Order Code RL34489

CRS Report for Congress

Climate Change: Costs and Benefits of S. 2191

May 15, 2008

Larry Parker and Brent Yacobucci
Specialists in Energy and Environmental Policy
Resource, Science, and Industry Division

Prepared for Members and Committees of Congress

Congressional Research Service

Climate Change: Costs and Benefits of S. 2191

Summary

This report examines six studies that project the costs of S. 2191 to 2030 or 2050. It is difficult (and some would consider it unwise) to project costs up to the year 2030, much less beyond. The already tenuous assumption that current regulatory standards will remain constant becomes more unrealistic, and other unforeseen events (such as technological breakthroughs) loom as critical issues which cannot be modeled. ***Long-term cost projections are at best speculative, and should be viewed with attentive skepticism.*** Despite models' inability to predict the future, cases examined here do provide insights on the costs and benefits of S. 2191.

First, if enacted, the ultimate cost of S. 2191 would be determined by the response of the economy to the technological challenges presented by the bill. The bill provides numerous incentives for technology innovation. The potential for new technology to reduce the costs of S. 2191 is not fully analyzed by any of the cases, nor can it be. Technology development is not sufficiently understood at the current time for models to replicate with confidence. Likewise, it is difficult to determine if available incentives are directed in an optimal manner. **The cases do suggest that S. 2191's Carbon Capture and Storage (CCS) bonus allowances would encourage deployment of CCS, accelerating development by 5-10 years.**

Second, a considerable amount of low-carbon generating capacity will have to be built under S. 2191 in order to meet the reduction requirement. How much capacity will be necessary depends on new and replacement capacity needs, along with consumer demand response to rising prices and incentives contained in S. 2191.

Third, offsets could be a valuable tool not only to potentially reduce costs, but also to buy time to permit further development of new, more efficient technologies. Cost could be lowered further by greater availability of offsets and international credits and with a broader definition of eligible international credits.

Fourth, the Carbon Market Efficiency Board could have an important effect on the cost of S. 2191 through its power to extend the availability of offsets and international credits. In this sense, the Board's powers could mesh with the previous insight about the potential effect of offsets on the bill's overall costs.

Fifth, the Low Carbon Fuel Standard could significantly raise fuel prices and limit supply. The effects will depend on what fuels are included, the emissions reductions achieved by alternatives, and the ability to produce those alternatives.

Finally, S. 2191's climate-related benefit is best considered in a global context and the desire to engage the developing world in the reduction effort. The United States and other developed countries agreed both to reduce their own emissions to help stabilize atmospheric concentrations of greenhouse gases (GHGs) and to take the lead in reducing GHGs when they ratified the United Nations Framework Convention on Climate Change (UNFCCC). **This context raises two issues for S. 2191: (1) whether S. 2191's GHG reduction program would be considered sufficiently credible by developing countries so that schemes for including them in future international agreements become more likely, and (2) whether S. 2191's reductions meet U.S. commitments to stabilization under the UNFCCC.**

Contents

List of Figures

List of Tables

Climate Change: Costs and Benefits of S. 2191

As Congress continues the debate on an appropriate response to the climate change issue, multiple bills have been introduced to begin reducing greenhouse gas (GHG) emissions. Of these, S. 2191 (the Lieberman-Warner Climate Security Act of 2008[1]) has received particular attention. Introduced by Senator Lieberman, S. 2191 was ordered reported by the Senate Committee on Environment and Public Works on December 5, 2007.[2] Numerous analyses have been done on its impacts, and as of April 2008, six studies had been released.

The most comprehensive analysis has been conducted by the U.S. Environmental Protection Agency (EPA). The report is entitled: *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008: S. 2191 in 110th Congress* (March 14, 2008).[3] The analysis employs a suite of models and basecases, along with some useful sensitivity analyses. This report will focus on three of the models, two basecases, and sensitivity analysis as appropriate.

- The first model is ADAGE: a computable general equilibrium (CGE) model developed by RTI International.[4] The case employing the reference basecase is designated EPA/ADAGE-REF in this report, while the case employing the high technology basecase is designated EPA/ADAGE-TECH.

- The second model is IGEM: a CGE model developed by Dale Jorgenson Associates.[5] The case employing the reference basecase is designated EPA/IGEM-REF in this report, while the case employing the high technology basecase is designated EPA/IGEM-TECH.

- The third model is IPM: a dynamic, deterministic linear programming model of the U.S. electric power sector developed by

---

[1] Originally titled America's Climate Security Act of 2007.

[2] As of May 14, 2008, the Ordered Reported version of the bill was available at Senator Lieberman's website: [http://lieberman.senate.gov/documents/lwcsa.pdf].

[3] The report and supporting model runs are available at [http://www.epa.gov/climatechange/economics/economicanalyses.html]

[4] For more information on the ADAGE model, see [http://www.rti.org/adage].

[5] For more information on the IGEM model, see [http://post.economics.harvard.edu/faculty/jorgenson/papers/papers.html].

ICF Resources. The case employing the IPM model is designated EPA/IPM in this report.[6]

A second analysis has been conducted by the Energy Information Administration (EIA). The report is entitled *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). The analysis employs EIA's NEMS model: a macroeconomic forecasting model with extensive energy technology detail.[7] In addition to conducting a "core" analysis of S. 2191 using its preliminary *2008 Annual Energy Outlook (AEO) Baseline*, EIA also conducts some useful sensitivity analyses that focus on the upside risk of increased energy prices under S. 2191 which are discussed as appropriate. The core S. 2191 analysis is designated EIA/NEMS in this report.

A third analysis has been conducted by the Massachusetts Institute of Technology (MIT) Joint Program on the Science and Policy of Global Change. The report is an appendix to a more comprehensive analysis of cap-and-trade programs released in 2007.[8] The appendix is titled: *Appendix D: Analysis of the Cap and Trade Features of the Lieberman-Warner Climate Security Act (S. 2191).* The appendix employs MIT's EPPA CGE model and presents some useful sensitivity analyses of S. 2191's offset and carbon capture and storage (CCS) bonus allowance provisions. The case that includes S. 2191's 15% international offset and CCS subsidies provisions is designated MIT/EPPA in this report.[9]

A fourth analysis has been conducted for the Clean Air Task Force (CATF) by OnLocation. The report is titled *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). Employing EIA's NEMS model, the CATF analysis is designated CATF/NEMS in this report.

A fifth analysis has been conducted for the American Council for Capital Formation (ACCF) and National Association of Manufacturers (NAM) by Science Applications International Corporation. The report is entitled *Analysis of The Lieberman-Warner Climate Security Act (S. 2191) Using The National Energy Modeling System (NEMS)*. Employing NEMS, ACCF/NAM employs two basic cases: (1) a high cost case using the most constrained and high cost assumptions of any of the analyses presented here (designated as ACCF/NAM/NEMS-HIGH) and (2) a low cost case using the second most constrained and high cost assumptions of any of the analyses presented here (designated as ACCF/NAM/NEMS-LOW).

---

[6] For more information on the IPM model, see [http://www.epa.gov/airmarkets/progsreg/epa-ipm/index.html].

[7] For more on the NEMS model, see [http://www.eia.doe.gov/oiaf/aeo/overview/index.html].

[8] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, Report No. 146 (April 2007).

[9] The primary scenario used for this report — the S. 2191, 15% Offsets and CCS Subsidy case — is summarized on p. D21. For more information on the EPPA model, see [http://web.mit.edu/globalchange/www/eppa.html].

A sixth analysis has been conducted for the National Mining Association (NMA) by CRA International. The report is entitled *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). The analysis employs CRA's MRN-NEEM macroeconomic model with extensive electric power sector detail.[10] The case employing the NMA analysis is designated NMA/CRA.

It should be noted that several of the studies examined in this report are published as presentations with limited documentation, making comparative analysis difficult. *Each presentation has selected features or impacts it is particularly interested in highlighting. The more comprehensive analyses are the work by EPA, EIA, and MIT. In order to increase the comparability of the various cases examined here, CRS has converted all publicly available data presented by the cases to 2005 dollars (where appropriate) and interpolated missing data where possible. Likewise, where studies have stated they used specific projections as a base case (such as EIA's Annual Energy Outlook 2007 or preliminary 2008 projections), CRS has assumed those assumptions have not been altered except as specifically stated by the study. This analysis considers the bill as ordered reported by the Senate Committee on Environment and Public Works, incorporating the proposed deficit reduction amendment. Other proposed amendments are likely if the bill moves to the floor, and these amendments, if adopted, could affect the costs and benefits of the overall bill.*

Overview of the Major Provisions of S. 2191

S. 2191, The Lieberman-Warner Climate Security Act of 2008, was introduced October 18, 2007, by Senator Lieberman. On December 5, 2007, the Senate Committee on Environment and Public Works ordered reported an amended version of the bill that would establish a mandatory cap-and-trade system to reduce greenhouse gas emissions from most sectors of the economy.[11] As ordered reported, S. 2191's emissions cap is estimated by its sponsors to require a 71% reduction from 2005 levels by 2050 from **covered** entities (estimated by the sponsors to account for 87% of total U.S. greenhouse gas emissions). Overall, the sponsors estimate that S. 2191 would reduce total U.S. greenhouse gas emissions by up to 66% from 2005 levels by 2050.

S. 2191 would establish an absolute **cap** on the emissions from covered sectors and would allow **trading** of emissions permits ("**allowances**") among covered and

---

[10] For more information on the MRN-NEEM model, see [http://www.crai.com/uploadedFiles/RELATING_MATERIALS/Publications/BC/Energy_and_Environment/files/MRN-NEEM%20Integrated%20Model%20for%20Analysis%20of%20US%20Greenhouse%20Gas%20Policies.pdf].

[11] For more a more detailed discussion of S. 2191 provisions, and a comparison with other proposals, see CRS Report RL33846, *Greenhouse Gas Reduction: Cap-and-Trade Bills in the 110th Congress*, by Larry Parker and Brent Yacobucci.

non-covered entities.[12] The bill achieves its broad coverage through an **upstream** compliance mandate on petroleum, natural gas, and fluorinated gas producers and importers, and a **downstream** mandate on coal consumers, such as electric generators. Specifically, the bill would limit greenhouse gas emissions from all petroleum producers/importers, all natural gas processors, all facilities that use more than 5,000 tons of coal per year, and entities that produce or import more than 10,000 tons annually (carbon dioxide equivalent) of fluorinated gases and other greenhouse gases.

S. 2191 does not have a "safety valve" — an alternative compliance option that permits covered entities to pay an excess emissions fee instead of reducing emissions. Instead, the bill creates a Carbon Market Efficiency Board with authority to temporarily adjust the availability of allowances through borrowing and other techniques; however, it is a zero-sum game. Allowances borrowed must be repaid, so the emissions cap is maintained. The bill limits the availability of domestic **offsets** to 15% of the allowance requirement, with allowances bought in an eligible international allowance market also limited to 15%. Both percentages may be increased by the Carbon Market Efficiency Board if market conditions suggest such action. The bill would permit **banking** of allowances.

For each year 2012 through 2050, the bill specifies the total number of allowances available, then explicitly states the percentage of those allowances that will go to **covered** and non-covered sectors,[13] as well as the share that will be **auctioned**. (See **Table 1**.) Over time, an increasing share of the allowances are auctioned, while the allowances to covered sectors decrease to zero. Auction proceeds are allocated for various purposes, including technology development and deployment, transition assistance, adaptation, and program administration.[14] (See **Table 2**.) Under a proposed amendment to make the bill revenue neutral, a percentage of allowances (starting at 6.1%, increasing to 15.99%) would be auctioned off-the-top for deficit reduction ("Deficit Reduction Fund"). After the Deficit Reduction allowances are allocated, the rest of the allowances ("remainder allowances") are allocated according to the bill as reported. For example, in 2012, 6.1% of the total number of allowances are auctioned for deficit reduction, and an additional 21.5% of the "remainder allowances" are auctioned for program management, technology deployment, adaptation, and other purposes.

---

[12] See "Common Terms" box for definitions. For more detailed definitions, see CRS Report RL33846.

[13] In addition to allowances given at no cost to covered sectors, the bill also allocates allowances to states and tribes for various policy objectives, to local energy distribution companies to reduce costs to low- and middle-income energy consumers, to the U.S. Department of Agriculture to fund sequestration projects, and other purposes. Non-covered entities must sell their allowances (for "fair market value") within one year of receipt and use the proceeds from those sales for specified purposes.

[14] For a more detailed description of the allocation of allowances and auction revenues under S. 2191, see CRS General Distribution Memo *Allocations of Carbon Allowances and Auctions under S. 2191 as Ordered Reported by the Senate Committee on Environment and Public Works*, dated May 13, 2008.

Common Terms

Allowance. A limited authorization by the government to emit 1 metric ton of carbon dioxide equivalent. Although used generically, an *allowance* is technically different from a *credit*. A credit represents a ton of pollutant that an entity has reduced in excess of its legal requirement. However, the terms tend to be used interchangeably, along with others, such as *permits*.

Auctions. Auctions can be used in market-based pollution control schemes to allocate some, or all of the allowances. Auctions may be used to: (1) ensure the liquidity of the credit trading program; and/or (2) raise (potentially considerable) revenues for various related or unrelated purposes.

Banking. The limited ability to save allowances for the future and shift the reduction requirement across time.

Cap-and-trade program. An emissions reduction program with two key elements: (1) an absolute limit ("cap") on the emissions allowed by covered entities; and (2) the ability to buy and sell ("trade") those allowances among covered and non-covered entities.

Coverage. Coverage is the breadth of economic sectors covered by a particular greenhouse gas reduction program, as well as the breadth of entities within sectors.

Emissions cap. A mandated limit on how much pollutant (or greenhouse gases) an affected entity can release to the atmosphere. Caps can be either an *absolute cap*, where the amount is specified in terms of tons of emissions on an annual basis, or a *rate-based cap*, where the amount of emissions produced per unit of output (such as electricity) is specified but not the absolute amount released. Caps may be imposed on an entity, sector, or economy-wide basis.

Greenhouse gases. The six gases recognized under the United Nations Framework Convention on Climate Change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFC), and perfluorocarbons (PFC).

Leakage. The shift in greenhouse gas (GHG) emissions from an area subject to regulation (e.g., cap-and-trade program) to an unregulated area, so reduction benefits are not obtained. This would happen, for example, if a GHG emitting industry moved from a country with an emissions cap to a country without a cap.

Offsets. Emission credits achieved by activities not directly related to the emissions of an affected source. Examples of offsets would include forestry and agricultural activities that absorb carbon dioxide, and reductions achieved by entities that are not regulated by a greenhouse gas control program.

Revenue recycling. How a program disposes of revenues from auctions, penalties, and/or taxes. Revenue recycling can have a significant effect on the overall cost of the program to the economy.

Sequestration. Sequestration is the process of capturing carbon dioxide from emission streams or from the atmosphere and then storing it in such a way as to prevent its release to the atmosphere.

In addition to the cap-and-trade program, S. 2191 has other key provisions to reduce greenhouse gas emissions.

- Title VI imposes an "international reserve allowance" requirement on certain "covered" imported goods as a prerequisite for entry into the country.[15] Unlike importers of covered fuels that create greenhouse gases when used (which are directly controlled as covered facilities under S. 2191), Title VI would affect certain bulk goods manufactured in processes that generate greenhouse gases (e.g. iron, paper, etc.) that would not be allowed into the country if the allowance requirement were not met. The amount and allocation of international reserve allowances would be determined by EPA, and a separate allowance trading system could be established (international reserve allowances could not be used for domestic compliance).

- Title VIII on carbon sequestration[16] requires: (1) EPA to amend regulations under the Safe Drinking Water Act to allow commercial-scale underground injection of carbon dioxide for sequestration, and to monitor such activity to reduce adverse impacts from such injection; (2) the Department of the Interior to assess U.S. capacity for geological sequestration; (3) the Department of Energy to assess the feasibility of CO_2 pipelines; and (4) EPA to establish a task force to study the issues related to federal assumption of liability for sequestration sites.

- Title IX permits the President to temporarily adjust or waive any regulations promulgated under the bill if a "national security emergency exists," and it is in the "paramount interest of the United States" to modify the requirements in response to that emergency.

- In addition to the limits under the cap-and-trade program, Title X requires EPA to establish a program limiting U.S. consumption of hydrofluorocarbons under a separate HFC allowance program.

- Title XI amends the Clean Air Act in three ways: (1) it requires EPA to establish a program to limit emissions of greenhouse gases not covered under the program; (2) it limits the sale and use of certain motor vehicle air conditioning fluids; and (3) it establishes a low

---

[15] For a further discussion of Title VI, see Jeanne Grimmett and Larry Parker, *Whether Import Requirements Contained in Title VI of S. 2191, the Lieberman-Warner Climate Security Act of 2008, as Ordered Reported, Are Consistent with U.S. WTO Obligations*, Congressional Distribution Memorandum (March 27, 2008). Available from the authors.

[16] For more information on carbon sequestration, see CRS Report RL33801, *Carbon Capture and Sequestration (CCS)*, by Peter Folger.

carbon fuel standard (LCFS) requiring per-unit-energy reductions in greenhouse gas emissions from transportation fuels.[17]

Earlier Versions of the Bill

Bill as Introduced. S. 2191 (originally titled America's Climate Security Act of 2007), as introduced October 18, 2007, by Senator Lieberman, would cap greenhouse gas emissions from the electric generation, industrial, and transportation sectors (for facilities that emit more than 10,000 metric tons of carbon dioxide equivalent). As introduced, the cap was estimated by the sponsors to reduce emissions to 15% below 2005 levels in 2020, declining steadily to 63% below 2005 levels in 2050. The program would be implemented through an expansive allowance trading program to maximize opportunities for cost-effective reductions. Credits obtained from increases in carbon sequestration and acquisition of allowances from foreign sources could be used to comply with 30% of reduction requirements. The bill also establishes a Carbon Market Efficiency Board to observe the allowance market and implement cost-relief measures if necessary.

Bill as Reported by Subcommittee. On November 1, 2007, the Senate Committee on Environment and Public Works' Subcommittee on Private Sector and Consumer Solutions to Global Warming and Wildlife Protection reported out a revised version of S. 2191. As reported from subcommittee, S. 2191 was estimated to reduce greenhouse gas emissions 19% below 2005 levels by 2020 (up from 15% as introduced) and 63% below 2005 levels by 2050. The increase in the estimated reductions in 2020 is the result of amended text that includes greenhouse gases from all natural gas uses under the overall emissions cap. Other amendments approved included modifications to eligibility requirements for the advanced technology vehicles manufacturing incentive program and the advanced coal generation technology demonstration program. Modifications were also made to the proposed allocation of allowances to help tribal communities respond to climate change and to encourage international forest carbon activities, along with 1% of allowances reserved for rural cooperatives and a corresponding reduction in allowances allocated to the rest of the electric power industry. The revised bill also added two new recipients of auction revenues: a Bureau of Land Management Emergency Firefighting Fund ($300 million) and a Forest Service Emergency Firefighting Fund ($800 million).

[17] This LCFS provision is discussed in more detail in the section below on the "Transportation Sector."

Table 1. Allocation of Allowances Under S. 2191

		2012	2020	2030	2040	2050
Total Allowances (millions)	Sec. 1201	5775	4924	3860	2796	1732
Deficit Reduction Fund	Sec. 3101 (as amended)	6.10%	8.40%	14.43%	15.99%	15.99%
Remainder Allowances (millions)	Sec. 3101 (as amended)	5423	4510	3303	2349	1455
Share of Remainder Allowances						
Early Auction	Sec. 3101	5%	0%			
Auction	Sec. 3102	21.5%	36.5%	62.8%	69.5%	69.5%
Early Action	Sec. 3201	5%	0%			
States	Secs. 3301-3304	10.5%	10.5%	10.5%	10.5%	10.5%
Tribal Communities	Sec. 3303(d)	0.5%	0.5%	0.5%	0.5%	0.5%
Low/Middle-Class Electricity Consumers	Sec. 3401	9%	9%	9%	9%	9%
Low/Middle-Class Natural Gas Consumers	Sec. 3501	2%	2%	2%	2%	2%
CCS Bonus Allowances	Sec. 3601	4%	4%	4%	0%	
Domestic Agriculture and Forestry	Sec. 3701	5%	5%	5%	5%	5%
International Forest Protection	Sec. 3803	2.5%	2.5%	2.5%	2.5%	2.5%
Transition Assistance						
Fossil Fueled Electric Plants	Sec. 3901	19%	16%	1%		
Rural Electric Cooperatives	Sec. 3901	1%	1%	1%		
Pilot Program for VA and MT	Sec. 3903(a)(2)	0.2%	0.2%	0%		
Energy-Intensive Manufacturing Facilities	Sec. 3901	10%	8%	0%		
Petroleum Production/Import Facilities	Sec. 3901	2%	2%	0.25%		
HFC Producers/Importers	Sec. 3901	2%	2%	0.25%		
Landfill and Coal Mine Methane Reduction	Sec. 3907	1%	1%	1%	1%	1%

Table 2. Allocation of Auction Revenue (excluding Deficit Reduction Fund) Under S. 2191

		2012	2020	2030	2040	2050
Off-the-Top Allocation of Auction Proceeds						
BLM Emergency Firefighting Fund	Sec. 4302(b)(1)	SSAN	SSAN	SSAN	SSAN	SSAN
Forest Service Emergency Firefighting Fund	Sec. 4302(b)(2)	SSAN	SSAN	SSAN	SSAN	SSAN
CSA Management Fund	Sec. 4302(b)(3)	SSAN	SSAN	SSAN	SSAN	SSAN
Percentage of Remaining Proceeds						
Technology Deployment	Sec. 4302(b)(4)(B)	52%	52%	52%	52%	52%
Energy Independence Acceleration Fund	Sec. 4302(b)(4)(C)	2%	2%	2%	2%	2%
Energy Assistance Fund	Sec. 4302(b)(4)(D)	18%	18%	18%	18%	18%
Climate Change Worker Training Fund	Sec. 4302(b)(4)(E)	5%	5%	5%	5%	5%
Adaptation Fund	Sec. 4302(b)(4)(F)	18%	18%	18%	18%	18%
Climate Change and National Security Fund	Sec. 4302(b)(4)(G)	5%	5%	5%	5%	5%

Note: SSAN = "such sums as necessary." For its analysis of S. 2191, EPA estimated total program costs ("CSA Management Fund") at 1% of the total value of allowances in a given year.

As Ordered Reported by Committee. On December 5, 2007, the full committee ordered reported a revised version of S. 2191 by an 11 to 8 vote. The revised bill expands the greenhouse gas reduction program coverage by replacing the previous definition of covered facility based on the electric power, transportation, and industrial sectors with an upstream definition for oil refineries and natural gas processing plants, and a downstream definition for coal consumers. Among the amendments agreed to by the full committee were a new Low Carbon Fuel Standard (LCFS) that would require the carbon intensity of transportation fuel to be frozen in 2011 and then reduced by 5% in 2015 and 10% in 2020. Other amendments agreed to would increase incentives for states to modify their utility regulatory structures to encourage energy efficiency, and would broaden the ability of states to use their allowance allocations to mitigate adverse economic impacts resulting from the bill's implementation.

Deficit Reduction Amendment. Finally, in April 2008, a proposed amendment to S. 2191 was submitted by the committee to the Congressional Budget Office (CBO) to be included in the scoring of the bill. The amendment would provide for some of the auctioned revenues to be put aside for deficit reduction purposes.

Introduction: Models Cannot Predict the Future Costs of a Climate Change Program

Lessons from SO_2 Cap and Trade Program

During the Clean Air Act debate in 1990 on the Title IV sulfur dioxide (SO_2) cap-and trade program, CRS found it difficult to analyze the cost of the bill beyond the first 10 years (1990-2000), and considered any breakdown of even 2000 data on a state-by-state basis as "not useful for any more than illustrative purposes."[18] As stated in 1990:

> It is difficult (and some would consider it unwise) to project costs up to the year 2000, much less beyond. The already tenuous assumption that current regulatory standards will remain constant becomes more unrealistic, and other unforeseen events (such as electric utility deregulation) loom as critical issues which can not be modeled. Hence, ***cost projections beyond the year 2000 are at best speculative, and are more a function of each model's assumptions and structure than they are of the details of proposed legislation*. Projections this far into the future are based more on philosophy than analysis.**[19] [emphasis in original]

The history of resulting SO_2 cap-and-trade program costs has proven illuminating. As indicated in **Table 3**, the 2010 cost estimates for the SO_2 cap-and-trade program made in 1990 proved to be substantially higher than what is now

[18] See CRS Report 90-63, *Acid Rain Control: An Analysis of Title IV of S. 1630,* by Larry Parker (January 31, 1990), p. 13. (Available from the author.)

[19] Ibid., p. 16.

estimated to be the program's actual costs. Indeed, the EPA-ICF low estimate — the estimate closest to the projected actual number — is both 50% higher than the actual number, and the estimate least focused-on in the original ICF report.[20] It is interesting that none of the analyses were willing to "speculate" with assumptions that would have created a 2010 cost estimate lower than EPA's current projection.[21]

Equally interesting is that the "best" 2000 estimate was off by almost the same 50% that the 2010 estimate was.[22] Like the 2010 estimates, the assumptions either underestimated the ingenuity and creativity of companies in responding to the SO_2 requirements, or mis-read the economics of the cap-and-trade process. As explained below by Chestnut and Mills in 2005, the gross over-estimates are essentially the product of the models' failure both to fully incorporate the flexibility that the cap-and-trade program provided participants and to employ sufficient imagination to explore the potential for technological breakthroughs and enhancements:

> Costs are lower than originally predicted primarily because flexibility occurred in areas that were thought to be inflexible and technical improvements were made that were not anticipated. Factors contributing to the lower costs included lower transportation costs for low-sulfur coal (attributed to railroad deregulation), productivity increases in coal production leading to favorable prices for low-sulfur and mid-sulfur coal, cheaper than expected installation and operation costs for smokestack scrubbers, and new boiler adaptations to allow use of different types of coal. It appears that Title IV has worked as expected to provide the flexibility and incentives for producers to find low-cost compliance options. [footnote omitted] Banking opportunities also induced early reductions in emissions for some facilities. Harrington et al (2000) compared estimates of actual costs of many large regulatory programs to predictions of those costs made while the regulatory programs were being developed and found a tendency for predicted costs to overstate the actual implementation costs, especially for market-based programs such as the SO_2 trading program. They cite technological innovation and unanticipated efficiency gains as key factors leading to lower than predicted costs. They noted that unit costs are often more accurately predicted than total costs because predicted emission reductions are sometimes

---

[20] The only 2010 national utility cost estimate mentioned in the summary of findings is for the High Case: "Longer-term costs reach about $5 billion [1988 dollars] per year by 2010 under both the High House and Senate cases, due to the provisions requiring new source emissions to be offset." The Low House and Senate cases for 2010 are not mentioned. See EPA-ICF: ICF Resources Incorporated, *Comparison of the Economic Impacts of the Acid Rain Provisions of the Senate Bill (S. 1630) and the House Bill (S. 1630),* Prepared for the U.S. Environmental Protection Agency (July 1990), p. 21.

[21] The implementation of the SO_2 provisions of the Clean Air Interstate Rule (CAIR) will significantly increase the stringency of the SO_2 cap for 23 states and the District of Columbia and will likely prevent EPA from estimating actual Title IV compliance costs in 2010 because of program interaction.

[22] In its 1990 analysis, CRS agreed with the range of estimates provided by the EPA-ICF analysis for 2000. As suggested above, CRS did not estimate the costs for 2010. See CRS Report 90-63, *Acid Rain Control: An Analysis of Title IV of S. 1630*, by Larry Parker (January 31, 1990), p. 56. (Available from the author.)

overstated, but they report that predicted unit costs and total costs were both overstated for Title IV.[23]

Table 3. Representative Sample of 1990 Estimates of Annual Compliance Cost for SO_2 Cap-and-Trade Program

(billions, 2005 dollars)

	2000	2010
EPA-ICF	$2.7-$3.6	$3.4-$8.0
NCAC-Pechan	$4.4-$4.6 (for 2000-2009)	no estimate
EEI-TBS[a]	$7.1-$8.7	$7.9-$11.2
Estimated Actual Costs 2000-2007: Ellerman, et al. 2010: EPA	$1.9 (for 2000-2007)	$2.2

Source: EPA-ICF: ICF Resources Incorporated, *Comparison of the Economic Impacts of the Acid Rain Provisions of the Senate Bill (S. 1630) and the House Bill (S. 1630)*, Prepared for the U.S. Environmental Protection Agency (July 1990); Pechan: E.H. Pechan & Associates, *Clean Air Act Amendment Costs and Economic Effects: A Review of Published Studies*, Prepared for the National Clean Air Coalition, National Clean Air Fund (October 1990); TBS: Temple, Barker & Sloane, Inc., *Economic Evaluation of H.R. 3030/S. 1490 "Clean Air Act Amendments of 1989": Title V, The Acid Rain Control Program*, Prepared for the Edison Electric Institute (August 30, 1989). **Estimated 2000-2007 actual cost** from A. Denny Ellerman, Paul L. Joskow, and David Harrison, Jr., *Emissions Trading in the U.S.: Experience, Lessons, and Considerations for Greenhouse Gases*, prepared for the Pew Center on Global Climate Change (November 2007) p. 15. **Estimated 2010 actual cost** from: EPA, *Acid Rain Program Benefits Exceed Expectations*, Figure 4, p. 4. Available at [http://www.epa.gov/airmarkets/cap-trade/docs/benefits.pdf]. All estimates converted to 2005 dollars using the GDP implicit price deflator.

a. Analysis of original Administration bill. EPA estimated that the final bill was $400 million (1988 dollars) annually more expensive than the original proposal. See EPA, Office of Air and Radiation, *Clean Air Amendments: Cost Comparison* (January 23, 1990).

An Illustrative Example from Analyses of S. 2191

There is no reason to believe that cost estimates for greenhouse gas reductions will be any more accurate than the 1990 SO_2 estimates; indeed, they are likely to be more unreliable. This is not to say that they will be too high; they may be too low. To illustrate, CRS examines some results of the modeling efforts with respect to the costs of S. 2191. To frame this illustration, we focus on the three primary drivers of greenhouse gas emissions: (1) population growth, (2) incomes (measured as per capita gross domestic product [GDP]), and (3) intensity of greenhouse gas emissions relative to economic activities (measured as metric tons

[23] Lauraine G. Chestnut and David M. Mills, "A fresh look at the benefits and costs of the US acid rain program," *Journal of Environmental Management* 77 (2005) p. 255.

of greenhouse gas emissions per million dollars of GDP). As shown in the following formula, a country's annual greenhouse gas emissions are the product of these three drivers:

$$(\textit{Population}) \times (\textit{Per Capita GDP}) \times (\textit{Intensity}_{ghg}) = \textit{Emissions}_{ghg}$$

This is the relationship for a given point in time; over time, any effort to change emissions alters the exponential rates of change of these variables. This means that the rates of change of the three left-hand variables, measured in percentage of annual change, sum to the rate of change of the right-hand variable, emissions.

Using the three drivers, **Table 4** provides the essential assumptions from three analyses of S. 2191 for the year 2050. Examining the "business-as-usual" reference cases, a range of assumptions are employed by the models. As suggested by the formula above, the differing assumptions result in very different 2050 baseline GHG emissions: 10.3 billion metric tons for EPA/ADAGE-REF, 11.1 billion metric tons for EPA/IGEM-REF, and 13.3 billion metric tons for MIT/EPPA — a 29% difference from the lowest to the highest. Interestingly, major sources of disagreement in the reference cases include per capita GDP and population projections — two variables that are generally not the focus of greenhouse gas reduction strategies.

Table 4. Reference Case and S. 2191 Analyses for 2050

Model	Population (millions)	Difference from lowest to highest model	GDP per capita (2005$)	Difference from lowest to highest model	GHG Intensity (GHG/ GDP)[a]	Difference from lowest to highest model
Reference Case Scenario						
EPA/ ADAGE-REF	400	9%	$106,800	17%	242	24%
EPA/ IGEM-REF	434		$95,400		269	
MIT/ EPPA	397		$111,300		300	
S. 2191 Scenario						
EPA/ ADAGE-REF	400	9%	$104,300	24%	127	48%
EPA/ IGEM-REF	434		$88,800		107	
MIT/ EPPA	397		$110,500		86	

Source: ADAGE and IGEM model assumptions from the "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html]. The EPPA model assumptions from Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). All estimates converted to 2005 dollars using the GDP implicit price deflator.

a. Measured in metric tons of greenhouse gas emissions per million dollars of GDP.

Moving to the S. 2191 scenario as modeled, the variability in the results widens for two of the three drivers (the 2050 reference case population remains constant in the three models). Not surprisingly, the range widens for the projected 2050 greenhouse gas emissions estimates: 5.3 billion metric tons for EPA/ADAGE-REF, 4.1 billion metric tons EPA/IGEM-REF, and 3.8 billion metric tons for MIT/EPPA — a 40% difference. In particular, the models' assumptions about the flexibility and responsiveness of the U.S. economy resulted in some interesting reversals: (1) The MIT/EPPA model, which has the closest relationship between GHGs and GDP in the reference case, has the most responsive assumptions resulting in the greatest reduction in GHG and GHG intensity under S. 2191; (2) In contrast, the EPA/ADAGE-REF model, which has the lowest GHG intensity assumption in its reference cases, has the highest GHG intensity result under S. 2191.

The MIT/EPPA model assumes more economic growth per capita and more responsiveness by the economy to GHG constraints; the EPA/ADAGE model assumes the most GHG-efficient economy, but the least amount of flexibility to respond to GHG constraints; and the EPA/IGEM model assumes the fastest growth in population.

The result of these different views of the economy is that the economic impact is less than the differences in the models' reference case assumptions. As indicated in **Table 4**, the MIT/EPPA model projection of the country's 2050 GDP per capita under S. 2191 is greater than the *basecase* projections of either of the other models. According to the MIT/EPPA model, the 2050 GDP per capita of the country is reduced by only 0.75% under S. 2191. The reduction under the other two models is 6.9% for EPA/IGEM-REF and 2.4% for EPA/ADAGE-REF — well within the variability of the reference cases.

The result is not significantly more consistent for projections for 2030, particularly with the addition of the EIA baselines.[24] The CATF/NEMS analysis uses the EIA baseline published in its *Annual Energy Outlook 2007* for its analysis.[25] The EIA/NEMS analysis uses a preliminary version of EIA's upcoming *2008 AEO* baseline.[26] As indicated in **Table 5**, the basecase assumptions for per capita GDP vary by a greater percentage for 2030 than they do for 2050. The introduction of the EIA 2008 baseline is responsible for much of the increase in GDP per capita variability (it would be 7% without it). Similarly, the inclusion of the 2007 and 2008 EIA baseline increases the variability of the greenhouse gas intensity driver (it would be 9% without it). Likewise, the GDP per capita impact of S. 2191 is within the noise of the reference cases as the estimated GDP per capita reduction under S. 2191 is only 0.3% for EIA/NEMS, 0.37% for EPPA, 0.90% for ADAGE, and 3.8% for IGEM.

The situation is more constant in the 2020 reference cases, although the impact of S. 2191 is still within the noise of the per capita GDP assumptions, with S. 2191 GDP per capita impact estimated at 0.3% for EIA/NEMS, 0.69% for EPA/ADAGE-REF, 0.78% for MIT/EPPA, and 2.6% for EPA/IGEM-REF.

The uncertainty about the future direction of the basic drivers of greenhouse gas emissions and the economy's responsiveness (economically, technologically, and behaviorally) illustrate the inability of models to predict the the ultimate macroeconomic costs of reducing greenhouse gases. Policy relevant analysis is analysis that provides insight into the features and design of proposals that increase or reduce compliance cost and under what economic, technological, and behavior conditions, and that identify potential intended and

---

[24] Currently, EIA makes projections only to the year 2030.

[25] EIA, *Annual Energy Outlook 2007 With Projections to 2030*, DOE/EIA-0383 (2007), (February 2007).

[26] Available at [http://www.eia.doe.gov/oiaf/aeo/index.html] EIA/NEMS and the two ACCF/NAM/NEMs cases also use the preliminary 2008 baseline. The NMA/CRA case is also based on the preliminary 2008 basecase, but CRA does not explain how it extends EIA's baseline beyond 2030 to 2050.

unintended consequences on the economy. Models cannot predict the future, but they can indicate the sensitivity of a program's provisions to varying economic, technological, and behavioral assumptions that may assist policymakers in designing a greenhouse gas reduction strategy.

Table 5. Reference Case Scenarios for 2020 and 2030

Model	Population (millions)	Difference from lowest to highest model	GDP per capita (2005$)	Difference from lowest to highest model	GHG Intensity (GHG/ GDP)[a]	Difference from lowest to highest model
Reference Case Scenario (2030)						
EPA/ ADAGE-REF	364	4%	$72,700	19%	344	12%
EPA/ IGEM-REF	372		$70,400		363	
MIT/EPPA	359		$73,700		374	
CATF/ NEMS[b]	365		$69,000		384	
EIA/ NEMS	366		$62,000		372	
Reference Case Scenario (2020)						
EPA/ ADAGE-REF	336	2%	$59,000	12%	417	5%
EPA/ IGEM-REF	342		$58,000		428	
MIT/EPPA	334		$59,200		435	
CATF/ NEMS**	337		$56,700		438	
EIA/ NEMS	338		$53,000		431	

Source: ADAGE and IGEM model assumptions from the "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html]. The EPPA model assumptions from Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). The AEO 2007 assumptions from Energy Information Administration, *Energy Market and Economic Impacts of S. 1766, the Low Carbon Economy Act of 2007* (January 2007). The AEO 2008 economic and population assumptions from EIA's website at [http://www.eia.doe.gov/oiaf/aeo/index.html]. The EIA/NEMS assumptions from EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). All estimates converted to 2005 dollars using the GDP implicit price deflator where necessary.

a. Measured in metric tons of greenhouse gas emissions per million dollars of GDP.
b. Based on the report's statement that it uses the 2007 *AEO* baseline projection for its analysis. All estimates converted to 2005 dollars using the GDP implicit price deflator.

Likelihood for More Noise in Greenhouse Gas Reduction Cost Estimates

The potential for noise is greater in estimating the costs of a GHG program than the simple three driver illustration presented above. In its analysis of S. 2191, EPA presents eight pages of bullets identifying various limitations on its modeling exercise and four pages of additional "qualitative" considerations.[27] This is a good indicator of the modeling complexity in attempting to estimate the impact of a greenhouse gas reduction bill. These modeling limitations reflect the inherent complexity of such strategies that cannot be quantified or predicted.

Complexity of the Problem

Compared with the complexity of implementing a greenhouse gas cap-and trade scheme, the SO_2 program was trivial. Conceptually, a CO_2 tradeable permit program could work similarly to the SO_2 program. However, significant differences exist between acid rain and possible global warming that affect current abilities to model responses. For example, the acid rain program involves up to 3,000 new and existing electric generating units that contribute two-thirds of the country's SO_2. This concentration of sources makes the logistics of allowance trading administratively manageable and enforceable. The imposition of the allowance requirement is straightforward. The acid rain program is a "downstream" program focused on the electric utility industry. The allowance requirement is imposed at the point of SO_2 emissions so the participant has a clear price signal to respond to. The basic dynamic of the program is simple, although not necessarily predictable.

A comprehensive greenhouse gas cap-and-trade program would not be as straightforward to implement. Greenhouse gas emissions sources are not concentrated. Although over 80% of the greenhouse gases generated comes from fossil fuel combustion, only about 33% comes from electricity generation. Transportation accounts for about 26%, direct residential and commercial use about 8%, agriculture about 6%, and direct industrial use about 16%.[28] Thus, small dispersed sources in transportation, residential/commercial, agriculture, and the industrial sectors are far more important in controlling greenhouse gas emissions than they are in controlling SO_2 emissions. This greatly increases the economic sectors and individual entities that may be required to reduce emissions.

It also affects the operation of a cap-and-trade program, as the diversity of sources creates significant administrative and enforcement problems for a tradeable permit program if it is meant to be comprehensive. A downstream approach is impractical for a comprehensive greenhouse gas program where the transportation sector and dispersed residential, commercial, and agricultural sources emit almost half the total emissions. One alternative is to move the imposition point more

---

[27] U.S. Environmental Protection Agency, *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008* (March 14, 2008), pp. 96-102, 108-115.

[28] U.S. Environmental Protection Agency, *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2006* (April 2008), p. ES-8.

"upstream" in those sectors, as is done by S. 2191. This complicates the economics of the program as the price signal has to work its way through multiple paths to the particular entities — utilities, consumers, industry — that are the ultimate sources of the greenhouse gases. Arguably, the primary purpose of an economic mechanism, such as a cap-and-trade program, is to put a price on greenhouse gas emissions. In the case of a comprehensive cap-and-trade program, the impact of that price signal will not be simple or straightforward, with unintended consequences likely.[29] In addition, attempts by analysts to capture the general equilibrium effects of the program's interaction with the overall economy add a layer of assumptions and opaqueness to the analysis that can hide insights the analysis may have on program design and implementation.

Flexibility of Cap-and-Trade Program

The flexibility envisioned by most cap-and-trade programs exceeds that of the SO_2 program. Acid rain is a regional problem that resulted in independent responses by the United States and Canada. The United States chose a cap-and-trade program that included important flexibility mechanisms like banking; Canada chose a variety of approaches and the entire process was later codified by treaty. Offsets (emission reductions made by entities not directly covered by the program) are not a major component of the SO_2 program. Uncovered industrial entities that want to participate in the program must become covered entities with their own baselines and monitoring equipment. The bill also sets up a small reserve of allowances to reward reductions through conservation and renewable energy efforts. With the sulfur dioxide cap-and-trade system being limited to the United States, there is no international trading in the acid rain program.

In contrast, most GHG cap-and-trade proposals expand the supply of available allowances by permitting offsets from a wide variety of sources, including agricultural practices, forestry projects, sequestration activities, and alternative energy projects. These diverse sources multiply as the trading extends globally and as other non-CO_2 greenhouse gases are included in the supply mix. Finally, the interaction of these various supply sources and the demand of other countries also reducing emissions (or who may decide to reduce in the future) provide for an almost infinite number of possible scenarios. Crucially, the availability of offsets may have a significant impact on compliance costs, particularly in the short-term.

Importance of Technology to Future Results

The three driver analysis illustrated the importance of reducing the greenhouse intensity of the economy to reducing overall greenhouse gas emissions. The other two drivers, population and economic growth, are generally not elements targeted for reduction under greenhouse gas reduction programs (indeed, by any federal program).

---

[29] This is particularly true if allowances are allocated to upstream entities at no cost. See Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (April 2007), p. 5.

The key factor in reducing the intensity driver over the long run is technology development. This is recognized in most greenhouse gas reduction bills, including S. 2191, with substantial funding, incentives, and price signals to encourage both accelerated deployment and the initiation of efforts to develop new generations of technology. **The effectiveness of these initiatives and price signals would be pivotal to the ultimate cost of any reduction strategy, particularly in the long term.** As stated by Houghton:

> Technology change is a particularly critical component of the climate change debate. For example, the cost of meeting stabilization levels is very sensitive to assumptions about future technologies. If assumed technology improvements lead to relatively low emissions, then it is relatively inexpensive to meet stabilization levels, and vice versa. Furthermore, technology research and development is a very significant policy instrument in the portfolio of options.[30]

Increasing Problems with Ceteris Paribus[31] Analysis

As was the case with analyses of the SO_2 cap-and-trade program, current studies of greenhouse gas reduction proposals assume that in the absence of new legislation EPA would take no action in this area between now and the year 2050, and no future initiatives would be enacted in related areas, such as energy policy. This seems unlikely. Indeed, the potential for a future requirement to reduce greenhouse gas emission may already be having an effect on decisions by industry and consumers. As noted by EIA:

> While forecasting policy change is beyond EIA's mandate, an argument can be made that, all else being equal, public and industry awareness of climate change as a major policy issue can potentially impact energy investment decisions even if no specific policy change actually occurs. Any adjustment to reflect the influence of climate change as an unresolved policy issue, while raising costs in the Reference Case, would generally reduce the estimated incremental impact resulting from the full implementation of a given policy response.[32]

Changing Baselines By Changing Laws. That the policy baseline for greenhouse gas emissions can be shifted significantly through new initiatives has already been illustrated by enactment of the 2007 Energy Independence and Security Act (EISA).

---

[30] John Houghton, "Introduction," *Energy Economics* 28 (2006), p. 535.

[31] From Latin, roughly meaning all else being held the same. In analysis, this refers to the practice of holding certain variables constant to isolate the effect of the variable being analyzed.

[32] Energy Information Administration, *Energy Market and Economic Impact of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008) p. viv.

On December 19, 2007, President Bush signed EISA (P.L. 110-140). EISA contains many energy provisions that could lead to reductions in greenhouse gas emissions, including,[33]

- more stringent fuel economy (CAFE) standards for passenger cars and light trucks;
- higher efficiency standards for appliances and lighting;
- higher efficiency requirements for government buildings; and
- research and development on renewable energy.

The American Council for an Energy-Efficient Economy estimates that the efficiency provisions in EISA will save roughly 700 million metric tons of carbon dioxide annually by 2030.[34] Most of this savings would come from tighter CAFE standards.

In addition to these indirect reductions, EISA also directly addresses climate change issues in several ways.

First, EISA expands the renewable fuel standard (RFS) established in P.L. 109-58. The EISA amendments to the RFS significantly expand the mandated level. Further, the new law requires that an increasing share of the RFS be met with "advanced biofuels," defined as having 50% lower lifecycle greenhouse gas emissions than petroleum fuels. Further, conventional biofuels from new refineries must have at least 20% lower lifecycle emissions. This is the first time that Congress has enacted national policy addressing the carbon content of motor fuels.

Second, Title VII of the new law focuses on research, development, and demonstration of technologies to capture and store carbon dioxide. DOE carbon storage R&D is expanded and is to include large-scale demonstration projects. The Department of the Interior must develop a methodology to assess the national potential for geologic and ecosystem storage of carbon dioxide, and must recommend a regulatory framework for managing geologic carbon sequestration on public lands.

In addition to the above programs, EISA also requires the establishment of an Office of Climate Change and Environment in the Department of Transportation (DOT). This office is to plan, coordinate, and implement research at DOT on reducing transportation-related energy use, mitigating the causes of climate change, and addressing the impacts of climate change on transportation.

The practical result of this is the necessary re-working of EIA's *AEO* 2008 baseline to reflect the energy and environmental impact of the new laws. More changes are likely over the 40-year time frame of S. 2191.

---

[33] For more information on EISA, see CRS Report RL34294, *Energy Independence and Security Act of 2007: A Summary of Major Provisions*.

[34] American Council for an Energy-Efficient Economy, *Energy Bill Savings Estimates as passed by the Senate* (December 14, 2007).

Changing Baselines By Changing Regulation.[35] The stringency of the SO_2 cap-and-trade is being changed by EPA's Clean Air Interstate Rule (CAIR). The baseline may also be influenced by future EPA initiatives not requiring new authority. The Clean Air Act is a powerful tool that could be used to regulate emissions of greenhouse gases from mobile sources of all kinds, their fuels (with the exception of jet fuel), and both large and small stationary sources. The possibility for regulation through existing Clean Air Act authority was recently outlined by EPA in congressional testimony.[36]

The key to such regulation is that the EPA Administrator issue appropriate findings on whether greenhouse gases "contribute to air pollution that is reasonably anticipated to endanger public health or welfare." It is difficult, bordering on impossible, to determine where such a finding would lead. The Administrator has substantial discretion in defining what emission limits should be set once he or she makes such a finding, and what sections of the act he or she might use. Greenhouse gases could be defined as criteria air pollutants, or not. They could be controlled in mobile sources of all kinds. They could be subject to New Source Performance Standards (NSPS), Prevention of Significant Deterioration (PSD), or Maximum Available Control Technology (MACT) requirements. Each of these has its own standard-setting process and criteria.

To some extent, the important question may be how an Administrator would define the source categories. If all power plants were considered in the same category, then the act's authority could be used to require the use of natural gas or cleaner fuels (or at least to set emission standards based on the emissions from plants using such fuels). If coal-fired plants were their own category or a technological approach were taken, the best technology could be carbon capture and storage (CCS). How the sources would be categorized would be at the discretion of the Administrator.

The Administrator would also get to make technical judgments concerning whether technologies were "available" or "achievable." These judgments could be crucial in determining how much technology-forcing the regulations would do.

Measuring the Noise: A Web of Cost Measures

Because of the economic complexities and interactions noted above, analysts have generally chosen to focus on estimating the macro-economic effects of proposals, such as GDP impacts. There are two components of macro-economic cost measures: (1) the direct abatement (or compliance) cost of a greenhouse gas reduction program, and (2) the general equilibrium effects of a greenhouse gas

---

[35] This section prepared by James McCarthy, Specialist in Environmental Policy.

[36] Robert J. Meyers, Principal Deputy Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Testimony before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives (April 10, 2008).

reduction program (i.e., the interactions of the direct abatement costs with the rest of the economy).

The most common measure presented is Gross Domestic Product (GDP). GDP measures the total value of goods and services produced within a nation's borders.[37] Although it is commonly used as a measure of quality of life, this application is problematic. Generally, it includes only those items for which there is a value defined in a market, and does not take into account some activities that have economic value, but no market valuation (e.g., leisure time, environmental quality, etc.). GDP is intended to be a measure of economic activity, not quality of life.

A second measure sometimes presented is consumption effects (sometimes called welfare effects). Unfortunately, the models do not measure consumption or welfare effects in a consistent fashion (the primary advantage of measuring GDP). For example, the MIT/EPPA analysis presents "welfare effects" in terms of changes in aggregate market consumption plus leisure. Measured as "equivalent variation," the change in welfare represents the amount of income needed to compensate for the change. In contrast, the EIA/NEMS model presents "real consumption impacts" in terms of consumer expenditures. This makes comparisons difficult and lessens the utility of the measure. For example, when analyzing proposed legislation, the "welfare effects" of legislation under the MIT/EPPA are usually less than the GDP effects, while the "real consumption impacts" under EIA/NEMS are usually greater than the GDP effects on a percentage basis. In addition, like GDP, none of the definitions of consumption or welfare currently employed quantify any environmental effects.

A third measure generally presented is allowance prices. These generally reflect to some degree the aggregate marginal cost of the program as estimated by the models. Marginal cost is the cost of reducing the last ton (and, therefore, the most expensive) of greenhouse gases required by the program at a specific point in time. Marginal costs are very useful to affected entities in choosing what reduction strategy would be the most cost-effective in achieving their assigned reduction requirement. They are not an average cost and therefore cannot be simply multiplied by the greenhouse gases reduced to estimate total compliance cost. They also need to be put into the context of the overall reduction achieved at the given point and time being examined.

However, allowance prices in most analyses are actually different from marginal costs because of program provisions, such as banking. Banking activity reflects the assumed foresight of affected entities to the likelihood of increasing allowance prices (in real terms) as the cap tightens. As indicated by the experience with the SO_2 program, entities will bank substantial allowances early and use them later as the program's requirements tighten. This results in allowance prices being higher than marginal costs in the early years of the program, and lower in later years. For

---

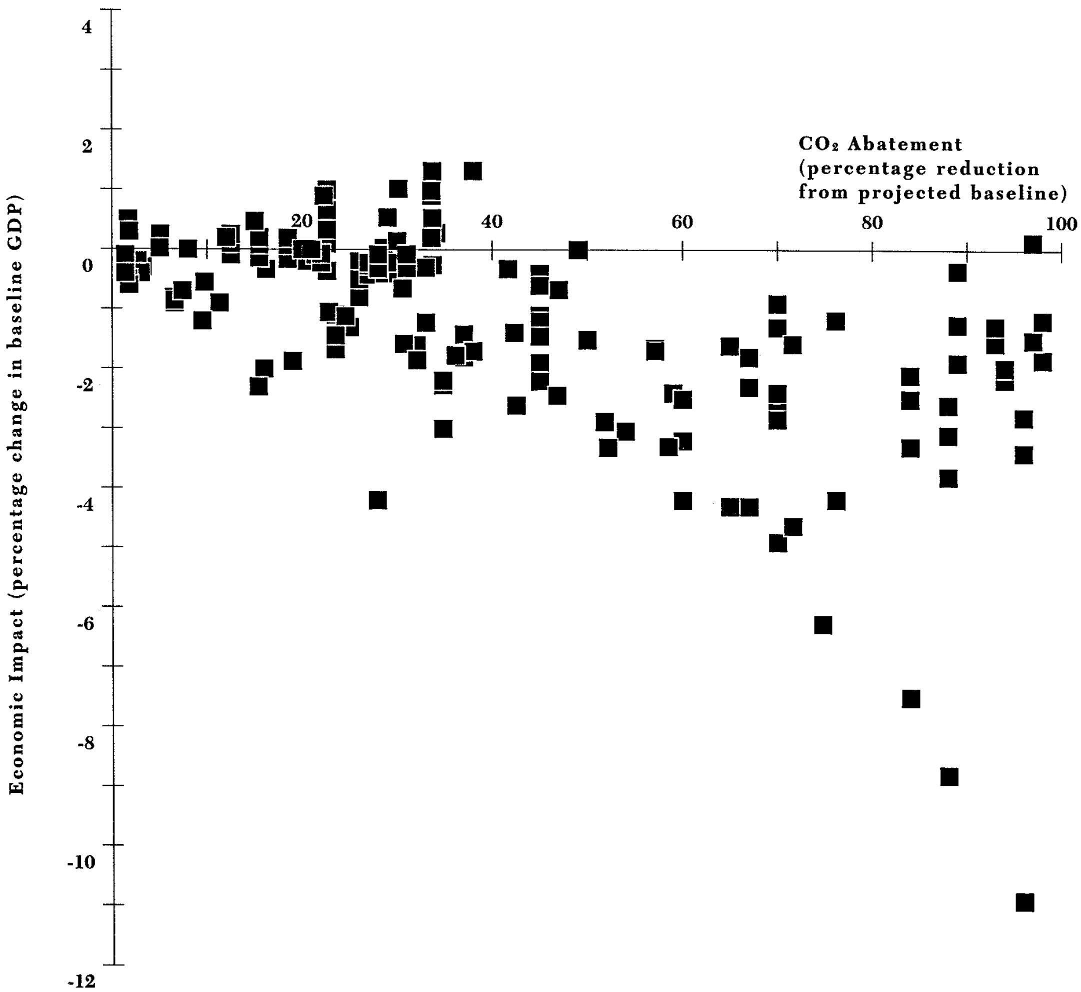
[37] It has four basic components: private consumption (including most personal expenditures of households); investments by business and households in capital (including new house purchases); government expenditures on goods and services (but not transfer payments, such as Social Security); and net imports.

example, the NMA/CRA International analysis of S. 2191 has a 2050 allowance price of about $352 under "no banking" assumptions, but an allowance price of about $195 with banking. In contrast, 2015 allowance prices are estimated at $51 for the "banking" scenario, but only $38 under the no banking scenario.[38] This ability to time-shift reduction requirements and compliance costs means that allowance price projections reflect the assumed foresight of affected entities as much as they do actual marginal costs.

In presenting cost measures, most analyses over-emphasize aggregate welfare indicators, such as GDP. As illustrated above, aggregate, macroeconomic cost results for S. 2191 fall into the noise of uncertainty about future conditions. In addition, aggregate macroeconomic measures reduce the transparency of the analyses' compliance strategies, and as a result, make them easier to dismiss. For example, **Figure 1** below shows a **1997** scatter-plot by World Resources Institute (WRI) of 162 predicted impacts estimates from 16 different economic models of the U.S. economy as a result of a CO_2 abatement program. As indicated, the vast majority of estimates fall with a range of 0%-4% of GDP, regardless of the reduction requirement. **Over-emphasis on GDP or other aggregate cost measures can obscure fundamental technological, economic, or behavioral insights the analyses may have in helping policymakers craft legislation. Instead, the analysis becomes a "black box" exercise with little enlightenment function.**

[38] W. David Montgomery and Anne E. Smith, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model*, CRA International (April 8, 2008) p. 18. Prices are in 2007$.

Figure 1. Predicted Impacts of Carbon Abatement on the U.S. Economy (162 Estimates from 16 Models)



Source: Robert Repetto and Duncan Austin, *The Costs of Climate Protection: A Guide for the Perplexed,* World Resources Institute, 1997.

This "fog" is inherent when analysts choose to include the general equilibrium effects of a program in their cost measure — a fog that can limit the explanatory value of the analysis. While supporting use of aggregate welfare cost measures, MIT notes:

> GE [general equilibrium] effects can stem from interactions with pre-existing distortions (e.g., taxes), from externally induced terms-of-trade effects, from the fact that the domestic policy itself creates terms-of-trade effects, and from other rigidities in the economy. Many aspects of model structure produce GE effects that are not easy to separately measure because of the inherent interactions in the economy.[39]

Generally, the cases examined here have not chosen to separate the two components of macro-economic cost measures: (1) the direct abatement (or compliance) cost of a greenhouse gas reduction program, and (2) the general equilibrium effects of a greenhouse gas reduction program (i.e., the interactions of the direct abatement costs with the rest of the economy).[40] The availability of compliance cost estimates would allow policymakers to put current greenhouse gas reduction proposals in the context of other environmental initiatives — be they acid rain or toxic air pollutants — and, indeed, to the overall environmental agenda, and greatly increase the transparency of the analyses' insights. It would also help relieve confusion between compliance costs, average costs (per ton reduced), and the other commonly presented costs, such as allowance prices.[41] It is argued that an aggregate macroeconomic cost measure provides a more complete view of the economic impact of proposed legislation, and helps identity potential unintended economic effects of compliance strategies. This may be true, particularly if, for example, auction revenues are being recycled via a reformed tax code. **However, as indicated here, aggregated macroeconomic cost measures, such as GDP, can also be interpreted to merely show that the United States has a massive economy that can absorb substantial shocks with limited long-term effect.**

Three Perspectives: Getting out of the Noise

Breaking through the fog of analyses and cost indicators, cost estimates to reduce CO_2 emissions vary greatly and focus attention on an estimator's basic beliefs about the problem and the future, in addition to simple, technical differences in economic assumptions. In a previous report, CRS identified three "lenses" through which people can view the global climate change issues, and their influence on cost

---

[39] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (April 2007), p. 27.

[40] The compliance cost estimates provided by EPA in its analyses are flawed. As noted by EPA, they are overestimates of actual costs. Worse, the overestimation increases as the tonnage reduction requirement and marginal costs increase. NMA/CRA provides an estimate of the net present value of S. 2191's total costs.

[41] For a good discussion of the confusion that can arise from mixing cost measures, see Anne E. Smith, Jeremy Platt, and A. Denny Ellerman, "The Cost of Reducing SO_2 (It's Higher Than You Think)," *Public Utilities Fortnightly* (May 15, 1998), pp. 22-29.

analysis.[42] These are summarized in **Table 6**. None of these perspectives is inherently more "right" or "correct" than another; rather, they overlap and to varying degrees complement and conflict with one another. People generally hold to each of the lenses to some degree.

Table 6. Influence of Climate Change Perspectives on Policy Parameters

Approach	Seriousness of problem	Risk in developing mitigation program	Costs
Technology	Is agnostic on the merits of the problem. The focus is on developing new technology that can be justified from multiple criteria, including economic, environmental, and social perspectives.	Believes any reduction program should be designed to maximize opportunities for new technology. Risk lies in not developing technology by the appropriate time. Focus on research, development, and demonstration; and on removing barriers to commercialization of new technology.	Viewed from the bottom-up. Tends to see significant energy inefficiencies in the current economic system that currently available (or projected) technologies can eliminate at little or no overall cost to the economy.
Economic	Understands issue in terms of quantifiable cost-benefit analysis. Generally assumes the status quo is the baseline from which costs and benefits are measured. Unquantifiable uncertainty tends to be ignored.	Believes that economic costs should be examined against economic benefits in determining any specific reduction program. Risk lies in imposing costs in excess of benefits. Any chosen reduction goal should be implemented through economic measures such as tradeable permits or emission taxes.	Viewed from the top-down. Tends to see a gradual improvement in energy efficiency in the economy, but significant costs (usually quantified in terms of GDP loss) resulting from global climate change control programs. Typical loss estimates range from 0-4% of GDP.
Ecological	Understands issues in terms of their potential threat to basic values, including ecological viability and the well-being of future generations. Such values reflect ecological and ethical considerations; adherents see attempts to convert them into commodities to be bought and sold as trivializing the issue.	Rather than economic costs and benefits or technological opportunity, effective protection of the planet's ecosystems should be the primary criterion in determining the specifics of any reduction program. Focus of program should be on altering values and broadening consumer choices.	Views costs from an ethical perspective in terms of the ecological values that global climate change threatens. Believes that values such as intergenerational equity should not be considered commodities to be bought, sold, or discounted. Costs are defined broadly to include aesthetic and environmental values that economic analysis cannot readily quantify and monetize.

---

[42] CRS Report 98-738, *Global Climate Change: Three Policy Perspectives*, by Larry Parker and John Blodgett. (Available from the authors.)

However, different combinations of these perspectives lead to very different cost estimates. A classic example of this is the contrast between the S. 2191 results obtained by the Clean Air Task Force (CATF) and the American Council for Capital Formation/National Association of Manufacturers (ACCF/NAM) using the same model: EIA's NEMS model. **Table 7** summarizes the general approach of the two analyses according to the three perspectives identified above. In its analysis, CATF expresses confidence in S. 2191's various technology and efficiency provisions and models the bill assuming EIA's Best Available Technology (BAT) case, banking, and offsets. In contrast, ACCF/NAM states that it is "unlikely" that technology, new energy sources, and market mechanisms (e.g., carbon offsets, banking) will be sufficiently available to achieve S. 2191's emission targets. Accordingly, ACCF/NAM's assumptions differ substantially from CATF's and other studies by excluding banking, significantly capping the availability of various technologies, and assuming higher construction costs.

Table 7. General Perspective of CATF and ACCF/NAM Cost Assumptions

	CATF	ACCF/NAM-Low	ACCF/NAM-High
Technology	Assumes no constraints on technology availability beyond those embedded in NEMS	Assumes significant constraints on technology availability and higher costs than those embedded in NEMS	Assumes substantial constraints on technology availability and higher costs than those embedded in NEMS
Economic	Assumes efficient decision-making via banking and offsets (30%) as allowed in S. 2191	Assumes short-term decision-making with no banking; amount of offsets allowed "greater than 20%"	Assumes short-term decision-making with no banking; offsets constrained to 15%-20%
Ecological	Assumes decisions made in favor of efficiency over price because of S. 2191 incentives and regulations	None — total GHG emissions reduction estimates not presented	None — total GHG emissions reduction estimated not presented

Source: CRS analysis of: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008); Science Applications International Corporation, *Analysis of The Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, a report by the American Council for Capital Formation and the National Association of Manufacturers (2008).

As indicated by **Table 8**, the widely different cost assumptions provided the expected results, although all three analyses remained in the 0-4% GDP range common for greenhouse gas reduction analysis. Allowance price estimates are widely different, but this cost measure tends to exaggerate differences between results and should not be confused with average costs or program costs. This is particularly true in this case, as ACCF/NAM did not publish its environmental results in terms of greenhouse gases reduced; thus, one can not compare the allowance price with what is being reduced over time. Unfortunately, the analyses do not present sufficient sensitivity analysis and other information to determine whether it is the economic assumptions (e.g., banking and offset availability), the behavioral assumptions (e.g., BAT), the technology assumptions (e.g., availability), or just the higher cost assumptions of the ACCF/NAM analysis that explains the difference in allowance prices.

Table 8. Selected Results from CATF and ACCF/NAM Analyses

	CATF	ACCF/NAM-Low	ACCF/NAM-High
GDP per capita Reduction 2020[a]	not discernable from graph	0.8%	1.1%
GDP per capita Reduction 2030[a]	0.9%	2.6%	2.7%
Allowance Price 2020 (2005$)	about $21	$52	$61
Allowance Price 2030 (2005$)	about $45	$216	$258
Greenhouse Gas Emissions 2020 (MMTCO2e)	about 5.5 (not including set-asides)	not published	not published
Greenhouse Gas Emissions 2030 (MMTCO2e)	about 5.4 (not including set-asides)	not published	not published

Source: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008); Science Applications International Corporation, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, a report by the American Council for Capital Formation and the National Association of Manufacturers (2008). All estimates converted to 2005 dollars using the GDP implicit price deflator.

a. Reduction is relative to the model's reference case baseline for 2020 and 2030.

Some attempts have been made to sort out the importance of various assumptions in analyzing the costs of greenhouse gas reduction proposals, beginning with Repetto and Austin's effort for the World Resources Institute (WRI) in 1997, with more recent efforts by Barker, Qureshi and Kohler in 2006 and Barker and

Jenkins in 2007.[43] Indeed, Dr. Repetto has set up a website where people may answer seven key questions about the cost and benefit assumptions they feel are most reasonable and find out how their choices would affect GDP.[44] Through meta-analysis of the results from multiple independent studies, the role of various assumptions and methodologies are quantified.[45] In general, these studies found seven underlying assumptions affecting results: (1) the efficiency of the economic response;[46] (2) availability of non-carbon technology;[47] (3) availability of the Kyoto mechanisms;[48] (4) method of revenue recycling; (5) method of incorporating technological advancements; (6) inclusion of non-climate-related environmental benefits; and (7) inclusion of climate-related benefits. **As none of the models reviewed in this report quantify any environmental benefits in their analyses, all models' results can be considered "worst-case" scenarios.**

Results for S. 2191

Impact on Greenhouse Gas Emissions

Figures 2 and 3 present greenhouse gas emissions under S. 2191 as estimated by the ten cases, relative to their baseline assumptions. The range might seem surprising, given the emission cap defined in the bill. The cause of the range is largely two-fold: (1) estimated emissions growth in the 10%-15% of the economy not covered under the bill, (2) estimated use of international credits to meet emission reduction requirements that do not reduce domestic emissions.

---

[43] Robert Repetto and Duncan Austin, *The Costs of Climate Protection: A Guide for the Perplexed*, World Resources Institute (1997); Terry Barker, Mahvash Saeed Qureshi, and Jonathan Kohler, *The Costs of Greenhouse Gas Mitigation with Induced Technological Change: A Meta-Analysis of Estimates in the Literature*, Tyndall Centre for Climate Change Research (July 2006); and Terry Barker and Katie Jenkins, *The Costs of Avoiding Dangerous Climate Change: Estimates Derived from a Meta-Analysis of the Literature*, A Briefing Paper for the Human Development Report 2007 (May 2007).

[44] [http://www.climate.yale.edu/seeforyourself/].

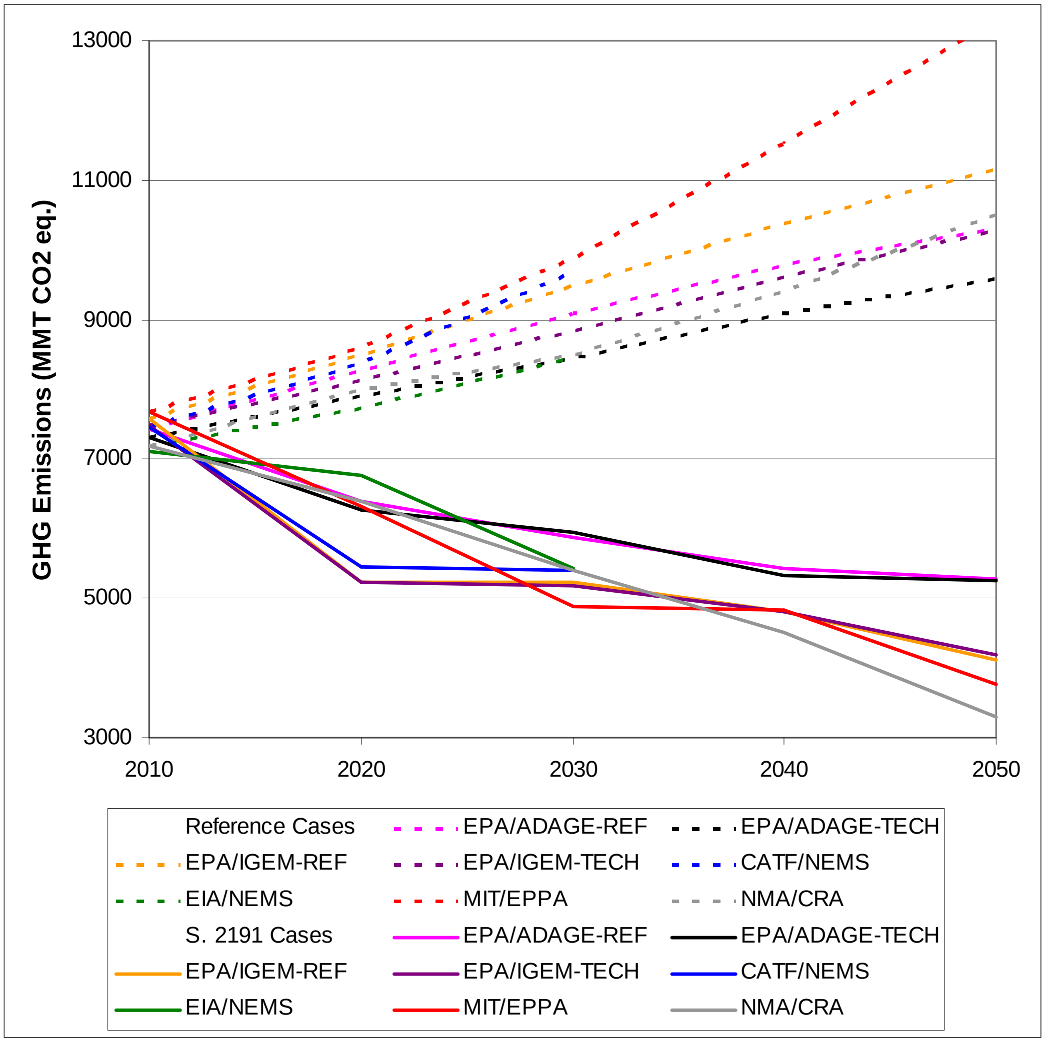
[45] As defined by Repetto on the "See For Yourself" website: "The meta-analysis was based on more than 1,400 policy simulations performed with the various models. It used statistical regression analysis to ascribe differences among models in the predicted economic cost of a given percentage reduction of greenhouse gas emissions to differences among models in specific assumptions. Though some of the models related only to the U.S. economy, others to the world economy, the meta-analysis found that both sets of models produced the same results."

[46] In this regard, Computable General Equilibrium Models (CGE) generally assume efficient economic responses to programs while macroeconomic models allow time for the economy to adjust, resulting in higher short-term costs.

[47] Some models include a "backstop" technology in unlimited amounts at a specified high price.

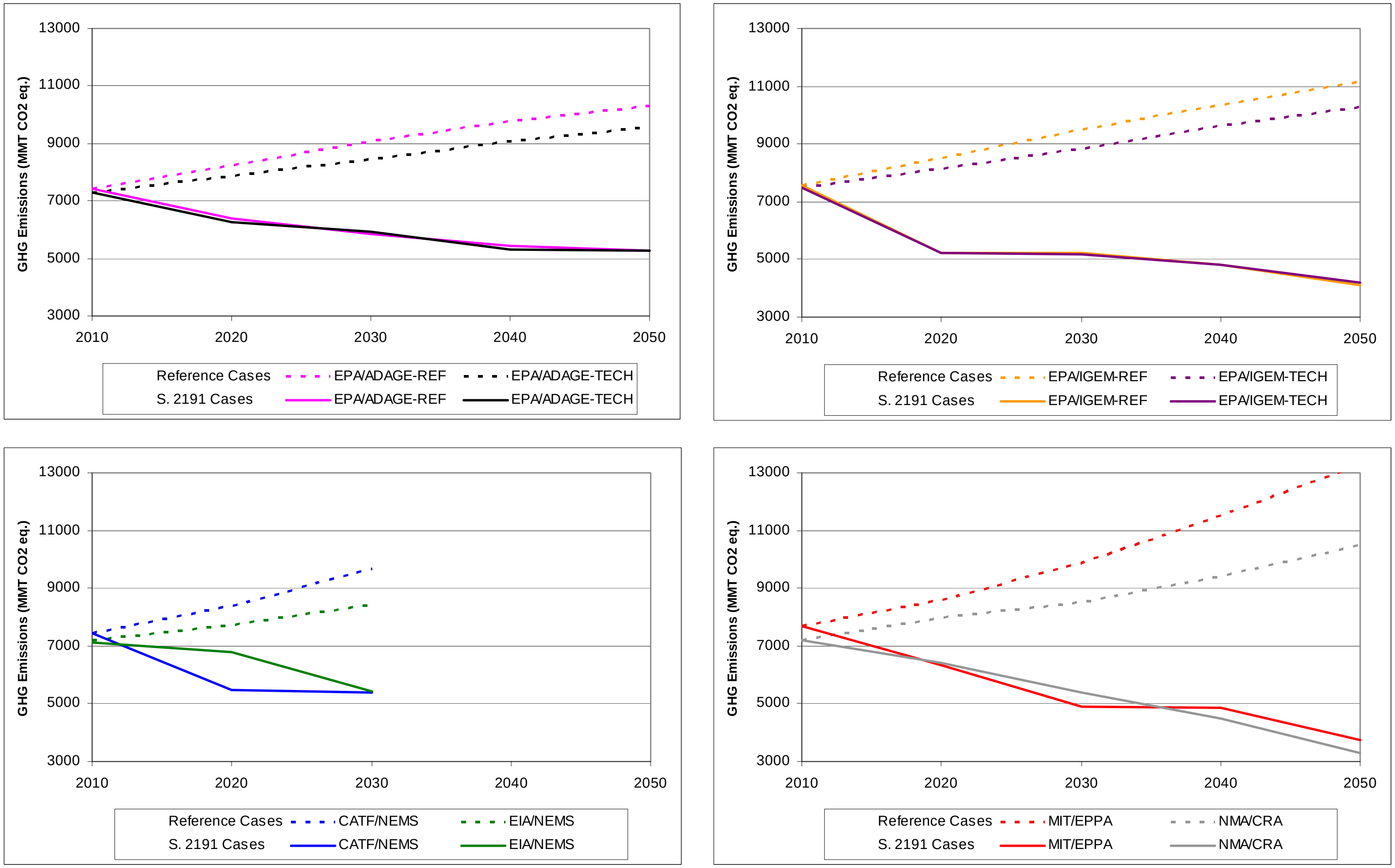
[48] Credits from the Clean Development Mechanism (CDM) and Joint Implementation (JI).

Figure 2. Total Estimated Greenhouse Gas Emissions Under S. 2191



Sources for Figures 2 and 3: EPA/ADAGE and EPA/IGEM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAM/NEMS: SAIC, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, report by the ACC. and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). Estimates extrapolated by CRS from available data where necessary.

Figure 3. Total Estimated Greenhouse Gas Emissions From Each Model Under S. 2191



The most stringent interpretation of S. 2191's emissions cap is by NMA/CRA. The resulting emissions estimates could be attributed to three factors: (1) NMA/CRA does not allow any international credits to be used to achieve reductions, (2) NMA/CRA uses the preliminary *AEO 2008* baseline, which may project lower emissions growth by non-covered sectors because of EISA or other factors; and (3) NMA/CRA also analyzes the effect of the bill's proposed Low Carbon Fuel Standard, which reduces emissions further, as discussed later.

The highest emissions permitted under the bill are estimated by the two EPA/ADAGE cases. This higher emissions level is probably the result of the substantial use of international credits and percentage of uncovered entities assumed by ADAGE.

Interestingly, the two ACCF/NAM/NEMS cases do not present any estimates of their total greenhouse gas emissions baseline, or the reduction calculated by their analysis. The closest they come to presenting emissions reductions is a chart with assumed increases in energy-related CO_2 emissions and their interpretation of the reductions S. 2191 would require on the energy sector.

Impact on Non-Greenhouse Gas Emissions

The only estimates of non-greenhouse gas emission reductions under S. 2191 are provided by EPA/IPM. Those projections are for the electric power sector only, assume implementation of the Clean Air Interstate Rule (CAIR) rule (currently in litigation), and only go to 2025. The projections also reflect the interaction of CO_2 reductions with the banking provisions of the Acid Rain and CAIR rules. This interaction results in the short-term changes (to 2015) in emissions being overstated. As indicated in **Table 9** below, one-third of the SO_2 reductions and one-sixth of the NO_x reductions are achieved in the last year of the projection. EPA/IPM also projected mercury emissions reductions; however, they were done in the context of the now-vacated mercury rule.[49] This eliminated their utility for this analysis.

Table 9. EPA/IPM Reduction of Conventional Air Pollutants from Electric Utilities

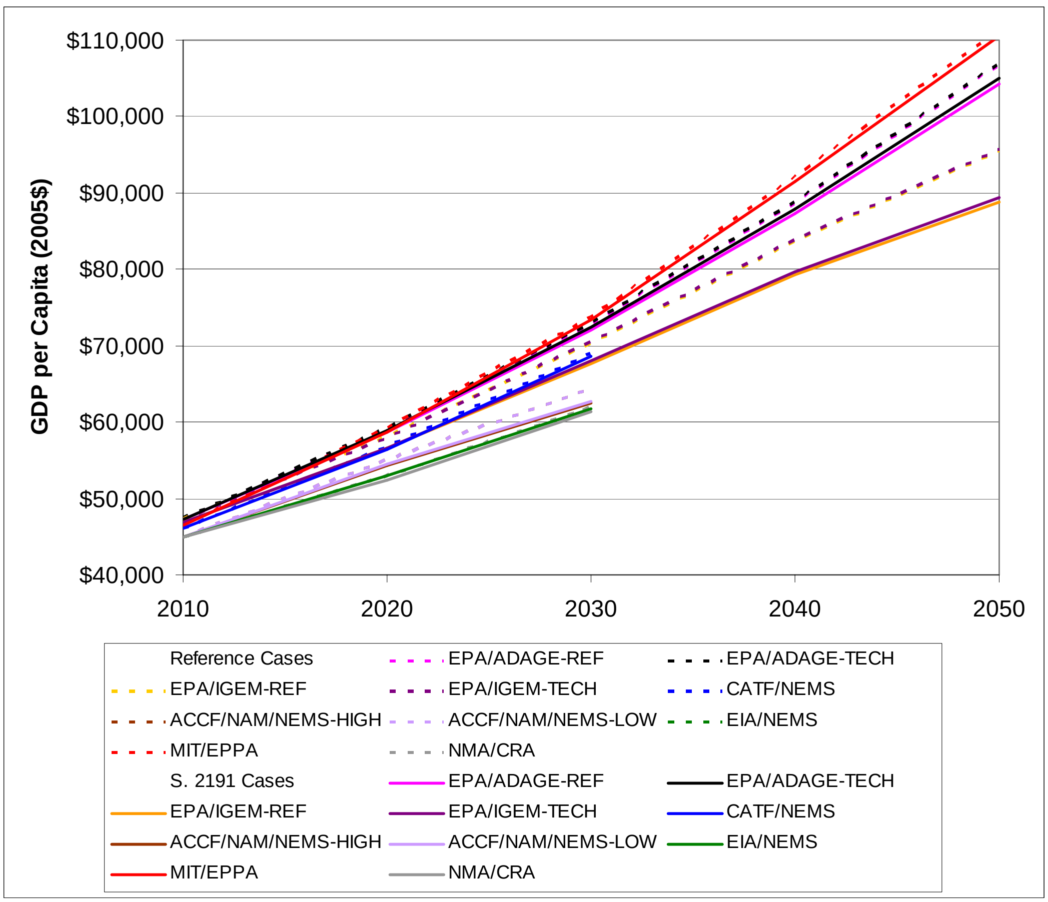
	S. 2191 Reduction from Reference Case: 2025 (short tons)	Cumulative Reduction from Reference Case 2010-2025 (short tons)
Sulfur Dioxide	1,064,000	3,000,000
Nitrogen Oxides	848,000	4,900,000

[49] For more information on the court decision, see CRS Report RS22817, *The D.C. Circuit Rejects EPA's Mercury Rules: New Jersey v. EPA*, by Robert Meltz and James E. McCarthy.

Impact on GDP Per Capita

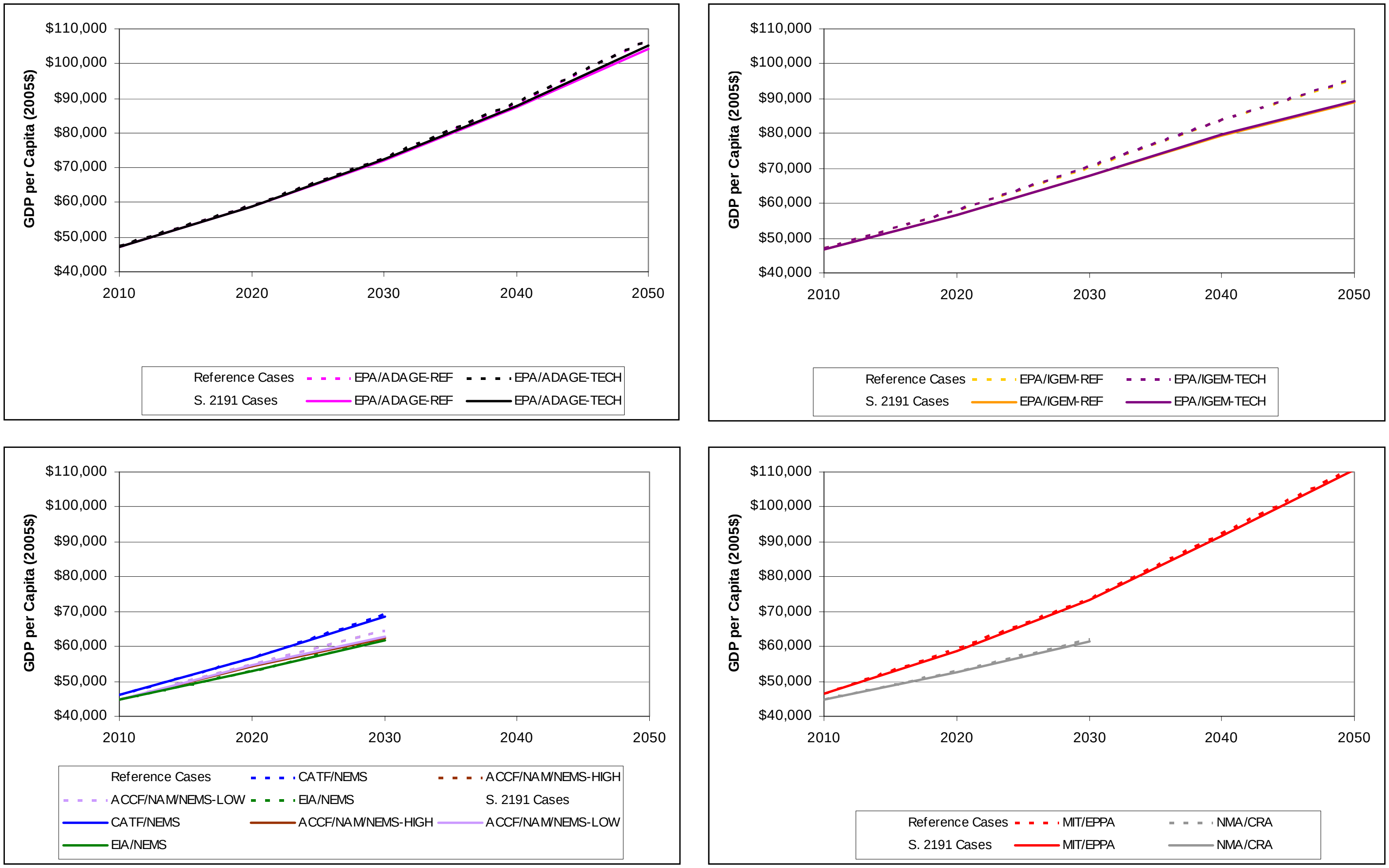
Figures 4 and 5 present the estimated GDP per capita in the baseline and S. 2191 scenarios for the various cases. As suggested by the discussion of "noise" earlier, uncertainty about the basecase assumptions absorbs the impact of S. 2191. Indeed, they are so intertwined as to make the results nearly meaningless in one sense. In another sense, the figures indicate the models' expectations that the economy continues to growth under S. 2191, albeit at a slower rate than under their respective reference cases.

Figure 4. GDP per Capita (2005$) Under S. 2191



Sources for Figures 4 and 5: EPA/ADAGE and EPA/IGEM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAM/NEMS: SAIC, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using The National Energy Modeling System (NEMS)*, report by the ACC. and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). Estimates extrapolated by CRS from available data where necessary. Estimates converted to 2005$ using GDP implicit price deflator.

Figure 5. GDP per Capita (2005$) from Each Model Under S. 2191



To sort the situation out a little further, **Figures 6 and 7** show percentage reductions in GDP per capita from S. 2191 (relative to the models' respective reference cases) according to the ten cases presented here. With the exception of the IGEM model, all projections for all years between 2020 and 2050 fell into a range between 0.3% (EIA/NEMS for 2020 and 2030) and 2.7% (ACCF/NAM-HIGH for 2030). As indicated in **Figures 6 and 7**, the EPA/IGEM cases produced 2050 estimates that were more than twice those of the other models.

The high estimates for GDP per capita reduction by the EPA-IGEM cases result from its structure and assumptions contained in the model. For example, the assumption about the relationship between leisure and consumption in IGEM is quite different from the other models. Essentially, as prices for goods and services increase, IGEM assumes a highly responsive relationship, with people deciding to work less and buy less. As a result, a small increase in prices will produce a relatively large loss of consumption, resulting in a larger impact on GDP and other cost measures. In contrast, other models are less responsive, assuming people will absorb higher prices without changing their work or consumption habits very much.[50] Other factors influencing IGEM's results include (1) a somewhat higher emissions baseline, (2) the lack of some less carbon-emitting technological alternatives, such as carbon capture and storage, (3) a U.S.-only context that affects the model's estimates of exports, and (4) elasticities that are calibrated based on historical data.

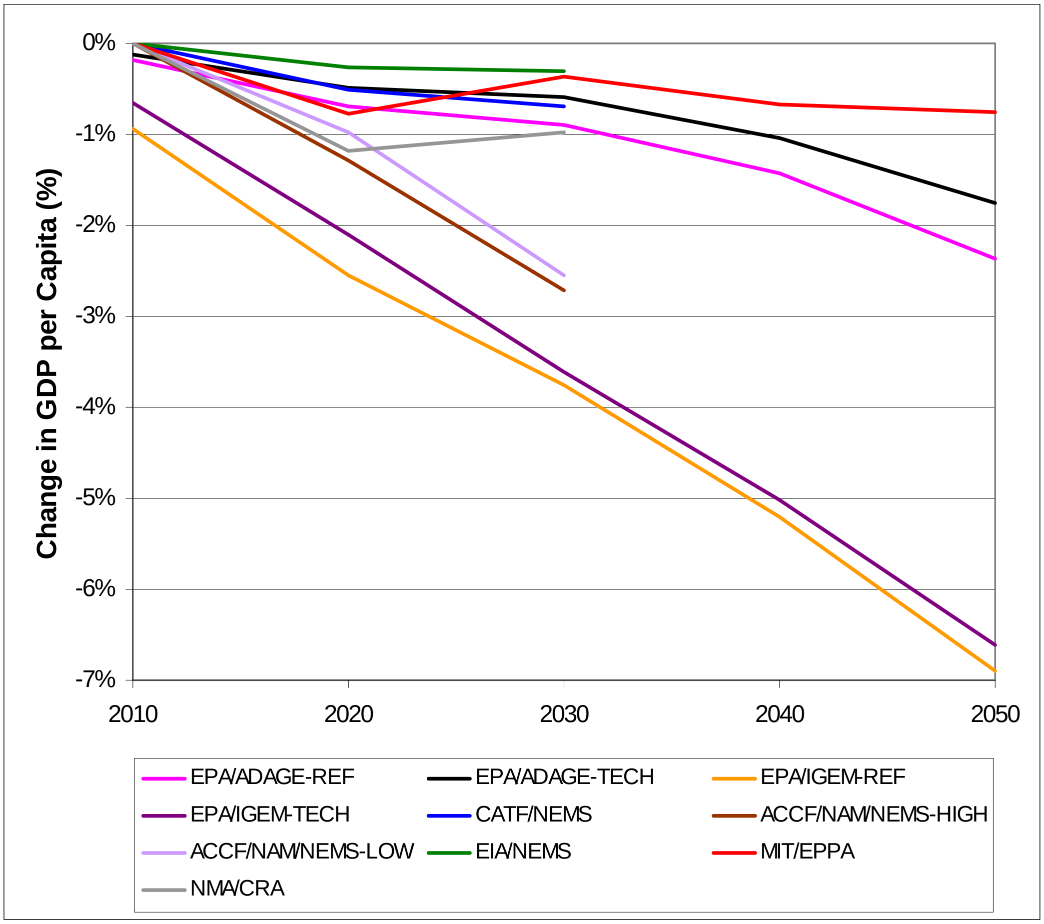
The only year for which GDP per capita estimates were presented for all cases is 2030.[51] Once again, the estimates from the IGEM model are substantially higher (3.6% and 3.8%) than the seven other cases for reasons noted above. The other cases fall into two categories. The largest category is six cases that estimate 2030 GDP effect at about 1% or less. These cases are: EPA/ADAGE-REF, EPA/ADAGE-TECH, CATF/NEMS, EIA/NEMS, MIT/EPPA, and NMA/CRA. The other category is the two ACCF/NAM/NEMS cases where the GDP effect is 2.6% and 2.7% in 2030. Thus, despite their restrictive assumptions, the ACCF/NAM/NEMS cases do not exceed the 0-4% range of GDP effects common to reduction programs.

---

[50] See Janet Peace and John Weyant, *Insights Not Numbers: The Appropriate Use of Economic Models*, Pew Center on Global Climate Change (April, 2008), pp. 18-19. This is an additional warning to readers about understanding the assumptions and limitations of models. As stated later by Peace and Weyant: "The sensitivity of modeling results to a single assumption — in this case, the elasticity of substitution between consumption and leisure — also serves to illustrate that important differences between models are not always obvious. Most casual users would never dive deep enough into model documentation to ascertain that IGEM and ADAGE utilize a different assumption about the tradeoff between consumption and leisure. For this reason, it is very important that model developers (a) make transparent their assumptions and inputs (as Jorgenson, Goettle, and Poss do) and (b) to the extent possible, characterize principal sources of uncertainty in the model design and identify limitations that influence model results." p. 20

[51] For the 2010 and 2020 estimates presented in Figures 4 and 5, CRS extrapolated the data for some of the presentations.

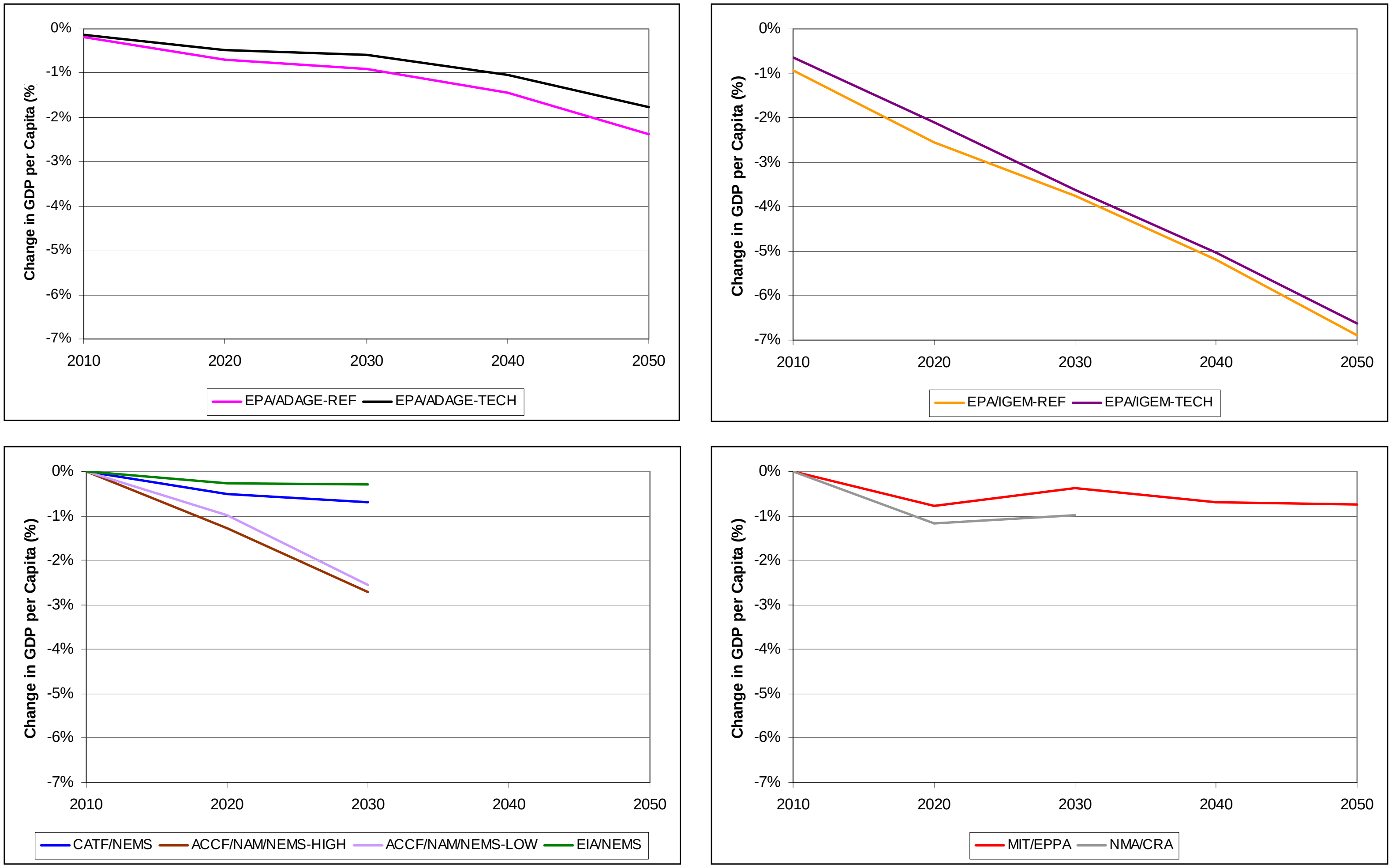
Figure 6. Percentage Change in GDP per Capita Under S. 2191



Note: Reductions are relative to each model's reference case baseline.

Sources for Figures 6 and 7: EPA/ADAGE and EPA/IGEM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS:.Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAM/NEMS: SAIC, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using The National Energy Modeling System (NEMS)*, report by the ACC. and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). Estimates extrapolated by CRS from available data where necessary. Estimates converted to 2005$ using GDP implicit price deflator.

Figure 7. Percentage Change in GDP per Capita from Each Model Under S. 2191



Allowance Price Estimates

Figures 8 and 9 present the estimated allowance prices for each of the ten cases examined here. In addition, we have included the Congressional Budget Office's estimates used in scoring S. 2191.[52] It is clear from the figures that the banking assumption of the different cases has a fundamental influence on projected prices. For example, as noted earlier, the ACCF/NAM/NEMS cases do not include banking — an expressed decision by ACCF/NAM and not an inherent part of the NEMS model as evident by the CATF/NEMS and EIA/NEMS cases. This assumption has a clear effect on the trajectory of their allowance prices. In contrast, the ADAGE, IGEM, MRN-NEEM, and EPPA models assume discount rates that tend to encourage banking.[53] As noted earlier, banking tends to increase allowance prices in the early years of the program and lower them in the out-years. This flattening effect results in the gentler slope of the allowance price curves evident in **Figures 8 and 9** below for these cases.

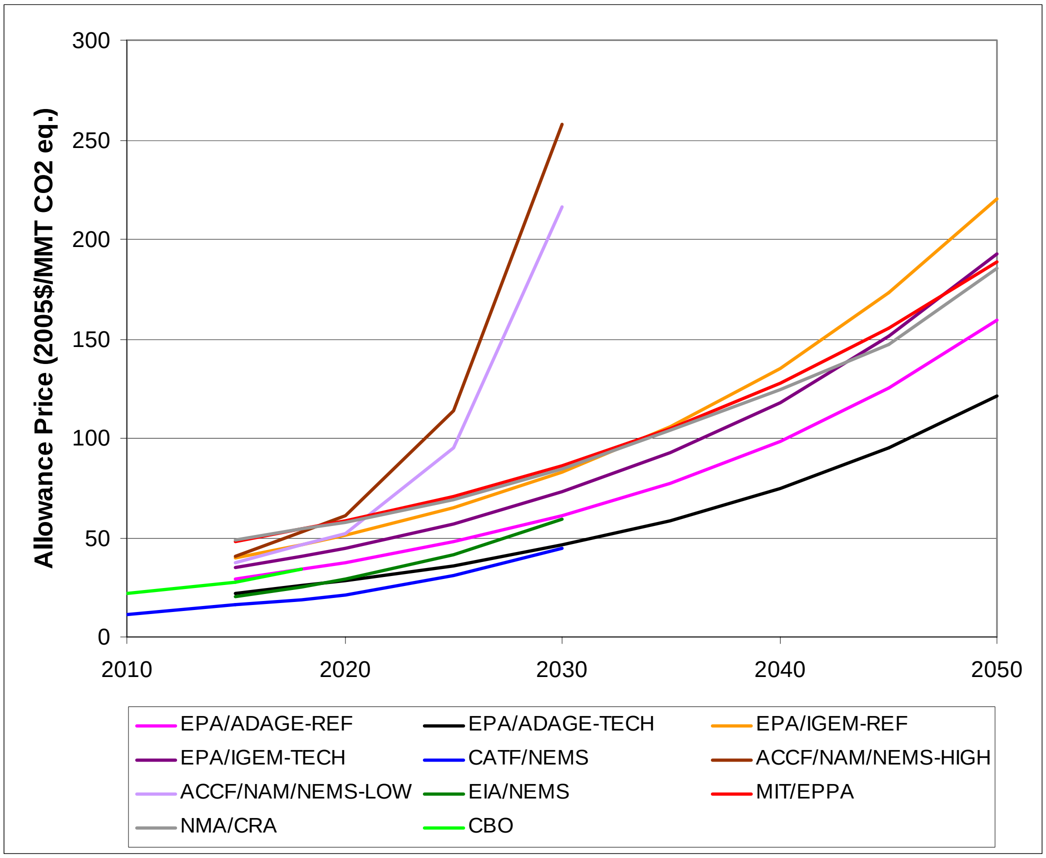
Of the 2030 estimates for the eight cases that include S. 2191's banking provision, four cases project allowance prices in the range of $45-$61 (CATF/NEMS, EIA/NEMS, and the two EPA/ADAGE cases) while the other four cases project allowance prices in the $73-$86 range (MIT/EPPA, NMA/CRA, and the two EPA/IGEM cases). The spread of allowance price estimates expands after 2030, as evident in the figures.

---

[52] Congressional Budget Office. *Cost Estimate: S. 2191: America's Climate Security Act of 2007* (April 10, 2008).

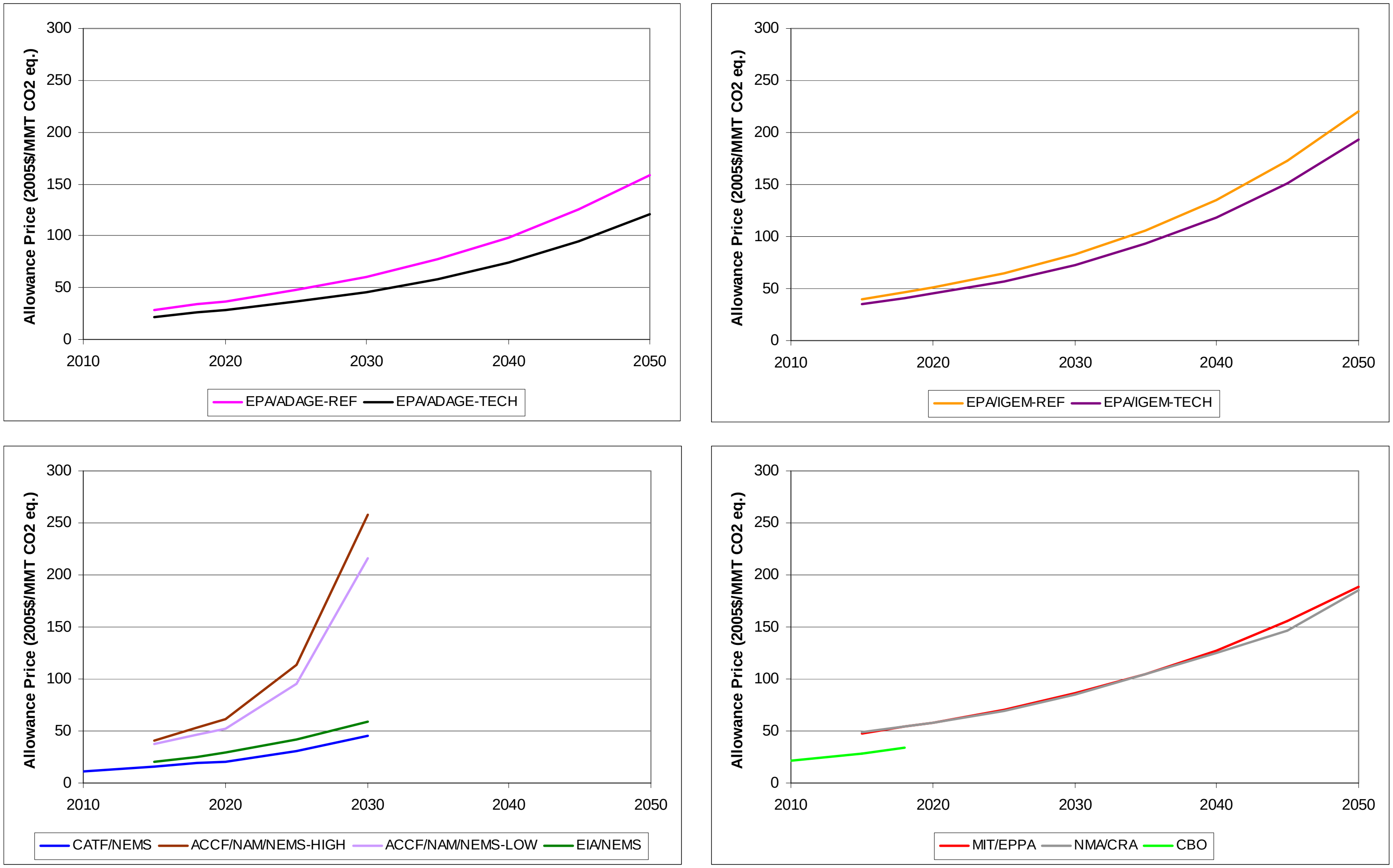
[53] For a discussion of the models' banking assumptions, see Congressional Budget Office, *Cost Estimate: S. 2191: America's Climate Security Act of 2007* (April 10, 2008), pp. 21-23.

Figure 8. Projected Allowance Prices Under S. 2191



Sources for Figures 8 and 9: EPA/ADAGE and EPA/IGEM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAMS/NEMS: SAIC, *Analysis of The Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, report by the ACCF and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). CBO: Congressional Budget Office, *Cost Estimate: S. 2191: America's Climate Security Act of 2007* (April 10, 2008). Estimates extrapolated by CRS from available data where necessary. Estimates converted to 2005$ using GDP implicit price deflator.

Figure 9. Projected Allowance Prices from Each Model Under S. 2191



Auction Revenue Estimates

None of the analyses examined were conducted after the proposed deficit reduction amendment was announced April 10, 2008.[54] Therefore, CRS has provided the following estimates based on two cases: a "high" revenue case based on the MIT/EPPA study, and a "low" revenue case based on the EPA/ADAGE-TECH case (**Figure 10**). In each case, the auction revenue estimates are calculated by multiplying the estimated allowance price in a given year by the number of allowances auctioned by the program for deficit reduction ("Deficit Reduction Fund") and the number of "remainder allowances" allocated for auction ("General Auction"). As the number of allowances for auction in a given year is set by the bill, the total auction revenue for that year becomes a function of the allowance price. A higher allowance price will lead to higher auction revenue. As shown in **Figure 10**, using the lower allowance prices in the EPA/ADAGE-TECH case, total auction revenues start in the tens of billions of dollars (2005$) and increase to over $100 billion before 2030. Using higher allowances prices, such as the MIT/EPPA case, total auction revenues exceed $100 billion before 2020. In comparison, currently the federal government spends roughly $5 billion annually for the Climate Change Science Program, the Climate Change Technology Program, and International Climate Change Assistance, combined.[55]

As indicated in **Table 10**, after the firefighting, deficit reduction, administration expenses, and other funds have been allocated, a substantial amount of auction revenue would remain available annually for technology deployment even in the low revenue EPA/ADAGE-TECH case. For example, the Advanced Technology Vehicles Manufacturing Incentive Program (Sec. 4405) would provide grants to automakers and parts manufacturers to develop the capacity to build plug-in hybrid and other advanced vehicles (and parts). Funds could be used for engineering integration of vehicles and retooling old plants to produce advanced vehicles. Using the lower allowance prices in the EPA/ADAGE-TECH case, this program would provide over $1 billion (2005$) annually in 2012, increasing to more than $7 billion by 2040. In comparison, DOE currently spends between $200 million and $400 million for advanced vehicle and hydrogen fuel R&D.[56] As noted in the next section, the effectiveness of these funds in accelerating technology development and commercialization — as well as agencies' and firms' capacity to absorb (in some cases) very large funding increases — could have a significant effect on the overall costs of S. 2191 and the ultimate success of the program.

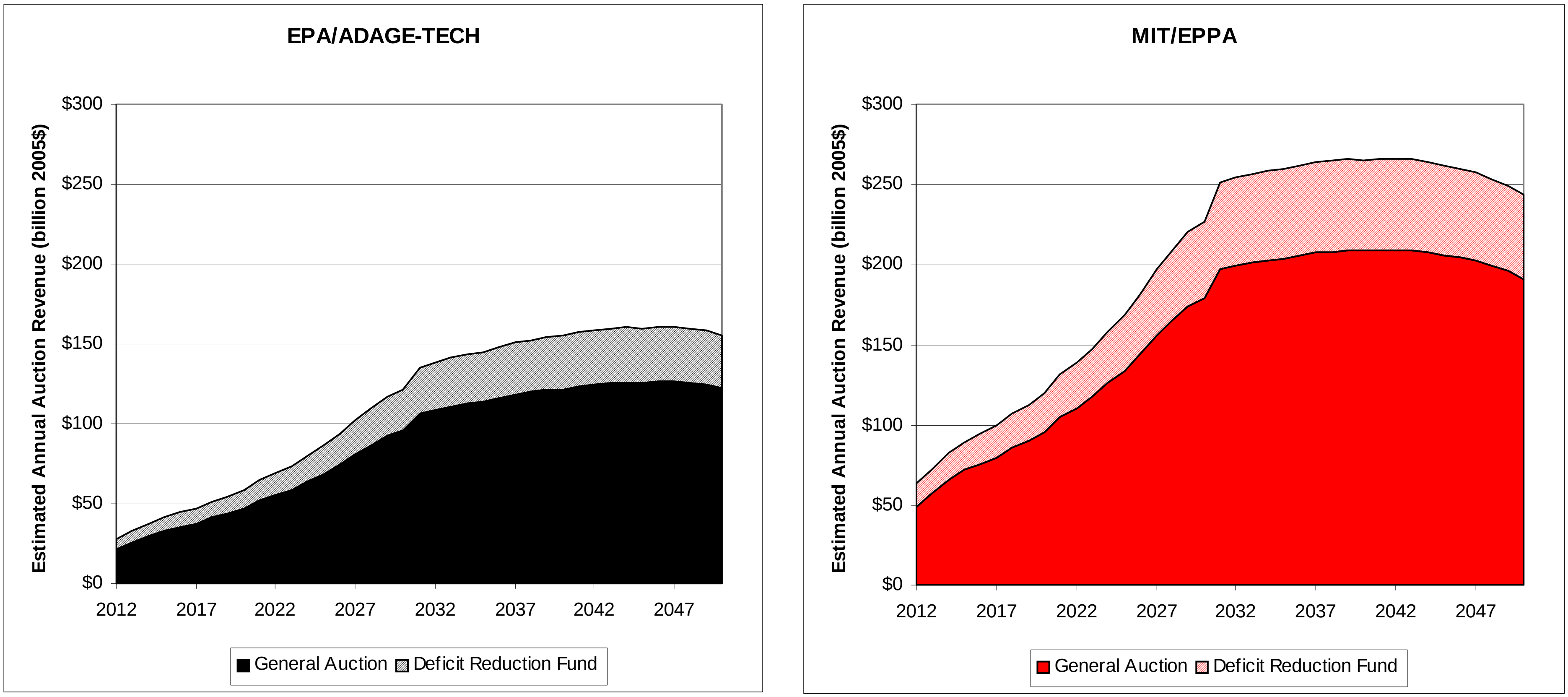
---

[54] Submitted to CBO April 9, 2008. CBO, *S. 2191, America's Climate Security Act, with an Amendment* (April 10, 2008).

[55] For more information on federal expenditures on climate change, see CRS Report RL33817, *Climate Change: Federal Funding and Tax Incentives*, by Jane A. Leggett.

[56] For more information on advanced vehicle R&D, see CRS Report RS21442, *Hydrogen and Fuel Cell Vehicle R&D: FreedomCAR and the President's Hydrogen Fuel Initiative*, by Brent D. Yacobucci.

Figure 10. Estimated Annual Revenues from Allowance Auctions Under S. 2191



Source: CRS Analysis of S. 2191 using allowance price estimates from EPA and MIT.

Table 10. Allocation of Estimated Annual Auction Revenue from S. 2191 Using EPA/ADAGE-TECH Case

(million 2005$)

Value of Auction Revenue	2012	2020	2030	2040	2050
Deficit Reduction Fund	$6,531	$11,705	$25,622	$33,352	$33,455
General Auction Revenue	$21,616	$46,590	$95,341	$121,784	$122,160
Off-the-Top Allocation of Auction Proceeds					
BLM Emergency Firefighting Fund	$150	$150	$150	$150	$150
Forest Service Emergency Firefighting Fund	$430	$430	$430	$430	$430
CSA Management Fund	$1,071	$1,393	$1,776	$2,086	$2,092
Value of Remaining Proceeds					
Technology Deployment	$10,382	$23,201	$48,352	$61,942	$62,134
Zero- or Low- Carbon Energy Technology	$3,322	$7,424	$15,473	$19,821	$19,883
Advanced Coal and Sequestration Technology	$2,595	$5,800	$12,088	$15,485	$15,533
Fuel from Cellulosic Biomass	$623	$1,392	$2,901	$3,717	$3,728
Adv. Tech. Vehicles Manufacturing Incentives	$1,246	$2,784	$5,802	$7,433	$7,456
Sustainable Energy Program	$2,595	$5,800	$12,088	$15,485	$15,533
Energy Independence Acceleration Fund	$399	$892	$1,860	$2,382	$2,390
Energy Assistance Fund	$3,594	$8,031	$16,737	$21,441	$21,508
LIHEAP	$1,797	$4,015	$8,369	$10,721	$10,754
Weatherization	$898	$2,008	$4,184	$5,360	$5,377
Rural Energy Assistance	$898	$2,008	$4,184	$5,360	$5,377
Climate Change Worker Training Fund	$998	$2,231	$4,649	$5,956	$5,974
DOE University Programs	$250	$558	$1,162	$1,489	$1,494
Adaptation Fund	$3,594	$8,031	$16,737	$21,441	$21,508
DOI - Wildlife Conservation and Restoration	$1,258	$2,811	$5,858	$7,504	$7,528
DOI - Adaptation Activities	$683	$1,526	$3,180	$4,074	$4,086
DOI - Cooperative Grant Programs	$180	$402	$837	$1,072	$1,075
DOI - Tribal Wildlife Grants	$36	$80	$167	$214	$215
Land and Water Conservation Fund	$359	$803	$1,674	$2,144	$2,151
DOI LWCF Sec. 6 Grants	$60	$134	$279	$357	$358
DOI LWCF Sec. 7 Acquisitions	$120	$268	$558	$715	$717
USDA Forest Legacy Program Sec. 7	$60	$134	$279	$357	$358
USDA LWCF Sec. 7 Acquisitions	$120	$268	$558	$715	$717
Forest Service Adaptation Activities	$180	$402	$837	$1,072	$1,075
EPA Adaptation Activities	$180	$402	$837	$1,072	$1,075
Army Corps of Engineers Adaptation Activities	$359	$803	$1,674	$2,144	$2,151
Department of Commerce Adaptation Activities	$359	$803	$1,674	$2,144	$2,151
Climate Change and National Security Fund	$998	$2,231	$4,649	$5,956	$5,974

Notes: CRS estimates based on EPA/ADAGE-TECH case allowance price projections. Higher allowance price estimates would lead to higher auction proceeds. For example, MIT/EPPA allowance price projections result in annual revenues roughly 50% to 100% higher, depending on the year.

CRS estimates of firefighting fund requirements based on historic data.

Estimate of administration cost ("CSA Management Fund") based on EPA's estimate of 1% of total allowance value.

Issues Raised by the Models

Technology Issues

A frontier area in model development is creating fuller representations of technology advancement. A substantial amount of technological change occurs within the economy without direct policy intervention — the free enterprise system provides significant rewards for those who develop cost-effective alternatives and introduce them into the market.[57] However, technological change is a very complex subject and can also be induced through a variety of policy levers, including prices (such as allowance prices), subsidies, and technology mandates or standards, along with both publicly and privately funded research and development.[58] This "induced technological change" (ITC) is not fully represented in the models used here, although it is a critical part of S. 2191. Observing that no single source dominates the process of technology change — a process that includes roles for research and development, learning-by-doing, and spillovers from other industries engaged in these activities, L. Clarke, et al. states:

> The lesson from these observations is to be cautious in interpreting the policy conclusions of models that assume only a single source of technological progress or that neglect critical factors such as spillovers. This includes virtually all formal models in use today, implying a need both for more comprehensive treatments of technological change and more research to understand the nature and magnitude of any distortions of policy conclusions from models with limited representations of technological change.[59]

That models used to project GHG reductions costs are deficient in treating technology change is a likely major source of error that will only become cognizable as the future unfolds. S. 2191 includes numerous incentives for technology development — incentives for which no model has (or could be expected to have) estimated the collective effect.

---

[57] Generally expressed in terms of autonomous energy efficiency improvement (or AEEI), those effects are generally estimated using historical data.

[58] For an overview of induced technological change, see Lawrence H. Goulder, *Induced Technological Change and Climate Policy*, Pew Center on Global Climate Change (October 2004).

[59] Leon Clarke, John Weyant, and Alicia Birky, "On the Sources of Technological Change: Assessing the Evidence," *Energy Economics* 28 (2006) p. 593.

Electric Power Sector. Most of the analyses examined here focus on technological alternatives in the electric power sector.

Availability of Technology. When and how quickly technology will be available is a difficult but critical issue. Indeed, the models examined here do not agree on the availability of current electric generating technology, such as nuclear or wind power, much less emerging technologies such as carbon capture and storage (CCS), or the potential for breakthroughs over the next 40 years. The general lack of detailed technology descriptions in the CGE models does not help in this regard. For example, the EPA/IGEM's presentation of the energy sector and technology options is too aggregated to be analyzed in terms of technology development under S. 2191.

Current Technologies. Several currently available technologies emit less greenhouse gases (or none) compared to a conventional coal-fired facility. Those technologies include electric generation from wind, biomass, landfill gas, nuclear, geothermal, and natural gas. Some of these sources, such as biomass and natural gas, have some repowering potential with respect to coal-fired generation.

The models do not provide much insight on the likely mix of these technologies under S. 2191. Some cases, like the ACCF/NAM/NEMS cases, strictly define the availability of these technologies; while others, like the CATF-NEMS and EIA/NEMS cases, allow the model to meet the requirements without any additional constraints. **Table 11** identifies some of the technology-availability limits assumed in the different model runs, along with the resulting capacity built to meet electricity demand from 2010 to 2030. Because the ACCF/NAM/NEMS cases heavily constrain the availability of most alternatives to natural-gas generation, it is not surprising that a substantial amount of natural gas capacity is assumed to be built under these cases during this time period. This result is confirmed by sensitivity analysis conducted by EIA that shows a movement to natural gas if the availability of nuclear power, renewable power, and coal with CCS are constrained. In contrast, the EPA/IPM, CATF/NEMS, and two EPA/ADAGE cases indicate little or no new construction of natural gas. Instead, these models allow a mix of renewable power (including wind and biomass), nuclear power, and coal-fired capacity with CCS to meet future demand and to begin replacing coal-fired capacity without CCS. In these cases, each model included the CCS subsidy contained in S. 2191. Finally, MIT/EPPA, EIA/NEMS, and NMA/CRA cases show a moderate role for natural gas during this time frame.

Table 11. Assumptions about the Construction of Generating Capacity Under S. 2191 to 2030

	Nuclear Power	Renewable Power	Natural Gas-fired	Coal with CCS
ACCF/NAM/NEMS-HIGH	10 GW (limit)	6 GW/year (limit)	about 284 GW (built)	25 GW (limit)
ACCF/NAM/NEMS-LOW	25 GW (limit)	6 GW/year (limit)	about 269 GW (built)	50 GW (limit)
MIT/EPPA	about 3-4 GW (built)	about 26 GW (built)	about 71 GW (built)	about 236 GW (built with subsidy)
NMA/CRA	40 GW (limit)	130.5 GW (limit)	about 33 GW (built)	107 GW (limit)
EPA/IPM (for 2025)	44 GW (limit)	61.3 GW (built)	5.5 GW (built)	80 GW (built with subsidy)
CATF/NEMS	104 GW (built)	54 GW wind power (built with subsidy) Biomass (constrained)	0	133 GW (built with subsidy)
EPA/ADAGE-REF	about 71 GW (built)	about 58 GW (built)	little	about 165 GW (built with subsidy)
EPA/ADAGE-TECH	about 70 GW (built)	about 61GW (built)	little	about 89 GW (built with subsidy)
EIA/NEMS	264 GW (built)	112 GW (built)	77 GW (built)	64 GW (built)
AEO 2007 baseline	**12.5GW**	**12.4 GW**	**88.2 GW**	**145 GW (no CCS)**

Source: EPA/ADAGE and EPA/IPM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAMS/NEMS: SAIC, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using The National Energy Modeling System (NEMS)*, report by the ACCF and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008).

Note: "**Limit"** is the maximum that the model assumes can be built — it is not necessarily the amount the model determined would be built. **"Built"** is the amount the model determined needed to be built. **"About"** is an estimate by CRS of the additional capacity necessary for the increased electricity production projected by the model between 2010 and 2030 under S. 2191 in the absence of capacity data being provided. The exception is where the natural gas-fired capacity was estimated from a chart. The estimates were calculated assuming an 80% capacity factor for biomass, 90% for nuclear power and coal, 48% for renewables, and 85% for natural gas.

In some ways, the interplay between nuclear power, renewables, and coal-fired capacity with CCS is a proxy for the need for a low-carbon source of electric generating capacity in the mid- to long-term. As indicated, a considerable amount of low-carbon generation will have to be built under S. 2191 to meet the reduction requirement. The amount of capacity constructed depends on the models' basecase assumptions about future supply and demand and need for capacity replacement/retirement under S. 2191, along with the degree of consumer response to rising prices and incentives contained in S. 2191.

To put these numbers into historical context, from 1963 to 1985, 78 GW of nuclear power were ordered, constructed and began operation.[60] For the 19-year period of 1966 through 1984, the country added 464 GW of total generating capacity, including 210 GW of coal-fired capacity, 38 GW of hydropower, 27 GW of natural gas capacity (steam technology), 46 GW of oil-fired capacity, and 54 GW of peaking capacity to improve system reliability after the 1965 blackout. In addition to new additions, between 1965 and 1972, about 400 coal-fired generating units were converted to oil to meet environmental requirements. After the 1973 oil embargo, this trend was reversed with 11GW of capacity converted back to coal by 1983.[61] For a more recent time period, from 2001 through 2005, the United States added about 180 GW of new capacity — almost all natural gas-fired.[62]

Beyond construction of new facilities and repowering of existing ones, conservation is likely to play an important role in reducing the need for new construction under S. 2191. In general, the models estimate a 10%-30% reduction in projected demand for electricity from the 2030 basecase level due to S. 2191.

Emerging Technologies. The emerging technology receiving the most attention in the models is carbon capture and storage (CCS). This is not surprising. The models generally agree that the long-term viability of coal-fired electric generation is dependent on developing a CCS system. Indeed, the models' various projections of coal consumption are a direct result of the models' assumptions about the introduction and commercialization of CCS. Of the numerous provisions in S. 2191 designed to promote emerging technologies, the CCS bonus allowance provision is the only one that received substantial attention by the models.

Table 12 indicates the various assumptions and limits the models placed on CCS deployment under S. 2191. As indicated, the cases that included the CCS subsidies contained in S. 2191 generally assumed that the technology would be available earlier and in increasing amounts over the cases that did not include the subsidies. For example, the EPA/IPM sensitivity analysis on S. 2191's CCS bonus allowance subsidy indicates that the subsidy (along with sufficiently high allowance prices) results in the technology emerging in the commercial market in 2015 with full

---

[60] Compiled from EIA's Reactor Status List available from EIA's website.

[61] Energy Information Administration, *Fuel Choice in Steam Electric Generation: Historical Overview*, DOE/EIA-0472 (August 1985), pp. 5 and 7.

[62] Environmental Protection Agency, *EPA Analysis of the Low Carbon Economy Act of 2007: S. 1766 in the 110th Congress* (January 15, 2008) p. 49.

production (as limited by the models) being achieved in 2025. The MIT/EPPA subsidy case agrees with a 2015 commercialization date while the EPA/ADAGE cases delay availability until 2020. EIA/NEMS states only that the subsidy makes the technology economical.

While the models agree that the CCS bonus allowance provisions are effective, they disagree on whether they are sufficient. For example, EIA/NEMS noted that the subsidy improves CCS's relative economics; however, nuclear and renewable fuels are projected to still play a larger role.[63] In contrast, EPA/IPM states that by 2025, coal with CCS is economic even without the subsidy. The advantage, according to EPA/IPM, is the earlier start-up resulting from the subsidy that would result in even more CCS being installed if the subsidy weren't capped and eventually ran out.[64] MIT/EPPA agrees that the bonus allowances would be over-subscribed for almost all years.[65]

Among the no-subsidy scenarios, only NMA/CRA views CCS as available before 2025.

---

[63] EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008) p. 23.

[64] U.S. Environmental Protection Agency, *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008* (March 14, 2008), p. 40.

[65] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (April 2007), Appendix D, p. D11.

Table 12. Assumptions about the Availability of CCS
(in Gigawatts [GW])

	2015	2020	2025	2030	Total
ACCF/NAM/ NEMS-HIGH (build limits)	*not presented*	*not presented*	*not presented*	*not presented*	25
ACCF/NAM/ NEMS-LOW (build limits)	*not presented*	*not presented*	*not presented*	*not presented*	50
MIT/EPPA (no subsidy)	0	about 10	about 10	about 42	about 63
MIT/EPPA (subsidy)	about 10	about 17	about 59	about 148	about 236
NMA/CRA (build limits)	2	15	30	60	107
EPA/IPM (no subsidy)	0	0	70	n/a	70
EPA/IPM (subsidy)	5	5	70	n/a	80
CATF/NEMS (subsidy)	about 1	about 8	about 51	about 73	133
EPA/ADAGE-REF (subsidy)	0	about 23	about 47	about 94	about 165
EPA/ADAGE-TECH (subsidy)	0	about 23	about 9	about 56	about 89
EIA/NEMS (subsidy)	about 8	about 16	about 24	about 16	64

Source: EPA/ADAGE and EPA/IPM: "Data Annex" available on the EPA website at [http://www.epa.gov/climatechange/economics/economicanalyses.html] MIT/EPPA: Sergey Paltsev, et al., "Appendix D" of Paltsev et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change (2007). EIA/NEMS: EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008). CATF/NEMS: Jonathan Banks, Clean Air Task Force, *The Lieberman-Warner Climate Security Act — S. 2191: A Summary of Modeling Results from the National Energy Modeling System* (February 2008). ACCF/NAMS/NEMS: SAIC, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, report by the ACCF and NAM (2008). NMA/CRA: CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008).

Note: GW estimates for MIT/EPPA and ADAGE calculated assuming a 90% capacity factor.

Future Technologies. The above discussion focuses on current perspectives on technological alternatives — alternatives that mostly rely on the construction of new facilities, be they nuclear power, biomass power, or coal-fired integrated gasification combined cycle (IGCC) with CCS. Many existing coal facilities are assumed to be retired early because, in the words of EIA/NEMS, retrofitting them with CCS technology "is generally impractical."[66] As suggested by MIT, this points out both a need and a concern:

> The need to phase out coal without CCS indicates the potential value of a CCS technology that could be used to retrofit existing generation plants, extending the life of existing investment and limiting the number of completely new plants that were needed. The capital intensity of these technologies are a concern as we find that the investment demand needed for such expansions crowds out investment in other areas of the economy, and thus increases the welfare cost of the policy.[67]

Such retrofitable post-combustion technologies are in development. For example, an ammonia-based, regenerative process for CO_2 capture from existing coal-fired facilities is being developed by Powerspan.[68] Called ECO_2, two commercial demonstrations (125 MW and 120 MW) have been announced with projected operations to begin in 2012 and 2011.[69] A second, chilled-ammonia-based post-combustion capture process is being developed by Alstom. In collaboration with American Electric Power (AEP) and RWE AG (largest electricity producer in Germany), Alstom has announced plans to demonstrate the technology on a 20 MW slip stream at AEP's Mountaineer plant with the captured CO_2 injected in deep saline aquifers on site.[70] Once commercial viability is demonstrated at Mountaineer, AEP plans to install the technology at its 450 MW Northeastern Station in Oologah, OK, early in the next decade.[71] Other solvent-based post-combustion processes are in the pilot stage.[72] To the extent these and other future retrofittable technologies become available, the mid- and long-term costs and capital investment projected by the models could be significantly mis-stated.

Effectiveness of Research, Development, Demonstration, and Deployment Efforts. One factor that will determine the availability of emerging and future technology is research, development, demonstration, and deployment funding. The potential for such subsidies to accelerate deployment is suggested by the previous discussion of CCS. However, S. 2191 contains numerous provisions with respect to technology. As noted in the previous discussion on auction/allowance

---

[66] EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008) p. iii.

[67] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, Report No. 146 (April 2007), pp. 33-34.

[68] Powerspan Corp. *Carbon Capture Technology for Existing and New Coal-Fired Power Plants* (April 15, 2008).

[69] One is to be sited at NRG's W.A. Parish plant in Texas and is to use a 125 MW slip stream. The second is to use a 120 MW slip stream from Basin Electric's Antelope Valley Station. The captured CO_2 is to be sold or used for Enhanced Oil Recovery (EOR).

[70] AEP News Release, *RWE to Join AEP in Validation of Carbon Capture Technology*, (November 8, 2007).

[71] The captured gas is to be used for Enhanced Oil Recovery.

[72] For a useful summary of carbon capture technology, see Steve Blankinship, "The Evolution of Carbon Capture Technology Part 1," *Power Engineering* (March 2008).

revenues, technology development will receive substantial funding under S. 2191. However, in general, only the bonus allowance incentives for CCS are explicitly modeled in any of the cases. The exceptions to this are some innovative efforts by the CATF/NEMS and EIA/NEMS cases to use various proxies to illustrate the potential of this funding. These are discussed later. In addition, NMA/CRA states that S. 2191 deployment subsidies "would be fully utilized by CRA's projected technology investments." NMA/CRA does not state whether they assumed that the technology subsidies had any effect on deployment schedules or amounts.

A basic question about S. 2191 technology development funding is: How much is enough? The amount provided by the bill dwarfs current efforts to develop and deploy reduction and low-carbon technologies. To put S. 2191's technology funding efforts into context, two proposed research, development, and demonstration strategies are summarized below.

Table 13 presents the Electric Power Research Institute's (EPRI's) estimated combined public and private research and development funding needs to obtain a "full portfolio" of electricity technologies to meet greenhouse gas reduction targets. The technology targets for 2030 are (1) 30% reduction in load growth by efficiency improvements; (2) 70 GW of non-hydro renewables; (3) 64 GW of new nuclear power; (4) new coal-plant efficiency of 49%; (5) CCS widely deployed after 2020; (6) plug-in hybrids as 39% of new car sales; and (7) distributed energy resources at 5% of baseload.[73]

---

[73] Electric Power Research Institute, *The Power to Reduce CO_2 Emissions: The Full Portfolio*, Discussion Paper (August 2007), p. 2-2. The targets do not reflect economic or potential regulatory and siting constraints.

Table 13. Estimated Incremental Annual Combined Public and Private Funding Needs to Achieve EPRI's Full Portfolio
(in million dollars annually)

	2005-2009	2010-2014	2015-2019	2020-2024	2025-2030	2005-2030 Average Annual
Distribution-enabled technologies	$250	$220	$140	$240	$240	$220
Transmission-enabled technologies	$100	$130	$120	$70	$60	$100
New/Extended Nuclear Power	$500	$520	$370	$370	$400	$430
Advanced coal and Carbon Capture and Storage	$830	$800	$800	$620	$400	$690
Annual Totals	$1,700	$1,700	$1,400	$1,300	$1,100	$1,400

Source: Electric Power Research Institute, *The Power to Reduce* CO_2 *Emissions: The Full Portfolio* (August 2007).

Note: "Distribution-enabled technologies" refers to deploying smart distribution grids and communications infrastructures to support commercialization of end-use energy efficiency, distributed energy resources, and plug-in hybrid electric vehicles.
"Transmission-enabled technologies" refers to deploying transmission grids and energy storage infrastructure to support as much as 20%-30% intermittent renewables in specific regions.

Table 14 presents the public funding needs for a strategy focused on commercializing various "clean coal" technologies funded over 18 years (2008-2025). The strategy would provide for several carbon capture and storage demonstration projects along with improvements to combustion technology and development of CCS retrofit technology.

Table 14. Total Public Funding Needs for 2007 CURC-EPRI Clean Coal Technology Roadmap over 18 Years (2008-2025)
(millions of dollars)

	Research and Development (80% Government Share)	Demonstration Projects (50% Government Share)	Totals
Integrated Gasification Combined-Cycle (IGCC)	$2,100	$2,000	$4,100
Combustion	$580	$2,240	$2,820
Innovations for Existing Plants (IEP)	$310	$480	$790
Sequestration (Storage — high CO2 scenario)	$180	$740	$920
Fuel Cells	$580	$430	$1,010
Turbines	$360	$160	$520
Totals	$4,110	$6,050	$10,160

Source: Coal Utilization Research Council, *The CURC-EPRI Clean Coal Technology Roadmap*, available at [http://www.coal.org/userfiles/File/Updated_CURC_EPRI_Clean_Coal__Technology_Roa.pdf].

The "Technology Deployment" funds allocated by S. 2191, as shown in **Table 10** (over $10 billion annually in 2012, nearing $50 billion annually by 2030) exceed the amounts estimated for the strategies identified above in **Table 13** and **Table 14** (combined, roughly $2 billion annually). Several organizations, including EPRI and the Pew Center for Global Climate Change, have called for at least a doubling of DOE's current funding of advanced coal options (2008 funding: $438 million).[74] This is not to say that S. 2191's allocations are optimal, only that S. 2191 funding would appear to fill a projected need for public funds to promote technology milestones to encourage the future availability of useful technology at the appropriate time.

Effectiveness of Economic and Regulatory Incentives. In addition to the CCS bonus allowance provision, S. 2191 contains funding for zero- or low-carbon energy technology, advanced coal and sequestration technology, fuel from cellulosic biomass, advanced technology vehicles (such as plug-in hybrids), and sustainable energy technology, including distributed energy systems. In addition, the bill calls for new appliance and building efficiency standards — some of which were included in EISA, as discussed earlier.

As noted earlier, the CATF/NEMS case attempted to model partially the effect of these incentives through proxies. Specifically, CATF/NEMS simulated the

[74] See John A. Bewick, "Cultivating Clean Tech: New Models for Energy RD&D," *Public Utilities Fortnightly* (May 2008) pp. 42-48.

incentives for low and no carbon power technologies by using a production tax credit for CCS and extending the wind production tax credit to 2030. CATF/NEMS also used EIA's "Best Available Technology" case as a proxy for the appliance and building standards included in the bill. The results are some of the lowest overall cost estimates of any of the cases, along with substantial development of coal-fired CCS, nuclear power and renewables.

Other innovative approaches were taken by EIA/NEMS, to attempt to mimic the impact of energy efficiency incentives by reducing the incremental cost of the most energy-efficient residential appliances by half — simulating a rebate for buying more efficient appliances. Likewise EIA/NEMS mimicked the incentives for stronger building codes by tightening the residential codes in the model by 30% in 2015 and 50% in 2025 compared with basecase levels. These proxies come in addition to the EISA provisions that are contained in the preliminary *AEO 2008* basecase used by EIA/NEMS. The proxies contribute to some of the lowest cost estimates of any of the cases.

The only other model to incorporate these initiatives was MNA/CRA, which incorporated the preliminary *AEO 2008* baseline that includes the EISA provisions. However, the NMA/CRA results do not separate out the efficiency standards from the new Corporate Average Fuel Economy (CAFE) or renewable fuel standard (RFS) requirements (see next section on "Transportation Sector").

Transportation Sector. The transportation sector presents particular problems for a cap-and-trade system. First, the sheer number of motorized and aviation vehicles effectively necessitates an upstream regulation of transportation fuels. It would be impracticable to place emissions monitors on the hundreds of millions of cars, trucks, motorcycles, off-road vehicles, boats, trains, and aircraft in the United States.[75] Likewise, requiring each motorist to submit allowances for his or her fossil fuel use would greatly increase the administrative costs of an emission reduction program.

Therefore, any regulation of transportation, especially motor vehicles, would likely occur upstream of the emitting source, as is the case with S. 2191. Emissions reductions from transportation generally must come in one of three ways: 1) reduce fuel consumption through more efficient vehicles or through reduction in vehicle-miles traveled (e.g., mass transit, carpooling, etc.); 2) reduce the carbon content of transportation fuels through the blending of lower-carbon fuels in conventional fuels; 3) switch from conventional fuels to alternatives with lower lifecycle emissions. Current federal policy attempts to address numbers 1 and 2. The federal Corporate Average Fuel Economy (CAFE) standards, as amended by EISA, require increasing fuel economy for new passenger cars and light trucks.[76] The renewable fuel standard

---

[75] The European Union has proposed a downstream reduction program for the aviation industry, whereby airlines would need to submit allowances to cover their own emissions. However, the number of aircraft is considerably smaller than the number of passenger and freight vehicles in either the EU or the United States.

[76] For more information on CAFE, see CRS Report RL33413, *Automobile and Light Truck*
(continued...)

(RFS), also amended by EISA, requires an increasing amount of renewable transportation fuel, and that an increasing share of that fuel have lower greenhouse gas emissions.[77] Both of these programs should help reduce the number of allowances needed by the petroleum industry by reducing the amount of fuel consumed, and the carbon content of the fuel supplied.

The cap-and-trade restrictions on petroleum would most likely be felt by transportation users through higher prices. Users would receive the price signal and decide whether to invest in new capital (e.g., purchase a new car), use less fuel (and drive less), or change fuels (if possible).

Low Carbon Fuel Standard. One key feature of S. 2191 and its impact on the transportation sector is the Low Carbon Fuel Standard (LCFS) in Section 11003. The LCFS requires a 5% reduction in lifecycle greenhouse gas emissions from transportation fuels from 2008 levels by 2015 and a 10% reduction from 2008 by 2020. This is similar to the proposed low carbon fuel standard established in California by Governor Arnold Schwarzenegger.[78]

A major question on the effects of the LCFS is the definition of "transportation fuel." In discussions over the California program, most stakeholders, including California Air Resources Board staff, argued that aviation fuel and bunker fuel should not be included in the standard.[79] Simply put, the more fuels included in the program, and the greater the volume that must be displaced, the more stringent the standard becomes. This is especially true for aviation fuel since there are currently few or no options to reduce jet fuel lifecycle greenhouse gases.[80] Therefore, the more jet fuel included in the program, the greater the reductions necessary from other fuels.

For example, EIA projects 15.79 million barrels per day of transportation fuel demand in 2020, or roughly 240 billion gallons annually.[81] To meet a 10% reduction requirement, 24 billion gallons of zero-carbon fuel would be needed, assuming equivalent energy content per gallon. However, many low-carbon fuels have less energy per gallon than petroleum fuels, and all have some associated carbon emissions. If cellulosic ethanol is found to have a 90% reduction in lifecycle emissions, and the fuel has 2/3 the energy content of gasoline, then roughly 40 billion

---

[76] (...continued)
Fuel Economy: The CAFE Standards, by Brent D. Yacobucci and Robert Bamberger.

[77] For more information on the RFS, see CRS Report RL33290, *Fuel Ethanol: Background and Public Policy Issues*, by Brent D. Yacobucci.

[78] Governor Arnold Schwarzenegger, *Executive Order S-01-07: the Low Carbon Fuel Standard*, January 18, 2007.

[79] See the California Air Resources Board page on the LCFS. [http://www.arb.ca.gov/fuels/lcfs/lcfs.htm]

[80] Further, EPA currently does not have the authority to regulate aviation fuels under the Clean Air Act; that authority rests with the Federal Aviation Administration. Since this provision would amend the Clean Air Act, EPA may not have the authority to include aviation fuel in the definition of transportation fuel.

[81] EIA, *Annual Energy Outlook*. Table 11.

gallons would be required. This is considerably more than the existing RFS mandate of 30 billion gallons of renewable fuels[82] in the same year. If, however, only motor gasoline and diesel fuel are considered, then the total volume is reduced to 13.47 million barrels per day, or 206 billion gallons annually. The equivalent amount of cellulosic ethanol required would be roughly 35 billion gallons, still a significant target.

The assumptions for the amount of low-carbon fuel available, the expected emission reductions for that fuel, and the total amount of fuel subject to the requirements would significantly affect the costs and feasibility of the LCFS program. The way the provisions are written in S. 2191, the LCFS program is separate from the cap-and-trade program, and there is no way to purchase credits or offsets from other sectors. If the necessary amount of low-carbon fuel is not available, then under the program fuel providers must reduce the amount of fuel they sell, or pay civil penalties. In its analysis of S. 2191, NMA/CRA states that in 2015 the LCFS "can only be met by a decrease in gasoline consumption to allow the limited supplies of low carbon biofuel to meet the averaging requirements of the standard."[83] Further, the model estimates that because of the decrease in supply, motor fuel prices increase 140% in 2015 over the baseline case.[84] The NMA/CRA analysis suggests that if the LCFS is construed to include all ground transportation fuels without exception, then it may be difficult to achieve it without reducing fuel demand.

Depending on the design of the program and what fuels are included, the effects on fuel supply and prices could be dramatic. However, if plug-in hybrid vehicles or large amounts of cellulosic biofuel are available earlier than expected, or if certain fuels such as aviation fuel and non-road fuels are excluded from the mandate, the costs could be lower.

Impact on Fuel Prices. Given the divergent projections by the various cases about future electric generating capacity illustrated in **Tables 11 and 12** and, with the exception of NMA/CRA, no detailed modeling of the transport sector, it is not surprising that their estimates of the fuel price impacts of S. 2191 vary widely. Also, perhaps more than any other results, the cases were very selective in terms of the results they chose to highlight in their studies and how they chose to present them. Hence, CRS highlighted general themes coming out of the cases to focus on the insights this wide variety of assumptions and calculations has to offer. A further discussion of the impact of energy costs on households and energy-intensive industries is presented later.

---

[82] It should be noted, however, that the RFS mandates only require 15 billion gallons of "advanced biofuel" with a 50% reduction in lifecycle emissions (as opposed to the 90% reduction in the example). The remaining 15 billion gallons of the RFS mandate are not required to have any emissions reductions.

[83] CRA International, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model* (April 8, 2008). p. 29.

[84] Ibid. p. 22.

Natural Gas Prices. Some of the most confusing results presented by the cases are for natural price prices. Besides different baselines, indices, and target categories (e.g., utility, industrial, residential, "average"), some prices presented include allowance costs, while others do not. Likewise, some cases include the "free" allowance allocations provided under S. 2191, others do not. In general the CGE models present natural gas prices without the added cost of allowances; NEMS cases present natural gas prices that include allowance costs.

In general, the incremental impact of S. 2191 on natural gas prices depends on the degree to which natural gas-fired generation is used to back out existing coal-fired capacity and to meet future demand. As discussed above, the cases fall into three categories with respect to future natural gas-fired generation: (1) little or no increased generation; (2) modest increased generation; or (3) substantial increased generation. Of the three cases included in the first category, the EPA/ADAGE-REF and EPA/ADAGE-TECH cases project declining natural gas prices that do not include any allowance costs. This compares with the CATF/NEMS case that projects natural gas prices increasing only 3% in 2030 over baseline levels with allowance costs included. The potential modest impact on natural gas prices would be consistent with a future generation mix that is not heavily reliant on natural gas.

The three cases that project some additional natural gas-fired capacity — MIT/EPPA, EIA/NEMS and NMA/CRA — vary in their results. For the two cases that do not include allowance costs, the MIT/EPPA case projects a substantial decline in natural gas prices through 2050, while NMA/CRA projects wellhead natural gas prices increasing over basecase levels about 20% by 2020, then declining to no increase by 2035 and declining steadily afterwards to about 25% below baseline projections by 2050. For delivered natural gas, NMA/NEMS projects prices with allowance costs at about 20% above basecase levels around 2025 and accelerating rapidly after 2040. For the EIA/NEMS case that includes allowance costs, prices for natural gas delivered to electric generators are projected to increase about 23% in 2020 and 40% in 2030; the price for natural gas delivered to residential consumers increases about 14% in 2020, increasing to 26% in 2030 (compared with basecase).

In contrast to the cases above, the two ACCF/NAM/NEMS cases (which project substantial increases in natural gas-fired capacity) estimate natural gas prices with allowance costs increasing 108% (Low case) and 146% (High case) by 2030 for both residential and industrial consumers. This result is consistent with the assumptions used by ACCF/NAM in its analysis, as identified in **Tables 7, 8, and 11**.

Petroleum Prices. With the exception of NMA/CRA, the cases examined here do not model the transportation sector in a detailed manner. As noted in the "Transportation Sector" discussion, perhaps the most important impact on petroleum prices under S. 2191 may come from the Low Carbon Fuels Standard (LCFS), at least in the short term. For the cases that did not model the LCFS, three cases — the two EPA/ADAGE cases and the MIT/EPPA case — project either modest increases or declines in petroleum prices compared with basecase projections (a substantial decline in the case of MIT/EPPA). These models are all global in scope, with the petroleum price reflective of what they see as occurring in the international oil market, and do not include the increased cost of carbon allowances.

The other four cases — the two ACCF/NAM/NEMS cases, EIA/NEMS and CATF/NEMS — focus on gasoline prices and the price increases from the allowance requirement. The CATF/NEMS case estimates gasoline price increases reaching about a quarter ($0.25) per gallon by 2030, while EIA/NEMS estimates a 2020 gasoline price increase of about $0.22 per gallon and a 2030 price increase of about $0.40 per gallon. EIA/NEMS also provides estimates for other transportation fuels, including diesel and jet fuel. The two ACCF/NAM/NEMS cases project more dramatic gasoline price increases of about $3.25 (High case) and about $1.70 (Low case) per gallon by 2030 (2005$).

Electricity Prices. Electricity price calculations by the various cases include allowance prices. However, like the presentation of natural gas prices, the cases use a confusing array of different baselines, indices values, and target categories (residential, industrial, average, etc.). This can lead to some misleading conclusions when comparing different cases. For example, the MIT/EPPA case estimates 2030 electricity prices under S. 2191 at 57% above 2005 prices, compared with EPA/ADAGE-REF's 2030 estimate under S. 2191 of 29% above 2005 prices. However, reflecting the critical role of basecase assumptions, the MIT/EPPA basecase 2030 electricity price estimate is 39% above 2005 prices — thus the incremental difference between the basecase and the S. 2191 estimate is 18 percentage points. In contrast, the EPA/ADAGE-REF basecase 2030 electricity price estimate is an 11% decline below 2005 prices — thus the incremental difference between the basecase and the S. 2191 estimate is 40 percentage points.

The only metric for which the cases provided sufficient data was percentage increases from basecase levels. For the EPA/ADAGE cases, the basecase assumes a decline in electricity prices from 2005 levels in 2030 (11%-15%). This compares with a 29% increase in basecase prices for MIT/EPPA, a 5.6% increase for the EIA/NEMS, NMA/CRA, and ACCF/NAM/NEMS cases, and a 0.5% decline for CATF/NEMS relative to 2005 prices. It should be noted that several cases do not state precisely what the 2005 electricity prices refers to — residential, industrial, all users, or something else.[85]

Relative to their respective baselines, three cases estimate electricity price increases under 15%: CATF/NEMS, EIA/NEMS, and MIT/EPPA, and three cases estimate price increases between 35%-45%: the two EPA/ADAGE cases and the NMA/CRA case. In contrast, the two ACCF/NAM/NEMS cases project prices substantially higher: 101% (Low case) and 129% (High case) in 2030.

---

[85] Electricity prices vary substantially by sector and region. For example, in 2006, EIA reports residential rates of $30.52 per million BTU compared with industrial rates of $17.97 (2006$).

Economic Issues

Availability of Offsets. Along with technology development, the availability and price of offsets is one of the critical factors determining the costs of S. 2191, particularly in the short- to mid-term. As noted by EIA: "the highest prices in the first 5 years of the cap-and-trade program occur when international offsets are not assumed to be available."[86] As stated more forcefully by EPA:

> From the various scenarios analyzed, the use or limitation of offsets and international credits has a larger impact on allowance prices than the modeled availability or constraint of key enabling technologies.[87]

However, this conclusion is not obvious from a first read of the cases. In its heavily constrained cases, ACCF/NAM/NEMS notes that "the purchase of relatively inexpensive offsets significantly constrains allowance prices until the early 2020s..." when the available offsets run up against the limits contained in the bill or in the model's assumptions.[88] In contrast, the NMA/CRA finds no such relief, stating that "since the limit on domestic offsets is projected not to be reached until after 2025, allowing greater use of domestic offsets does not reduce near term costs."[89] Obviously, there is significant disagreement on the availability and cost-effectiveness of domestic and international offsets.[90]

A critical factor in this uncertain situation is the availability of international credits. The EPA/ADAGE, EPA/IGEM, and EIA/NEMS cases assume the availability of substantial international credits at reasonable prices. Sensitivity analysis by EPA indicates that if domestic and international credit availability were unlimited, 2050 allowance prices would fall by 71%. It should be noted that, subject to changes in the international framework for international commitments and trading, S. 2191 would not allow U.S. companies to obtain credits via mechanisms such as the Clean Development Mechanism (CDM), either directly or through a secondary market as currently written (Section 2502).[91] Instead, participation would be indirect

---

[86] EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008) p. xi.

[87] EPA, *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008: S. 2191 in 110th Congress* (March 14, 2008), p. 3.

[88] Science Applications International Corporation, *Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS)*, a report by the American Council for Capital Formation and the National Association of Manufacturers (2008) p. 9.

[89] W. David Montgomery and Anne E. Smith, *Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model*, CRA International (April 8, 2008) p. 12

[90] For more information on the role of offsets in a cap and trade system, see CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns,* by Jonathan L. Ramseur.

[91] Because the United States has not ratified the Kyoto Protocol, it is not eligible to
(continued...)

via substitutions of CDM-style credits for eligible allowances (such as those used by the EU-ETS) by other controlled countries and then sold to U.S. companies. The EPA/ADAGE, EPA/IGEM, and EIA/NEMS cases assume this interpretation of Section 2502.

Of course, given the long time frame of S. 2191, projecting the availability and prices of international credits is an uncertain business. For example, the European Commission (EC) has not decided on the status of credits from the Clean Development Mechanism (CDM) for the post-Kyoto period. Given the indirect arrangement necessary for those credits to impact S. 2191 compliance costs, this uncertainty can not be readily resolved.

NMA/CRA disagrees that substantial international credits would be available at reasonable prices. NMA/CRA argues that since the countries involved must have programs of "comparable stringency," the allowance prices are likely to be similar to U.S. prices and excludes them from its analysis. As suggested by sensitivity analysis conducted by EPA, EIA, and MIT, restrictions on international credits substantially increase the cost of S. 2191. EIA estimates that the unavailability of international credits would increase allowance prices 39% in 2030; for 2050, MIT estimates an allowance price increase of 15% while EPA projects that increase at 34%.

The impact of domestic offsets in reducing costs is projected to be less dramatic than for international credits, although the incentives available for domestic offsets could alter this. EPA sensitivity analysis indicates that unlimited domestic offsets would reduce allowance prices by 26% (p. 6).[92]

Impact of Banking. Experience with the acid rain program strongly indicates that participants bank allowances in the face of price uncertainty. In the case of greenhouse gas reductions, the availability of offsets and international credits also interacts with the banking provisions. As noted earlier, the ACCF/NAM/NEMS cases do not include banking: this fact helps explain their dramatically increasing allowance prices. All other cases include banking.

The models suggest two important results from banking. First, as noted earlier, banking has a flattening effect on allowance prices as participants buy more than they need early, raising prices, and use them later, lowering prices from the levels they would be otherwise. Second, and perhaps more critically, banking allows participants more control over the scheduling of reduction efforts. Given the pivotal nature of technology development to the ultimate success of any greenhouse gas reduction program, the ability to delay making major capital investments is very important. In the EPA/ADAGE and EPA/IGEM cases, entities bank allowances until around 2030 (depending on the scenario). This is possible because of the availability of offsets and international credits. In the EIA/NEMS case, it is modeled in a manner to ensure

---

[91] (...continued)
participate in the CDM.

[92] This estimate includes reductions associated with allowance set-asides in Title III, Subtitle G (agriculture and forestry) and Title III, Substitle J (landfill and coal methane).

a 5 billion allowance bank remains at the end of 2030 as a proxy to reflect allowance needs in the post-2030 period (EIA/NEMS does not project beyond 2030).

Impact of Carbon Market Efficiency Board. The models generally do not consider the Carbon Market Efficiency Board (established by Title I, Subtitle F). However, one can infer from the models' results that the most important power that the Board may have is the ability to increase the availability of domestic offsets and international credits. As noted, increasing the availability of domestic offsets and international credits could have a significant effect on overall costs. If the Board chose to "loosen" the limitation on offset and international credit availability, the cost reductions could be substantial as indicated by the EPA cases. In addition, if the Board determined that technology development was not occurring on schedule and causing volatility in the allowance markets, loosening constraints on offsets and international credits could allow covered entities to bank more, allowing more time for technology development, if necessary. However, the Board is primarily designed to deal with short-term volatility due to episodic events in the allowance market and has only short-term powers. Whether it could coordinate a longer term strategy, if necessary, with its proposed authority is not known.

Impact of Revenue Recycling. As indicated in the "Auction Revenue Estimates" section, S. 2191 could redirect hundreds of billions of dollars annually through the economy. Only the NMA/CRA case states it captured the effects of this redirection. The other models generally assume the effect on the economy is similar to a lump-sum adjustment to taxes designed to keep S. 2191 deficit- and revenue-neutral.

International Leakage. International leakage is the shift in GHG emissions from a country subject to regulation (e.g., cap-and-trade program) to an unregulated country, so reduction benefits are not obtained. This would happen, for example, if a GHG emitting industry moved from a country with an emissions cap to a country without a cap. Only the EPA/ADAGE cases looked at the international trade aspect of Title VI of S. 2191. EPA's sensitivity analysis indicates that if countries without legally binding commitments to reduce greenhouse gases commit to maintaining their 2015 levels beginning in the year 2025, and to returning their emissions to 2000 levels by 2050, no international emission leakage occurs (p. 82). Imports of energy-intensive goods are projected to fall under this scenario, while exports expand as developing countries cope with their new emission limits.

In a worst case scenario, EPA's sensitivity analysis looked at a no-international-actions-to-2050 scenario. In this scenario, the International Reserve Allowance provisions of Title VI are assumed to be triggered because of the lack of international action. Emissions from countries without legally binding commitments are estimated to rise by 350 million CO_2e by 2030 and 385 million by 2050 — less than 1% of their basecase levels under ADAGE. It would be equivalent to U.S. emission leakage rates of approximately 11% in 2030 and 8% in 2050. These emissions compare with increases of 361 million and 412 million for 2030 and 2050 respectively if Title VI is not implemented. EPA describes the impact of Title VI on leakage as "minimal."[93]

The impact on imports is more significant. Without the International Reserve Allowance Requirement, imports from countries without legally binding commitments are projected to increase 5.4% in 2030, rising to 7% in 2050. In contrast, under Title VI, imports are estimated to increase about 1% in 2030 and decline about 5% in 2050. U.S. exports decline in both cases as countries use more of their domestic manufacturing (p. 85).

If the EPA projections are reasonable, the differential effect of Title VI on trade versus emissions leakage could present problems if the title is brought before the World Trade Organization (WTO).[94]

Ecological Issues

Climate Change Benefits. None of the cases examined here attempt to quantify or monetize the benefits of reducing greenhouse gases. Indeed, with the exception of MIT's overall study of cap-and-trade proposals, the environmental benefits of reducing greenhouse gases are generally not discussed.[95] This hole in reports designed to discuss the impacts of S. 2191 is not surprising. Like the cost estimates discussed above, benefit estimates are fraught with uncertainty. Thus, this discussion should be considered illustrative — more research and resources devoted to benefits analysis are necessary before more comprehensive reports will be available.

Monetizing Benefits: Some Illustrations. Monetizing benefits from reducing air pollutants has been attempted for decades. For example, during the debate in the 1980s on controlling sulfur dioxide, EPA conducted an illustrative analysis of the health benefits of promulgating a 1-hour sulfur dioxide National Ambient Air Quality Standard (NAAQS) as part of its Regulatory Impact Analysis (RIA).[96] Based on partial analysis of health impacts, EPA's illustrative exercise put the potential health benefits from stringent sulfur dioxide control at between zero and $385 billion (1984$) annually. These health-based benefits were in addition to a CRS

---

[93] EPA, *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008: S. 2191 in 110th Congress* (March 14, 2008) p. 84.

[94] For a further discussion of S. 2191, Title VI and WTO, see Jeanne Grimmett and Larry Parker, *Whether Import Requirements Contained in Title VI of S. 2191, the Lieberman-Warner Climate Security Act of 2008, as Ordered Reported, Are Consistent with U.S. WTO Obligations*, Congressional Distribution Memorandum (March 27, 2008). Available from the authors.

[95] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, Report No. 146 (April 2007) pp. 45-55. Available at [http://mit.edu/globalchange].

[96] Office of Air and Radiation, Environmental Protection Agency. *Regulatory Impact Analysis on the National Ambient Air Quality Standards for Sulfur Oxide (Draft)*. Research Triangle Park (1987), appendix B.

partial estimate of welfare benefits from reducing sulfur dioxide that exceeded $4 billion (1985$) annually.[97]

Because climate change is a global problem, monetizing benefits from reducing greenhouse gases is difficult. Indeed, some consider the effort impossible, bordering on the unethical. The complexity of the global response is magnified by the need to value benefits that accumulate over 100 years or more. Discount rates — economics' approach to valuing time — used in attempts to value long-term damage from climate change range from 0 to 4-5% in the literature.[98] Indeed, the effect of discounting is so great on a long-term marginal damage estimate of climate change that "using standard assumptions about discounting [i.e., 4-5%] and aggregation, the marginal damage costs of carbon dioxide emissions are unlikely to exceed $50 tC [$14 tCO_2], and probably much smaller."[99] Indeed, estimates of the Social Cost of Carbon (SCC) — the marginal damage resulting from the addition of one more ton of CO_2 — span over three orders of magnitude: from zero to over a $500 a ton.[100]

However, most current attempts to monetize environmental benefits are incomplete. The matrix presented in **Table 15** illustrates the problem. Most studies that attempt to monetize benefits focus on the market impact of predictable, average changes in climate (the "easiest to measure" box of **Table 15**). Only a few attempt to value non-market impacts or extreme events and fewer still consider catastrophes or socially contingent impacts.[101] In reviewing 28 studies the UK Government had analyzed in re-examining its estimate of an appropriate Social Cost of Carbon, Ackerman and Stanton observed:

> That is, all of the studies that estimate the social cost of carbon base their numbers on an incomplete picture of climate risks — often encompassing only the simplest and most predictable corner of the vast, troubling canvas that has been painted by climate science. There is, of course, no way to assign monetary values to the global response to the possibility of widespread droughts across large parts of Asia, or an increase in the probability of a sudden change in ocean currents that would make the UK as cold as Canada, but in the understandable absence of such impossible monetary values, it is important to remember the disclaimer from the DEFRA [Department for Environment, Food & Rural Affairs] review: all estimates of the SCC [Social Cost of Carbon] omit some of

---

[97] *The Clean Air Standards Attainment Act: An Analysis of Welfare Benefits From S. 1894*, CRS Report 88-298 ENR (April 15, 1988) by Larry Parker (available from the author). For a further discussion of benefits, see CRS Report 90-72 ENR, *Potential Benefits of Enacting Clean Air Act Amendments* by John Blodgett. (Available from the author).

[98] Richard S.J. Tol, "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," *Energy Policy* (2005), pp. 2064-2074.

[99] Ibid., p. 2064.

[100] For a discussion of SCC uncertainty and the UK shadow cost of carbon, see Simon Dietz, *Review of DEFRA paper: "The Social Cost of Carbon and the Shadow Price of Carbon; What They Are, and How to Use Them in Economic Appraisal in the UK"* Review Comments (September 2007).

[101] Frank Ackerman and Elizabeth Stanton, *Climate Change — the Costs of Inaction,* Report to Friends of the Earth England, Wales and Northern Ireland (October 11, 2006), p. 26.

the most important unpriced risks of climate change. The same disclaimer applies to virtually any quantitative economic estimate of climate impacts.[102]

Table 15. Matrix of Climate Risks

	Type of Impact (to the right)	**Market Impacts**	**Non-market physical Impacts**	**Socially contingent Impacts**
Predicatability (below)	*Examples of impacts (to the right and below)*	Agricultural output, health costs, property loss	Deaths, extinctions, ecosystem damages	Migration, response to food & water shortages
Averages	Temperature, sea levels, atmospheric CO2 steadily rising	***(Easiest to measure)***		
Extremes	Increased frequency and strength of heat waves, storms, droughts, floods			
Catastrophes	Polar ice sheets melting, "turning off" major ocean currents			***(Hardest to measure)***

Source: Tom Downing and Paul Watkiss, Overview: The Marginal Social Cost of Carbon in Policy Making: Applications, Uncertainty, and a Possible Risk Based Approach, *DEFRA International Seminar on the Social Costs of Carbon* (2003), as adapted by Frank Ackerman and Elizabeth Stanton, *Climate Change — the Costs of Inaction,* Report to Friends of the Earth England, Wales and Northern Ireland (October 11, 2006).

The matrix also indicates the moral dilemma presented by efforts to monetize benefits — a dilemma magnified by the issue of intergenerational discounting. The notion that deaths, extinctions, and other such potential impacts are less important because they occur in some future generation is, for some, morally problematic. Criticizing the UK government attempt to put a price on climate change, the UK House of Commons Select Committee on Environmental Audit stated:

> Furthermore, given the inherent difficulties in putting a price on climate change, the Government's first priority in deciding on the merits of potential policies and construction projects ought to be deciding how they affect UK carbon budgets,

[102] Ibid., p. 26.

> and only secondly on what the monetary value of resulting carbon emissions would be.[103]

Besides moral considerations, one's valuation of the social cost of carbon is dependent on one's assumptions about the emissions path the world is on.[104] This is due to the relationship between atmospheric concentrations of GHGs and radiative forcing (i.e., the higher the atmospheric concentration, the less the effect of one more ton on warming), the relationship between climate change and economic impacts (i.e., the higher the damage, the less the effect of one more ton on that damage), and discounting (impacts occurring earlier are valued more than impacts occurring later).[105] This phenomenon is illustrated in *The Stern Review* on the economics of stabilizing climate change.[106] As shown in **Table 16**, the SCC declines as the path of emissions is projected to result in less severe damages. Such estimates would increase over time as the damage got closer and closer.

Table 16. *The Stern Review* Estimates of Social Cost of Carbon for Three Emissions Paths

Stabilization Scenario	Social Cost of Carbon (per metric ton, 2005$)
Business-as-usual (no effort to stabilize emissions beyond basecase levels)	$95
On a path to stabilize GHG concentrations at 550 ppm	$34
On a path to stabilize GHG concentrations at 450 ppm	$28

Source: Sir Nicholas Stern, *The Economics of Climate Change: The Stern Review* (2006) p. 304. Estimates converted to 2005$ using the GDP implicit price deflator.

In an attempt to respond to the implications of climate change and *The Stern Review*, the UK Government has instituted a shadow price for carbon to be used in official cost-benefit analyses.[107] A shadow price is a little different from a Social Cost of Carbon value. The latter is an attempt to determine the marginal damage resulting

---

[103] The United Kingdom Parliament, Select Committee on Environmental Audit, *Third Report* (February 26, 2008), in press.

[104] Simon Dietz, *Review of DEFRA paper: "The Social Cost of Carbon and the Shadow Price of Carbon; What They Are, and How to Use Them in Economic Appraisal in the UK"* Review Comments (September 2007) pp. 5-10.

[105] Ibid., p. 6.

[106] Sir Nicholas Stern, *The Economics of Climate Change: The Stern Review* (2006).

[107] UK Department for Environment, Food, and Rural Affairs, *The Social Cost of Carbon And The Shadow Price of Carbon: What They Are, And How To Use Them In Economic Appraisal In The UK* (December 2007).

from the addition of one more ton of CO_2 — it indicates what people should be willing to pay now to avoid the future damage caused by more carbon emissions. In contrast, a shadow price represents a cost or benefit from a good when the market price is a poor indicator of economic value or there is no market at all. The UK shadow price of carbon is based on the Social Cost of Carbon of a 550 ppm stabilization goal as determined in *The Stern Review*, plus consideration of abatement costs and the value of UK leadership in encouraging global participation and from being out front in developing new technology. The result is a shadow price of about $43 a ton in 2012 (2005$), rising 2% annually thereafter in real terms.

Using this shadow price of carbon and the UK Green Book discount rates of 3.5% for the first 30 years and 3.0% afterward, the net present value (NPV) of S. 2191's estimated reductions would range from $4.2 trillion (ADAGE-REF case) to $5.5 trillion (MIT/EPPA case) in 2005 dollars. To complete this illustrative exercise, NMA/CRA case estimates the net present value of the total cost of S. 2191 (presumably not including general equilibrium effects) of about $4.5 trillion (2005$) (p. 18). NMA/CRA did not disclose the discount rate used in making this estimate.

Not surprisingly, the estimates illustrated here have been criticized by some (including the UK Parliament) for being too low and incomplete. Likewise, others have criticized the estimates as too large and inflated. For example, in its recent assessment of new average fuel economy standards, the U.S. National Highway Traffic Safety Administration (NHTSA) chose to value carbon reductions at $7 a ton and employ a 7% discount rate.[108] Applied to the reduction estimated under S. 2191, the resulting NPV would be about one order of magnitude lower than the UK shadow price-based estimates. Thus, reminiscent of EPA's illustrative calculation of the health benefits of a 1-hour sulfur dioxide standard, the illustration here results in a range of climate-related benefits from reducing greenhouse gases under S. 2191 at between zero and $200-$260 billion annually (2005$).[109]

---

[108] For a discussion of NHTSA's rationale for its estimate, see Department of Transportation, National Highway Traffic Safety Administration, *Average Fuel Economy Standards: Passengers and Light Trucks: Model Years 2011-2015*, Notice of Proposed Rulemaking (April 2008) pp. 216-222.

[109] A zero or near-zero estimate could result from one of three lines of thought: (1) denial that climate change is occurring; (2) belief that the potential benefits of a warmer climate cancel out the damages from that change; or (3) the damages will not be great (at least for the United States) and are far in the future — justifying a low damage evaluation and a high discount rate. It appears that NHTSA employed the final line of thought in its proposed rulemaking. As stated by NHTSA: "Although no estimates of benefits to the U.S. itself that are likely to result from reducing CO_2 emissions are currently available, NHTSA expects that if such values were developed, the agency would employ those rather than global benefit estimates in its analysis. NHTSA also anticipates that if such values were developed, they would be lower than comparable global values, since the U.S. is likely to sustain only a fraction of total global damages resulting from climate change." Department of Transportation, National Highway Traffic Safety Administration, *Average Fuel Economy Standards: Passengers and Light Trucks: Model Years 2011-2015*, Notice of Proposed Rulemaking (April 2008) p. 220.

As illustrated with the long-term cost estimates presented in this report, attempts to monetize climate-related benefits currently reflect much about the philosophies and assumptions of the people doing the estimating. As stated in *The Stern Review*: "It is very important ... to stress that such estimates [NPV of climate change policy benefits] reflect a large number of underlying assumptions, many of which are very tentative or specific to the ethical perspectives adopted."[110]

Putting Emission Reductions under S. 2191 into Context. It is difficult to put the actions of one country's emissions reduction plan in the context of a fragmented global effort to address climate change. One useful perspective is provided by MIT's general study of cap and trade bills.[111] Using the MIT Integrated Global System Model (IGSM), MIT explored the climate response to different stabilization goals being discussed in the international community. It developed parameterizations of IGSM that represented each of three major atmosphere-ocean general circulation models (AO GCMs) that would help illustrate the uncertainty in translating emission trends into an estimate of climate change: those of the Goddard Institute for Space Studies (CISS-SB), the Geophysical Fluid Dynamics Laboratory (GFDL-2.1), and the National Center for Atmospheric Research (CCSM3).

MIT simulated the climate effects of six different policy scenarios through 2100. Four of these are of interest in exploring S. 2191: (1) a reference scenario that assumes no specific global climate policy (*Reference*); (2) a global participation scenario (*Global Participation, 203 bmt case*), (3) a global participation scenario where abatement efforts in developing countries are delayed until 2050 (*Developing Countries Delayed*); and (4) a partial participation scenario where no abatement efforts occur in developing countries (*Developed Only*). Under scenarios 2, 3, and 4, developed countries (including the United States) are assumed to have reduced emissions by 50% below 1990 levels by 2050 (and held them there through 2100). This assumption is in the ballpark of U.S. reductions anticipated under S. 2191. For developing countries, scenario 2 assumes their emissions reductions begin in 2025, with emissions returning to their 2015 levels, and with additional reductions beginning in 2035 with emissions returning to their 2000 levels, and are held there; scenario 3 assumes emissions reductions are delayed until 2050, at which point they return to 2000 levels; and scenario 4 assumes developing country emissions are not stabilized at all.

The climate effects of these scenarios as simulated by MIT IGSM replication of the three AO GCMs identified above is shown in **Figure 11**. As indicated by the red line, the impact of S. 2191, combined with that of the other developed countries (all of which have ratified the Kyoto Protocol), is to reduce by 0.5 degrees C the projected 3.5 degrees C to 4.5 degrees C increase in global mean temperatures suggested by the simulations. If the United States chose not to reduce, the impact would be to move the red, green, and blue lines closer to the reference case line. With respect to the red line, it should be noted that, in 2000, the United States'

---

[110] Sir Nicholas Stern, *The Economics of Climate Change: The Stern Review* (2006) p. 304.

[111] Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, Report No. 146 (April 2007). Readers are urged to consult the report for details on the analysis discussed here.

greenhouse gas emissions were about 40% of the developed world's total emissions. In terms of the effect of any U.S. reductions on global mean temperatures, that is about all that can be said in isolation. As noted by MIT:

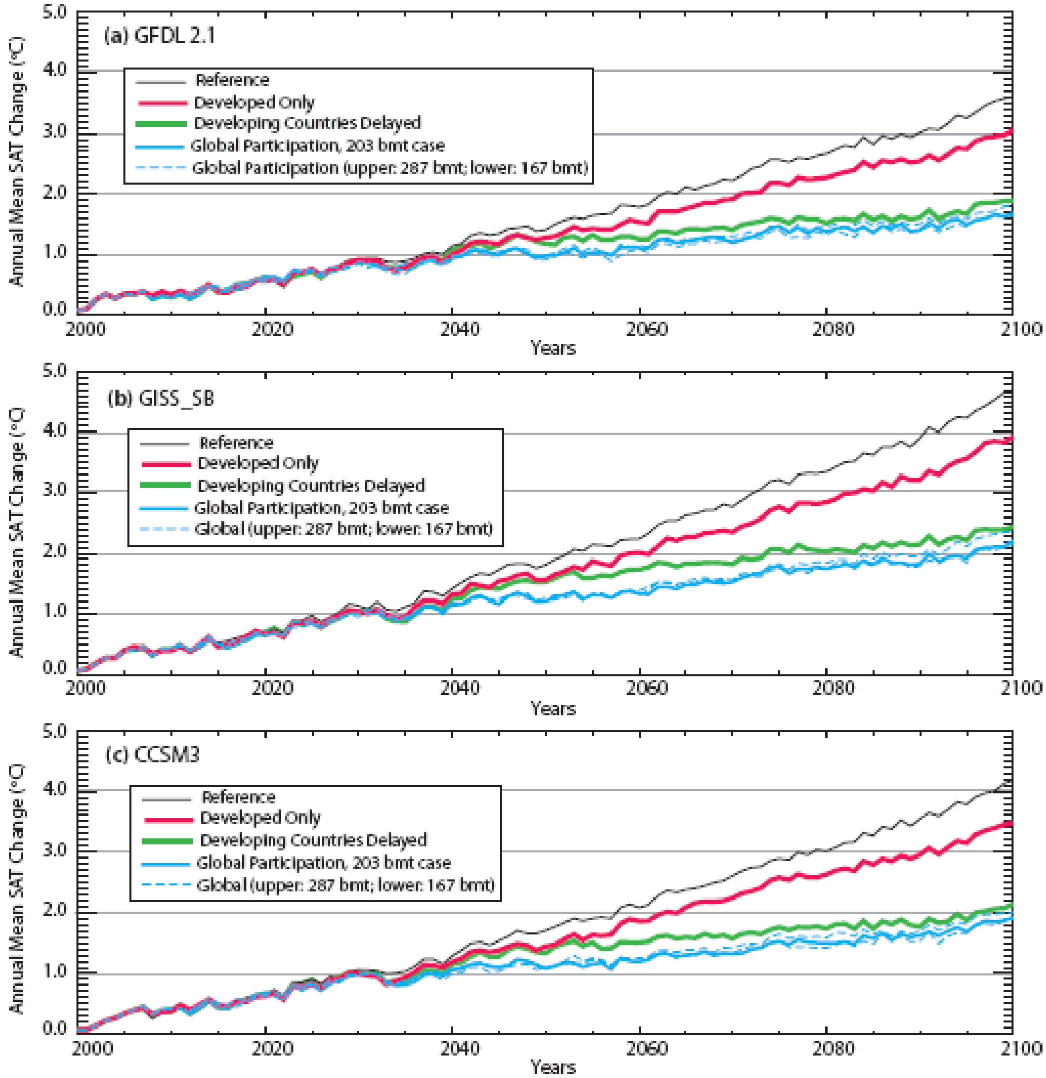
> ...it is not possible to connect specific U.S. policy targets with a particular global concentration or temperature target, and therefore the avoided damages, because any climate gains depend on efforts in the rest of the world.... If a cooperative solution is at all possible, therefore, a major strategic consideration in setting U.S. policy targets should be their value in leading other major countries to take on similar efforts.[112]

Instead, S. 2191's climate-related environmental benefit must be considered in a global context and the desire to engage the developing world in the reduction effort. It is in this context that the United States and other developed countries agreed both to reduce their own emissions to help stabilize atmospheric concentrations of greenhouse gases and to take the lead in reducing greenhouse gases when they ratified the 1992 United Nations Framework Convention on Climate Change (UNFCCC). **This global context raises two issues for S. 2191: (1) whether S. 2191's greenhouse gas reduction program and other provisions would be considered sufficiently credible by developing countries so that schemes for including them in future international agreements become more likely, and (2) whether S. 2191's reductions meet U.S. commitments to stabilization under the UNFCCC and occur in a timely fashion so that global stabilization may occur at an acceptable level.**

---

[112] ibid., p. 55.

Figure 11. Global Mean Surface Air-Temperature Increase in Six Scenarios Using the MIT IGSM



Source: Sergey Paltsev, et al., *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, Report No. 146 (April 2007) p. 51. Available at [http://mit.edu/globalchange]. Used by permission. Readers are urged to consult the report for details on the analysis discussed here.

Non-Climate Change Air Quality Benefits. As noted earlier, only the EPA/IPM study included any estimates of emission reductions from non-greenhouse gas air pollutants. Only two pollutants were analyzed, and the resulting estimates reflect short-term interactions between S. 2191 and existing cap and trade programs. However, it should be noted that values have been assigned to these pollutants from time to time. For example, in the notice of proposed rulemaking for the new average fuel economy standard, the Department of Transportation assigned emission damage costs of $3,900 a short ton for nitrogen oxides, $16,000 a short ton for sulfur dioxide, and $164,000 a short ton for particulate matter — all pollutants that are also emitted from coal-fired generating facilities.[113] This is an incomplete set of pollutants that would be reduced by S. 2191. Other benefits may occur from reductions of pollutants such as mercury and carbon monoxide.

Impact on Behavior. The impact of any price increases from S. 2191 on households, industries, and businesses would depend on their responsiveness to the price signal, the distribution of safety net funds under S. 2191, and the impact of various other provisions of the bill that encourage, or could be used to encourage, conservation and new technology development. Simple attempts by some presentations to break down the cost by industrial sector or by state "should be viewed with attentive skepticism"[114] for at least two reasons. First, baseline forecasts are even less accurate at a sector level than they are at an aggregate national level. As noted by Winebrake and Sakva, sector level baseline forecasts have significantly higher errors compared with aggregate estimates, nor have sector estimates improved over the past two decades:

> We find that low errors for total energy consumption are concealing much larger sectoral errors that cancel each other out when aggregated. For example, 5-year forecasts made between 1982 and 1998 demonstrate a mean percentage error for total energy consumption of 0.1%. Yet, this hides the fact that the industrial sector was overestimated by an average of 5.9%, and the transportation sector was underestimated by an average of 4.5% We also find no evidence that forecasts within each sector have improved over the two decades studied here.[115]

Second, particularly with respect to industry, the effect of S. 2191 is likely to be very site-specific, particularly as the primary impact will be indirect in terms of added energy costs, not direct compliance costs. An industry-by-industry approach masks the interplay of companies that would be affected differently by S. 2191.

Most industries face a competitive market (sometimes international in scope) both in terms of producers of the same products and producers of substitute products.

---

[113] Department of Transportation, National Highway Traffic Safety Administration, *Average Fuel Economy Standards: Passengers and Light Trucks: Model Years 2011-2015*, Notice of Proposed Rulemaking (April 2008), p. 182.

[114] As noted by CRS with respect to acid rain costs estimates in 1990. See CRS Report 90-63, *Acid Rain Control: An Analysis of Title IV of S. 1630*, by Larry Parker. (Available from the author.)

[115] James J. Winebrake and Denys Sakva, "An Evaluation of Errors in US Energy Forecasts: 1982-2003," *Energy Policy* 34 (2006), p. 3475.

Also, in some cases, an industry may face a fairly elastic demand for its product. Thus, most industries are price sensitive, and therefore any increase in manufacturing costs hurts the competitiveness of a firm. This complex situation is further complicated for energy-intensive industries in the case of S. 2191 as competitors within the same industry may experience different energy price increases (particularly for electric power), depending on their individual energy needs and power arrangements. Thus individual facilities within the same industry will be affected differently by S. 2191 and other unforeseen events in the future. For example, an aluminum plant receiving power from a hydro-electric facility may not be affected the same way as a similar plant with a power contract with a coal-fired power supplier.

This differential effect on individual companies under S. 2191 could have several potential impacts. First, as noted above, it may affect the competitive balance of specific facilities in the United States. Second, investment decisions by industries could be affected, particularly with respect to technology. New, more efficient technology is emerging for some processes. The combination of current price signals being sent from the energy markets and potential ones from S. 2191 could speed their development. If commercialized, new technology would reduce the impact of S. 2191 and, indeed, improve competitiveness. Not surprisingly, none of the cases presented here have sufficient industry sector detail to examine this possibility, nor did any attempt to develop proxies to explore the possibilities for industrial technology over the next 40 years.

S. 2191 attempts to ameliorate these effects somewhat by providing a subsidy for such industries facing international competitiveness issues. The degree to which the subsidy could address the issue was not examined by any of the cases presented here. Likewise, the sufficiency of the funds was not examined. Interestingly, such an approach to exposed industry has some parallels to recommendations that have been made with respect to carbon intensive industries in Europe facing reduction requirements and increased fuel cost from the EU's Kyoto Protocol, and post-Kyoto commitments. For example, one such recommendation by the UK Carbon Trust suggested the following:

> For a very small number of carbon-intensive, internationally exposed activities headed by steel and cement production, governments should establish a transitional 'compensating rate of free allocation' on an activity-specific basis, based upon the likely degree of cost pass-through given international trade conditions. The scale of free allocation to electricity-intensive activities in the EU-ETS (notably pulp and paper) should also take account of their electricity consumption, whilst manufacturing of fertilisers and basic chemicals might benefit from being brought into the EU-ETS on a similar basis. Together with aluminium smelting these constitute four trade-exposed electricity-intensive activities for which additional measures, linked to redistribution of auction revenues or equivalent 'downstream' allocation of electricity-related allowances, could be considered.... However, focused measures to facilitate direct, long-term

investment in low carbon electricity generation may offer the best long-term solution.[116]

For households, the interplay of price signals, conservation, and regulations is difficult to separate in the CGE models, such as ADAGE, IGEM, and EPPA. NEMS does break down the residential sector into both residential energy consumption and residential prices by fuel. However, any estimates from such a breakdown can only be considered illustrative at best. For example, the CATF/NEMS analysis illustrates that if S. 2191 results in only a moderate increase in electricity and natural gas prices, then households could, on average, respond with sufficient conservation and efficiency improvements to overcome the projected price increases and reduce their monthly bill compared with business as usual levels. If allowance prices are higher, this become more difficult. An effort by Keohane and Goldmark to estimate the monthly increase in residential electric bills based on MIT/EPPA's higher allowance prices resulted in a 6% increase in those bills in 2030.[117] Impacts on residential monthly natural gas bills would follow a similar pattern. The CATF/NEMS analysis indicates that an aggressive demand response by consumers almost eliminates the projected modest increase in natural gas prices. In contrast, Keohane and Goldmark calculations based on the higher allowance prices of the MIT/EPPA analysis result in a 14% increase in monthly natural gas prices in 2030.[118]

As with the energy-intensive industries discussed above, S. 2191 attempts to ameliorate the impact of projected energy price increases for low- and middle-income households by providing funds for states to provide electricity and natural gas impact assistance. The EIA/NEMS analysis breaks out the estimated impact of the electricity impact assistance funds in its calculation of household impacts. Assuming the value of the allowances allocated would be passed on to all consumers — not just low-income — EIA/NEMS estimates the reduction at one-half cent per kilowatthour (KWH) or about a 5% reduction in rates. If the money were directed toward low-income consumers, the impact would be greater. Including the effects of the impact assistance, EIA/NEMS estimates the average monthly household energy bill (excluding transportation) under S. 2191 would increase about $3 a month in 2020, rising to about $6 a month in 2030.

Overall, EIA/NEMS estimates that the Consumer Price Index (CPI) for energy in 2030 would be 18% higher for residential consumers and 29% higher for industrial consumers than basecase levels. To put these potential increased costs into context, EIA/NEMS compared its estimated incremental consumer and industrial energy prices increases under S. 2191 with those of the past 5 years. As indicated in **Figure 12** and stated by EIA/NEMS, "if measured from 2008 energy prices, it takes 22 years

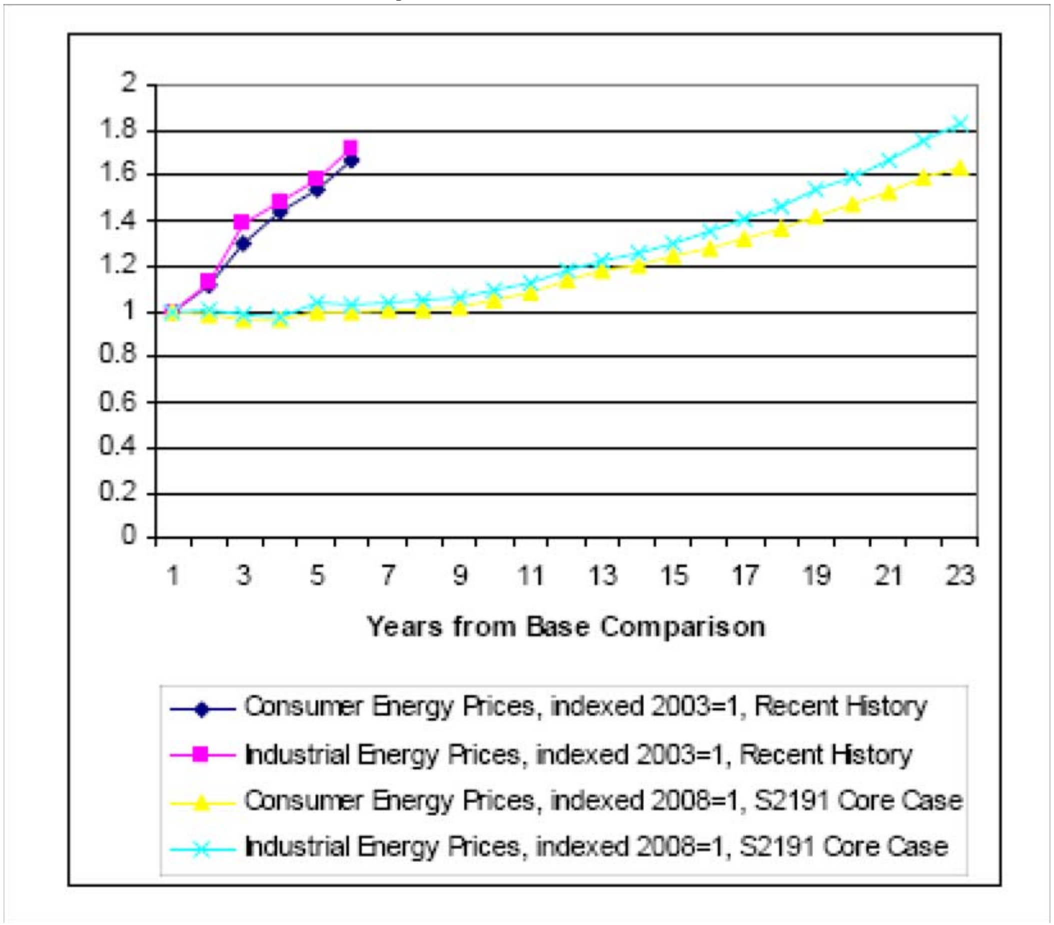
[116] Carbon Trust, *EU ETS Impacts on Profitability and Trade: A Sector by Sector Analysis* (January 2008) p. 8.

[117] Nataniel Keohane and Peter Goldmark, *What Will it Cost to Protect Ourselves from Global Warming? The Impacts on the U.S. Economy of a Cap-and-Trade Policy for Greenhouse Gas Emissions*, Environmental Defense Fund (2007), p. 16.

[118] Ibid, p. 17

in the S. 2191 Core Case to reach the same percentage change that current energy prices have increased from 2003 to 2008."[119]

Figure 12. Energy Price Change: Recent History Versus the S. 2191 Core Case



Source: Energy Information Administration, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008), p. 34.

Conclusion

This report examines six studies that project the costs of S. 2191 to 2030 or 2050. It is difficult (and some would consider it unwise) to project costs up to the year 2030, much less beyond. The already tenuous assumption that current regulatory standards will remain constant becomes more unrealistic, and other unforeseen events (such as technological breakthroughs) loom as critical issues which cannot be modeled. Hence, ***long-term cost projections are at best speculative, and should be viewed with attentive skepticism.*** In the words of the late Dr. Lincoln

[119] EIA, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007* (April 2008) p. 32.

Moses, the first Administrator of the Energy Information Administration: "There are no facts about the future."[120]

Models cannot predict the future, but they can indicate the sensitivity of a program's provisions to varying economic, technological, and behavioral assumptions that may assist policymakers in designing a greenhouse gas reduction strategy. The various cases examined here do provide some important insights on the costs and benefits of S. 2191 and its many provisions.

First, if enacted, the ultimate cost of S. 2191 would be determined by the response of the economy to the technological challenges presented by the bill. The bill provides numerous price, research and development, deployment, and regulatory incentives for technology innovation. The potential for new technology to reduce the costs of S. 2191 is not fully analyzed by any of the cases examined, nor can it be. The process of technology development and dissemination is not sufficiently understood at the current time for models to replicate with any long-term confidence. In the same vein, it is difficult to determine whether the various incentives provided by S. 2191 are directed in the most optimal manner.

Second, in some ways, the interplay between nuclear power, renewables, natural gas, and coal-fired capacity with CCS among the cases is a proxy for the need for a low-carbon source of electric generating capacity in the mid- to long-term. A considerable amount of low-carbon generation will have to be built under S. 2191 in order to meet the reduction requirement. The cases presented here do not agree on the amount of new generating capacity necessary under S. 2191 or the mix of fuels and technologies that would be employed. The estimated amount of capacity constructed depends on the cases' assumptions about the need for new capacity and replacement/retirement of existing capacity under S. 2191, along with consumer demand response to the rising prices and incentives contained in S. 2191.

Third, the cases suggest that the CCS bonus allowance allocation under S. 2191 is effective in encouraging deployment of CCS, accelerating development by 5-10 years. However, the cases disagree on whether the bonus amount provided by S. 2191 is sufficient, or needs to be extended additional years.

Fourth, the cases generally indicate that offsets could be a valuable tool for covered entities not only to potentially reduce costs, but perhaps more importantly, to buy time to further develop new, more efficient technologies. The availability of offsets could be complemented by the bill's provisions permitting banking, allowing companies more time to develop long-term investment and strategic plans, and to pursue technology development. Cost could be lowered further by allowing greater availability of offsets and international credits and with a broader definition of eligible international credits. A more direct path for permitting international credits from mechanisms such as the CDM would also reduce one of the more important cost uncertainties revealed by the cases' varying interpretations of international credit eligibility requirements and their projected price.

---

[120] Lincoln E. Moses, Administrator, Energy Information Administration, *Annual Report to Congress — 1977, Volume 2*, (1978).

Fifth, the Carbon Market Efficiency Board could have an important effect on the cost of the program through its power to increase the availability of offsets and international credits. The cases generally do not consider the Board in their analyses, however, one can infer from the cases' results that the most important power that the Board may have is the ability to increase the availability of domestic offsets and international credits (although not the authority to change the eligibility requirements for domestic offsets and international credits). In this sense, the Board's powers could mesh with the previous insight about the importance of offsets and banking to the cost-effectiveness of S. 2191. However, the Board is primarily designed to deal with short-term volatility due to episodic events in the allowance market and has only short-term powers. Whether it could coordinate a longer term strategy, if necessary, with its proposed authority is not known.

Sixth, the Low Carbon Fuel Standard could significantly raise fuel prices and limit supply. The effects will depend on what fuels are included in the LCFS, the level of emissions reductions achieved by alternatives, and the ability of suppliers to produce those alternatives. If plug-in hybrid vehicles or large amounts of cellulosic biofuel are available early, or if certain fuels such as aviation fuel are excluded from the mandate, the costs could be lower. Only one case provided any analysis of the LCFS.

Seventh, S. 2191's climate-related environmental benefit is best considered in a global context and the desire to engage the developing world in the reduction effort. It is in this context that the United States and other developed countries agreed both to reduce their own emissions to help stabilize atmospheric concentrations of greenhouse gases and to take the lead in reducing greenhouse gases when they ratified the 1992 United Nations Framework Convention on Climate Change (UNFCCC). **This global scope raises two issues for S. 2191: (1) whether S. 2191's greenhouse gas reduction program and other provisions would be considered sufficiently credible by developing countries so that schemes for including them in future international agreements become more likely, and (2) whether S. 2191's reductions meet U.S. commitments to stabilization under the UNFCCC and occur in a timely fashion so that global stabilization may occur at an acceptable level.**