential. The bill requires individual covered entities to submit allowances equal to their emissions but does not otherwise limit their emissions. Entities could buy and sell allowances and bank allowances for future use. Under limited conditions, covered entities could borrow allowance credits against future emissions reductions.[8]

The emission caps begin in 2012 and are reduced in 2020, 2030, and 2050. The caps apply to the emissions in the covered sectors, excluding emissions from the residential sector, the agriculture sector, and U.S. territories.[9] The specified caps are to be reduced to adjust for emissions by any exempted sources in those sectors in the first year of each interval. The specified caps, before the adjustments, in million metric tons of CO_2 equivalent, are:

2012 to 2019. . . . . . . 6,130 (equal to 2004 emissions)
2020 to 2029. . . . . . . 5,239 (equal to 1990 emissions)
2030 to 2049. . . . . . . 4,100 (about 22 percent below 1990 emissions)
2050 and beyond . . . .2,096 (about 60 percent below 1990 emissions)

With future emissions of the exempted sources not known precisely, the adjusted caps are somewhat uncertain. Another source of uncertainty stems from the bill's requirement for a biennial review of the caps, given the latest science, data, and environmental and health impacts of greenhouse gas concentrations.

Covered entities can also satisfy up to 30 percent of their annual allowance obligation through various alternative compliance options, or offsets.[10] Offset sources include: 1) registered reductions in emissions by non-covered entities, 2) registered increases in carbon sequestration, 3) greenhouse gas emission allowances from other countries with comparable cap and trade programs, and 4) certified credits for project-specific emission reductions in other countries. Entities that wish to satisfy more than 15 percent of their allowance obligation through offsets would be required to submit 1.5 percent of their obligation with carbon sequestration credits from agricultural soils.

The percentage of free allowances allocated to covered entities is not specified in the bill, although various criteria are identified on which to base the distribution. Among the allocation criteria is a program to reward covered entities for emission reductions made

[8] This provision requires any borrowed emission credits to be returned with an additional 10 percent of future allowances for each year borrowed. This relatively high "real" rate of interest would discourage the use of borrowing allowances.
[9] The emissions caps for 2012 and 2020 cited in the bill match the 2004 and 1990 aggregate emission levels, respectively, for the four covered sectors as reported in the Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004,* EPA 430-R-06-002 (Washington, DC, April 2006), Table 2-14.
[10] As an incentive for early action, entities reducing their emissions below 1990 levels by 2012 may be granted an increased limit of 40 percent of allowances from alternative compliance sources from 2012 to 2017.

from 1990 through 2011. Entities with creditable reductions are granted a corresponding increase in their future allocation of allowances in the compliance period beginning in 2012. These credits for early action by *covered entities* do not affect the overall compliance cap; they only affect the allocation of free allowances to covered entities. *Non-covered entities*, however, can register emission reductions undertaken between 1990 and 2011 and obtain allowance offset credits that can be sold to covered entities. Therefore, early-reduction credits by non-covered entities effectively ease the caps on emissions, while those by covered entities do not.

The bill establishes a nonprofit Climate Change Credit Corporation (CCCC) to manage the emission allowance market and distribute auction proceeds for the following programs, with minimum spending percentages as indicated:

- Offset increased costs borne by consumers through such methods as cash rebates, discounts, and subsidies
- Provide transition assistance to dislocated workers and communities (20 percent initially, declining 2 percentage points per year)
- Fund climate change adaptation and mitigation programs to aid low-income populations (10 percent)
- Fund programs to promote fish and wildlife habitation to climate change (10 percent), and
- Establish a program to support technology deployment and innovation (50 percent).

Methodology and Assumptions

This section describes the methodology used in this analysis and identifies key assumptions made to address uncertainties in the interpretation of the bill and its impacts. Key assumptions regarding the interpretation of the bill were provided in a follow-up letter to the original request for this analysis (Appendix B).

Emission Cap and Coverage Assumptions

S. 280 exempts entities in covered sectors having no facilities with emissions over a threshold of 10,000 metric tons of CO_2 equivalent. In each year that a new emission cap is established (2012, 2020, 2030, and 2050), the stated caps are to be reduced to adjust for the future emissions of these uncovered entities in the first year the cap is imposed. As a result, deriving an estimate of the actual caps depends on emissions projections of exempted sources in the covered sectors. Table 1 presents the derivation of the adjusted S. 280 emissions caps. Table 1 reflects the following assumptions made to estimate the adjusted caps:

- Baseline energy-related CO_2 emissions are from the reference case of the *Annual Energy Outlook 2007* and are consistent with EIA emissions accounting assumptions.

- Baseline growth rates in non-CO_2 energy-related greenhouse gases are based on EPA's projections in their no-measures case as published in a 2006 report,[11] as applied to EIA's 2005 greenhouse gas emissions data.
- Direct energy-related CO_2 emissions in the commercial sector are assumed to be exempt, as emissions in individual buildings would rarely exceed the 10,000-metric-ton threshold. While emissions of multi-building facilities could exceed the threshold and entities controlling or owning such facilities would be covered, data sources to ascertain such situations and the extent of coverage are inadequate. Since the share of direct commercial energy emissions subject to regulation is expected to be small, the entire sector is treated as exempt in this analysis.
- All sources of energy-related CO_2 emissions in the industrial sector are assumed to be covered, except emissions in the agriculture sector, which is an uncovered sector, and the construction industry, where the emission threshold exemption would likely apply. While some additional industrial entities would be exempted based on the emissions threshold, data to distinguish such entities and disaggregate their emissions are unavailable.
- All sources of energy-related CO_2 emissions in the electricity sector are assumed to be covered. Emissions of virtually all fossil-fueled plants would exceed the emissions exemption threshold.
- Energy-related CO_2 emissions from petroleum in the transportation sector are assumed to be covered. Natural gas use for vehicles in the transportation sector is assumed to be uncovered, while natural gas used for pipelines is assumed to be covered.
- Emissions of methane from coal mining are assumed to be covered. All other potential methane sources, including emissions from landfills, mobile sources, agriculture, oil and natural gas systems, are assumed to be uncovered or exempt due to measurability considerations or the 10,000-metric-ton threshold provision.
- Emissions of nitrous oxide from nitric and adipic acid production are assumed to be covered. Nitrous oxide emissions from agriculture are uncovered, and mobile sources are assumed to be exempt based on the bill's measurability provisions.
- All emissions of fluorinated gases are assumed to be covered. However, emission caps and allowance requirements for fluorinated gases are assumed to be based on the year the emissions ultimately occur, as opposed to the year in which the gases are produced or imported, as specified in S. 280.
- Non-energy process emissions of CO_2 in the industrial sector associated with the production of cement and lime are assumed to be covered. The National Energy Modeling System (NEMS) was modified to estimate emissions from these sources endogenously, with adjustments to exclude process emissions of imported cement. Other non-energy-related CO_2 emissions are assumed to be uncovered and grow at 1 percent per year.

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[11] Environmental Protection Agency, *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990-2020*, (Washington, DC, June 2006), www.epa.gov/nonco2/econ-inv/downloads/GlobalAnthroEmissionsReport.pdf.

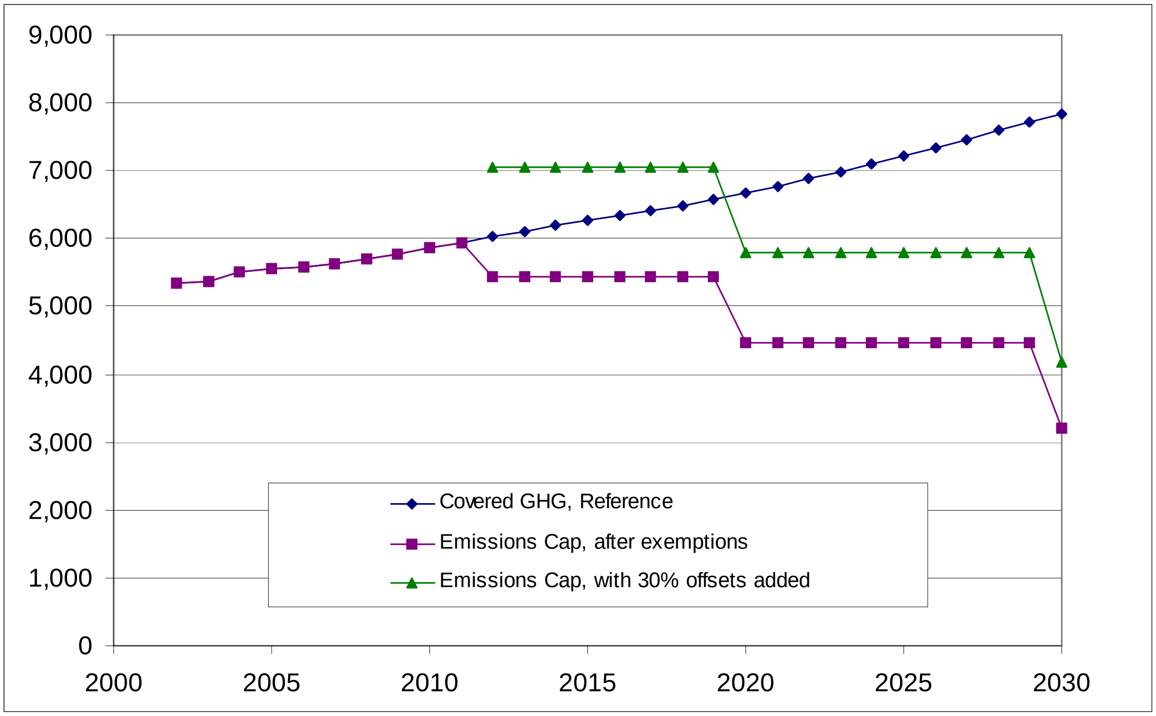
Table 1. Reference emissions and emission cap derivation, 2005-2050
(million metric tons CO_2 equivalent)

	2005	2012	2020	2030	2050
Emissions in covered sectors					
Nonexempt sources					
Energy-related carbon dioxide					
Industrial (excluding agriculture and construction)	902	954	992	1119	
Transportation, petroleum	1922	2053	2288	2626	
Natural gas used in pipelines	30	36	42	42	
Electric power sector	2375	2571	2832	3338	
Non-energy related carbon dioxide (cement and lime production)	60	65	72	80	
Methane (coal mining)	66	69	70	76	
Nitrous oxide (includes adipic and nitric acid)	34	36	38	41	
Fluorinated gases (HFCs, SF_6, and PFCs)	160	239	340	518	
Total non-exempt covered emissions	**5548**	**6023**	**6673**	**7839**	**9565**
Exempt sources					
Energy-related carbon dioxide					
Commercial	230	248	270	298	
Construction	63	63	70	77	
Natural gas, transportation	2	4	5	6	
Other carbon dioxide (including accounting adjustments)	4	3	2	2	
Methane					
Landfills	156	158	163	172	
Natural gas and oil systems	154	182	221	284	
Nitrous oxide (mobile sources)	53	44	47	52	
Total, exempt sources	**661**	**701**	**779**	**891**	**1087**
Emissions in noncovered sectors					
Energy-Related carbon dioxide					
Residential	368	387	393	390	
Agriculture	54	54	53	55	
Methane (agriculture)	237	239	239	241	
Nitrous oxide (agriculture)	280	292	302	316	
Total, noncovered sectors	**939**	**971**	**987**	**1001**	**1222**
Total Gross GHG Emissions (excludes changes in carbon sinks)	**7147**	**7696**	**8439**	**9731**	**11874**
S.280 Emission Cap, Before Exemptions		**6130**	**5239**	**4100**	**2096**
Exempted emissions in covered sectors		701	779	891	1087
S.280 Emission Cap, After Exemptions		**5429**	**4460**	**3209**	**1009**

Sources: **History:** EIA, Emissions of Greenhouse Gases in the United States 2005, DOE/EIA-0573(2005) (Washington, DC, November 2006).
Projections through 2030: **CO_2 Emissions**: EIA, *Annual Energy Outlook 2007*, with additional sectoral breakouts and non-energy emissions estimated by the EIA Office of Integrated Analysis and Forecasting.
Non-CO_2 Emissions: 2005-to-2020 growth rates from EPA, *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990-2020*, supplementary spreadsheets, case without methane and fluorinated gas technology adoption measures.
2050 Figures: extrapolation from 2030 at 1 percent per year growth for illustrative purposes.

Figure 1 presents the adjusted emissions caps, or targets, compared with projections of covered emissions in the reference case. The gap between the reference case emissions and the cap represents the combined amount of emissions reductions and emissions offsets that must take place to comply with the bill. Since covered entities can meet up to 30 percent of their allowance requirements with emission offsets, their direct emissions can be substantially higher than indicated by the emission target. To illustrate this flexibility, the figure also presents the emissions target with a 30-percent offset adjustment. As shown, if all entities were to take full advantage of the offset provisions in all years, the covered emissions could remain above the 2005 level through 2029, even without the emissions banking.

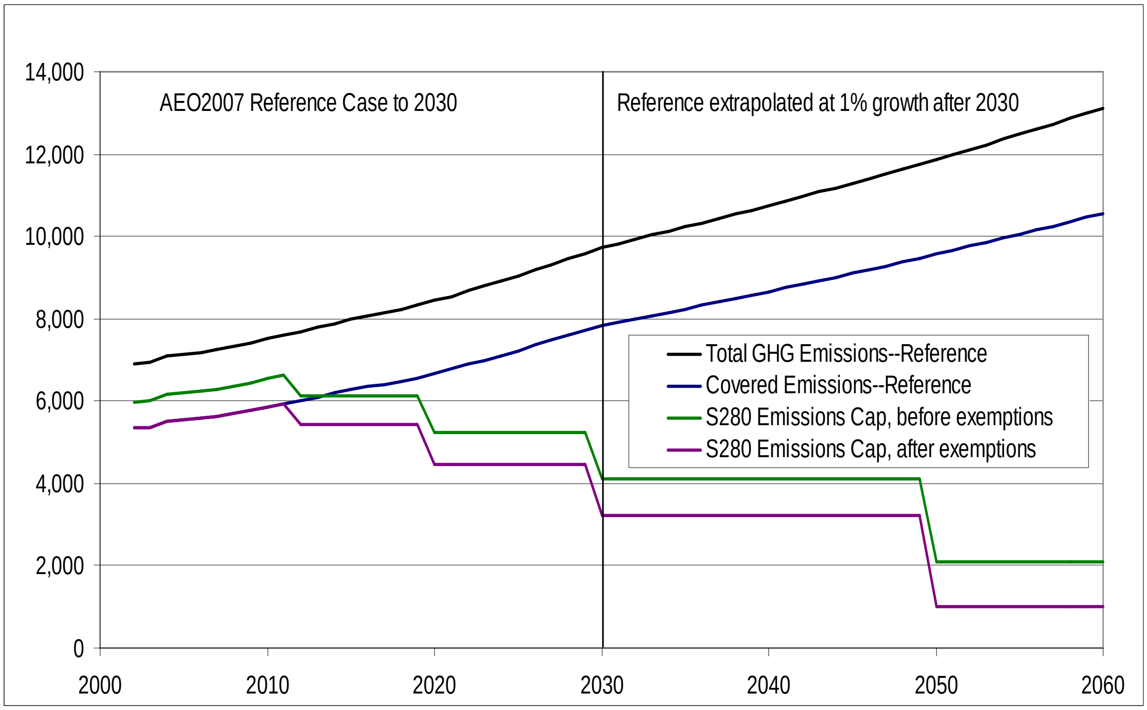
Figure 1. Reference Covered Emissions and Adjusted Emission Cap, 2002-2030
(million metric tons CO_2 equivalent)



Source: See Table 1.

Note that Figure 1 only reflects the emissions of covered entities, not total GHG emissions, and that S. 280 also specifies emissions caps through 2050. Figure 2 presents S. 280 emissions targets in the context of total GHG emissions and extrapolates the reference case emissions projection through 2060 at a 1-percent growth rate. This shows that the gap between the emissions cap *before exemptions* and the emissions cap *after exemptions* widens over time, as emissions of exempted sources continue to grow. As a result, the adjusted emissions cap in 2050 is roughly half the unadjusted cap and less than 10 percent of the unregulated emissions projection in 2050.

Figure 2. Greenhouse Gas Emissions and S. 280 Emissions Cap, 2002-2050
(million metric tons CO_2 equivalent)



Source: See Table 1.

Modeling Approach

The analysis of energy sector and energy-related economic impacts of the various GHG emission reduction proposals in this report is based on results from EIA's NEMS. 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, an updated reference case[12] based on the *AEO2007* reference case was developed. Among the updates was the addition of a methodology to estimate non-energy process emissions of CO_2 associated with cement production and lime (discussed further below). Other process CO_2 emissions were assumed to grow at 1 percent per year.

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 allowances needed to cover the emissions produced when they are used. These adjustments influence energy demand and energy-related CO_2 emissions. The GHG allowance price also determines the reductions in the emissions of other GHGs and from international offsets based on abatement cost relationships discussed in the next section. With emission allowance banking, NEMS solves for the time path of permit prices such that cumulative emissions match the cumulative emissions target without requiring

[12] See Appendix C for a discussion of updates to the *AEO2007* reference case.

allowance borrowing and with price escalation consistent with the average cost of capital to the electric power sector.

The NEMS Macroeconomic Activity Module (MAM), which is based on the Global Insight U.S. model, interacts with the energy supply, demand, and conversion modules of NEMS to solve for an energy-economy equilibrium. In an iterative process within NEMS, MAM reacts to changes in energy prices, energy consumption, and allowance revenue, solving for the effect on macroeconomic and industry level variables such as real gross domestic product (GDP), the unemployment rate, inflation, and real industrial output. These economic impacts, in turn, feed back into the energy sectors of NEMS. The cycle is repeated until an integrated solution is obtained. The economic impacts of the legislation stem partly from its impact on energy prices and its effects on production, imports, and exports of energy goods and services. In addition, the auction and distribution of the GHG allowances generate revenue streams to the government and private sectors. The MAM represents the revenue streams accruing to these sectors based on the allowance allocations specified in the bill or guidance provided by Senate staff. Together, these energy-related price, quantity, and revenue allocation effects impact the aggregate level of prices, output, and employment within the economy.

Representation of Non-CO_2 GHG Abatement and International Offset Opportunities

Assessing S. 280 requires an analysis of energy-related CO_2 emissions and non-CO_2 GHG emissions. NEMS represents U.S. energy markets and the associated CO_2 emissions and abatement opportunities endogenously. Non-CO_2 greenhouse gas emissions and international offsets are represented using exogenous baseline emissions projections and schedules of abatement opportunities.

The availability and price of international offsets from energy- and non-energy-related greenhouse gas emission reductions will depend on the supply of and demand for emissions reductions throughout the world. U.S. entities' demand for offshore offsets will compete with the demand for emissions abatement outside the United States, which, in turn, will depend on the emissions reduction commitments undertaken by other countries. Covered entities will be able to directly submit allowances purchased from countries that have established enforceable cap-and-trade systems. Covered entities can also submit verified offsets from countries without enforceable cap-and-trade systems, but there may be substantial costs involved to certify that the offsets will represent true emissions reductions.

For this study, the EPA provided EIA with a memorandum and spreadsheets containing information regarding the potential supply of emission reductions from domestic covered and offset sources, as well as international sources (Appendix D). Specifically, EPA provided a set of baselines and marginal abatement curves (MACs) for emissions of greenhouse gases other than energy-related CO_2 emissions and for carbon sequestration in forestry and agriculture in the United States.

International MACs were also provided for two non-United States country groupings—one including Europe, Japan, Canada, and Australia (Group 1) and the other (Group 2) including developing countries. EPA also provided a set of proposed assumptions regarding future foreign emissions reduction commitments that could be used to generate a schedule of foreign demand for emissions abatement.

Without EPA's assistance in this area, it would have been very difficult to complete this study in a timely fashion. EIA carefully reviewed the emissions baselines and MACs provided by EPA. The general approach was to rely on the information provided by EPA unless there were significant differences in areas addressed by EIA's own projections and prior analyses. EIA's use of the EPA-supplied information also reflected its own understanding of factors affecting the demand and supply of offsets based on its modeling experience and review of existing international emissions mitigation commitments and recent experience with project-based emission reduction programs in developing countries. Following this approach, EIA made adjustments in the following areas:

Foreign Energy Demand Growth

EIA's projections of foreign energy demand growth from the *International Energy Outlook 2007,* are the basis for the foreign CO_2 emissions baseline. EIA has somewhat higher projected growth than EPA in energy use and baseline CO_2 emissions growth in the developing countries and somewhat lower growth in developed countries. Relative to EPA's assumptions, EIA's baseline reduces demand for mitigation in developed countries and increases demand for mitigation in the developing countries.

Foreign Emission Mitigation Commitments

The actual commitments undertaken by foreign countries will affect their demand for abatement and, potentially, their abatement supply curves. For developed countries (Group 1), more stringent commitments generally imply greater internal abatement demand and lower offset supply to other countries.

For developing countries (Group 2), mitigation commitments have a mixed effect. More stringent and/or earlier commitments increase their demand for mitigation, but they also increase the potential supply of offsets to external markets, since mitigation commitments likely reduce transactions costs associated with the "export" of credible offsets.

Any schedule of mitigation commitments is necessarily speculative. EPA's spreadsheets presented a schedule of mitigation commitments used in a recent academic study. However, the European Union, (EU) which constitutes the bulk of developed country energy-related emissions outside the United States, has recently committed to reduce its GHG emissions 20 percent below the 1990 level by 2020, a timeline of emissions reduction commitments that is significantly more stringent than the schedule of commitments assumed by EPA (7 percent below 1990 by 2020, growing to 10.3 percent and 15.1 percent below 1990 in 2025 and 2030 respectively). Furthermore, the EU has committed to further emissions reductions if other Annex 1 countries also undertake emissions mitigation. For purposes of this analysis, EIA believes that the publicly-announced EU commitment by the EU heads of government provides the most appropriate basis for an assumption about future EU mitigation commitments. Consequently, emissions mitigation commitments for developed countries were adjusted to reflect the stated EU commitment of 20 percent below the 1990 level beginning in 2020. The commitment was assumed to change to 30 percent below the 1990 level in 2030. In addition, the commitment of the remainder of Group 1 countries, accounting for about 36 percent of the Group 1 emissions, was adjusted to reflect a commitment of 10 percent below the 1990 level beginning in 2020 and 20 percent below in 2030.

Assumptions made regarding commitments for developing countries are even more critical, since those assumptions will significantly impact both abatement demand and mitigation supply. EPA's analysis of international abatement demand assumes that developing countries adopt a binding commitment to return emissions to the 2015 level by 2025, followed by a return of emissions to the 2000 level by 2035. Given the primacy of developing countries' interest in economic development, their projected rapid growth in energy use and emissions over the next 20 years, and disparities in historical per-capita emissions, the commitment assumption proposed by EPA may be optimistic. For purposes of this analysis, EIA maintained the 2025 date for developing country commitments, but assumed that the initial commitment would involve stabilization of emissions at the 2020 level rather than the 2015 level. Table 2 presents the resulting emissions baseline, abatement commitments, and abatement demand assumed for this study.

Table 2. International Emissions Baseline, Abatement Commitments, and Assumed Abatement Demand, 2010-2030

(million metric tons carbon dioxide equivalent)

	Emissions Baseline		Abatement Commitment		Cap		Abatement Demand		
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Total
1990	8,188	16,268	Baseline	Baseline	8,188	16,268	0	0	0
2010	9,027	24,463	5.0% below 1990	Baseline	7,778	24,463	1,248	0	1,248
2015	9,184	27,389	8.2% below 1990	Baseline	7,516	27,389	1,667	0	1,667
2020	9,317	30,289	16.4% below 1990	Baseline	6,845	30,289	2,472	0	2,472
2025	9,412	32,856	16.4% below 1990	2020 levels	6,845	27,389	2,567	2,567	5,134
2030	9,520	35,527	26.4% below 1990	2020 levels	6,026	27,389	3,494	5,238	8,732

Relationship of Marginal Abatement Curves to the Supply of Non-Energy-Related Offsets

The relationship of MACs to the supply of offsets is also a critical issue. In a major published report on global mitigation of non-carbon dioxide GHGs,[13] EPA included the following statement:

> *While the results presented in this report can inform economic models, caution should be taken not to apply the MAC data directly as offset curves. Offset curves*

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[13] Environmental Protection Agency, *Global Mitigation of Non-CO_2 Greenhouse Gases*. (Washington, DC, June 2006), web site: www.epa.gov/nonCO2/econ-inv/international.html.

are a supply curve of emissions permits that could potentially be available in the market at a given carbon-price environment. However, a price signal alone is not likely to bring about all of the mitigation opportunities available along the MACs presented in this report. Other nonprice factors, such as social acceptance, tend to inhibit mitigation option installation in many sectors. ... Thus, the MACs in our analyses do not represent a supply curve of emissions permits that would be available for purchase, but rather the technical mitigation potential at a given carbon price.

EIA shares the concerns expressed above and does not believe that MACs for non-energy emissions can be used directly as offset supply curves. A number of specific issues that enter into the relationship between MACs and offset supply functions are likely to vary in importance from sector to sector and country to country.

First, the identification of specific technical opportunities in MACs may not reflect all costs that are relevant to decision makers. The identification of a significant set of "negative cost" opportunities to abate emissions reflects some combination of unidentified costs and/or other barriers, including the availability of relevant information to decision makers, which impede implementation. Information and other non-cost barriers can likely be overcome more easily than actual unidentified costs of abatement, but the respective roles of the different factors in driving observed behavior is not clear.

Second, even in the case where MACs fully characterize abatement costs, experience suggests that the diffusion of information and technology necessary to implement abatement will occur over time. Diffusion rates will likely be affected by both the profitability of the economic opportunity and institutional factors. For example, a new agricultural practice providing abatement benefits would likely diffuse more rapidly among large farms and well-educated farmers than among small traditional farmers.

A third factor affecting supply relates to perceptions regarding the marketability of particular offsets. For example, while forestry projects in developing countries show significant potential according to the MACs, experience with the current Clean Development Mechanism (CDM) shows minimal activity in this abatement category. As discussed below, concerns about baselines, leakage, and the difficulty of applying counterfactual ("but for") tests to forestry projects pose a significant barrier.

Consideration of the above-mentioned factors creates challenges for EIA in bringing the EPA-supplied MACs into this analysis. For non-energy related gases outside of the agriculture and forestry sectors, the MACs provided by EPA were reduced by 25 percent in developing offset supply curves. To reflect lags in information and technology diffusion, the offset supply curves also incorporate a diffusion function that is sensitive to both time and the economic return to abatement. A similar approach is used for forest sequestration activities in the United States and other developed countries and for agricultural sequestration activities worldwide. The diffusion parameter for activities related to rice agriculture in developing countries is slower than that used for developed countries, reflecting the institutional features of a sector in which extremely small farms and traditional agriculture play a much more significant role.

Forest Sequestration Activities in Developing Countries

Based on our review of the present programs and institutions and discussions with outside experts, EIA believes that forest sequestration activities in developing countries are unlikely to provide a major source of offset credits over the analysis horizon of 2030 for several reasons.

First, the EPA analysis measures sequestration relative to a business-as-usual forest carbon storage baseline that is sharply declining in South America, Africa, and Southeast Asia, three developing regions that supply most of the identified low-cost forest sequestration opportunities. As a practical matter, offsets would not provide an increase in observed forest carbon but rather a slowing of the rate of forest carbon decline. Implementation of such a program is inherently difficult and at a minimum would engender transactions costs that are not incorporated in the EPA analysis.

Second, forest sequestration projects are particularly subject to leakage concerns, since modification of forestry practices or forest preservation to generate offsets at particular sites can be offset by increased exploitation of non-participating forests. It will be exceedingly difficult to assure that claimed offsets from forest sequestration are actually valid on a "net" basis absent participation by all major forest areas, even if appropriate local baselines for all areas can actually be identified and agreed upon.

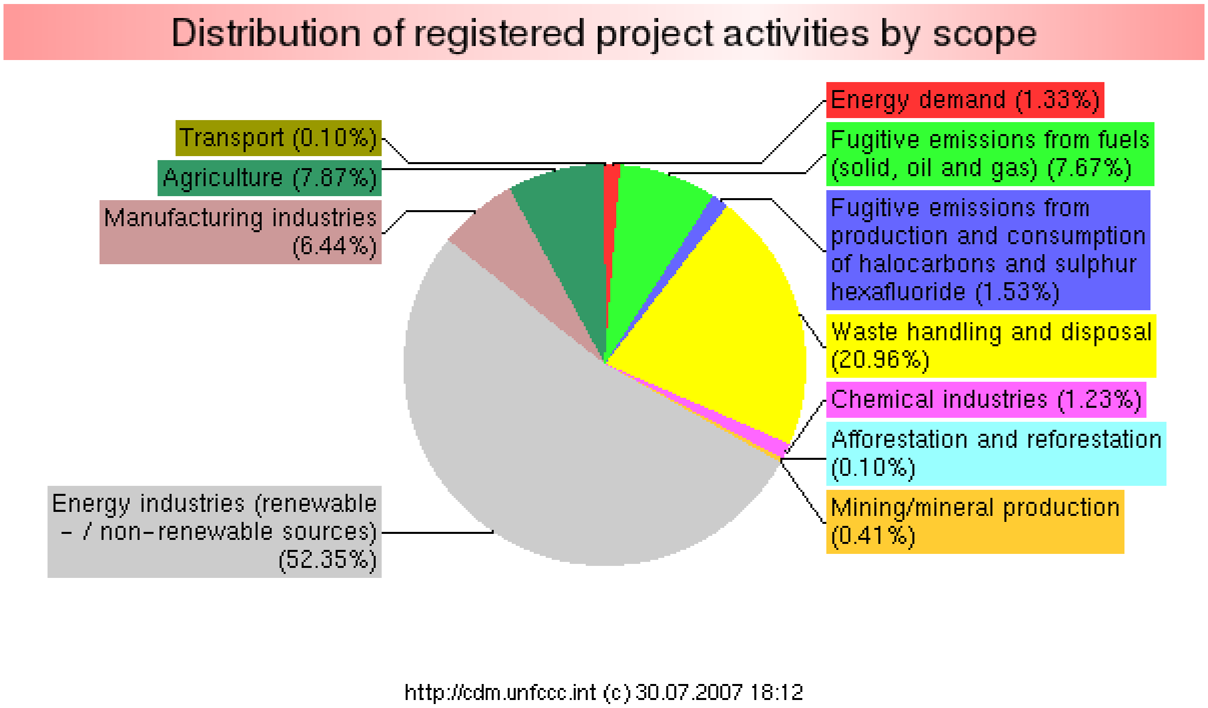
Third, forest sequestration does not appear to be a preferred source of CDM credits, despite the identification of significant potential for low-cost reductions. The latest "State of the Carbon Markets" report indicates that less than 1 percent of all CDM activities currently involve forest carbon or agricultural soils. As of May 22, 2007, only 1 of the 674 registered CDM projects is classified in the category of afforestation and reforestation (Figure 3). CDM activity is heavily concentrated in "industrial" activities that offer opportunities for clear project-level baselines. Section 145 (b) (1) of S.280 requires that the EPA Administrator ensure tradability of emission reductions earned under this program with reductions earned under other similar international programs. This provision may itself present a hurdle to inclusion of developing countries' forest carbon sequestration on a project basis.

These concerns lead EIA to exclude consideration of forestry offsets in developing countries from the international offset supply.

Summary of Non-CO_2 Emission Reductions and Offset Assumptions

Tables 3 to 11 quantify the emission reduction assumptions from domestic non-CO_2 gases, carbon sequestration in U.S. forestry and agriculture, and surplus international emissions offsets. Each table is a schedule of emission reductions or offsets over a range of allowance prices. The tables reflect materials from EPA regarding marginal abatement costs after discounting to reflect the market penetration assumptions discussed in the previous section. Assumptions for intervening years and prices are obtained by linear interpolation.

Figure 3. Clean Development Mechanism Project Summary



Source: Clean Development Mechanism Website, http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByScopePieChart.html, Accessed May 22, 2007

Tables 3 to 5 present non-CO_2 abatement supply from assumed covered sources: coal-related methane, nitrous oxide from adipic and nitric acid production, and fluorinated gases. The abatement schedule for fluorinated gases does not include some additional reductions for voluntary technology adoption programs that are reflected in the policy cases. These additional reductions are represented implicitly by using EPA's no-measures baseline for non-CO_2 gases in the reference case, while using their technology-adoption baseline in the policy cases.

Tables 6 to 10 present domestic offsets supplied from non-covered and exempt emissions sources: methane from natural gas and oil systems, landfills, agriculture; nitrous oxide from agriculture, and carbon sequestration from agriculture and forestry. Table 11 presents the potential supply of surplus international offsets to the United States, reflecting international abatement supply from Group 1 and Group 2 countries, less abatement demand. Negative values in Table 11 reflect excess demand for abatement at the given prices and, as a result, an absence of offsets available to the United States. The minimum allowance prices at which a surplus of abatement becomes available to supply U.S. offsets are indicated in Table 11.

Table 3. Abatement Supply of Coal-Related Methane, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	14.5	16.1	18.4	21.2	23.5
3	15.0	16.9	19.5	22.4	24.8
5	15.5	17.6	20.5	23.6	25.8
10	16.6	19.4	22.8	25.8	27.7
15	17.7	21.1	24.6	27.3	28.7
20	18.8	22.7	26.1	28.3	29.3
30	20.7	25.3	28.0	29.4	29.8
40	22.4	27.3	29.0	29.7	29.9
50	23.8	28.7	29.5	29.9	29.9
60	24.9	29.7	29.7	29.9	29.9

Table 4. Abatement Supply of Nitrous Oxide from Adipic and Nitric Acid Production, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	1.8	2.1	2.8	3.2	3.5
3	6.9	8.3	10.7	12.4	13.7
5	8.1	9.8	12.8	14.7	16.1
10	8.7	10.8	14.2	16.1	17.2
15	9.3	11.7	15.3	17.0	17.9
20	9.9	12.6	16.2	17.6	18.2
30	10.9	14.1	17.5	18.3	18.5
40	11.8	15.2	18.1	18.5	18.6
50	12.5	16.0	18.4	18.6	18.6
60	13.1	16.5	18.5	18.6	18.6

Table 5. Abatement Supply of Fluorinated Gases, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	8.8	12.8	21.8	25.1	27.8
3	10.2	15.2	26.4	30.5	33.6
5	11.7	17.8	31.4	36.1	39.6
10	15.8	24.9	44.9	50.9	54.6
15	20.3	32.7	59.5	66.0	69.3
20	23.0	37.8	66.4	72.1	74.6
30	25.5	42.1	72.6	76.2	77.2
40	27.6	45.5	75.5	77.4	77.8
50	29.3	48.0	77.0	78.0	78.2
60	30.6	49.7	77.7	78.2	78.3

Table 6. Offsets from Methane, Natural Gas and Oil Systems, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	3.8	4.5	5.9	6.8	7.6
3	4.6	5.6	7.4	8.5	9.4
5	4.9	6.0	8.0	9.2	10.1
10	5.3	6.7	8.9	10.1	10.9
15	5.8	7.3	9.8	10.9	11.4
20	7.9	10.2	13.4	14.6	15.0
30	11.5	15.0	18.9	19.8	20.1
40	14.0	18.3	22.2	22.8	22.9
50	14.9	19.3	22.6	22.9	23.0
60	15.7	20.0	22.8	23.0	23.0

Table 7. Offsets from Methane, Landfills, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	8.9	10.1	12.1	13.9	15.4
3	17.6	20.3	24.4	28.2	31.1
5	19.8	23.0	27.9	32.1	35.2
10	28.5	33.9	41.5	47.1	50.5
15	30.4	36.9	45.0	49.9	52.5
20	37.6	46.2	55.4	60.0	62.0
30	44.6	55.6	64.1	67.2	68.2
40	48.2	59.9	66.4	68.1	68.4
50	51.2	63.0	67.5	68.4	68.5
60	53.7	65.2	68.1	68.5	68.5

Table 8. Offsets from Methane, Agriculture, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	0.2	0.2	0.3	0.4	0.5
3	0.6	0.7	0.9	1.2	1.5
5	0.9	1.0	1.5	2.8	2.5
10	1.7	2.2	3.6	3.6	4.4
15	2.5	3.1	4.2	5.3	5.8
20	3.3	4.0	5.7	7.0	7.0
30	5.2	6.4	8.7	10.4	9.6
40	7.3	9.1	11.7	13.7	12.0
50	9.5	11.8	14.7	16.9	14.4
60	11.9	14.5	17.6	20.1	16.8

Table 9. Offsets from Nitrous Oxide, Agriculture, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	1.2	1.4	1.6	1.7	1.3
3	3.7	4.3	4.8	5.1	4.0
5	4.6	5.4	6.9	8.3	6.6
10	6.0	7.2	9.9	12.3	10.6
15	7.5	9.2	12.8	15.9	13.8
20	9.2	11.3	15.8	19.4	16.9
30	12.7	15.9	21.7	26.2	23.1
40	16.5	20.6	27.5	32.7	29.0
50	20.5	25.4	33.0	39.1	34.9
60	24.7	30.1	38.4	45.4	40.8

Table 10. Offsets from Carbon Sequestration, 2012-2030

(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	9.7	11.1	6.3	-0.9	10.0
3	29.3	33.9	19.4	-2.8	30.4
5	41.4	48.3	31.2	3.7	57.2
10	69.1	82.7	91.9	92.4	159.5
15	99.9	121.8	165.3	200.8	264.8
20	134.5	166.2	246.0	315.4	371.4
30	208.9	261.2	413.0	547.1	582.8
40	292.0	364.6	582.8	777.8	791.7
50	380.7	470.5	750.6	1006.2	999.4
60	473.2	576.3	915.9	1233.1	1206.6

Other Offset Assumptions

As directed in the letter from Senate staff outlining key assumptions for this analysis (Appendix B), the aggregate use of emissions offsets by covered entities is limited to 30 percent, the limit on each individual entity. Under S. 280, a 15-percent limit on offsets is available to all covered entities on an unrestricted basis, while a 30-percent limit is available to entities that supply at least 1.5 percent of their allowance commitment from carbon sequestration offsets associated with agricultural soil management practices. Also by request, a sensitivity case is included that relaxes the 30-percent limit and allows unlimited use of offsets

Table 11. Offsets from International Sources, 2012-2030
(quantities in million metric tons of CO_2 equivalent; prices in 2005 dollars per metric ton of CO_2 equivalent)

Allowance Price	2012	2015	2020	2025	2030
1	-1092.4	-1346.2	-1923.3	-4256.0	-7097.1
3	-836.8	-1145.7	-1753.2	-3309.9	-5871.4
5	-594.7	-918.2	-1465.9	-2406.1	-4861.3
10	-169.7	-442.8	-831.7	-449.2	-2749.0
15	266.4	121.7	0.2	1295.4	-905.7
20	665.7	651.9	840.3	2958.1	666.2
30	1411.2	1592.4	2230.9	6134.7	3672.7
40	2138.3	2456.2	3361.7	8444.1	6489.0
50	2868.9	3304.7	4467.0	10676.2	8488.0
60	3603.0	4138.8	5562.0	12929.3	10511.6
	Price at which Surplus Becomes Available				
	2012	2015	2020	2025	2030
	12	14	15	11	18

An additional source of S. 280 offsets not quantified in this analysis is associated with past emission reductions of non-covered entities. Non-covered entities can register emission reductions associated with voluntary activities from 1990 through 2011. These registered reductions can be then be sold as offsets beginning in 2012. Because the provision applies only to non-covered entities, the potential size of this offset pool is relatively small and unlikely to affect the outcome of this analysis. S. 280 also allows covered entities to obtain credit for early emission reductions, but the credits only influence the share of free allowances allocated to the entities and do not affect the supply of offsets.

Allowance Banking Assumptions

S. 280 allows unused allowances to be banked for future use. Banking of allowances is assumed to occur in anticipation of future allowance price increases and increasingly stringent caps on emissions. This analysis assumes that allowance prices under banking will escalate no higher than 8 percent per year, a rate equal to the average cost of capital in the electric power sector, where a significant share of emissions reduction investments would take place.[14] Borrowing allowances for future submission is allowed under S. 280, but repayment penalties essentially reflect a 10-percent real rate of interest that would presumably limit such borrowing. As a result, allowance prices are estimated such that allowance borrowing does not occur while also equilibrating the long-term supply and demand for allowances

[14] The 8-percent real rate assumes that investors will demand a rate of return that reflects some of the financial risk of holding allowances. This assumption effectively determines the growth rate of allowance prices and influences the amount of emissions banking that will occur. As a sensitivity case, a rate of 4 percent (real) is assumed, a rate representing a required return on a risk-free, or fully diversified (zero-beta) portfolio.

Since the timeline of this analysis of S. 280 only extends through 2030, assumptions had to be made regarding the post-2029 reductions in the emissions caps. Because of the reductions in the emissions cap in 2030 and 2050, entities would be expected to build up a bank of allowances in the early phases and hold a positive bank balance in 2030. EIA estimated a required allowance balance for 2030 to reflect the likely accumulation of allowances sufficient to meet the more stringent, post-2030 emission caps. The 2030 bank balance was set by solving for the 2030 bank withdrawal and setting the 2030 target bank balance so that it would be drawn down to zero over the subsequent 10 years assuming that the annual withdrawal would decline exponentially from the 2030 level at a rate of 25 percent a year. In the core policy case, the target allowance balance at the end of 2030 was set at 3,116 million metric tons carbon dioxide equivalent, based on 2030 withdrawals in test runs of about 1,100 million metric tons CO_2 equivalent. At best this is a rough approximation of the market behavior that might occur and larger or smaller bank balances might be realized.

Auction Share and Revenue Allocation

Under S. 280, a portion of the emission allowances is to be distributed for free to covered entities and the rest sold at auction. The letter providing guidance for this analysis specified an assumed share of allowances to be auctioned by the CCCC of 30 percent initially, increasing at constant rate to reach 90 percent in 2030. As a sensitivity case, the auction share is 70 percent initially, rising to 90 percent in 2030. The letter also specified assumed shares for the allocation of funds by the CCCC for its various programs, as well as the split between consumers and businesses for energy technology deployment programs, and rebates for the purchase of energy-efficient appliances. These assumptions have a bearing on the macroeconomic analysis and implications for consumer incentives to promote energy efficiency, as discussed in the next section.

Residential and Commercial Rebates and Technology Assumptions

Under S. 280, the CCCC is to use proceeds of the allowance auction to fund deployment of emissions reduction technologies. In addition, a share of the proceeds is to be used to mitigate economic impacts of the policy on energy consumers through rebates and subsidies for energy-efficient appliances. To simulate these programs, EIA was asked to assume that more efficient technologies would be available for appliances in the residential and commercial sectors as a result of the technology deployment initiative, similar to methodologies used in previous studies. The technologies assumed to be available are the same as those assumed in the *AEO2007* integrated high technology case. EIA also assumed that the incremental cost of those technologies is reduced by one-half due to the rebate initiative.

Changes to NEMS to Represent Industrial Process Emissions of CO_2

The industrial module in NEMS was modified to calculate process emissions of CO_2 from cement kiln operations. This change was undertaken because the cement industry is the largest contributor of process-related CO_2 emissions in the United States. The cement industry produces cement by heating limestone in kilns. The resulting chemical reactions produce CO_2 as a by-product. Since the industrial module explicitly represents cement kiln production, the process emissions can be calculated by applying the methodology used in the EIA *Greenhouse Gas Inventory 2005.*[15] In 2005, U.S. cement kiln CO_2 emissions were 46 million metrics tons, or 40 percent of total U.S. process-related CO_2 emissions.

In addition, the cement industry model was revised to reduce U.S. cement clinker production if energy prices, including the cost of allowances, increase sharply compared with the reference case. In effect, this change increases the import share of U.S. cement consumption. As a result, some of the emissions reduction in the United States is offset by increased CO_2 emissions abroad.

The industrial model was also revised to calculate process-related CO_2 emissions from the lime manufacturing industry, which was the second largest source of process-related CO_2 emissions in 2005 (15.7 million metric tons). The NEMS industrial module does not have an explicit representation of the lime manufacturing industry. Consequently, these emission projections are based on the output of the miscellaneous stone, clay, and glass industry. While no explicit abatement technologies are represented, changes in industrial output as a result of the policy influence the lime industry's CO_2 emissions.

Non-Modeled Provisions

EIA was unable to model some programs specified under S. 280. These programs include those described under Title III that establish incentives for innovation in climate-related technologies and promote development of advanced technologies and practices. EIA is also unable to address the impacts of climate-change adaptation programs, nor are the potential benefits of S. 280 in mitigating climate change assessed.

Analysis Cases

To examine the impacts of S. 280, simulations of NEMS were made with and without the policy. The list of cases examined is shown in Table 12. The two cases without the policy are shown in the upper section of the table. These include an update to the *AEO2007* reference case, which assumes a continuance of current laws and regulations. Also included is an update to the *AEO2007* integrated high technology case. Updates from the comparable *AEO2007* cases include corrections and modeling revisions needed

[15] The calculation is described in Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0638(2004) (Washington, DC, December 2006), pp. 35-38, www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2004).pdf.

Table 12. Analysis Cases

Case Name	Description and Assumptions
Non-Policy Cases	
Reference	Updated *AEO2007* reference case with some modeling revisions as described in Appendix D. Non-CO_2 emissions growth based on EPA "no measures" and "no voluntary technology adoption" cases
High Technology	Updated *AEO2007* integrated high technology case (without S. 280): • Includes more optimistic characteristics for energy technology, including a combination of earlier availability of advanced technologies, lower costs, and better performance.Applies to residential, commercial, industrial, transportation, and electric power sectors
Main Policy Cases	
S. 280 Core	Primary Policy Case. Key assumptions include: • Updated *AEO2007* reference case assumptions • Discount rate for allowance banking: 8 percent • Allowance auction share: 30 percent in 2012. growing linearly to 90 percent in 2030 • Commercial sector entities treated as exempt • Half of the incremental cost of energy-efficient appliances in the residential and commercial sector assumed to be subsidized through CCCC rebates and subsidies, as a result of S. 280 economic impact measures and innovation programs • In aggregate, up to 30 percent offsets allowed as determined from offset supply curves • Non-CO_2 emissions growth, before abatement, based on EPA "with measures" and "voluntary technology adoption" cases. • Non-CO_2 abatement, biogenic carbon sequestration, and international offset supply assumptions derived from EPA sources (Appendix D) by discounting to account for incomplete market penetration, exclusion of international forestry offsets from developing countries, and alternative foreign abatement targets
No International	Allowance offsets from international sources unavailable
Fixed 30 Percent Offsets	Offsets meet a fixed, 30-percent share of allowances, and: • Offsets prices match the prevailing allowance price • International sources assumed to provide the balance of the 30 percent of offsets not met by domestic sources
Alternative Policy Cases	
Unlimited Offsets	An unlimited share of allowance obligations can be met by offsets.
Low Discount	The discount rate for allowance banking is 4 percent
High Auction	The allowance auction share is 70 percent in 2012, growing to 90 percent in 2030
No Nuclear	No nuclear generating plant additions beyond the reference case level allowed.
Commercial Covered	All commercial sector entities treated as covered without exemptions; S. 280 caps adjusted accordingly.
S. 280 High Technology	S. 280 Core with integrated high technology case assumptions.

to complete this analysis and other post-*AEO2007* analysis requests. The three main policy cases that will be discussed throughout the report are shown in the middle section of the table. Alternative policy sensitivity cases that will be discussed in sections of the report where they are important are shown in the lower section of the table. The cases include scenarios specifically identified in a letter providing guidance for the analysis request, as well as several additional cases that demonstrate impacts of various analytical assumptions. The alternative policy cases incorporate all of the assumptions used in the S. 280 Core case except where identified in the description and assumptions section of the table.

Because of uncertainty about the availability and cost of offsets, particularly international offsets, three main policy cases were prepared. The S. 280 Core case incorporates the offset supply curves described previously. The No International case assumes that international offsets are unavailable or available at such high cost that they are economically unattractive. This might occur if the rest of the world were to increase their demand for emissions reductions by adopting aggressive emission reduction goals. On the other hand, the Fixed 30 Percent Offsets case assumes that sufficient economically-attractive international offsets are available in all years so that covered entities can take full advantage of the 30-percent offset limit in S. 280. These three cases are meant to illustrate the importance of the supply of offsets.

The alternative cases were prepared to explore the impacts of additional areas of uncertainty:

- The **Unlimited Offsets case** examines the impact of removing the 30 percent offset limit in S. 280. This limit is particularly important in the later phases of the proposal when the emissions caps, and the offset limit tied to them, are lowered sharply.
- The **Low Discount case** assumes that investors will only require a 4-percent return on allowances rather than the higher rate of return investors generally require for large plant investments such as power plants. Recent analysis at the Massachusetts Institute of Technology examined the returns on sulfur dioxide emission allowances (SO_2) and found that they were generally not correlated with market returns, suggesting that financial investors would treat them as relatively low risk assets.[16] It is unclear whether a similar relationship might be seen in GHG allowance markets since GHG emissions are so ubiquitously linked to economic activity.
- The **High Auction case** was prepared in response to a request from Senate staff to examine the impact of assuming that a larger share of the allowances distributed each year are auctioned rather than given out for free.
- The **No Nuclear case** examines the impacts of limiting the penetration of new nuclear capacity to the level seen in the reference case. Earlier EIA analyses have suggested that nuclear power could be an important option for reducing power sector GHG emissions. However, while interest in new nuclear plants appears to be growing,

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[16] Ellerman, Denny A. and Montero, Juan-Pablo, *The Temporal Efficiency of SO_2 Emissions Trading*, Joint Center of the Department of Economics, Laboratory for Energy and the Environment, and Sloan School of Management, September 2002, web.mit.edu/ceepr/www/2002-003.pdf.

uncertainty about the costs of new plants and public concerns about safety and long-term waste disposal could limit their penetration.

- The **Commercial Covered case** examines the impacts of assuming that all entities in the commercial sector were covered. As explained, while detailed data are not available, very few buildings are expected to meet the 10,000-metric-ton facility emission threshold in S. 280, but this case examines the potential impact if a larger than expected number did.
- The **S. 280 High Technology** case examines the impact of the provisions of S. 280 using more optimistic assumptions about improvements in technology. This case should be seen as a "what if" case, rather than predictive of the impacts of S. 280 from innovation incentives and technology deployment programs.

2. Energy Market Impacts of Reduction Greenhouse Gas Emissions

Greenhouse Gas Emissions and Permit Prices

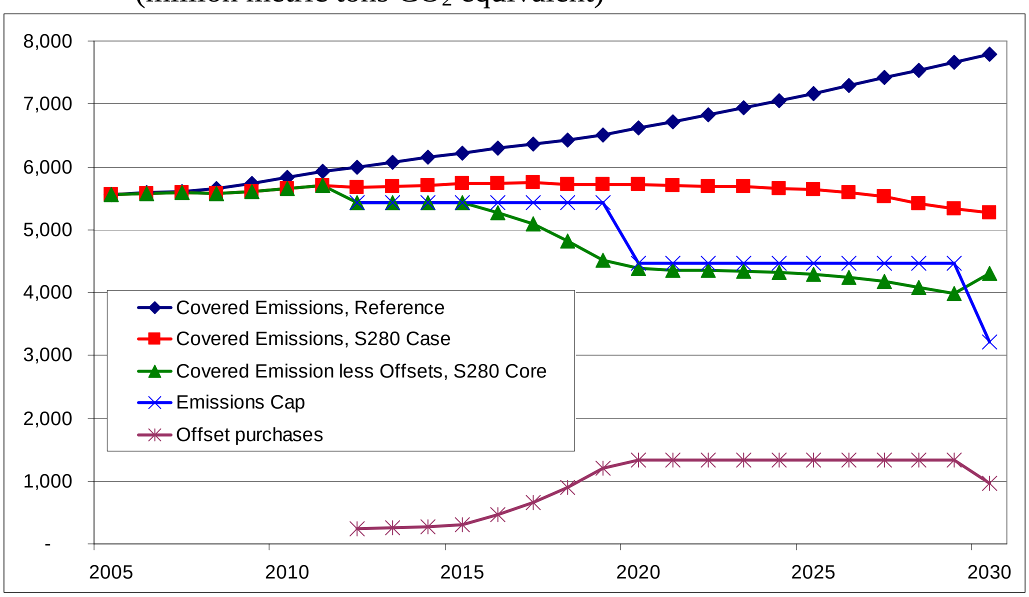
This section discusses the modeling results simulating the effects of S. 280 and compares those results to a policy-neutral reference case. The availability and cost of international emissions offsets is a potential source of low-cost emission reductions, but also a significant source of uncertainty. To highlight this uncertainty, the results throughout this section frame the S. 280 Core case with two alternative cases that provide bounds on international offset availability. The Fixed 30 Percent Offsets case assumes a sufficient supply of international offsets is available to supplement domestic offsets such that the 30-percent limit is used in all years, while the No International case allows only domestic offsets. Results of other sensitivity cases are also discussed to a lesser extent to illustrate effects of other key factors. A full set of tables for all cases is available on the EIA web site. Table 13 summarizes key results of the three main policy cases with a comparison to the reference case.

Greenhouse Gas Emissions

Under S. 280, covered entities will reduce their GHG emissions to levels governed by the quantity of allowances issued each year, the availability and limits on offsets, and the economics of holding allowances for future use. Figure 4 compares projections of covered emissions in the reference case and the S. 280 Core case, relative to the emissions cap. Because entities can meet up to 30 percent of the allowance obligation with offsets, the graph also depicts the projected offsets purchased, along with the covered emissions net of offsets for comparison to the cap.

Figure 4. Covered Emissions and Offset Usage in the Reference and S. 280 Core case, 2005-2030

(million metric tons CO_2 equivalent)



Sources: National Energy Model System runs S280BASE.D060107A and S280.D060107A.

Table 13. Summary of Emissions and Energy Market Results
(emissions in million metric tons CO_2 equivalent; other results in indicated units)

	2005	2020				2030			
		Refer-ence	S.280 Core	Fixed 30% Offset	No Inter-national	Refer-ence	S.280 Core	Fixed 30% Offset	No Inter-national
Greenhouse gas emissions									
Energy-related carbon dioxide	5945	6879	6116	6351	5878	7888	5520	6446	4995
Nonenergy carbon dioxide	63	76	72	74	71	84	76	78	74
Methane	612	694	542	563	525	772	573	557	552
Nitrous oxide	367	388	355	360	348	410	375	368	361
Fluorinated gases	160	340	268	279	264	518	443	444	443
Total	7147	8377	7353	7627	7086	9672	6987	7893	6425
Covered energy-related carbon dioxide	5242	6090	5333	5568	5092	7064	4702	5635	4174
Other covered emissions	323	524	390	407	382	719	567	570	565
Total covered emissions	5565	6614	5722	5974	5474	7783	5269	6205	4739
Offsets									
Noncovered emission reductions	0	0	94	71	115	0	99	122	134
Biogenic carbon sequestration	0	0	260	156	424	0	360	604	830
International sources	0	0	984	1112	0	0	505	237	0
Total offsets	0	0	1338	1338	538	0	964	963	964
Compliance summary									
Allowances issued (cap)	NA	NA	4461	4461	4461	NA	3209	3209	3209
Covered emissions, less offsets	5565	6614	4385	4636	4935	7783	4305	5242	3776
Net allowance bank change	NA	NA	76	-176	-475	NA	-1096	-2033	-566
Allowance price (2005 dollars per metric ton CO2 equivalent)	NA	NA	22.2	14.4	30.6	NA	47.9	31.0	57.6
Offset Price (2005 dollars per metric ton CO2 equivalent)	NA	NA	20.9	14.4	30.6	NA	19.5	31.0	41.8
Delivered energy prices (2005 dollars per unit indicated)(includes allowance cost)									
Motor gasoline, transport (per gallon)	2.32	1.97	2.14	2.08	2.20	2.21	2.56	2.46	2.62
Jet fuel (per gallon)	1.77	1.40	1.60	1.53	1.67	1.64	2.04	1.93	2.13
Diesel (per gallon)	2.41	2.10	2.30	2.24	2.38	2.34	2.78	2.66	2.87
Natural gas (per thousand cubic feet)									
Residential	12.80	10.83	10.62	10.72	10.58	11.66	11.33	11.60	11.28
Electric power	8.41	5.91	6.73	6.45	7.07	6.42	8.38	7.82	8.85
Coal, electric power sector (per million Btu)	1.53	1.57	3.59	2.88	4.35	1.70	5.85	4.45	6.63
Electricity (cents per kilowatthour)	8.10	7.91	8.72	8.40	8.99	8.05	9.75	9.37	10.03
Primary energy use (quadrillion Btu)									
Liquid fuels	40.7	46.5	45.2	45.6	45.0	52.1	49.3	50.0	48.9
Natural gas	22.7	27.1	26.3	26.5	25.7	26.9	25.0	26.1	24.8
Coal	22.9	27.1	20.4	22.5	18.4	34.1	12.1	20.9	7.4
Nuclear power	8.1	9.2	10.4	9.8	10.4	9.1	19.9	12.2	23.0
Renewable	5.9	8.5	11.9	10.5	13.8	9.0	17.0	15.4	17.8
Other	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.2
Total	100.3	118.4	114.3	115.0	113.4	131.1	123.5	124.7	122.1
Purchased electricity	12.5	15.5	14.7	14.9	14.7	17.6	16.2	16.3	16.0

Note: For simplicity the "delivered" prices of coal and natural gas to the electric power sector represent the effective delivered cost, including the cost of emissions allowances.

Sources: National Energy Model System runs S280BASE.D060107a, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

As indicated in Figure 4, covered emissions net of offsets are projected to match the S. 280 cap from 2012 to 2015. Beginning in 2016, covered emissions less offsets in the S. 280 Core case are below the cap, and a bank of allowances accumulates prior to the 2020 emissions cap reduction. A second, more gradual period of allowance accumulation starts in 2025 in advance of the cap reduction in 2030. Because the modeling horizon ends in 2030, an allowance bank balance in 2030 was estimated that would be sufficient to cover post-2030 withdrawals. As a result, cumulative emissions net of offsets through 2030 are projected to be somewhat lower than strictly required over that period. Because of the use of offsets, actual covered emissions in the S. 280 Core case only fall slightly below their 2005 level by 2030.

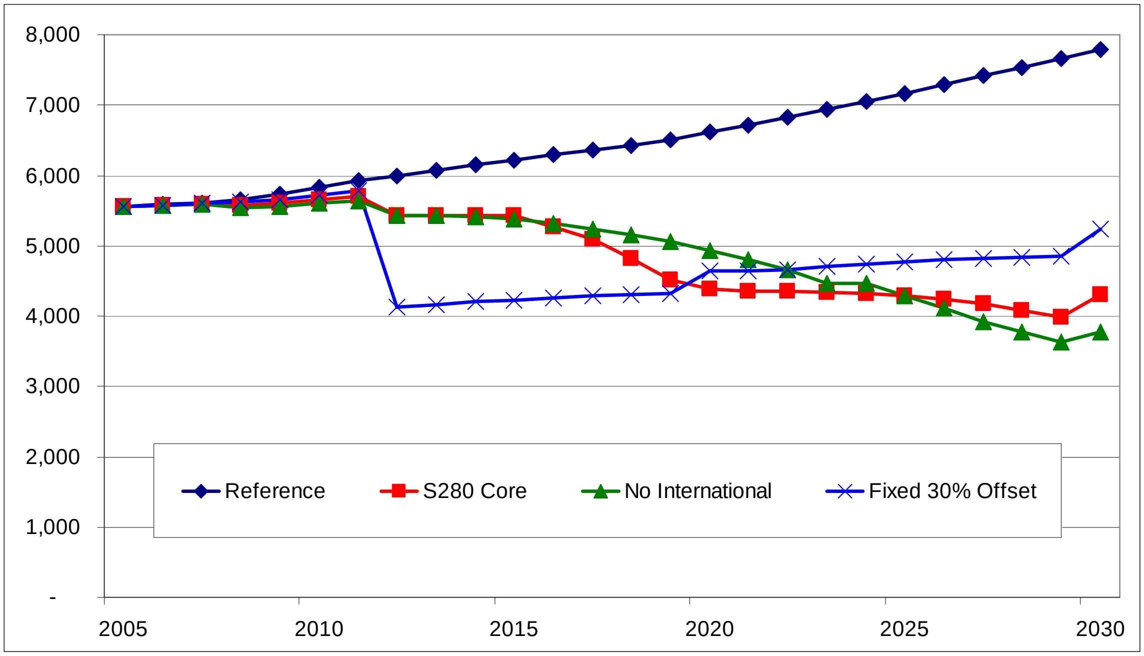
The 30-percent offset limit becomes binding in the S. 280 Core case in 2020, when the reduction in the emission cap also cuts the allowable level of offsets in absolute terms. From 2020 to 2030, offsets remain at 30 percent of the allowance cap, with the absolute level of offsets dropping in 2030 when the emissions cap is reduced again.

The patterns of emissions and allowance banking depend greatly on the assumed availability of international offsets. Projected emissions in the Fixed 30 Percent Offsets case and the No International cases are compared to those in the S. 280 Core case in Figure 5, and the patterns of allowance bank accumulation are shown in Figure 6. In the Fixed 30 Percent Offsets case, covered emissions net of offsets remain lower than the S. 280 Core case through 2019 and a large balance of allowances accumulates. The large bank build-up allows post-2020 emissions to remain correspondingly higher, and most of that bank balance is depleted over the next 11 years.

In contrast, relatively little allowance banking is undertaken in the No International case. Without international offsets, greater reductions in domestic energy-related CO_2 are needed to meet the emissions caps from 2012 to 2020. With a more significant early investment in carbon-neutral technologies required through 2020, allowances prices rise sooner. After 2020, the emission caps can be met for a few years without driving up allowance prices enough to induce allowance banking. Once allowance prices resume an 8-percent growth, a relatively small allowance balance begins to accrue in 2026, and by 2030 a balance builds up sufficiently high to supply the expected post-2030 withdrawals. The estimated ending balances for these three cases differ to account for the variation in allowance withdrawals in 2030.

Compliance with the S. 280 cap-and-trade program is expected to result in substantial covered emissions reductions, both from CO_2 and other GHG emissions. Under the offset provisions, emission reductions from non-covered entities also occur, together with increases in biogenic carbon sequestration from domestic forestry and agriculture, and credited decreases in emissions abroad. As seen in Figure 7, emissions reductions from CO_2 account for less than half of the total compliance response in the initial phase of the program, when lower cost offsets and non-CO_2 abatement opportunities predominate. The CO_2 share of compliance measures increases over time with more stringent reduction requirements and with greater turnover of electric power plants, energy-using equipment, vehicles, and appliances. This growing contribution of CO_2 reductions occurs in the other policy cases as well, but the degree of response and the relative share of offsets used in the compliance response differs among the cases (Figures 8 and 9).

Figure 5. Covered Emissions Net of Offsets in the Reference and Main Policy Cases, 2005-2030 (million metric tons CO_2 equivalent)



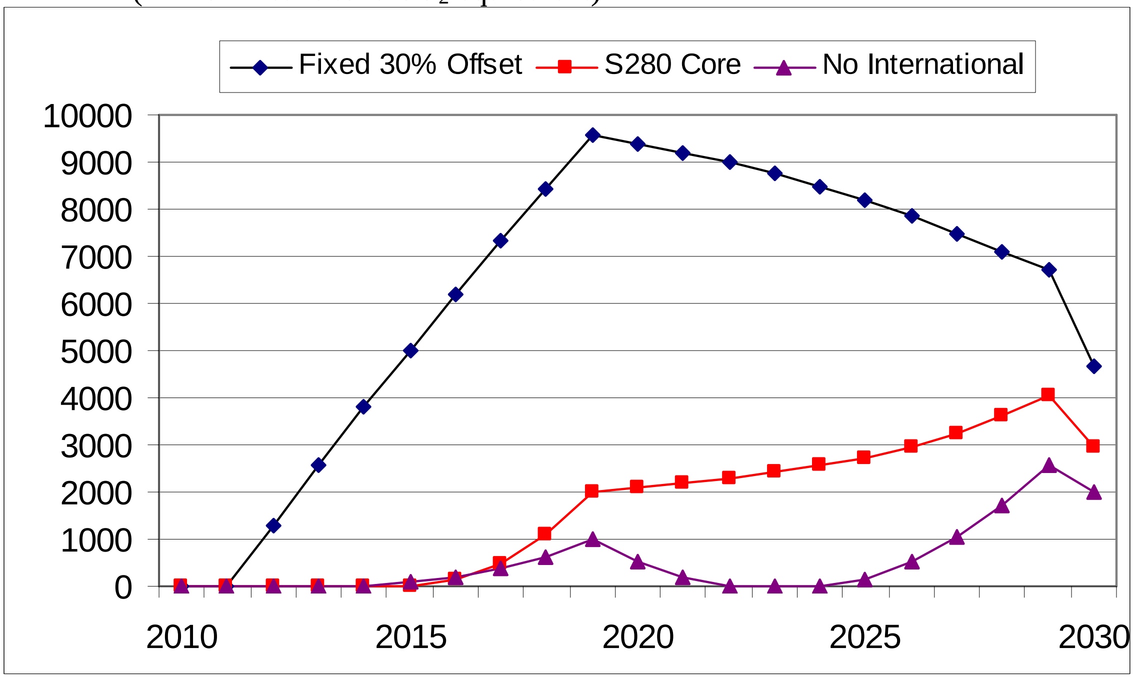
Sources: National Energy Model System runs S280BASE.D060107a, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

In the Fixed 30 Percent Offsets case, the role of international offsets plays a much greater role than in the S. 280 Core case from 2012 to 2020, and incentives to bank allowances promote a much greater overall response over that time frame. In the No International case, overall emission reductions are higher than in other two cases in the second phase of the program, as are the CO_2 reductions. The greater emissions reductions arise as the allowance prices are driven higher in the No International case, and with less accumulation of banked allowances, emissions reductions are deferred to the end of projection horizon.

Among the additional sensitivity cases examined, the compliance measures taken in the Unlimited Offset case are noteworthy (Figure 10). With no limit on offsets, a much greater use of international offsets can be used to comply after 2020 compared with the S. 280 Core case, where the offset limit is binding beginning in 2020. In 2025, the developing countries are assumed to adopt national cap-and-trade policies, and by assumption, this allows their excess CO_2 reductions to enter world markets as tradable allowances, without the marketability and acceptance restrictions that arise with CDM-

Figure 6. Comparision of Accumulated Emissions Banking in the Main S. 280 Cases, 2012-2030

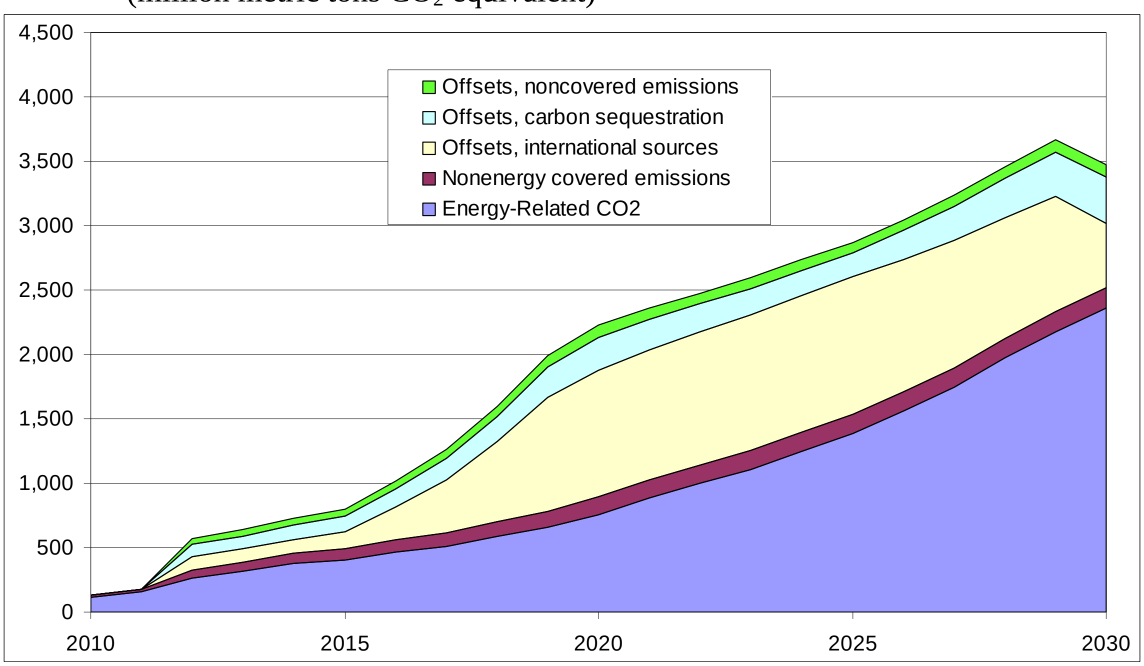
(million metric tons CO_2 equivalent)



Sources: National Energy Model System runs S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

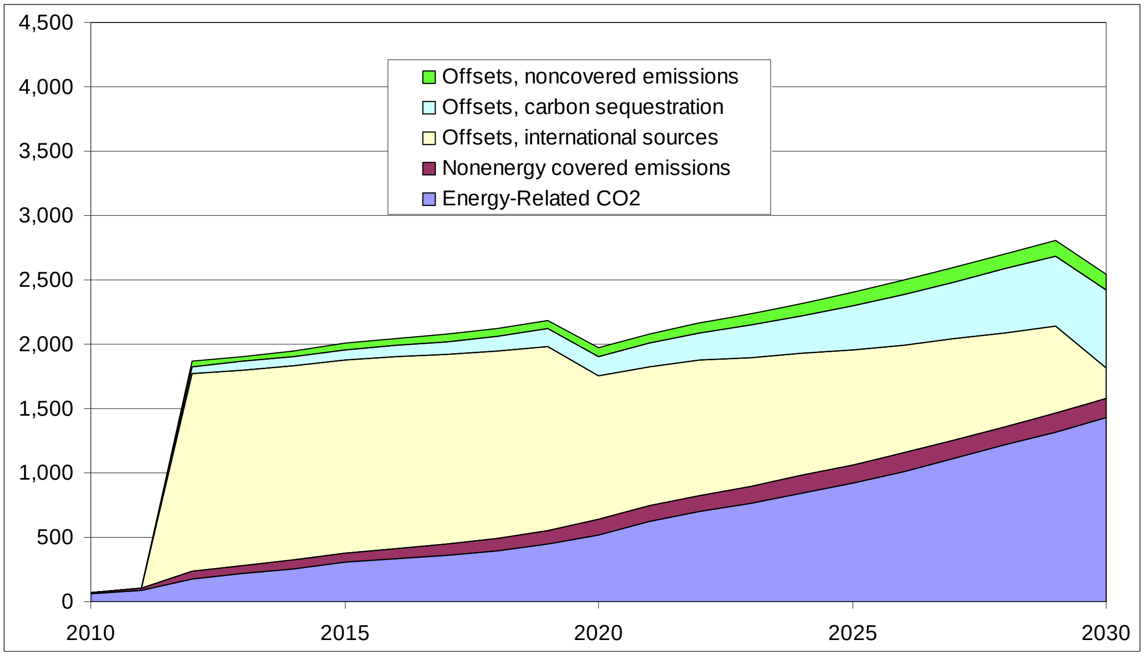
Figure 7. Emission Reductions and Offsets in the S. 280 Core Case

(million metric tons CO_2 equivalent)



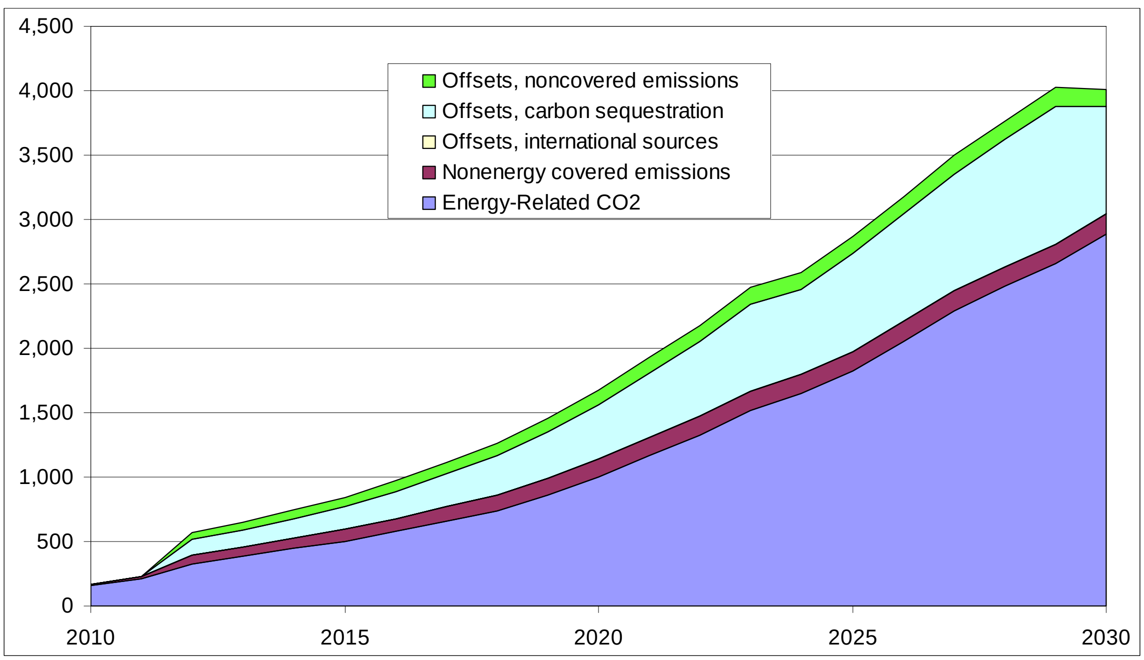
Source: National Energy Modeling System run: S280.D060107A.

Figure 8. Emission Reductions and Offsets in the Fixed 30 Percent Offsets Case
(million metric tons CO_2 equivalent)



Source: National Energy Modeling System run: S280straw.D060207A.

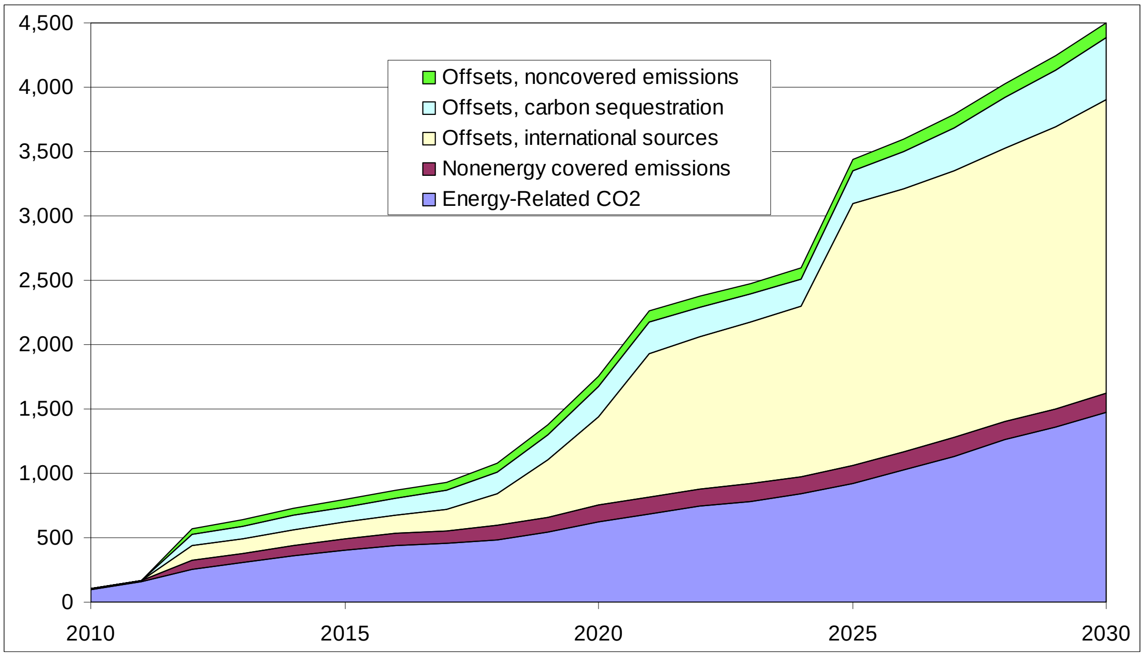
Figure 9. Emission Reductions and Offsets in the No International Case
(million metric tons CO_2 equivalent)



Source: National Energy Modeling System run: S280NOINTL.D061507A.

type reduction projects. With unlimited offsets allowed, covered entities in the United States could then increase their use of international offsets beginning in 2025 to take advantage of the availability of tradable allowances entering the market from developing countries. While the purchase of domestic offsets increases somewhat in the unlimited offset case compared to the S. 280 Core case, the main impact is to increase international offset purchases.

Figure 10. Emission Reductions and Offsets in the Unlimited Offset Case
(million metric tons CO_2 equivalent)



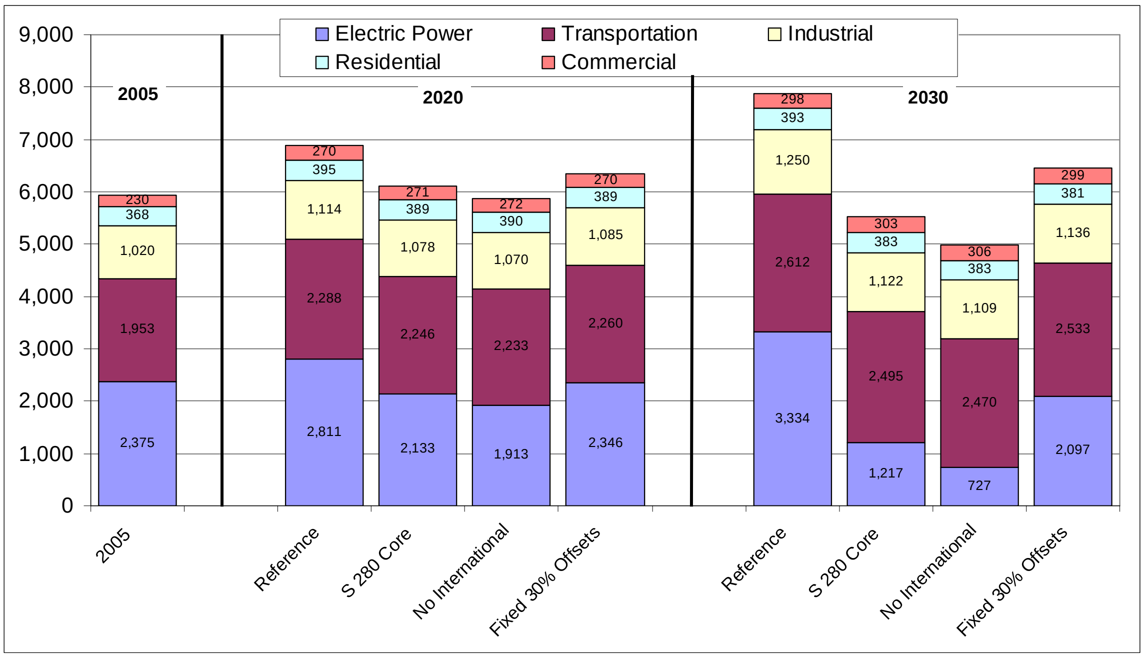
Source: National Energy Model System run S280VHIOFF25.D061607A.

In the energy markets, the electric power sector accounts for the vast majority of the CO_2 emissions reductions (Figure 11). This occurs because of fuel switching within the sector and reduced electricity consumption as consumers and business react to the higher electricity prices and take advantage of technology rebates available from the S. 280 technology deployment programs. Since the residential and commercial sectors are not covered, direct CO_2 emission in those sectors change very little. Transportation and industrial sector CO_2 emissions fall modestly in the main S. 280 cases in response to energy price changes as well as impacts on economic activity, particularly in the industrial output of energy-intensive manufacturing industries. These impacts will be discussed in greater detail in subsequent sections.

Allowance Prices

Under S. 280, a market for the tradable allowances will develop, with the potential supply of allowances in any given year including those auctioned by the CCCC, as well as allowances allocated for free and those allowances held from prior years. For this analysis, a single, annual market price for allowances is assumed, but the combination of government auctions and private trading would likely result in variations in allowance pricing. A related market for offsets is also assumed to develop for trade in emission reductions credits from non-covered entities, carbon sequestration credits, and international allowances and credits.

Figure 11. Energy-Related CO_2 Emission Reductions in the S280 Core Case (million metric tons CO_2)



Source: National Energy Modeling System run: S280.D060107A.

The markets for the allowances and offsets will establish price signals to influence emissions-related decisions by covered and non-covered entities. Reducing emissions may require investment in more energy-efficient technology or equipment using alternative fuels, and current and expected allowance prices will affect what investments are undertaken. In a competitive allowance market, the allowance price will tend to reflect the marginal cost of reducing emissions across all covered sectors.

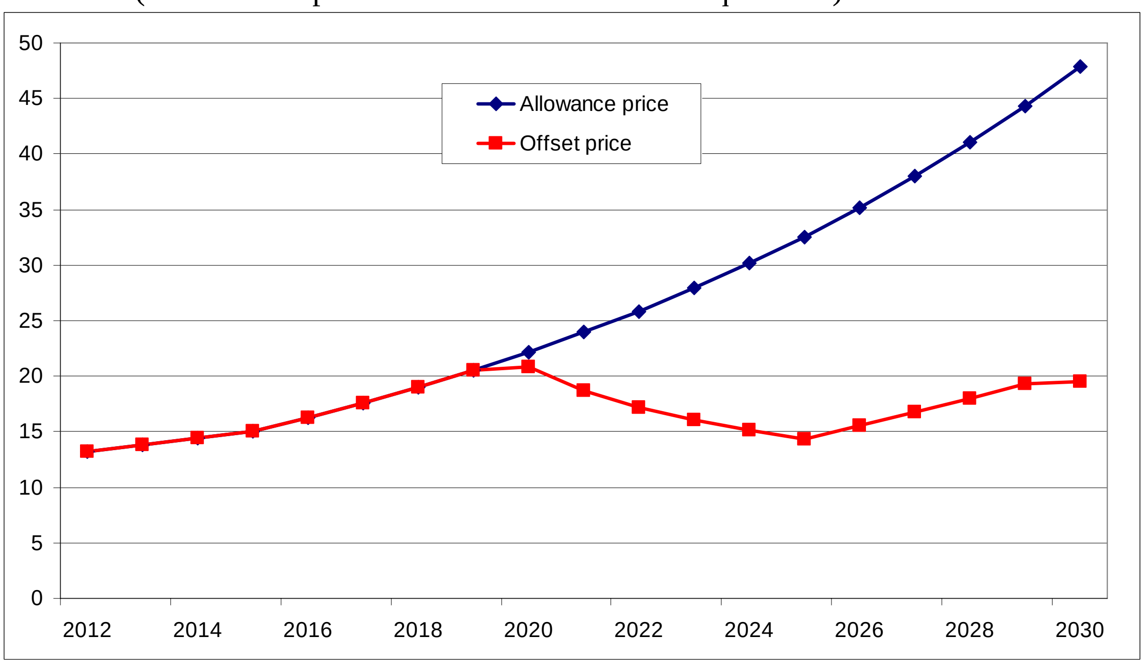
Allowance prices will be reflected in fossil fuel prices either directly, as in the transportation sector where petroleum suppliers will pass on allowance costs in the prices they charge, or indirectly, as opportunity costs of using fossil fuels subject to allowance requirements. Because allowances can be sold or held for future use, covered entities will have an incentive to reduce emissions even if they are allocated sufficient allowances to cover their annual emissions. Electricity prices will also adjust to account for allowance costs as well as the capital and operating cost implications of various compliance measures.

The ability to sell or hold allowances for the future is expected to promote a gradual escalation in allowance prices. Investors will tend to equate the current value of an allowance to the present discounted value of an allowance in the future. For this analysis, a real discount rate of 8 percent was assumed. As a result, allowance prices are assumed to escalate annually at a maximum rate of 8 percent. In reality, allowance prices would fluctuate around some long-term trend in reaction to imperfect information and unanticipated events, as do prices of other commodities.

Figure 12 plots the projected allowance and offset prices in the S. 280 Core case. The allowance and offset markets are projected to clear at the same price through 2019, a period in which the use of offsets remains below the 30-percent limit. Beginning in 2020, when the lower emissions cap reduces the allowable level of offsets, the 30-percent limit on offsets becomes a binding constraint. In this situation, competition to supply a fixed quantity of offsets will tend to drive down the offset price below the domestic allowance price.

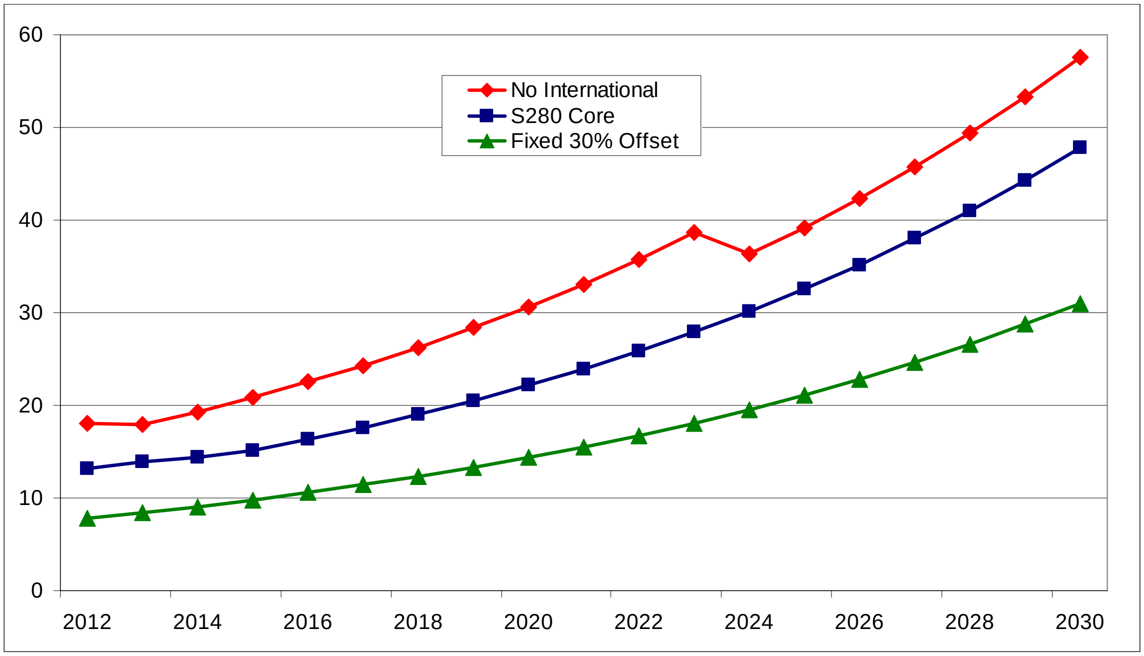
Allowance prices in the three main policy cases are compared in Figure 13. Allowance prices in the No International case are driven higher than in the S. 280 Core case by the need to meet emissions goals solely from domestic sources. Allowance prices moderate for a short period beginning in 2022 in the No International case, before resuming an 8-percent growth over the rest of projection. Lower allowance prices in the Fixed 30 Percent Offsets case reflect the optimistic supply assumptions regarding international offsets and a greater reliance on allowance banking than in the other cases to control compliance costs.

Figure 12. Allowance and Offset Prices in the S. 280 Core Case, 2012-2030
(2005 dollars per metric ton carbon dioxide equivalent)



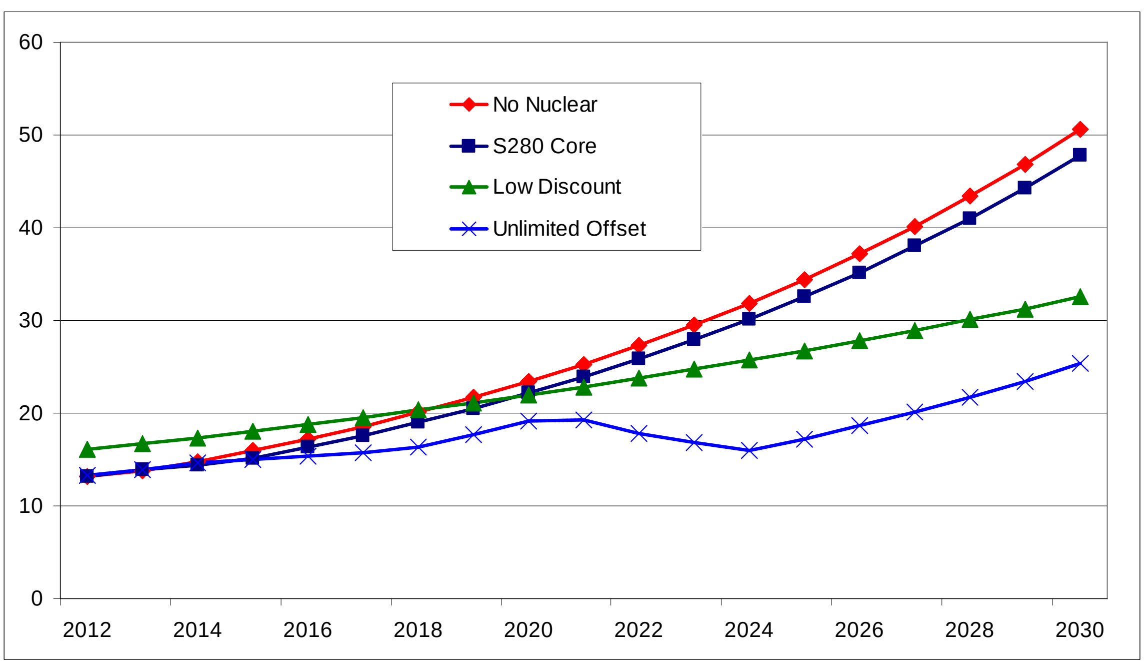
Source: National Energy Model System run S280.D060107A.

Figure 13. Allowance Prices in the Main Policy Cases, 2012-2030
(2005 dollars per metric ton carbon dioxide equivalent)



Sources: National Energy Model System runs S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

Figure 14. Allowance Prices in the Alternative Policy Cases, 2012-2030
(2005 dollars per metric ton carbon dioxide equivalent)



Source: Sources: National Energy Model System runs S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

The projected allowance prices vary in response to several other key assumptions. Figure 14 presents estimated allowances prices in the alternative policy cases. A key assumption that determines the maximum escalation rate of allowance prices is the assumed discount rate for allowance banking. The Low Discount rate case assumes a 4-percent discount rate, compared to the 8-percent rate in the S. 280 Core case.[17] A lower discount rate leads to higher allowance prices in the initial phase of the allowance program from 2012to 2020 than in the S. 280 Core case and lower prices after 2020. With higher allowance prices initially, covered entities have a greater incentive to over-comply and build up allowance deposits, then later make greater use of the banked allowance in the second phase of the program.

Allowance prices in the Unlimited Offset case are the lowest among the cases considered. Unlike in the other cases, relatively little allowance banking is generated in the Unlimited Offset case, at least in the initial compliance phase. While allowance prices are driven up to meet the more stringent cap in 2020, allowance prices drop after 2021 as relatively cheap international offsets supply much of the compliance requirements. The allowance prices begin growing after 2025 and a substantial allowance bank balance is built up through continued rapid growth in international offsets.

Somewhat higher allowance prices are projected in the No Nuclear case compared to the S. 280 Core case. Without additional nuclear generation as an option, complying with the emissions caps requires higher allowance prices to stimulate greater use of offsets and renewable sources and adoption of carbon capture and storage technologies. Carbon reductions by sector are discussed in more detail in the sections that follow.

Primary Energy Impacts

Energy consumers are expected to face higher effective costs of using energy as a result of the bill's allowance program. In the transportation sector, end-use consumers will face higher delivered prices of refined products, because refiners must obtain allowances for the GHG emissions associated with petroleum-based fuels sold for transportation. The cost of the allowances will be included in prices of the fuels. Covered entities in the commercial,[18] industrial, and electric power sectors will implicitly face a higher cost of consuming fossil energy, because they will be required to obtain allowances for the CO_2 emitted in direct fuel use. To the extent that electricity generators can pass through the opportunity cost of allowances and related incremental capital costs to their customers, electricity prices will increase in all consuming sectors. The increased energy costs, whether incorporated directly in delivered prices or reflected implicitly as the emissions related opportunity costs of consuming energy, will affect all energy sectors of the

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[17] In theory, a low discount rate approximating a risk-free return would be adequate for investors able to fully diversify allowance investments, assuming variation in allowance prices is uncorrelated with market returns. However, it is unclear whether GHG allowance markets will exhibit such behavior.

[18] While entities in the commercial and industrial sector with emissions greater than 10,000 metric tons of CO_2 are covered by the bill's allowance program, EIA assumed in the S. 280 Core case that no commercial entities are covered and that all industrial entities, with the exception of agriculture and construction, are covered.

economy. To simplify discussion of energy costs, the delivered prices of energy discussed in this chapter represent the effective delivered cost of using energy, including the direct and indirect costs of emissions allowances as applicable to a given sector.[19]

Table 13 presents a summary of the effects of S, 280 on energy prices and energy consumption across the main S. 280 policy cases. By 2030, the overall mix of fuels consumed in the S. 280 Core case differs significantly from the reference case (Figure 15). Consumption of coal, liquid fuels (mainly petroleum), and natural gas all decline relative to the reference case, while the use of nuclear power and renewable energy increase. Total energy consumption in 2030 in the S. 280 Core case is 3 percent lower than the reference case in 2020 and 6 percent lower in 2030, as conservation and improvements in energy efficiency are induced. Overall, projected liquid fuels and natural gas consumption in 2030 in the S. 280 Core case is higher than present levels, and the consumption of liquid fuels continues to grow throughout the projection.

Electricity Sector Emissions, Generation, and Prices

Implementing the proposed GHG emissions reduction program would have significant impacts on power sector CO_2 emissions, generation by fuel, generating technology selection, electricity sales, and electricity prices. The power sector shifts away from its long-term reliance on coal-fired generation, towards increasing reliance on nuclear, non-hydroelectric renewable, and natural gas generation. These changes lead to lower emissions but, the increased capital expenditures for these technologies, together with higher fossil fuel prices[20], result in higher electricity prices. The magnitude of the changes in the power sector are sensitive to the GHG allowance price, with higher prices leading to larger reduction in coal use and increased use of nuclear, renewable, and, to a lesser extent, fossil technologies with carbon capture and storage (CCS) equipment.

CO_2 Emissions

In the reference case, power sector CO_2 emissions are projected to increase 40 percent between 2005 and 2030 as the industry increases its use of fossil fuels, particularly coal (Figure 16). In the main S. 280 cases,[21] power sector CO_2 emissions are expected to be 17 percent to 32 percent below the reference case level in 2020 and 37 percent to 78 percent below the reference case level in 2030. In the S. 280 Core case, CO_2 emissions are forecast to decrease by 49 percent between 2005 and 2030, due to a greater reliance on nuclear and renewable generation and a less carbon-intensive fossil fuel mix.

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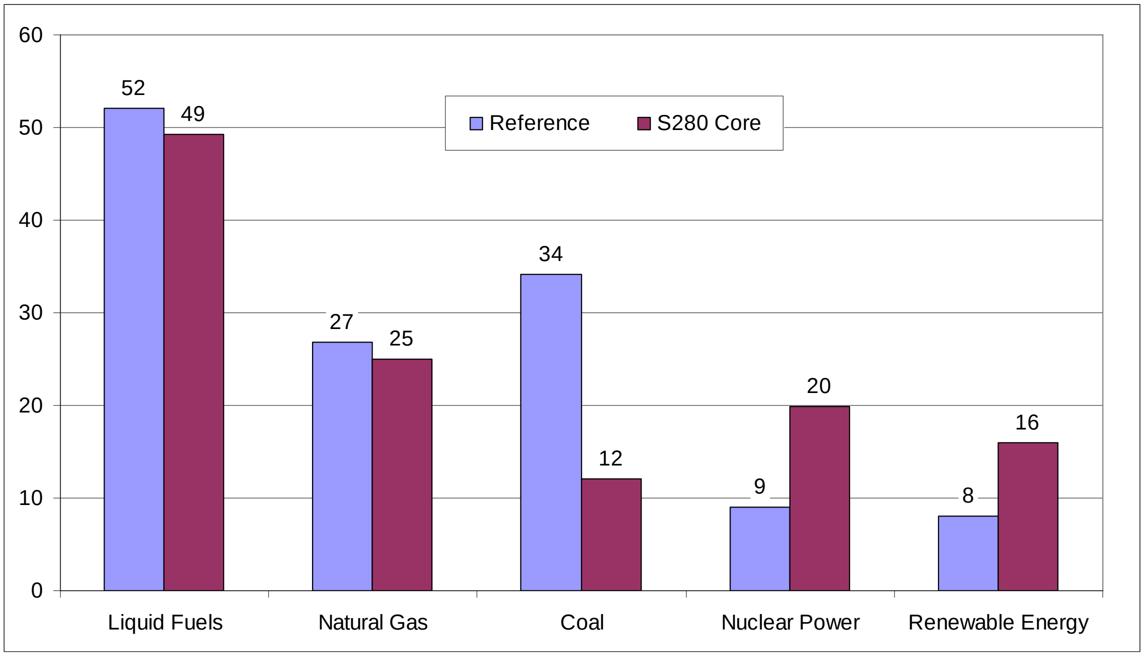
[19] The prices that do not include allowances costs are for fossil fuels used by non-covered entities in the residential, commercial, and industrial sectors, which do not need to submit allowances.
[20] Unless otherwise noted, the reported delivered fossil fuel prices include the costs of greenhouse gas allowances.
[21] The main S. 280 cases are the S. 280 Core case, the Fixed 30 Percent case, and the No International case.

Figure 15: Primary Energy Consumption by Fuel Source in the Reference and S. 280 Core Cases, 2030
(quadrillion Btu)



Sources: National Energy Model System runs S280BASE.D060107A and S280.D060107A.

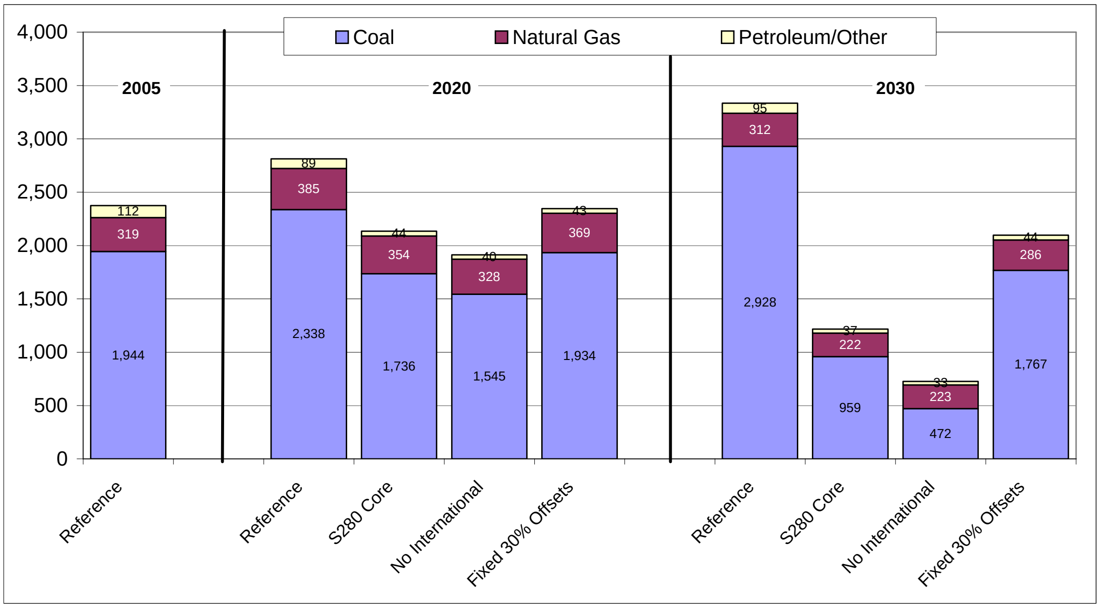
Generation by Fuel

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). Coal generation in 2030 in the main S. 280 cases is below current levels, ranging from 7 percent below in the Fixed 30 Percent Offsets case to 70 percent lower in the No International case. Coal generation in the S. 280 Core case is 26 percent below the reference case level in 2020 and 69 percent lower in 2030, a reduction of 2,295 billion kilowatthours. Relative to the 2005 level, coal generation in the S. 280 Core case is 48 percent lower in 2030. In the reference case, coal accounts for 58 percent of total generation in 2030, but its share falls to between 11 percent and 35 percent in the main S. 280 cases.

The higher coal costs in the main S. 280 cases greatly influence the relative economics of new generating plants. In the reference case, 163 gigawatts of new coal capacity are projected to be added between 2005 and 2030. In the main S. 280 cases, new coal additions are between 16 and 21 gigawatts through 2030 and most of these are already under construction. In the No International case, which has the highest allowance price, 11 gigawatts of coal with carbon capture and sequestration are projected to be built, but

Figure 16. Power Sector CO_2 Emissions

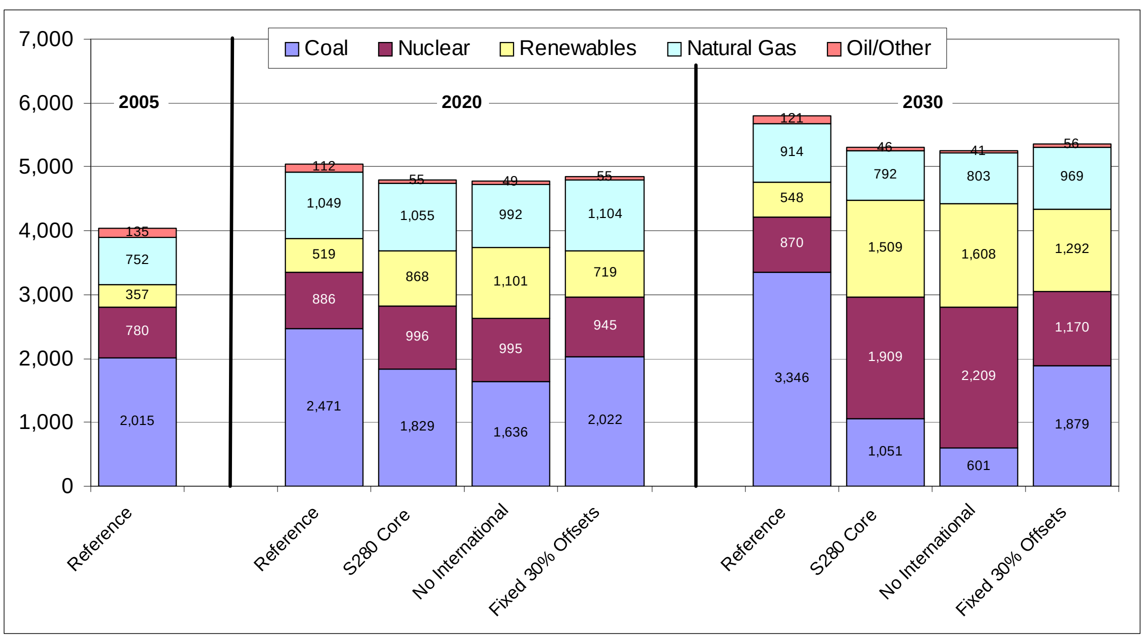
(million metric tons CO_2)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

Figure 17. Generation by Fuel

(billion kilowatthours)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

in the other cases, the allowance prices are not generally high enough to compensate for the additional capital and operating expenses of this technology, and it is less competitive against other low-carbon technologies, such as nuclear and various renewables. The higher coal costs also affect retirement decisions across the cases. In the Fixed 30 Percent Offsets case, most existing coal capacity remains on-line, although operating at lower levels, but in the S. 280 Core case nearly one-third of existing coal capacity is projected to be retired, and coal retirements in the No International case are more than one-half of existing capacity.

In contrast to the situation for coal generation, nuclear generation is projected to increase significantly in the main S. 280 cases. In the reference case, nuclear generation is projected to increase by 89 billion kilowatthours (11 percent) from 2005 to 2030, as existing plants are upgraded by 3 gigawatts and 9 gigawatts of new capacity, partially stimulated by incentives in the Energy Policy Act of 2005 (EPACT2005), are added. The 145 gigawatts of nuclear capacity added in the S. 280 Core case increases nuclear generation to 1,909 billion kilowatthours in 2030, 120 percent above the reference case level in 2030. Across the main S. 280 cases, nuclear generation in 2030 provides from 22 percent to 42 percent of total electricity generation, much greater than the 15 percent provided in the reference case.

Renewable generation is also expected to see significant growth in the main S. 280 cases. In the reference case, renewable generation is projected to increase by 191 billion kilowatthours (54 percent) between 2005 and 2030. Part of this growth is stimulated by tax incentives for certain renewable technologies in EPACT2005. The renewable share of total generation in 2030 is 9 percent in the reference case, and grows to between 24 percent and 31 percent across the main S. 280 cases. Growth occurs mainly in new biomass capacity and increased biomass co-firing in coal plants, as well as new wind capacity additions. In the reference case, biomass generation grows from 38 billion kilowatthours in 2005 to 111 billion kilowatthours in 2020 and 131 billion kilowatthours in 2030. In the S. 280 Core case, biomass generation in 2020 is over three times that of the reference case, and by 2030 is almost 8 times greater than the reference level. Following a similar pattern, wind generation grows from 15 billion kilowatthours in 2005 to 51 billion kilowatthours in 2020 and remains at that level through 2030 in the reference case. In the S. 280 Core case, wind generation in 2020 is more than double that of the reference case, and by 2030 is 2.5 times greater than the reference level.

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 the electricity market, falls even further in the main S. 280 cases. Natural gas impacts depend on the level of the carbon allowance fee. In the Fixed 30 Percent Offsets case, natural gas generation in 2030 is 6 percent above that of the reference case, as new natural-gas-fired combined–cycle plants replace some of the coal builds in the reference case. In the S. 280 Core and No International cases the allowance price is higher than in the Fixed 30 Percent Offsets case and even new natural-gas-fired generation is no longer attractive, and new builds are primarily nuclear or renewable technologies. In these two cases, natural gas generation in 2030 is 12 percent to 13 percent lower than the reference case level.

What if increased nuclear use for electricity generation is limited?

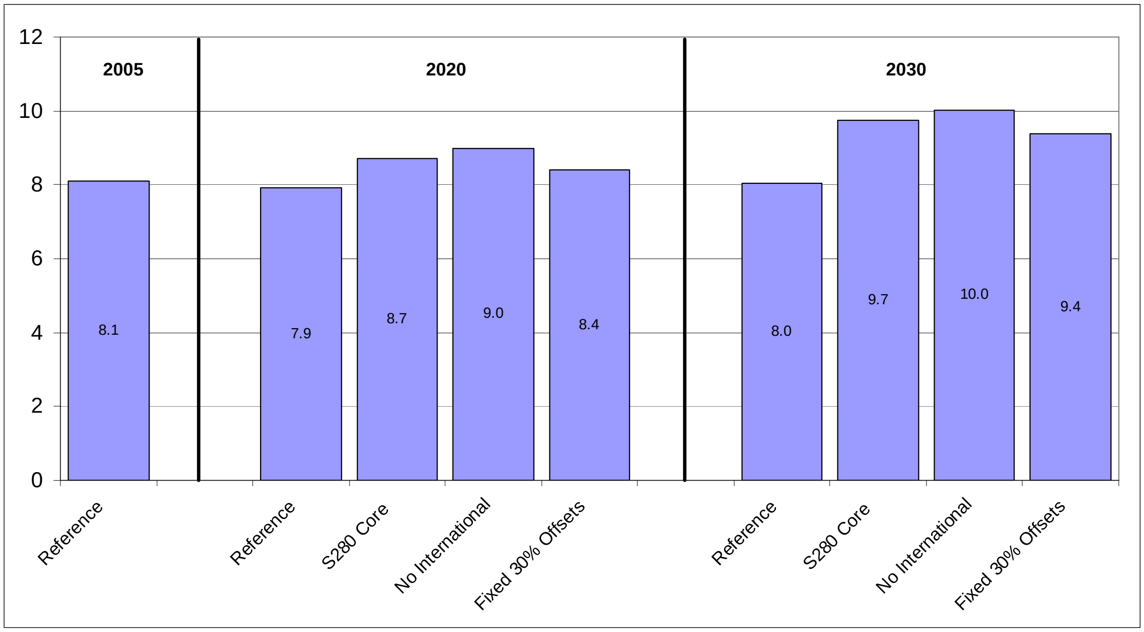
In the main S. 280 cases, new nuclear plants are a key technology the power sector is projected to rely on to reduce GHG emissions. However, many factors could limit their use. There are siting, environmental, political, and public opinion barriers to new nuclear capacity in the United States. While some companies are actively pursuing new nuclear plants at this time, especially due to the tax credits provided by EPACT2005, it has been nearly 30 years since the last new nuclear plant that was completed was ordered. There is also considerable uncertainty surrounding the costs and construction times for new units, as well as concerns over long-term nuclear waste storage.

A No Nuclear case was analyzed to examine the impacts of restricting new nuclear capacity growth (beyond that added in the reference case) under the S. 280 Core assumptions. The allowance price in the No Nuclear case is 6 percent higher than the S. 280 Core case in 2030 and power sector CO_2 emissions are about 3 percent higher. The power sector turns to increased investment in renewables (mainly biomass and wind) as well as significant investment in new coal plants with carbon capture and sequestration and natural gas. In the No Nuclear case, 70 gigawatts of new coal plants with carbon capture equipment are built. Total coal production in 2030 in the No Nuclear case is more than 100 million tons higher than in the S. 280 Core case. The higher allowance price and more costly capacity investment in this case lead to average delivered electricity prices in 2030 that are 8 percent higher than the S. 280 Core case. In turn, the higher prices have an impact on electricity sales, which are 2 percent lower in 2030 in the No Nuclear case than in the S. 280 Core case.

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 18). In the reference case, average delivered electricity prices fall from 8.1 cents per kilowatthour in 2005 to 7.7 cents per kilowatthour in 2015, then rise gradually as fuel prices rise, reaching 7.9 cents per kilowatthour in 2020 and 8.0 cents per kilowatthour in 2030. Electricity prices across the main S. 280 cases are 6 percent to 14 percent higher than the reference in 2020 and 16 percent to 25 percent higher in 2030 as the allowance prices rises throughout the forecast. Consumers' total electricity bills in 2020 in the S280 Core case are $18 billion (5 percent) higher than in the reference case, with a range of 2 percent higher in the Fixed 30 Percent Offsets case to 8 percent higher in the No International case. By 2030, the increase in consumer bills above the reference case ranges from $33 billion (8 percent) to $75 billion (18 percent).

Figure 18. Electricity Prices
(2005 cents per kilowatthour)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

The different regulatory regimes in the various regions of the country do affect the electricity prices in the main S. 280 cases, due to the initial allocation of allowances. It is assumed that 70 percent of allowances are allocated to the covered sectors in 2012, but this share is reduced over time to just 10 percent allocated in 2030. In regulated regions, it is assumed that the value of allowances will be passed on to consumers, so the price increases are not as great, relative to unregulated regions, where the value of allowances is assumed to accrue to stockholders. However, as more allowances are auctioned off throughout the forecast, the regulated regions see more significant price increases as well.

End-Use Energy Consumption

In response to higher delivered fossil fuel and electricity prices in the main S. 280 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.

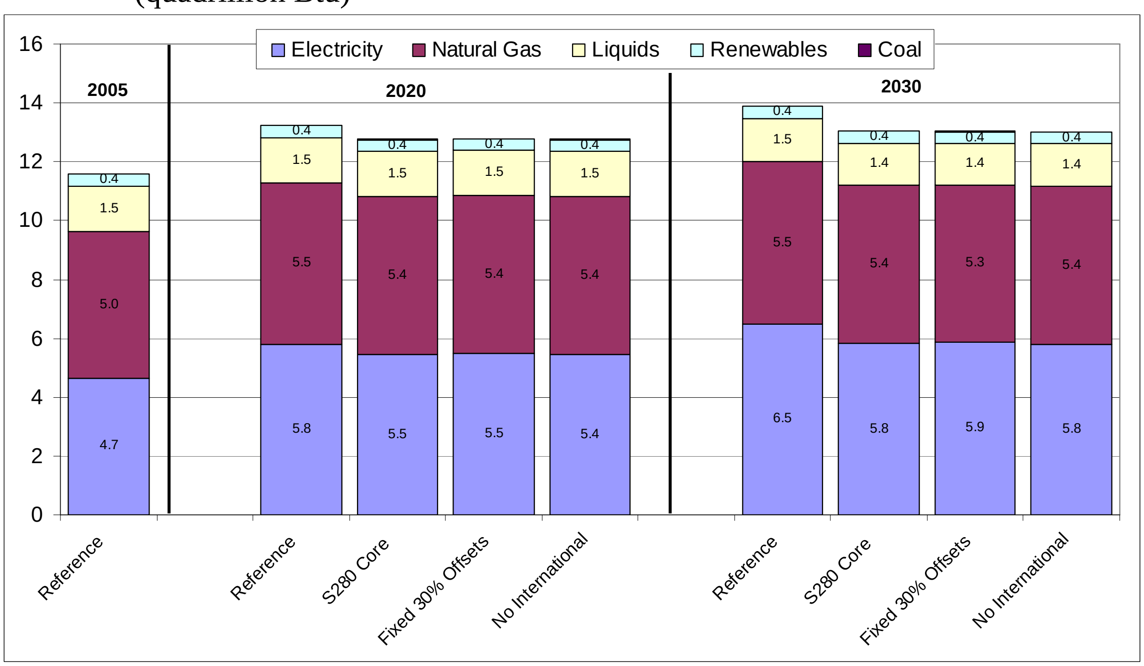
Residential and Commercial

Higher electricity prices under the proposed GHG cap and trade program, combined with greater adoption of more efficient technologies, reduce the use of electricity in the residential and commercial sectors. Residential electricity use is between 5 percent and 6 percent lower in 2020 and between 10 percent and 11 percent lower in 2030 in the main

S. 280 cases than in the reference case (Figure 19). Residential total delivered energy use[22] in the main S. 280 cases is lower by a smaller amount, 3 percent in 2020 and 6 percent in 2030. The changes in the commercial sector mirror those of the residential sector. When compared to the reference case, electricity use in the main S. 280 cases shows the largest change, ranging from 3 percent to 4 percent lower in 2020 and between 7 percent and 8 percent lower in 2030. Relative to the reference case, overall delivered energy consumption in the main S. 280 cases is 2 percent lower in 2020 and from 3 percent to 4 percent lower in 2030 (Figure 20). In both sectors, the consumption of fuels other than electricity change very little because emissions associated with their use are not covered by the program.

With the exception of electricity, the price of fuels to residential and commercial consumers falls in the main S. 280 cases, relative to the reference case because these consumers do not have to submit allowances for their emissions. In the No International case, electricity prices in the residential sector are 12 percent higher in 2020 and 22 percent higher in 2030, relative to the reference case. Natural gas prices, on the other hand, are 2 percent lower in 2020 and 3 percent lower in 2030, when compared to the reference case. In 2020, overall residential energy expenditures range from 1 percent ($18 per household) lower in the Fixed 30 Percent Offsets case to 2 percent ($36 per household) higher in the No International case, relative to the reference case. However,

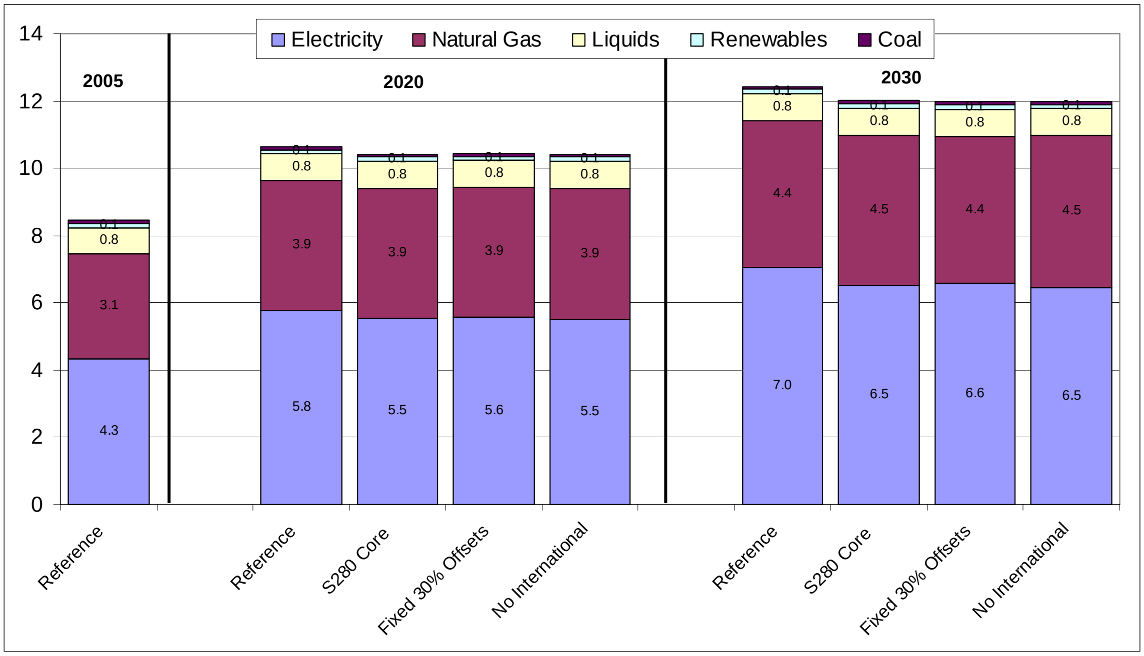
Figure 19. Delivered Residential Energy Consumption
(quadrillion Btu)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, S280NOINTL.D061507A, and S280HT.D060207A.

[22] Delivered energy does not include losses associated with the conversion and distribution of electricity.

Figure 20. Commercial Energy Consumption
(quadrillion Btu)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, S280NOINTL.D061507A, and S280HT.D060207A.

by 2030 the rising allowance prices in the main S. 280 cases leads to higher residential energy costs in all of the cases. In 2030, residential energy expenditures in the main S. 280 cases, range from 1 percent ($26 per household) higher in the Fixed 30 Percent Offsets case to 4 percent ($78 per household) higher in the No International case.

The price changes in the main S. 280 cases in the commercial sector are similar to those found in the residential sector, but the range is wider. Relative to the reference case, electricity prices to the commercial sector in the main S. 280 cases are projected to be between 7 percent and 15 percent higher in 2020 and between 17 percent and 25 percent higher in 2030. Natural gas prices to the commercial sector, on the other hand, are between 1 percent and 3 percent lower in 2020 and between 1 percent and 4 percent lower in 2030 in the main S. 280 cases, when compared to the reference case. The change in relative prices brings about an increase in investment in natural-gas-fired combined heat and power plants (CHP) in the commercial sector. Natural-gas-fired CHP capacity is between 3 percent and 16 percent higher in 2020 and between 31 percent and 267 percent higher in 2030, as relative prices for on-site generation of electricity become increasingly favorable in the main S. 280 cases.[23]

[23] Very few buildings have electricity or thermal requirements large enough to support CHP systems that would trigger the 10,000 metric ton emission size cutoff for coverage.

Residential energy savings, rebates, and energy efficiency

An integral element of S. 280 is the creation of the Climate Change Credit Corporation (CCCC), which is funded by the proceeds of buying, selling, and trading GHG allowances. One of the many roles of the CCCC is to establish a funding stream for technology deployment and rebates to the purchasers of energy-efficient appliances. In order to represent the potential effects of this provision, in the S. 280 cases, it is assumed that more efficient technologies are available to consumers as a result of the technology deployment initiative and that the incremental cost of the technologies is reduced by one-half due to the rebate initiative.[1] This assumption implies that a consumer purchasing an efficient heat pump with an incremental cost of $1000 over the base unit would only pay an additional $500. The rebates, combined with higher electricity prices, have a noticeable impact on energy efficiency for some appliances. The stock of residential air-source heat pumps is 6 percent more efficient in the S. 280 Core case in 2030 and 12 percent more efficient in the S 280 High Technology case in 2030.

The increase in efficiency does come at a cost to the CCCC. Over the 2012 to 2030 time period, the CCCC pays out $80 billion (in 2005 dollars) in the S. 280 Core case in order to fund the rebates to residential consumers which helps achieve the stated goal of reducing energy costs borne by consumers as the result of the GHG reduction scheme. Of the $80 billion distributed to residential consumers over the 2012-2030 time period, $45 billion is claimed by consumers who would have purchased more efficient technologies without the rebate, meaning that over half (56 percent) of the consumers are “free riders.” Consumers, for their part, spend an additional $32 billion for the more efficient appliances, but save $121 billion in fuel costs through 2030.

[1] For detailed information on the technology profiles, see: Energy Information Administration, Technology Forecast Updates – Residential and Commercial Buildings Technologies – Advanced Adoption Case (Navigant Consulting, September 2004 and January 2006).

Which buildings will be covered?

The EIA commercial buildings survey data indicate that less than 0.01 percent of commercial buildings used enough fuel, excluding electricity, in 2003 to meet the emissions coverage threshold of 10,000 metric tons of CO_2 emissions per year in S. 280.[1] Large office buildings that generate electricity for their own use and large hospitals were most likely to meet the emissions threshold at the building level. While one surveyed shopping mall consumed enough natural gas in 2003 to produce over 2,500 metric tons of CO_2 emissions, the average for enclosed malls was 45 metric tons of CO_2 emissions based on natural gas and fuel oil use. Every surveyed building that met the threshold in 2003 is part of a multi-building facility and/or generates electricity within the building. While a multi-building facility may exceed the threshold, there are no comprehensive data sources that provide commercial energy consumption or emissions at the facility level to make that determination. Given that the vast majority of commercial buildings would not meet the emissions threshold, it is assumed that the commercial sector is not covered by the bill in the main S. 280 cases.

The Commercial Covered sensitivity case was prepared to illustrate the impact of removing this assumption and treating the entire commercial sector as covered. Directly limiting commercial sector emissions in the Commercial Covered case causes commercial sector delivered energy use to be one percent lower in 2020 and 3 percent lower in 2030 than in the S. 280 Core case. Annual energy expenditures by commercial consumers are 2 percent higher ($4 billion) in 2020 and 4 percent higher ($10 billion) in 2030 in the Commercial Covered case relative to the S. 280 Core case. Although treating the commercial sector as covered results in higher energy expenditures, mandatory commercial participation in the allowance system has little impact on allowance prices, with less than one dollar difference between the two cases in 2020. Overall CO_2 emissions also change very little; by 2030 emissions are 0.9 percent higher in the Commercial Covered case than in the S. 280 Core case.

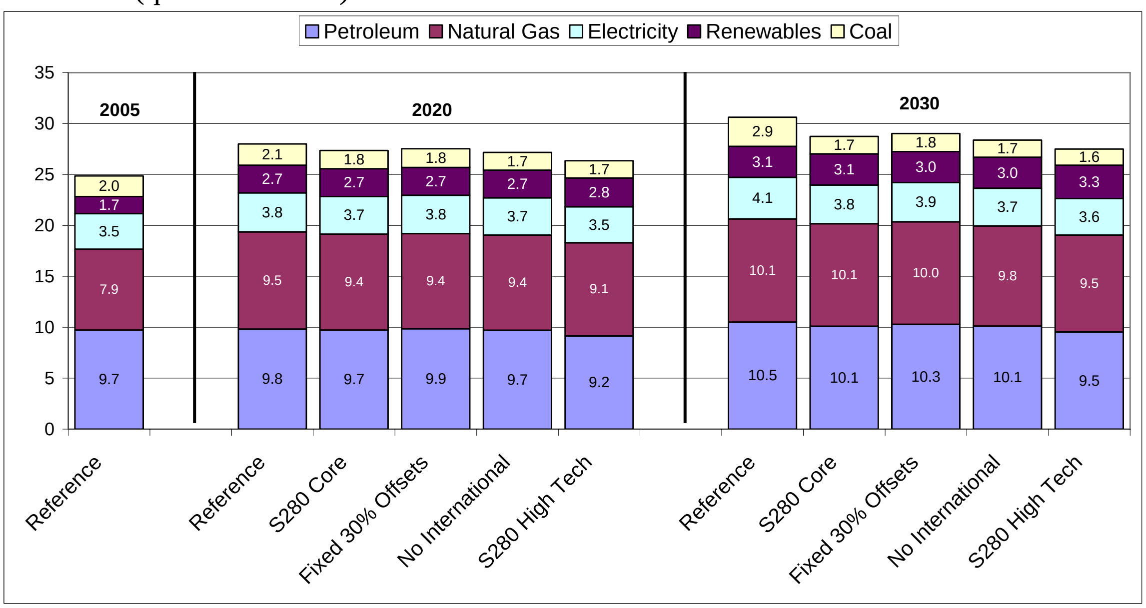
[1]Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey, Public Use Files (December 2006), www.eia.doe.gov/emeu/cbecs/cbecs2003/public_use_2003/cbecs_pudata2003.html.

The use of renewable energy sources in the end-use sectors is expected to increase in the main S. 280 cases relative to the reference case. In the residential sector, the market share of ground-source (geothermal) heat pumps more than quadruples by 2030, reaching 3 percent of the residential heating market in the S. 280 Core case, much larger than the 0.6 percent share reached in the reference case. Commercial sector photovoltaic (PV) system capacity is 211 percent to 276 percent higher by 2030 in the main S. 280 cases while residential rooftop PV units are 42 percent to 94 percent higher, further reducing the need for grid-supplied electricity in both sectors.

Industrial

As in the buildings sector, higher energy prices caused by the GHG reduction program lead industrial consumers to reduce their energy use, particularly their use of coal. In the main S. 280 cases, total industrial sector energy consumption in 2020 is projected to be 0.5 quadrillion to 0.8 quadrillion Btu (2 percent to 3 percent) lower than in the reference case. By 2030 the difference grows to 1.6 quadrillion to 2.2 quadrillion Btu (5 percent to 7 percent) lower.[24] The vast majority of this difference is seen in industrial coal consumption which is 11 percent to 16 percent lower in 2020 and 38 percent to 41 percent lower in 2030 in the main S. 280 cases than in the reference case (Figure 21). Purchased electricity is also noticeably lower in the main S. 280 cases because industrial consumers increase their use of self-generation. The increased use of natural gas for self-generation nearly offsets the reduction in natural gas consumption for other uses. As a result, there is little change in total industrial sector natural gas use in the main S. 280 cases.

Figure 21. Industrial Energy Consumption
(quadrillion Btu)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, S280NOINTL.D061507A, and S280HT.D060207A.

The change in energy consumption varies noticeably by case across industries in the industrial sector. Coal use declines sharply in refining due to the elimination of coal-to-liquids in the GHG constrained cases. By contrast, coal use is projected to grow rapidly in the reference case in the later years of the projection when coal-to-liquids plants are introduced. In the reference case, 434 thousand barrels per day of liquids are produced

[24] For this analysis, the agriculture and constructions portions of the industrial sector are not "covered" sectors within the meaning of S. 280.

from coal in 2030. In the main S. 280 cases, none is produced. Since agriculture and construction are not required to purchase GHG permits, they incur lower energy prices and increase energy consumption slightly in the S. 280 cases.

Projected energy prices increase primarily due to the GHG fee that results from the emissions cap and trade program. The price increases are generally in line with the carbon content of various fuels. Consequently, coal prices increase more rapidly than do other industrial energy prices. In 2020, industrial coal prices are 59 percent to 126 percent higher in the main S. 280 cases than in the reference case. By 2030, industrial coal price increases ranged from 119 percent to 217 percent higher in the main S. 280 cases than in the reference case. In comparison, in 2020 industrial natural gas prices are 11 percent to 23 percent higher than the reference case. By 2030, industrial natural prices ranged between 24 percent and 41 percent higher than in the reference case.

Industrial sector energy expenditures increase sharply as a result of the higher energy prices. In the reference case, industrial sector energy expenditures in 2020 are projected to be $195 billion (2005 dollars). In the main S. 280 cases, energy expenditures increase by $13 billion to $26 billion (7 percent to 14 percent). In 2030, industrial energy expenditures in the main S. 280 cases increase by $32 billion to $50 billion (14 percent to 22 percent) compared to the reference case.

Industrial combustion-related CO_2 emissions in the reference case grow from 1,682 million metric tons in 2005 to 1,810 million metric tons in 2020 and 2,021 million metric tons in 2030. In the main S. 280 cases, industrial sector CO_2 emissions are 133 million metric tons to 263 million metric tons lower (7 percent to 15 percent) in 2020 and 390 million metric tons to 744 million metric tons lower (19 percent to 37 percent) in 2030.

Industrial output is reduced significantly across all affected sectors (agriculture and construction are not covered sectors for this analysis). The coal mining industry and energy-intensive manufacturing industries are the most adversely affected subsectors (Figure 22):

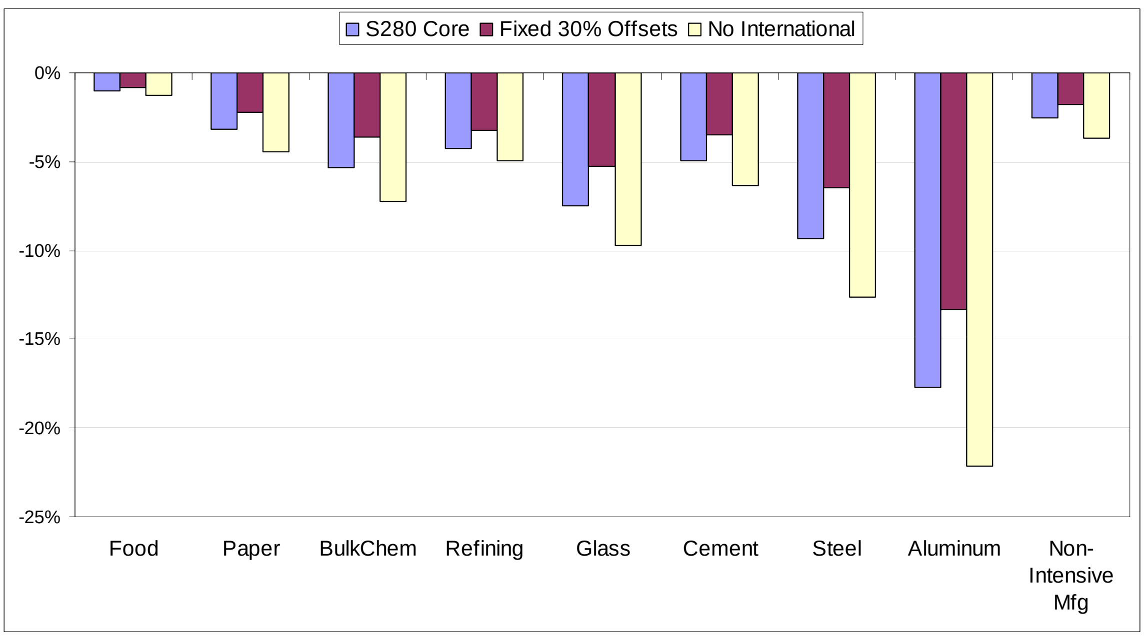
- In 2020, total industrial output is $49 billion to $137 billion (2000 dollars)[25] (1 percent to 2 percent) lower in the main S. 280 cases than in the reference case. In 2030, industrial output is $161 billion to $321 billion lower (2 percent to 3 percent) than in the reference case.
- The coal mining industry experiences the most severe fall in output, ranging from 17 percent to 32 percent lower than the reference case in 2020 and from 40 percent to 74 percent lower in 2030.
- Among the manufacturing industries in 2020, the aluminum industry's output has the largest reductions, 5 percent to 12 percent in 2020 and 13 percent to 22 percent in 2030, compared to the reference case.
- Output of the steel industry is 3 percent to 7 percent lower than in the reference case in 2020 and 6 to 13 percent lower in 2030.

[25] Note that unlike other dollar-denominated values in this report, industrial output is defined as value of shipments in 2000 dollars.

- Glass, cement, and bulk chemicals experience output reductions of between 4 percent and 10 percent in the main S. 280 cases in 2030.

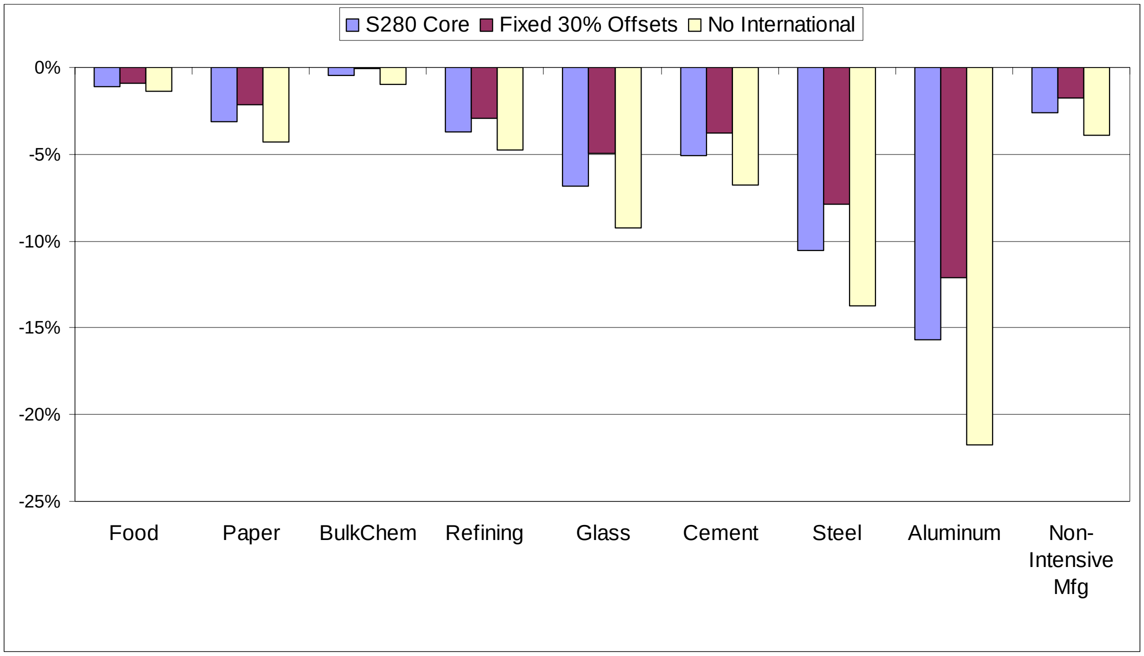
Higher energy prices and reduced output have impacts on industrial employment (Figure 23). The employment impacts parallel the output impacts discussed above. The coal industry experiences the sharpest fall in employment followed by energy-intensive manufacturing industries. In the main S. 280 cases, total industrial employment is 105 thousand to 293 thousand lower (1 percent) in 2020 and 250 thousand to 529 thousand lower (1 percent to 2 percent) in 2030 than in the reference case (Figure 23). While the largest percentage fall among the manufacturing sectors occurs in the energy-intensive industries (cement, glass, steel, and aluminum), the largest reductions in the number of employees are in the transportation equipment (37 thousand to 70 thousand), machinery (29 thousand to 69 thousand), and fabricated metals (21 thousand to 56 thousand) industries.

Figure 22. Reduction in Manufacturing Output, 2030
(percent change from reference case)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A and S280NOINTL.D061507A.

Figure 23: Reduction in Manufacturing Employment, 2030
(percent change from reference case)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A and S280NOINTL.D061507A.

Potential impacts on carbon-intensive industries: cement and lime production

A program to reduce GHG emissions would have the largest impacts on industries whose production processes are most carbon intensive—industries like the cement industry. The U.S. cement industry produced a record 99.3 million metric tons of cement and imported a record 30.4 million metric tons in 2005.[26] The share of U.S. cement consumption met by imports grew to 23 percent in 2005, continuing a trend of increasing imports that has been apparent for at least 10 years. Canada accounted for 16 percent of U.S. cement imports in 2005, while China accounted for 14 percent.

The cement industry is one of the largest producers of process-related CO_2 emissions due to the baking of limestone to produce clinker, an intermediate product in cement production. Production of 1 metric ton of cement produces approximately 0.5 metric tons of CO_2.[27] In 2005, the U.S. cement industry produced an estimated 46 million metric

[26] The cement data used in this section are from Hendrik G. van Oss, "Cement," *2005 Minerals Yearbook*, February 2007, U.S. Geological Survey, minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmyb05.pdf.
[27] The calculation is described in Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0638(2004)(Washington, DC, December 2006), pp. 35-38,,http://www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2004).pdf. For additional information about the cement production process and CO_2 emissions, see Hendrik G. van Oss and Amy C.

tons of CO_2, 62 percent of total industrial process emissions of CO_2.[28] In addition, the cement industry's combustion-related CO_2 emissions are estimated to be 40 million metric tons in 2005, making the total CO_2 emissions of the industry nearly 90 million metric tons.

If the U.S. cement industry is required to reduce CO_2 emissions but other countries are not, it is probable that the upward trend in cement imports will rise faster. There are few options for the cement industry to reduce process-related emissions. One option, however, is to increase the amount of blended cement production. For example, clinker can be combined with fly ash to produce blended cements. This option is already used extensively for some purposes, e.g., highway construction in California.[29]

In the main S. 280 cases, U.S. clinker production in 2020 is projected to fall 4 percent to 7 percent, relative to the base case, due to a combination of increased production of blended cements and increased imports of finished cement. Reference case process-related CO_2 emissions and combustion-related emissions[30] are projected to be 52 million metric tons and 42 million metric tons, respectively, in 2020. In the main S. 280 cases, in 2020, process-related CO_2 emissions are reduced by 2 million metric tons to 4 million metric tons, and combustion-related CO_2 emissions are reduced by 3 million metric tons to 6 million metric tons (Figure 24). In 2030, reference case process-related CO_2 emissions are projected to be 57 million metric tons and combustion-related CO_2 emissions are projected to be 44 million metric tons. In the main S. 280 cases, U.S. clinker production in 2030 is 10 percent to 13 percent lower than in the reference case while process-related CO_2 emissions are 5 million metric tons to 7 million metric tons lower (10 percent to 13 percent) and combustion-related CO_2 emissions are 7 to 13 million metric tons lower (17 percent to 30 percent). The fall in cement industry CO_2 emissions is due to the combined effects of increased blending and imports, increased energy efficiency, and reduced industry output.

Padovani, "Cement Manufacture and the Environment," *Journal of Industrial Ecology*, Volume 6, Number 1 (2002), pp. 89-105.

[28] Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2005,* DOE/EIA-0573(2005)(Washington, DC, November 2006), p. 22, www.eia.doe.gov/oiaf/1605/ggrpt/pdf/057305.pdf.

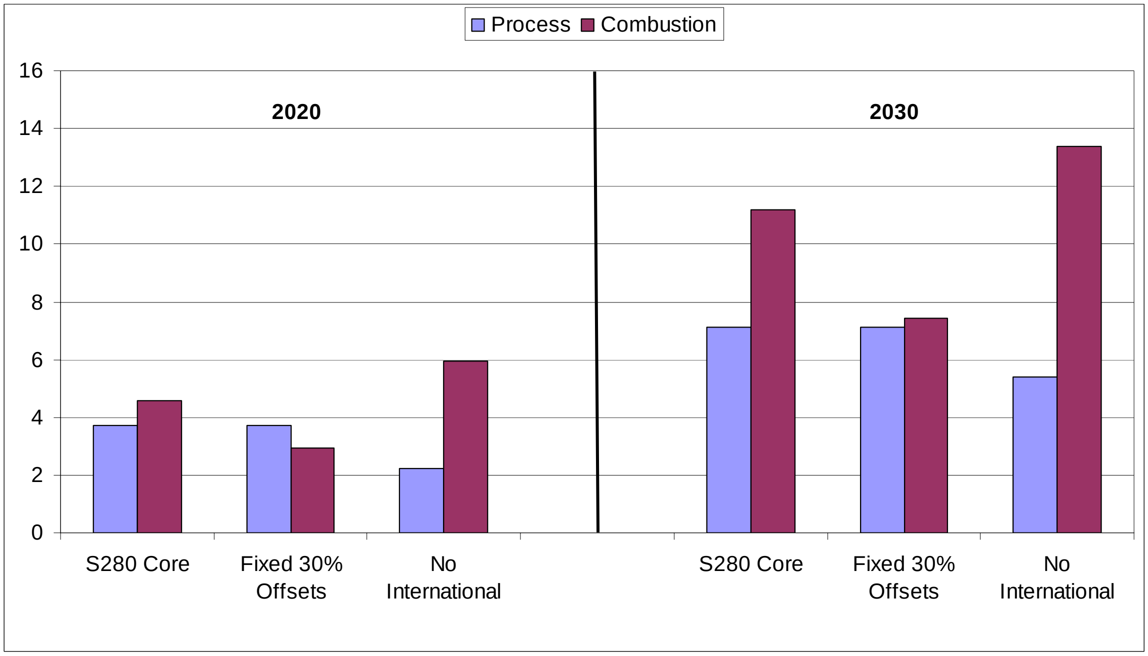
[29] California Department of Transportation, *Climate Action Program at Caltrans 2006*, December 2006. The typical concrete mix is about 25 percent fly ash …" , p. 14, www.dot.ca.gov/docs/ClimateReport.pdf.

[30] The figures cited on combustion-related CO_2 emissions include indirect emissions from electricity generation. Under S. 280, the allowance requirement for the cement industry would be based on direct emissions only.

[31] Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005)(Washington, DC, November 2006), p. 28, www.eia.doe.gov/oiaf/1605/ggrpt/pdf/057305.pdf.

[32] Consumption lime by consuming industry is given in M. Michael Miller, "Lime," *2005 Minerals Yearbook*, June 2006, U.S. Geological Survey, www.minerals.usgs.gov/minerals/pubs/commodity/lime/lime_myb05.pdf.

Figure 24: Reduction in Cement Industry CO_2 Emissions, 2030
(percent change from reference case)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A and S280NOINTL.D061507A.

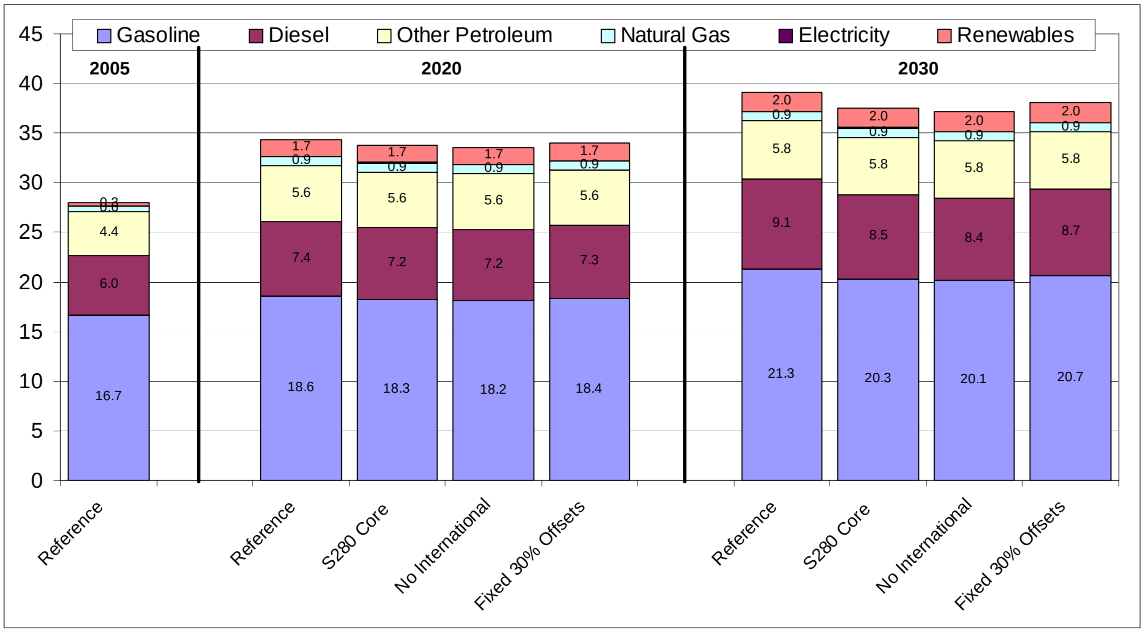
The lime production industry is the second largest producer of process-related CO_2 emissions. In a process similar to cement clinker production, limestone is heated in a kiln to drive off the carbon to create lime. While there are energy efficiency improvements that could be undertaken in the lime production process, lime production inherently produces carbon dioxide. In 2005, the lime production industry's process-related CO_2 emissions were 15.7 million metric tons of CO_2, second only to the cement industry.[31] Lime is used in many manufacturing industries as well as in construction and a variety of environmental-related uses, such as flue-gas desulfurization.[32] While the lime manufacturing industry does not presently encounter appreciable import competition, the advent of a GHG fees will have an adverse impact on the manufacturing industries that use lime in their production processes. As a result, process-related CO_2 emissions from lime manufacturing in 2030 are projected to fall by 1 million metric tons (4 percent) to 21.9 million metric tons in the S. 280 Core case.

Transportation

Similar to the other demand sectors, the transportation sector also reduces energy consumption under the GHG cap and trade proposal (Figure 25). Relative to the reference case, reductions in transportation energy demand in the main S. 280 cases are projected to range between 1 percent and 2 percent in 2020 and 3 percent and 5 percent in 2030, with the greatest reductions occurring in the No International case. Because the

GHG cap and trade proposal does not directly impact the transportation sector, reductions in energy demand are driven by consumers' response to higher fuel prices, reductions in industrial output, and reductions in coal shipments.

Figure 25: Transportation Sector Energy Consumption by Fuel Type
(quadrillion btu)



Sources: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280STRAW.D060207A, and S280NOINTL.D061507A.

The higher fuel prices projected in the main S. 280 cases stimulate consumer demand for more efficient vehicles. However, the fuel price increases are not large enough to create dramatic shifts in consumer behavior. Relative to the reference case, the price of motor gasoline in the main S. 280 cases increases from 6 percent to 12 percent ($0.11 and $0.23 per gallon, respectively) in 2020 and from 11 percent to 19 percent ($0.25 and $0.41 per gallon, respectively) in 2030. In 2030, the consumer response to higher fuel prices drives a market shift in new vehicle sales from light trucks to cars in the S. 280 cases. In the reference case, 2030 car sales account for 44 percent of new light-duty vehicle sales. In the main S.280 cases, the percent of new vehicles sold in 2030 that are cars increases to between 47 percent and 49 percent. In addition to the shift in vehicle sales, increased sales of hybrid and diesel vehicles, as well as other advanced technologies, results in an overall improvement in new light-duty vehicle fuel economy ranging between 2 percent (0.6 miles per gallon) to 3 percent (1.0 miles per gallon) by 2030.

Lower transportation energy consumption also results from reduced travel in response to higher fuel prices. In 2020, the reduction in light-duty vehicle miles traveled from the reference case ranges between 29 billion miles (1 percent) to 54 billion miles (2 percent) in the main S. 280 cases. By 2030, the reduction in light duty vehicle travel increases to between 72 billion miles (2 percent) and 114 billion miles (3 percent). Reductions in freight truck travel are very similar, on a percentage basis, to those projected for light duty vehicles and are due to lower industrial output.

Though energy use by railroads accounts for only a small part of overall transportation energy use, projected growth in railroad shipments is expected to be significantly impacted by large reductions in the projected growth of coal demand in the main S. 280 cases. Relative to the reference case, 2020 rail ton-miles traveled in the main S. 280 cases are between 154 billion ton-miles (8 percent) and 293 billion ton-miles (15 percent) lower. With a growing reduction over time in coal use relative to the reference case, reductions in rail ton-miles in the main S. 280 cases in 2030 range from 470 billion ton-miles (19 percent) to 884 billion ton-miles (36 percent).

Fuel Supply

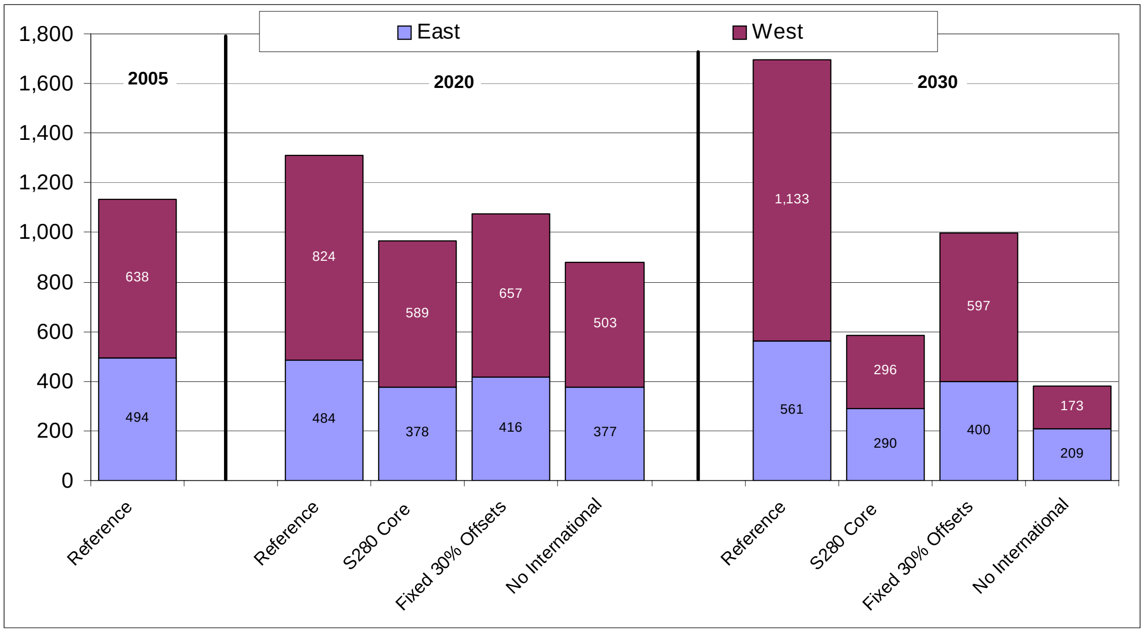
Coal

Relative to the reference case, total U.S. coal production in 2020 is projected to be between 18 percent (235 million tons) and 33 percent (429 million tons) lower in the main S. 280 cases (Figure 26). By 2030, the gap between the reference and the main S. 280 cases becomes even larger, with total coal production in these cases projected to be between 41 percent (697 million tons) and 78 percent (1,313 million tons) less than in the reference case. Moreover, in 2030, total coal production in these cases is projected to be between 12 percent (135 million tons) and 66 percent (750 million tons) less than production in 2005.

The caps on greenhouse gas emissions have a disproportionately larger impact on coal production west of the Mississippi River. This is primarily because this region supplies most of the growing demand for coal projected in the reference case for the electricity sector and for coal-to-liquids (CTL). In addition, eastern coal mines are the primary source of supply for the industrial sectors and for export, and the demand for coal in these markets is less affected by constraints on greenhouse gas emissions than is the demand for coal in the electric power sector and for the production of coal-based synthetic liquids. None of the 15 coal-to-liquids plants built in the reference case are projected to come on line in the main S. 280 cases. In the reference case, coal consumption at CTL plants reaches 109 million tons in 2030.

Reduced demand for coal in the main S. 280 cases is primarily attributable to the allowance cost, which effectively raises the delivered price of coal. In the electricity sector, the delivered price of coal in 2030 in the main S. 280 cases is between 162 percent ($2.75 per million Btu) and 291 percent ($4.93 per million Btu) higher than the price of $1.70 per million Btu projected in the reference case.

Figure 26. Coal Production by Region
(million tons)



Sources: National Energy Modeling System runs S280BASE.D060107A; S280.D060107A; S280STRAW.D060207A; and S280NOINTL.D061507A.

Natural Gas

In contrast to coal, the impact on natural gas markets is more modest. S. 280 results in higher delivered natural gas prices to the industrial and electric power sectors, because of the costs associated with GHG emissions allowances. The average delivered end-use natural gas price in 2030 is projected to be between 11 and 18 percent higher than in the reference case in the main S. 280 cases. In contrast, 2030 wellhead natural gas prices, which do not include the cost of allowances, are projected to be between 8 to 34 cents per thousand cubic feet lower (1 to 6 percent) in the S. 280 cases, because the higher delivered cost of natural gas reduces gas demand, which in turn, reduces wellhead natural gas prices.

Delivered natural gas prices to residential and commercial consumers are lower in the S. 280 cases, because these sectors are not covered by the bill's allowance provisions. However, these lower natural gas prices do not result in higher residential natural gas consumption because S. 280 allowance auction revenues are assumed to be deployed by the CCCC to reduce the cost of energy-efficient appliances by providing rebates for such appliances. These rebates significantly reduce the cost of energy-efficient appliances, thereby causing a higher penetration rate of these appliances in the S.280 policy cases relative to the reference case. Consequently, the CCCC rebate program is projected to reduce residential natural gas consumption, even though the S. 280 policy results in slightly lower residential natural gas prices, which would otherwise encourage a higher consumption of natural gas.

Unlike the residential and commercial sectors, the industrial and electric power sectors face higher delivered natural gas prices. The impact on natural gas consumption in these sectors varies considerably, based on whether there are cheaper alternative fuel sources which can be deployed and/or the degree to which energy efficiency improvements are employed to reduce the overall cost of using fossil fuels. Although the delivered cost of natural gas is projected to increase substantially in the main S. 280 cases, there are few lower cost substitutes for natural gas in the industrial sector. Much of the natural gas consumed in the industrial sector is used for chemical and refining feedstocks and for direct-heat applications where the avoidance of product contamination is critical.
In contrast, natural gas consumption in the electric power sector is projected to be between 0.3 to 1.0 trillion cubic feet (4 to 15 percent) lower in the in the main S. 280 cases in 2020, than in the reference case. By 2030 this difference grows to between 0.5 and 1.7 trillion cubic feet (8 and 29 percent).

Overall natural gas consumption in the main S. 280 cases is between 0.6 and 1.3 trillion cubic feet (2 and 5 percent) lower in 2020, than in the reference case. By 2030 this difference grows to between 0.7 and 2.0 trillion cubic feet (3 and 8 percent).

Liquid Fuels and Other Petroleum Products

Similar to the situation for natural gas, the consumption of liquid fuels and other petroleum products is somewhat lower in the main S. 280 cases than it is in the reference case, as consumers respond to the higher delivered product prices that result from cost of allowances under S. 280. Liquid fuels consumption in 2020 ranges from 0.5 to 0.8 million barrels per day (2 to 3 percent) lower in the main S. 280 cases. By 2030 the difference grows to between 1.0 and 1.6 million barrels per day (4 and 6 percent). However, domestic crude oil production is relatively unaffected because the world crude oil prices are assumed to be unchanged. The reduction in petroleum supply comes from reductions in imports and reductions in domestic CTL production. In the main S. 280 cases, CTL production is no longer economical, removing 70 thousand barrels per day, or 1 percent, of distillate production relative to the reference case in 2020. By 2030, the change is 0.4 million barrels per day, or 7 percent. The cost of allowances increases the cost of using coal, making CTL production much less competitive with imported and domestic oil.

Economic Impacts

Implementing a GHG emissions cap and trade program to reduce GHG emissions will have impacts on the economy through multiple 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 will generate revenues for the government, which, through various government programs, will be spent by businesses and consumers to reduce their emissions or help ameliorate the impacts associated with higher energy prices.

The variation in aggregate GDP impacts among the main S. 280 cases can be traced primarily to the different energy price impacts in each case. The changes in energy prices are the dominate factor affecting the economy under S. 280. For example, in the S. 280 Core case, higher energy prices between 2010 and 2030 contribute to cumulative GDP losses of $577 billion (discounted present value)[33]. Revenue recycling alone increases cumulative GDP by $126 billion, and buying international offsets alone causes a cumulative GDP loss of $83 billion, for an aggregate net cumulative GDP loss of $533 billion, or 0.22 percent.

Permit Revenues

Projected revenues generated from the allowance program are a function of the market price of the allowances and the number of allowances made available. The value of allowances allocated for free can be considered a revenue transfer in the sense that recipients will accrue revenue from the resale of these allowances or avoid costs by holding the allowances for their own use. For simplicity in the following discussion, allowances allocated for free by the Federal government are treated as a revenue transfers. All other permits are auctioned and the revenue flows to the CCCC for disbursement. Table 14 describes the allocation of GHG permits and the associated revenue in the S. 280 Core case. Each of the main S. 280 cases incorporates the distribution of allowances shown in Table 14.

Table 14. Allocation of Revenues for the S280 Core Case

Type of Revenue	Allocation Share	Destination
Permit Revenue not allocated to CCCC	Starting in 2012, 70%, falling to 10% by 2030	Business
CCCC Auction Share	Starting in 2012, 30%, rising to 90% by 2030	See Below
Allocation of CCCC Auction Revenue		
Transition and Adaptation	In 2012, 20%, falling 2% per year	Consumers
Mitigation and Adaptation	10% of CCCC Revenues	Consumers
Fish and Wildlife Adaptation	10% of CCCC Revenues	Government
Technology Deployment	50% of CCCC Revenues	10% to Consumers; 90% to Business
Other CCCC Programs	10% of CCCC revenue, rising to 30% by 2030	Government

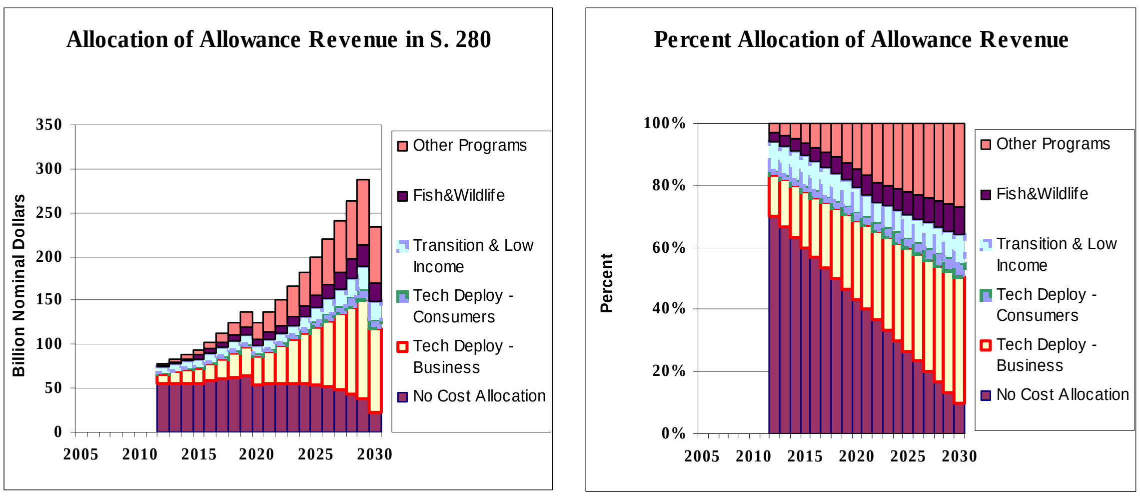
Source: See Appendix B.

[33] A 4 percent discount rate was used.

Figure 27 shows the amount of allowance revenue generated annually in the S. 280 Core case and the shares allocated to each of the programs. By 2029 the total revenue rises to $287 billion, but then falls to $233 billion in 2030 when the emissions cap is lowered, reducing the overall number of allowances allocated and auctioned.

Over time, the largest components of total permit revenue consist of the no-cost allocation of permits to business, followed closely by the distribution of CCCC funds to businesses to spur technology deployment. In 2012, the total flow of funds to business makes up nearly 85 percent of the total amount of allowance related revenues. While the no-cost-allocation share declines over time, the amount going to CCCC, and therefore, to technology deployment for business grows. By 2030, business still receives over 50 percent of the total amount of GHG permit-related revenue. Moving out in time, funding for other CCCC Programs becomes a growing proportion of the total revenue collected. Consumers receive funds designated for transition and mitigation as well as 10 percent of the technology deployment funds. The CCCC also funds specific fish and wildlife projects and numerous other programs that are treated as increased government expenditures.

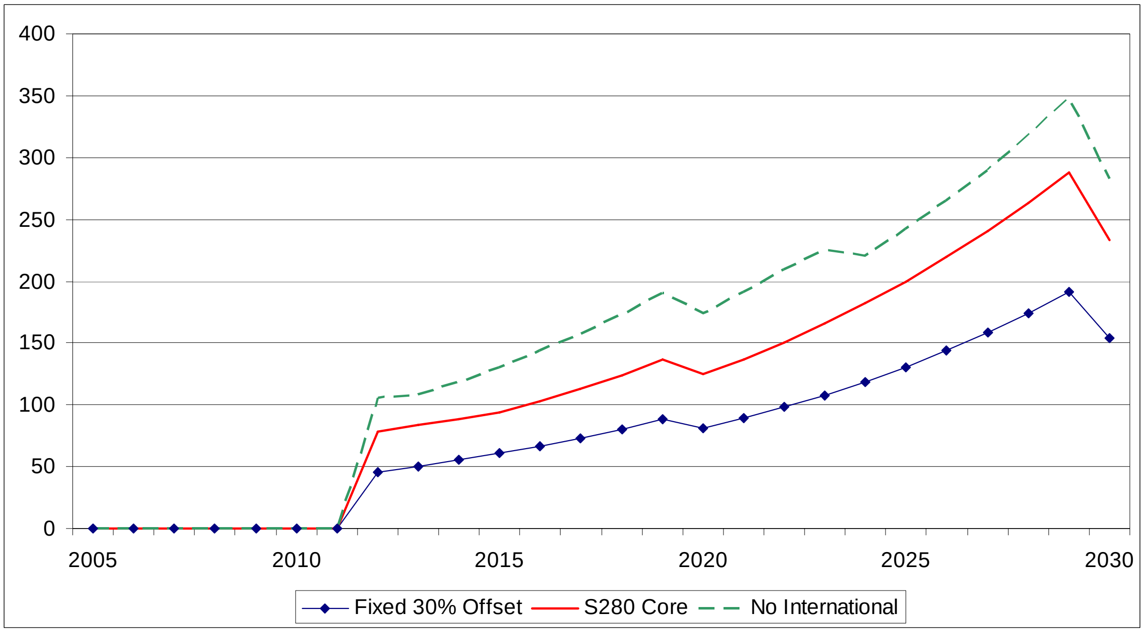
Figure 27. Allocation of Allowance Revenue in the S. 280 Core Case
(billion nominal dollars)



Source: National Energy Modeling System runs, S280BASE.D060107A and S280.D060107A.

Figure 28 shows a comparison of the total value of allowances in the main S. 280 cases. In the No International case, total annual GHG permit-related revenue peaks at $348 billion in 2029, while in the Fixed 30 Percent Offsets case these revenues rise to just under $200 billion in 2029. The cumulative 2012 through 2030 GHG permit related revenue in the main S. 280 cases ranges from 1.9 to 3.9 trillion nominal dollars ($1.2 to $2.6 discounted).

Figure 28. Allowance Revenue Comparison
(billion nominal dollars)

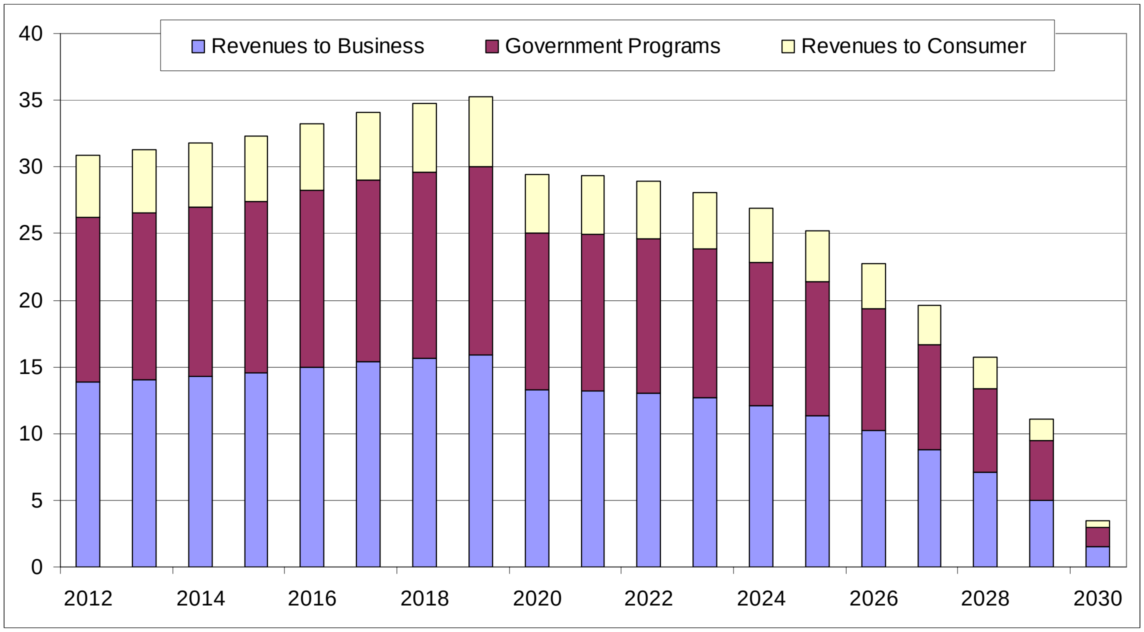


Source: National Energy Modeling System runs S280.D060107A, S280NOINTL.D061507A and S280STRAW.D060207A.

The High Auction Case

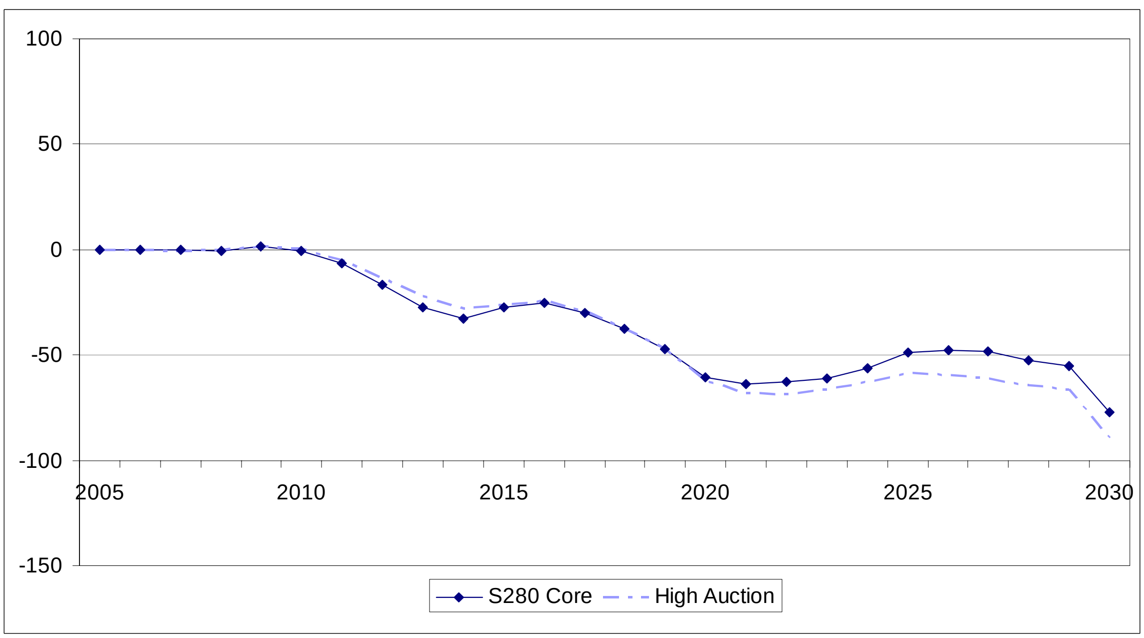
S. 280 does not specify the share of allowances to be allocated for free or the share to be auctioned off by the CCCC. Senate staff specified that EIA should assume that the auction share would start at 30 percent in 2012 and grow to 90 percent in 2030. However, they also requested a sensitivity case, in which the auction share started at 70 percent in 2012 and ramped up linearly to 90 percent in 2030—the same final target as in the main S. 280 cases. In the High Auction case, the difference in the amount of revenue recycled was relatively small, since allowance prices are fairly low in the early years when the auction share was increased. Figure 29 shows the difference in total revenues by destination between the High Auction case and the S. 280 Core case. Relative to the overall policy these changes are fairly small, and the impact on the economy is further muted because there is really little difference economic difference between giving allowances directly to business or auctioning off allowances and giving the revenue to business to support technology deployment programs. As a result, the change in real GDP in the S. 280 Core and High Auction cases are nearly identical (Figure 30).

Figure 29. Change in CCCC Revenues in High Auction Case
(difference from the S. 280 Core case in billion nominal dollars)



Note: Government programs include programs for fish and wildlife, program administrative costs and other programs.
Source: National Energy Modeling System runs S280.D060107A and S280CC70.D060207A

Figure 30. Change in Real GDP, S. 280 Core and High Auction Cases
(billion 2000 dollars)

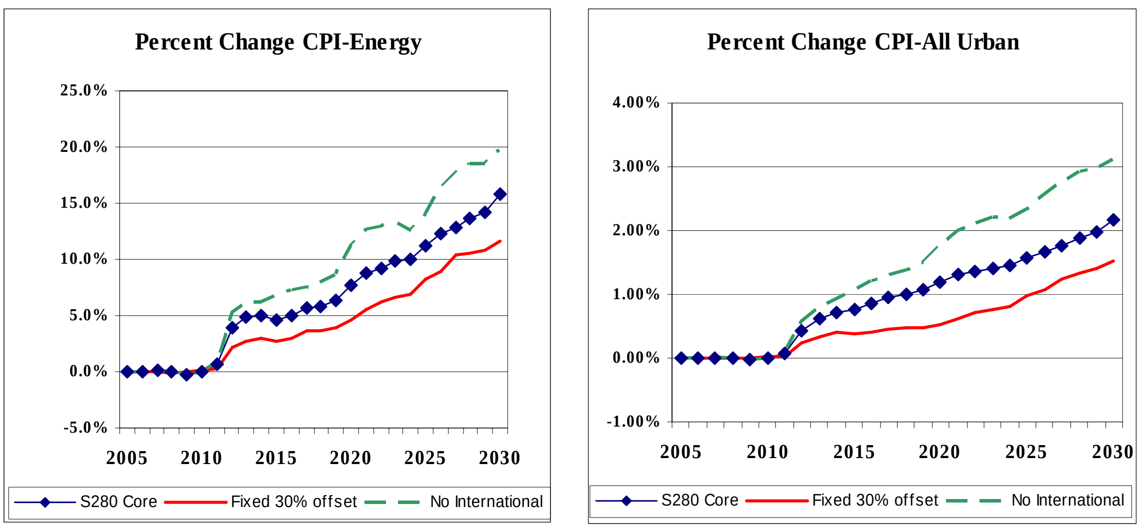


Runs: S280.D060107A and S280CC70.D060207A

Impacts on Energy and Aggregate Prices

Rising energy costs influence the aggregate economy through higher energy expenditures and through higher prices for other goods and services where energy is an input cost. Figure 31 shows the percentage changes in the consumer price index (CPI) for energy and the All-Urban CPI, a measure of aggregate consumer prices in the economy, in the main S. 280 cases. The CPI for energy, a summary measure of energy prices facing households at the retail level, increases by approximately 16 percent above the reference case level by 2030 in the S. 280 Core case. Ultimately the consumer sees higher prices directly through final prices paid for energy related goods and services, and higher prices for other goods and services rise as a result of higher energy price changes and changes in interest rates. Differences in the consumer price impact on the economy in the main S. 280 cases can be traced to the different energy price paths in each of the cases.

Figure 31. Impacts on the CPI for Energy and the All-Urban CPI
(percent change from reference case)



Source: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280NOINTL.D061507A, S280STRAW.D060207A, S280CC70.D060207A.

Real GDP and Consumption Impacts[34]

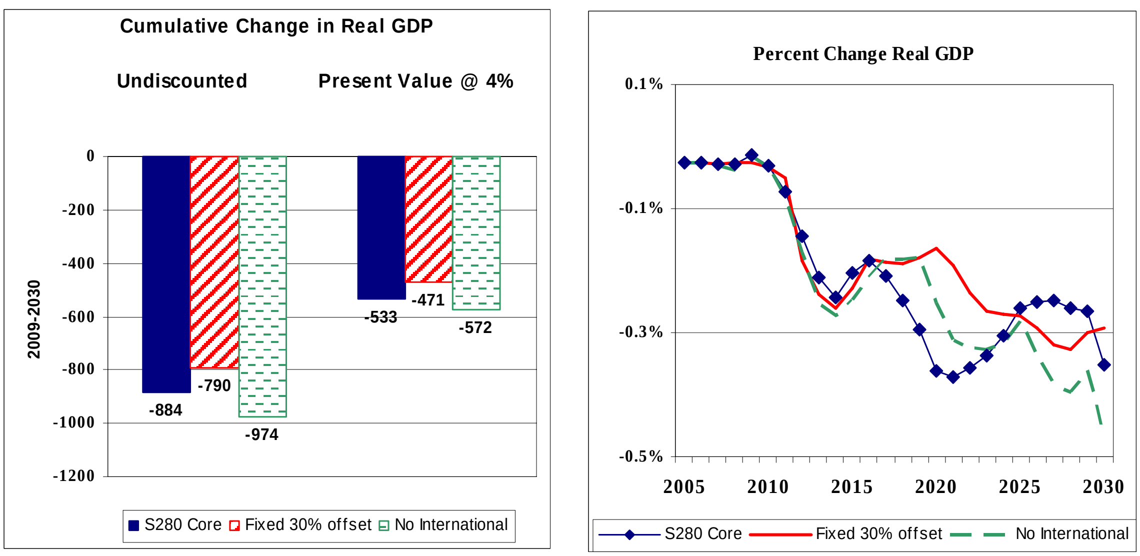
The higher delivered energy prices lower real output for the economy. They reduce energy consumption but also indirectly reduce real consumer spending for other goods and services due to lower purchasing power. The lower aggregate demand for goods and services results in lower real GDP relative to the reference case (Figure 32). Real GDP in 2030 is between 0.3 percent and 0.5 percent lower in 2030 in the main S. 280 cases than in the reference case. Total discounted GDP over the 2009 to 2030 time period is $533 billion (0.22 percent) lower in the S. 280 Core case and ranges from $471 billion (0.19

[34] All dollar values reported in this section and beyond are expressed in real 2000 dollars unless otherwise stated.

percent) lower in the Fixed 30 Percent Offsets case to $572 billion (0.23 percent) lower in the No International case. Projected GDP impacts generally increase over time, as the cap-and-trade program requires larger changes in the energy system.

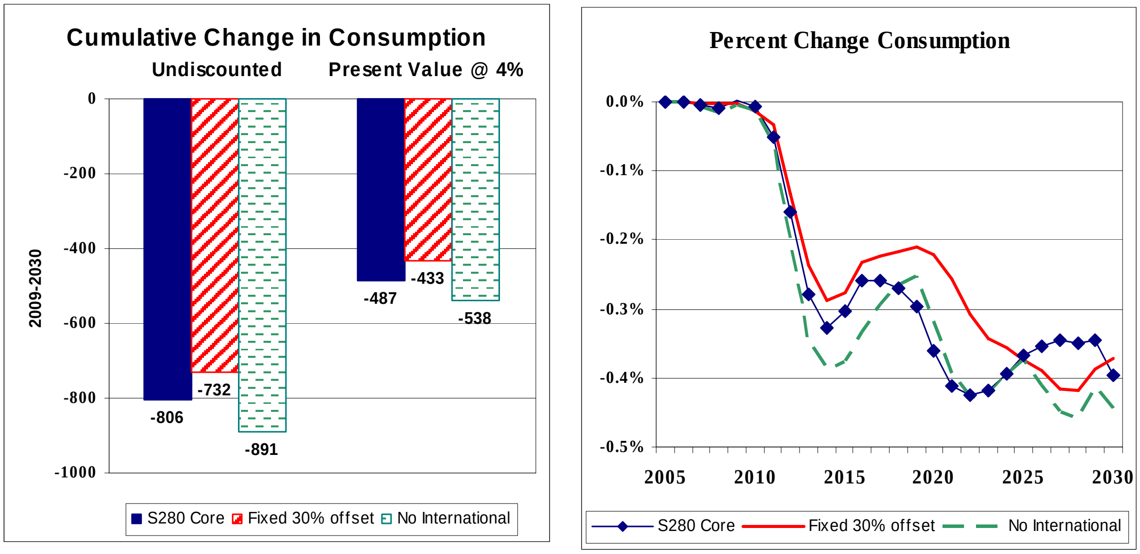
While real GDP is a measure of what the economy produces, the composition of GDP may change considerably between the major components—consumption, investment, government, and net exports. The bottom line for the consumer is how many goods and services can they purchase—the consumption component of GDP. Figure 33 shows two measures of consumption impacts: the cumulative discounted loss in consumption over the 2009 to 2030 period and the percentage change in consumption compared to the reference case. The cumulative losses of consumption are $487 billion (0.28 percent) in S. 280 Core case and $538 billion (0.31 percent) and $433 billion (0.25 percent) in the No International and Fixed 30 Percent Offsets cases, respectively. Consumption impacts, like GDP impacts, generally grow over time.

Figure 32. Real GDP Impacts



Source: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280NOINTL.D061507A, S280STRAW.D060207A,.

Figure 33. Real Consumption Impacts



Source: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280NOINTL.D061507A, S280STRAW.D060207A.

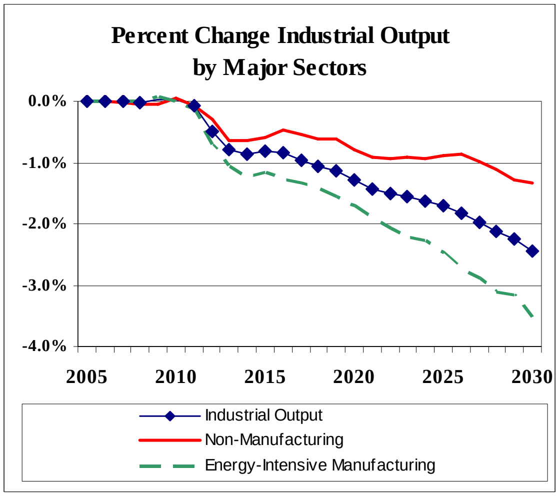
Industrial Output

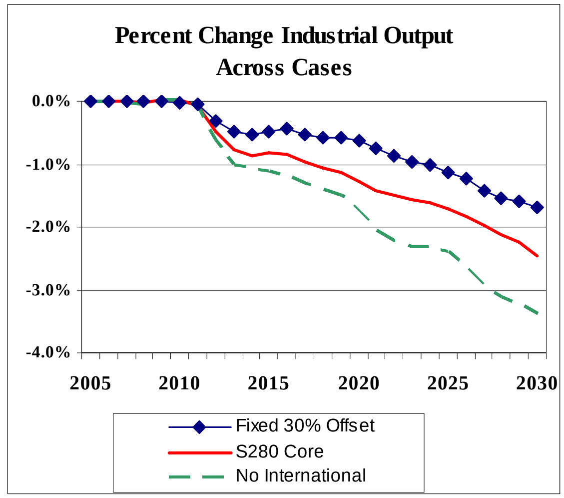
As energy prices increase, the energy-intensive sectors, including food, paper, bulk chemicals, petroleum refining, glass, cement, steel and aluminum, show greater losses compared to the rest of the industrial sectors, falling 3.5 percent below the reference case level by 2030 in the S. 280 Core case. The left side of Figure 34 depicts impacts by industry in the S. 280 Core case while the right side shows the change in total industrial output in the main S. 280 cases. The industrial sector (all non-service industries) is down 2.5 percent relative to baseline, as higher inflation and lower demand impact industrial activity. The right side of Figure 34 shows industrial sector impacts across the main S. 280 cases with the change in 2030 varying from 1.7 percent to 3.4 percent below the reference case level.

Uncertainty and Limitations

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. Under S. 280, this analysis finds 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. Sensitivity analyses suggest that the economic impacts can change significantly under alternative assumptions regarding the cost and availability of new technologies. In addition, the cost and availability of offsets outside of the energy sector, both domestically and internationally, is a significant area of uncertainty.

Figure 34. Impacts on Industrial Output
(percent change from base)





Source: National Energy Modeling System runs S280BASE.D060107A, S280.D060107A, S280NOINTL.D061507A, S280STRAW.D060207A, S280CC70.D060207A.

This analysis suggests that increasing the use of nuclear and renewable power is an economical compliance strategy, with nuclear generating capacity more than doubling over the next 25 years. However, concerns about siting, waste disposal, and project risk could deter nuclear development. The **No Nuclear case** holds nuclear capacity to the reference case level, driving allowance prices 6 percent higher than those in the S280 Core case by 2030. Similarly, there are questions about the potential development of a large scale bio-power industry. For example, the analysis does not assume enactment of a significant new mandate for the use of biofuels in the transportation sector, which would tend to reduce the availability of biomass for electricity generation. The costs of integrating large quantities of wind into the power grid are another issue. If nuclear and renewable generation cannot grow rapidly, the deployment of CCS technology would be more likely. However, the industry would again be relying on a technology about which there is considerable uncertainty.

The effects uncertainty regarding the potential role of international offsets is illustrated by the range of allowance prices, an indicator of marginal compliance costs, across cases with different assumptions about offset availability. Relative to the S.280 Core case, allowance prices in 2030 are 20 percent higher in the No International case and 35 percent lower in the Fixed 30 Percent Offsets case.

The analysis of S. 280 is subject to a number of additional limitations that deserve emphasis. S. 280 calls for a reduction in the emission caps in 2030 and 2050, but the modeled time horizon in this study extends through 2030. While EIA has attempted to take into account investor behavior anticipating the post-2030 regulations, such as advanced allowance banking, the economic implications of S.280 on the economy after 2030 have not been evaluated. Our analysis suggests that large reductions in carbon dioxide emissions in the electric power sector will be necessary to achieve the emissions caps through 2030. Meeting the 2050 caps would likely require a nearly carbon-free electric power supply and a substitution of petroleum-based fuels in transportation, a potentially costly transition from current trends.

The reference case used as the baseline for this analysis is only one of many possible paths representing future economic and energy markets trends under current laws and policies. The *Annual Energy Outlook 2007* presents a range of cases reflecting alternative growth and price paths. All else equal, higher growth in the U.S. economy raises baseline emissions and increases the total amount of reductions required to comply with a cap linked to historical emissions, while lower growth has the opposite effect. Assuming fixed emissions objectives for other countries, higher growth abroad would increase their internal requirement for emissions reductions and reduce the availability of international offsets to U.S. entities covered under S.280, while lower growth has the opposite effect. A baseline with higher conventional energy prices tends to increase both energy efficiency and the penetration of alternative energy sources, reducing the burden of compliance with a cap linked to historical emissions, while lower prices have the opposite effect.

Appendix A. Analysis Request Letter

United States Senate
WASHINGTON, DC 20510

February 5, 2007

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

Dear Administrator Caruso:

We are writing to request that EIA estimate the economic impacts of S. 280, the Climate Stewardship and Innovation Act of 2007. A similar request is being forwarded to the Environmental Protection Agency.

EIA has analyzed an earlier version of this legislation, as well as other proposals for reducing emissions of greenhouse gases in the United States. We believe EIA's analysis of S. 280 would prove useful to us and other members of the Senate as we craft measures to combat global climate change.

We ask that EIA begin this process by meeting with our staff as soon as possible to discuss the parameters, methods, and duration of the analysis. Please call David McIntosh in Senator Lieberman's office at (202) 224-5016 or Floyd DesChamps in Senator McCain's office at (202) 224-5184.

Thank you for your assistance with this analysis.

Sincerely,

Joseph Lieberman
UNITED STATES SENATOR

John McCain
UNITED STATES SENATOR

Appendix B. Analysis Clarification Letter

March 30, 2007

Dr. Howard Gruenspecht
Deputy Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Gruenspecht:

In a letter dated February 5, 2007, Senators Lieberman and McCain requested that the Energy Information Administration (EIA) analyze the economic impacts of S. 280, the Climate Stewardship and Innovation Act of 2007. Recently, we met with your staff regarding the interpretation of specific aspects of the bill and certain key assumptions to be used in the analysis. We are writing to provide further clarification of the request in light of our discussion at that meeting.

Reference Case: Evaluate the proposed bill relative to the reference case of the *Annual Energy Outlook 2007*, or a comparable update to the reference case that reflects any additional technology options or modeling features that are necessary for this analysis.

Emission Caps and Banking: Based on discussion with your staff, we expect you will assess the bill's impacts through 2030. However, since the draft bill lowers the cap on covered sectors' emissions in 2030, entities should have an incentive to over comply – "bank allowances" – in years immediately before 2030 so that they can use these allowances to smooth the impact of the stepwise reduction in the emissions cap that occurs in those years. Your analysis should address this incentive by choosing an emissions trajectory that is consistent with achieving the specified emissions targets without reliance on the use of banked allowances at some point in the decade after 2030, but is also consistent with the over compliance that is expected in the early phases of the emission reduction program.

Auction Share: The bill does not specify the percentage of allowances that would be allocated to the Climate Change Credit Corporation (CCCC) for auction. Assume that 30 percent of the 2012 allowances are allocated to the CCCC, and that the percentage increases at a constant annual rate to reach 90 percent of the 2030 allowances. As a sensitivity case, assume that 70 percent of the 2012 allowances are allocated to the CCCC, and that the percentage increases at a constant annual rate to reach 90 percent of the 2030 allowances.

Allocation of CCCC Funds: For macroeconomic impact analysis, assume that funds for transition assistance and adaptation (Sec. 202 (b)(2)), starting at 20 percent in 2012 and falling 2 percent per year there after, are allocated to consumers. Similarly assume that the 10 percent of the CCCC proceeds for adaptation and mitigation assistance for low income persons and communities (Sec. 202 (b)(4)) also flows to consumers. Assume that the 10 percent of the CCCC funds allotted for adaptation assistance for fish and wildlife habitat (Sec. 202 (b)(5)) will lead to increased government expenditures. For all the remaining funds of the CCCC that will be allocated for technology deployment programs (Sec. 202 (b)(6)), assume a 10/90 split between consumers and businesses. Assume that some of the funds to consumers are used for rebates on energy efficiency measures, similar to the assumptions made in your 2003 study of S. 139.

Early Auction: For the early auction of allowances under Sec. 162(g), assume that half of the 2012 allowances to be auctioned are auctioned in 2008 and the remainder in 2012. Assume that one fourth of the proceeds of the early auction are expended in each subsequent year, 2008 to 2011. Assume that 10 percent of the proceeds funds consumer-oriented energy efficiency programs and that 90 percent flows to business.

Technology Impact: To the extent you cannot address the bill's positive effects on the cost, performance and availability of specific technologies to reduce greenhouse gas emissions, provide a sensitivity case to examine the bill's impacts under the more optimistic technology development assumptions in your Annual Energy Outlook 2007 integrated high technology case.

Allowance Offset Percentage: Assume that all covered entities will take advantage of the 30 percent offset provision, if it is economical to do so. In aggregate, then, assume up to 30 percent of the allowance requirements can be met through offsets. As a sensitivity case, assume up to 100 percent of the allowance requirements can be met through offsets.

While we want as thorough an analysis as you can provide, a report by mid-June would be helpful. Please note that timing is an important priority for this request, even if is necessary to forego more in-depth analysis or additional sensitivity cases in order to respond in a timely manner.

Please clearly identify any aspects of the bill and its impacts that your analysis does not address.

Please do not hesitate to contact us should you have questions regarding any of the above.

Sincerely,

David McIntosh
Office of Senator Lieberman

Floyd Des Champs
Committee on Commerce, Science and Transportation

cc: Pat Hamman, Congressional Affairs, EPA

Appendix C. Updates to Reference Case

The following list identifies the enhancements made to the *AEO2007* reference in the preparation of the reference case for this analysis.

Macroeconomic Changes from *AEO2007* Reference Case

- Ethanol was included in the transportation fuels as input to the Global Insight macroeconomic model because of its magnitude.

Petroleum Market Model Changes from *AEO2007* Reference Case

- Added an improved representation of international ethanol import supply as a function of price.

- Updated the cellulose ethanol representation from a simple input supply curve to a merchant plant representation that incorporates capital investment and production decision making as well as technology learning.

- Updated the biodiesel representation to a merchant plant representation and added the ability to process animal fats.

- Incorporated the flexibility to choose between imports of petroleum gasoline or gasoline blending components.

- Increased the ethanol blending percentage in non-California reformulated and oxygenated gasoline to 10 percent. The change represents a recent EIA reassessment of the market.

- Lowered the DDGS netback price for ethanol production whenever corn-ethanol production exceeds 18 billion gallons.

- Adjusted maximum build rates for ethanol plants consistent with current market investment trends.

The *AEO2007* analysis assumed that the maximum ethanol import quantity that would be available at any price through the entire projection horizon would be about 900 million gallons per year. A review of a recent study for potential Brazilian ethanol production and exports to the U.S. through 2012 provided new data points through which simple exponential supply curves were estimated by year.[35] Whether the levels of ethanol supply from Brazil to the United States will increase as assumed by these curves will depend critically on the level of investments made in Brazil to expand their sugar cane crop production and ethanol conversion facilities and the competition for the ethanol from the rest of the world.

The study sited above claims that there are over 90 million hectares (over 200 million acres) of cleared but idle, non-environmentally sensitive, land available for development of ethanol production. If the land was aggressively developed for sugar cane production,

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[35]University of Campinas, Sao Paulo, Brazil, *Study of the Possibilities and Impacts of the Production of Large Quantities of Ethanol with the Aim to Partially Replace Gasoline in the World.*

Brazilian ethanol production could grow to over 50 billion gallons per year. Large-scale investments for plant and infrastructure, estimated to be between $150 billion to $250 billion dollars, would be required to build roads, purchase farming equipment, expand the ethanol transportation infrastructure, build new conversion plant facilities, and provide for port and ship expansions. One of the scenarios addressed in this analysis, the Low Import Cost Case assumes that such investments are made for Brazilian ethanol development.

Renewable Market Model Changes from *AEO2007* Reference Case

- Added offshore wind technology as a capacity expansion option in selected coastal regions, with revised cost and performance estimates.

- Updated corn and biomass feedstock costs consistent with University of Tennessee POLYSYS study.

EIA's estimates of biomass supply curves were taken from the U.S. Department of Agriculture's latest estimates through 2015, which were developed under contract with Dr. Ugarte at the University of Tennessee using an integrated land and crop competition model. EIA contracted with Dr Ugarte to extend these curves through 2030. The corn supply curves also were developed using POLYSYS and were generally higher-priced than those in *AEO2007* for the same level of demand; however, the maximum availability of corn supply in the new estimate is much larger than the *AEO2007* Reference Case and allows for corn imports when corn prices and demand are sufficiently high. In addition to the Reference Case, a High Yield Case was constructed to evaluate the impact of potentially higher biomass crop yields. Similar to the reference case, the biomass supply curves through 2015 were obtained from the USDA and extended through 2030 by Dr. Ugarte under contract to the EIA.

Electricity Market Models Changes from *AEO2007* Reference Case

- Modified the interregional transmission cost structure to allow renewable capacity additions from one region to serve adjacent regions, with higher associated transmission costs.

- Improved the representation of competition for biomass for electricity generation and cellulosic ethanol production.

- Added offshore wind technology as a capacity expansion option in selected coastal regions, with revised cost and performance estimates.

Appendix D. EPA Memorandum on Offsets

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

OFFICE OF AIR AND RADIATION
OFFICE OF ATMOSPHERIC PROGRAMS
CLIMATE CHANGE DIVISION

MEMO

TO: John Conti, EIA, Andy Kydes, EIA, and Dan Skelly, EIA

FROM: Steven Rose, Shaun Ragnauth, Jules Siedenburg, Christa Clapp, Allen Fawcett

CC: Dina Kruger, Francisco de la Chesnaye, Reid Harvey

DATE: March 26, 2007

SUBJECT: EPA S.280 mitigation cost schedules for capped sectors and domestic and international offsets

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Purpose

EIA has requested EPA's greenhouse gas emissions projections and mitigation cost schedules for: (a) domestic and international non-CO_2 greenhouse gases (GHGs), (b) domestic and international terrestrial carbon sinks, (c) domestic biomass fuel substitutes for fossil fuel use, and (d) international energy-related CO_2. The emissions projections and mitigation cost schedules are included with this memorandum, as well as estimated international demands for offsets. Below we provide an overview of EPA's methods for producing the mitigation cost schedules and international offsets demand. The memo consists of a brief background discussion of relevant portions of the S.280 bill, followed by an overview of EPA's methods, including mitigation cost schedule categories and data sources.

Background

Section 121 of S.280 requires GHG emissions allowances for emissions from "covered entities." Sections 104 and 144 provide the EPA Administrator, in coordination with the Secretary, the Secretary of Energy, and the Secretary of Agriculture, discretion in establishing CO_2 and non-CO_2 GHG emission reduction and carbon sequestration standards for domestic reductions by covered entities and domestic and international reductions as mitigation activities that provide additional allowances to offset covered entity emissions. Section 144 lists four offset alternatives for helping to meet the domestic cap:

1. Tradable allowances from another nation's market in greenhouse gas emissions

2. Net increases in sequestration (which by Section 3 of S.280 "sequestration" includes terrestrial sequestration while also allowing for inclusion of geologic sequestration)
3. Emissions reductions by "non-covered entities" (in covered and non-covered sectors)
4. Developing country greenhouse gas emissions reduction projects (details in Section 145)

As a result of these provisions, EPA has evaluated the domestic and international non-energy CO_2 and non-CO_2 emissions and sequestration mitigation options and defined their potential eligibility for future capped (i.e., covered) and offset allowance programs. The next section summarizes EPA's methods for and results from defining eligibility for the following mitigation categories:

(a) Domestic non-CO_2 GHG emissions reductions – capped and offset
(b) Domestic biomass fuel substitutes (liquid and solid) for fossil fuel use – capped
(c) International non-CO_2 GHG emissions reductions – offset
(d) Domestic and international increases in terrestrial carbon sinks (soil and plant carbon stocks) – offset
(e) International energy-related CO_2 mitigation – offset

Methodology Overview

EPA's March 6, 2007 memo to EIA ("Emissions that Fall under the Cap under S.280") identified U.S. emissions from "covered sectors," "covered entities," and "non-covered entities" as defined in S.280. The memo also described EPA's recommendation for adjusting the 2012 6,130 $MMTCO_2e$ cap, based on the allocation of emissions sources into economic sectors in 2004. We have applied the information in EPA's March 6th memo to EPA's economy-wide domestic modeling structure and designated U.S. sectors as either capped sectors or non-capped sectors, where sectors designated as capped are, as a whole, subject to the S.280 emissions caps over time, and sectors designated as non-capped can provide offset emissions allowances. Overall, EPA is designating emissions sources associated with electricity generation, transportation, and industry (as defined in EPA's March 6 memo) as capped, and all other sources as non-capped.

We have applied the capped/non-capped sector designations to EPA's domestic mitigation cost modeling for non-CO_2 GHGs, terrestrial sinks, and biofuel substitutes. Per Section 144, we have characterized all international CO_2 and non-CO_2 GHG mitigation options as offset activities. We, therefore, generate four different types of mitigation cost schedules:

1. Domestic capped
2. Domestic offsets
3. International offsets – Group 1 countries
4. International offsets – Group 2 countries

The international country groupings (Group 1 and Group 2) and related time periods are discussed further below.

As noted in the Background section, S.280 gives the EPA Administrator, in consultation with others, discretion to establish emission reduction and offset standards. Therefore, EPA has evaluated each individual domestic and international mitigation option to determine potential eligibility and feasibility over time for a future mitigation program. The mitigation cost schedules therefore represent the costs associated with the "eligible" mitigation options. This detailed vetting of individual options, based on EPA's substantial emissions inventory and mitigation program expertise, substitutes and improves upon previous post-processing adjustments to the mitigation cost schedules of 50 percent domestically and 90 and 75 percent internationally (USEPA, 2005a; USEPA, 2001).[36] Exceptions are methane emissions from the natural gas and oil sectors, and international energy-related CO_2 emissions.[37]

The following four steps were taken to generate the capped and offset schedules for domestic non-CO_2 emissions, biofuels, and terrestrial sinks:

1. For each source type, emissions were divided into capped and non-capped emissions
2. For each mitigation option, a determination was made as to whether the option applied to a capped or non-capped emissions source
3. For each mitigation option, a determination was made regarding potential eligibility for a future mitigation program. Eligibility was not determined for methane from the natural gas and oil sectors (see footnote 2). In this case, uniform adjustments were applied.
4. Capped and offset mitigation cost schedules were constructed with the eligible or adjusted options. Rising carbon price pathways were run for agriculture, forestry, and biofuels mitigation (discussed below).

The following three steps were taken to generate the international non-CO_2 and terrestrial sinks schedules:

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[36] Adjustments were made following the methodology developed in cooperation with the White House Council of Economic Advisors for the use of mitigation schedules to analyze an offsets program (USEPA, 2001 and USEPA, 2005a). The adjustments were meant to take into account the difficulties in measuring, monitoring, and verifying offset reductions in countries without a market-based greenhouse gas emissions policy, as well as the lack of a clear market signal that the allowance price in the model run assumes. EPA's detailed vetting of mitigation technologies for this S.280 analysis considered these and other issues in determining the eligibility of each mitigation option.

[37] For methane from the gas and oil sectors, we were not able to vet the extensive list of complex mitigation technologies given time constraints. Therefore, we applied a 50 percent reduction both domestically and for international regions assumed to have a market-based emissions policy. We applied a 75 percent reduction internationally for the periods before a market-based emissions policy is assumed to be in place. For international energy-related CO_2 emissions, the full abatement potential is available as a potential offset when a region has a market based greenhouse gas policy in place. When a region does not have a market-based emissions policy in place, the abatement potential is reduced by 90 or 75 percent, depending on the year.

1. The timing of regional participation in carbon market systems was designated.
2. For each mitigation option a determination was made regarding potential eligibility for a future U.S. mitigation program. Eligibility was not determined for methane from the natural gas and oil sectors, so uniform adjustments were applied.
3. Offset mitigation cost schedules were constructed with eligible or adjusted options for the two country groupings. Rising carbon price pathways were run for forestry and CO_2 emissions mitigation (discussed below).

International energy-related CO_2 abatement schedules were developed using the MiniCAM model. Specifically, the model was run using the reference case developed for the U.S. Climate Change Science Program Synthesis and Assessment Product 2.1a ("CCSP SAP 2.1a", USCCSP, 2006). Rising carbon price pathways, as discussed below, were run for all regions to generate the CO_2 mitigation cost schedules. Adjustments were made to the resulting schedules as noted above.

A 5% discount rate was applied across our analyses.

Rising prices – In order to capture very important investment behavior associated with price expectations, we ran rising carbon price pathways (vs. constant) in our dynamic modeling for estimating mitigation supplies for domestic agriculture, forestry, and biofuels, as well as international forestry and energy-related CO_2 emissions mitigation. For domestic agriculture, forestry, and biofuels we draw from two rising price scenarios from USEPA (2005b): \$3/tCO_2eq in 2010 rising at 4%/yr with a cap of \$30/tCO_2eq, and \$20/tCO_2eq in 2010 rising at \$1.30/yr with a cap of \$75/tCO_2eq. For international forestry and international energy-related CO_2 emissions, we ran four exogenous rising carbon price pathways: \$1, \$5, \$15, and \$30/tCO_2eq in 2010 rising at 5%/year and capped at \$250/tCO_2eq. The resulting average annual mitigation estimates over time for 2010-2050 are provided for the four price scenarios.

Country groupings – The Group 1 and 2 country groupings are listed in Table 1. Group 1 countries are assumed to participate in carbon market systems (i.e., take on national emissions caps) throughout the S.280's time horizon (2010-2050). Group 2 countries are assumed not to be participating in carbon market systems until 2025, after which they are assumed to participate in a system through 2050. These assumptions are drawn directly from MIT's new analysis of cap-and-trade programs (Paltsev *et al.*, 2007).

Table 1: Region Groupings

Region		Timing of national emissions cap 2012-2025	2025-2050
Group 1	Europe	x	x
	Japan	x	x
	Canada	x	x
	Australia	x	x
	New Zealand	x	x
Group 2	Rest of World		x

Notes:
1. Europe includes EU-15, Eastern Europe, and Non-EU Europe
2. Rest of World includes Africa, CIS, Latin America and the Caribbean, Middle East, South/SE Asia

International carbon policies – Also drawn from MIT's analysis are the emissions cap levels adopted by the Group 1 and Group 2 countries, as described below in Table 2. Group 1 countries follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050. Group 2 countries adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050.

Table 2: Regional Emissions Caps

Year	Emissions Cap Levels: Group 1	Group 2
2010	5.0% below 1990 levels	No Cap
2015	5.3% below 1990 levels	No Cap
2020	7.0% below 1990 levels	No Cap
2025	10.3% below 1990 levels	2015 levels
2030	15.1% below 1990 levels	2015 levels
2035	21.5% below 1990 levels	2000 levels
2040	29.4% below 1990 levels	2000 levels
2045	38.9% below 1990 levels	2000 levels
2050	50.0% below 1990 levels	2000 levels

International demand for abatement – The emissions cap levels described in Table 2 are subtracted from reference case emissions for Group 1 and Group 2 countries in order to determine their respective demands for emissions abatement. The reference case emissions paths used were derived from the MiniCAM model's CCSP SAP 2.1a reference case (USCCSP, 2006). To facilitate modeling of the availability of international offsets to the S.280 domestic program, we have included our estimates for international emissions abatement demand.

Summary of the data files provided – Table 3 summarizes the 25 data files that accompany this memo. They include 24 files with mitigation schedules, one for each mitigation category considered by EPA, and one file with the international derived demand for GHG abatement. For each of the mitigation files, Table 3 lists the types of mitigation supply schedules provided and the data source from which the schedules were

Table 3: Data files provided

Mititigation category		Domestic: Capped	Domestic: Offset	International offsets: Group 1	International offsets: Group 2	Data source
1	CH_4 from landfills	--	2010, 2020+	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
2	CH_4 from coal mines	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
3	CH_4 from the natural gas sector	--	2010, 2020+	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
4	CH_4 from the oil sector	--	2010, 2020+	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
5	N_2O from adipic acid production	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
6	N_2O from nitric adic production	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
7	HFC from refrigeration and air conditioning	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
8	HFC, HFE, and PFC from solvents	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
9	HFC from foams	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
10	HFC from aerosols - MDI	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
11	HFC from aerosols - Non-MDI	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
12	HFC from fire extinguishing	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
13	PFC from aluminum production	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
14	HFC-23 from HCFC-22 production	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
15	PFC and SF_6 from semiconductor manufacturing	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
16	SF_6 from electric power systems	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
17	SF_6 from magnesium (Mg) production	2010, 2020+	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
18	Domestic agriculture, forest, and biofuel (includes biofuel energy supply)	2010-2050	2010-2050	--	--	USEPA (2005b)
19	Intl CH_4 & N_2O from livestock manure management	--	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
20	Intl CH_4 from livestock enteric fermentation	--	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
21	Intl CH_4, N_2O, & soil carbon from paddy rice	--	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
22	Intl N_2O & soil carbon from cropland	--	--	2010, 2020+	2010, 2020, 2025-2050	USEPA (2006)
23	Intl forest carbon sequestration	--	--	2010-2050	2010-2050	Sohngen and Mendelsohn (2006)
24	Intl energy-related CO_2 emissions reductions	--	--	2010-2050	2010-2050	USCCSP (2006)

Additional data file		Domestic: Capped	Domestic: Offset	International: Group 1	International: Group 2	Data source
25	Intl derived abatement demand	--	--	2010-2050	2010-2050	USCCSP (2006)

Notes:

1. Domestic baseline projections include reductions from voluntary programs.
2. Baseline projections for SF_6 from electric power systems, PFC and SF_6 from semiconductor manufacturing, SF_6 from magnesium production, PFC from aluminum production, and HFC-23 from HCFC-22 production incorporate the planned reductions from the “Technology-Adoption” baselines (EPA, 2006).
3. 2020+ schedules are to be applied for the period 2020-2050.
4. For domestic agriculture, forests, and biofuel, international forest, and international energy-related CO_2 reductions, mitigation pathways are provided for the entire period 2010-2050 from the rising carbon price runs discussed in the text.
5. In addition to mitigation supply, biofuel energy supply is also provided in the Domestic agriculture, forest, and biofuel spreadsheet.

derived. Each mitigation file includes projected baseline emissions, mitigation eligibility designations, and the mitigation cost schedules.

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