U.S. Environmental Protection Agency
Office of Atmospheric Programs

EPA Analysis of the Lieberman-Warner Climate Security Act of 2008

S. 2191 in 110th Congress

March 14, 2008*

* This version was updated on 5/5/08 to reflect minor changes to slides 25, 60, 74, 79, 82, 155, 156, 165, 166, 167. Additionally slides 189 – 192 were added to cover power sector natural gas issues and global CO_2 concentrations.

Request for EPA Analysis

United States Senate
WASHINGTON, DC 20510

November 9, 2007

The Honorable Stephen L. Johnson
Administrator
Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Dear Administrator Johnson:

We are writing to request that EPA estimate the economic, greenhouse-gas emissions, and atmospheric greenhouse-gas concentration impacts of S.2191, America's Climate Security Act of 2007. A similar request is being sent to the Energy Information Administration.

We ask that EPA begin this process by meeting with our staff as soon as possible to discuss the parameters, methods, and duration of the analysis. Please call David McIntosh in Senator Lieberman's office at (202) 224-5016 or Chelsea Maxwell in Senator Warner's office at (202) 224-6283.

Thank you for your assistance with this analysis.

Sincerely,

Joseph I. Lieberman
UNITED STATES SENATOR

John Warner
UNITED STATES SENATOR

- On November 9, 2007 Senators Lieberman and Warner requested that EPA estimate the economic impacts of the S. 2191, the 'Climate Security Act of 2007' (now the 'Lieberman-Warner Climate Security Act of 2008').
- This document constitutes EPA's analysis in response to this request. The analysis is available online at:

www.epa.gov/climatechange/economics/economicanalyses.html

- The analysis was conducted by EPA's Office of Atmospheric Programs.
  Contact: Francisco de la Chesnaye.
  Tel: 202-343-9010.
  Email: delachesnaye.francisco@epa.gov.

Key Results & Insights

S. 2191 places declining GHG emission caps upstream on petroleum, natural gas, as well as manufacturers of F-gases and N_2O and downstream on coal facilities. The bill establishes a market-driven system of tradable emission allowances and permits the use of domestic offsets and international credits. There also are bonus allowances for carbon capture and storage and set-asides for agriculture & forestry sequestration and landfill and coal mine methane mitigation.

There are many uncertainties that affect the economic impacts of S. 2191, key among them are the availability of mitigation technologies and the level of international action on climate change. EPA analyzed ten different scenarios to evaluate a range of assumptions and key parameters. This analysis does not necessarily reflect EPA's views on what is most likely to occur.

<u>Emissions Impacts</u>

- Under S. 2191 total U.S. GHG emissions are approximately 40% lower (~ 3,749 $MtCO_2e$) than reference case emissions in 2030 (~11% below 1990 levels) and 56% lower (~ 6,030 $MtCO_2e$) in 2050 (~25% below 1990 levels).
- S.2191 covers 82% of total U.S. GHG emissions in both 2030 and 2050.
- While the impacts of S. 2191 on global CO_2 concentrations are not explicitly analyzed here, based on EPA's previous analysis of the Lieberman-McCain bill (S. 280) and the fact that S. 2191 requires greater emissions reductions than that bill, the incremental impact of S. 2191 on global CO_2 concentrations would likely be greater than 25 ppm in 2095. Assuming Kyoto countries (excluding Russia) reduce emissions to 50% below 1990 levels by 2050, and all other countries adopt GHG emissions targets in 2025 and return emissions to 2000 levels by 2035, the global CO_2 concentration in 2095, while not stabilized, would likely be lower than 491 ppm if the US adopts S. 2191.
  - EPA plans to release the revised version of this analysis in early June, 2008 that will incorporate the Energy Independence and Security Act into the baseline. This revised analysis will also include an explicit analysis of global CO_2 concentrations.

<u>Sector Impacts</u>

- The greatest emission abatement under S. 2191 occurs in CO_2 emissions from the electricity sector.
- The transportation sector provides a relatively small proportion of CO_2 emissions abatement. This result reflects relatively modest indirect price signal an upstream cap and trade program sends to the transportation sector.
  - The price signal provided by S. 2191 (~$0.53 increase in the price of gasoline in 2030, ~$1.40 increase in 2050), is not high enough to cause large changes in the demand for transportation or changes in how transportation services are provided.
  - This analysis did not estimate the reductions that could be achieved under a direct fuel and vehicle regulatory framework.

Key Results & Insights (con't)

Economic Impacts

- In the S.2191 Scenario, modeled allowance prices range between \$61 - 83/tCO_2e in 2030, and \$159 - 220/tCO_2e in 2050. Under an alternative reference scenario with lower emissions in the baseline, modeled allowance prices range between \$46 - 73/tCO_2e in 2030, and \$121 - 193/tCO_2e in 2050.
- 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.
- By 2030, GDP and consumption are projected to increase 97% from 2007 levels in the Reference Scenario. By 2050, the projected increase in GDP and consumption from 2007 levels is 215%.
- Under S.2191, GDP is modeled to be between 0.9% (\$238 billion) and 3.8% (\$983 billion) lower in 2030 and between 2.4% (\$1,012 billion) and 6.9% (\$2,856 billion) lower in 2050 than in the Reference Scenario. Consumption is modeled to be between 0.9% (\$180 billion) and 1.4% (\$233 billion) lower in 2030 and between 2.1% (\$670 billion) and 3.3% (\$843 billion) lower in 2050 than in the Reference Scenario.
- The average annual growth rate of consumption is ~0.08 percentage points lower than the reference case. In 2030 per household average annual consumption is ~\$1,375 lower and gasoline prices increase ~\$0.53 per gallon. In 2050 per household average annual consumption is ~\$4,377 lower and gasoline prices increase ~\$1.40 per gallon.
- Electricity prices are projected to increase 44% in 2030 and 26% in 2050, assuming the cost of allowances can partially be passed on to consumers (as is the case in a full auction). If allowances are given directly to power companies, the cost of those allowances would not be passed on to consumers in regulated electricity markets, so electricity price increases would be smaller in much of the country.
- In our modeling, market outcomes are invariant to the auctioning of allowances given the assumption of lump sum transfers of auction revenues back to households. If the auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower. Other uses of auction revenues have the potential to increase the costs of the policy.
- The economic benefits of reducing emissions were not determined for this analysis.

Key Results & Insights (con't)

Enabling Technologies

- Different assumptions in the economy-wide model and the detailed energy sector model demonstrate the importance of key enabling technologies, specifically Carbon Capture and Storage (CCS) and nuclear power.
  - While not yet proven on a commercial scale, CCS has been the focus of considerable R&D funding. The combination of allowance price and subsidy for CCS causes the technology to deploy before 2020. Detailed electricity sector modeling shows CCS penetration by 2015.
- Detailed electricity sector modeling suggests many existing coal plants are no longer economic to run and operate. Economy-wide models indicate that fossil fuel usage peaks in 2010 with a slow decline to 2050.
- The rate of CCS penetration is subject to a great deal of uncertainty. Given our assumptions about availability, cost, and performance of CCS technology, economy-wide modeling shows a small amount of CCS built in 2020 with the rate increasing until most all traditional fossil is displaced by 2040. Detailed electricity sector modeling suggests that the initial penetration of CCS may be much faster.
- In economy-wide modeling, other non-fossil generation (e.g. biomass, wind and solar) plays a significant role under S. 2191.
- In the core scenarios, nuclear power grows by ~150% by 2050 from 2005 levels. In scenarios where technologies were constrained, i.e., nuclear power growth limited to ~ 75%, delay of CCS deployment until 2030 or limited use of biomass for electricity generation, costs were significantly higher: GHG allowances prices increased more than 80% in 2030 and 2050 and GDP losses increased by more than 150% in 2030 and 80% in 2050.

Key Results & Insights (con't)

Regional Impacts

- Regional impacts depend on a variety of factors, including economic base, energy use, electricity generation, and allowance allocation.
- Across all regions, the most significant emissions reductions are from coal use, with the largest reductions coming in the South and Midwest regions. By 2030, electricity generation is switching from coal to natural gas and CCS.
- In the majority of regions, GDP and consumption impacts are less than 3% in 2030 and 2050. The largest GDP and consumption impacts are in the Plains region. (This is driven by among other things, regional differences in the energy and manufacturing industry composition; regional energy use patterns including household heating and cooling needs, and average distance traveled; and existing fossil fuel capacity in the electricity sector).

Emissions Leakage and International Climate Policy Sensitivity

- Under the core S. 2191 international assumptions, no international emissions leakage occurs. In fact, emissions in Group 2 countries fall by over 12,000 million metric tons CO_2 equivalent ($MtCO_2e$) as they adopt emission targets beginning in 2025.
- As Group 2 countries adopt targets, the U.S. imports fewer energy-intensive manufacturing goods from Group 2, and exports more.
- Under Alternative International Action assumptions, Group 2 countries do not take any action. Emissions leakage occurs under these assumptions, with Group 2 emissions rising by 350 $MtCO_2e$ in 2030, and 385 $MtCO_2e$ in 2050 from the reference case. This is a less than 1% increase in Group 2 emissions from the reference levels, and is equivalent to U.S. emissions leakage rates of approximately 11% in 2030 and 8% in 2050.The amount of leakage is somewhat limited by the purchase of international offsets from Group 1 Countries to meet the U.S. cap.
- It is assumed that the International Reserve Allowance Requirement is triggered in the Alternative International Action scenario, which limits the emissions leakage marginally. Without this import requirement, emissions leakage is 361 $MtCO_2e$ in 2030, and 412 $MtCO_2e$ in 2050, which is equivalent to the same leakage rates as with the international allowance requirement.
- Under Alternative International Action, the U.S. exports less energy-intensive manufacturing goods to Group 2, as Group 2 countries use more of their domestic energy-intensive manufacturing, resulting in increased emissions in Group 2. Imports of energy-intensive manufacturing goods from Group 2 to the U.S. rise in 2030 since Group 2 is not taking any emission action. In the absence of the International Reserve Allowance Requirement, imports from Group 2 would increase to a greater extent.

Key Results & Insights (con't)

Offsets Sensitivities

- If the use of domestic offsets and international credits is unlimited, then allowance prices fall by 71% compared to the bill as written.
  - In this scenario 52% of abatement comes from international credits in 2030, and 45% of abatement comes from international credits in 2050. In terms of compliance obligation (which is limited to 15% for international credits in the bill as written) 65% comes from international credits in 2030, and 169% comes from international credits in 2050.
- If the use of domestic offsets is unlimited, and international credits are still limited to 15% of compliance obligation, then allowance prices fall by 26% compared to the bill as written.
  - In this scenario 26% of abatement comes from domestic offsets in 2030 and 15% of abatement comes from domestic offsets in 2050. In terms of compliance obligation (which is limited to 15% for domestic offsets in the bill as written) 33% comes from domestic offsets in 2030, and 41% comes from domestic offsets in 2050.
- If international credits are not allowed (or are more expensive than U.S. GHG allowances), and domestic offsets are still limited to 15%, then allowance prices increase by 34% compared to the bill as written.
- If domestic offsets and international credits are not allowed, and the caps must be met solely through emissions reductions in covered sectors, then allowance price increases by 93% compared to the bill as written.

Alternative Reference Sensitivities and the Energy Independence and Security Act of 2007

- This analysis of S. 2191 was initiated before the signing of the Energy Independence and Security Act (EISA) of 2007. The Act is not included in EPA Reference Scenario which is based on EIA's AEO 2006 Reference case.
- Since AEO 2006 there have been important updates to EIA's most current reference case in the AEO 2008 that are relevant to the analysis of S. 2191, particularly in projected energy consumption and CO_2 emissions.
- EISA is also expected to have implications for the U.S. Reference Case emissions of greenhouse gases.
- EPA analyzes an Alternative Reference Scenario and the effects of S. 2191 on that reference case. The Alternative Reference Scenario assumes earlier adoption of energy efficient and low emitting technology. In this sense, they are qualitatively similar to a reference case reflecting the Energy Security and Independence Act of 2007. EPA has not yet modeled the Energy Act. We expect the difference between the economic impacts in the Reference analysis and the Alternative Reference Scenario analysis to be directionally similar to forthcoming runs incorporating the AEO 2008 assumptions which will include the incentives and standards of the Energy Act.
- Under Alternative Reference Scenario assumptions, in 2030 the reference case emissions are ~7% (~650 $MtCO_2e$) lower than under the core technology assumptions.
- Under S. 2191 Alternative Scenario, total U.S. GHG emissions are approximately 35% (~3,100 $MtCO_2e$) lower than the Alternative Reference Scenario emissions in 2030, and 52% (~5,200 $MtCO_2e$) lower in 2050.

Key Uncertainties

- There are many uncertainties that affect the economic impacts of S. 2191.
- This analysis contains a set of scenarios that cover some of the most important uncertainties:
  - The extent and stringency of international actions to reduce GHG emissions by developed and developing countries.
  - The availability of foreign credits and international offset projects.
  - The availability of domestic offset projects.
  - The degree to which new nuclear power is technically, politically, and socially feasible.
  - Whether or not carbon capture and storage technology will be available at a large scale.

Contents

Legislative Assessment and Analytical Approach

"Lieberman-Warner Climate Security Act of 2008" (S. 2191) Bill Summary

- Economy-wide coverage:
  - Upstream on petroleum, natural gas, as well as manufacturers of F-gases and N_2O
  - Downstream on coal facilities (that use over 5,000 tons of coal per year)
- GHG emission targets for covered sectors (targets decline in each calendar year):

  2012: 5,775 $MtCO_2e$
  2020: 4,924 $MtCO_2e$
  2030: 3,860 $MtCO_2e$
  2050: 1,732 $MtCO_2e$ (70% below 2005 emissions levels from covered facilities)

- Establishes a market-driven system of tradable emission allowances
- Establishes a separate cap and trade system for the consumption of HFCs
  - EPA's mitigation estimates for HFCs are based on production of the chemicals; the bill calls for reductions in HFC consumption. EPA is currently revising its mitigation estimates to more appropriately analyze this provision of the bill and will provide the analysis in the revised version of the full analysis in early June.
- Domestic offsets may be used to meet 15% of compliance obligation
- International credits may be used to meet 15% of compliance obligation
- Establishes a Carbon Market Efficiency Board
- Set-asides for agriculture and forestry sequestration as well as landfill and coal mine methane
- Bonus allowances for CCS*
- International reserve allowance requirement*

* The bonus allowances for CCS, and the international reserve allowance requirement provisions are similar to provisions in the Bingaman Specter bill (S. 1766). EPA's analysis of S. 1766 is available at:www.epa.gov/climatechange/economics/economicanalyses.html

Note: Additional Provisions of the bill that are not modeled are discussed in Appendix 1: Modeling Approach and Limitations

Analytical Scenarios

The assumptions about other domestic and international policies that affect the results of this analysis do not necessarily reflect EPA's views on what is most likely to occur.

1) EPA Reference Scenario

- This reference scenario is identical to the reference scenario used in the EPA analyses of S. 280 and S. 1766
  - Does not include any additional climate policies or measures to reduce international GHG emissions
  - For domestic projections, benchmarked to AEO 2006 (which does not include the Energy Independence and Security Act).
  - For international projections, uses CCSP Synthesis and Assessment Report 2.1 A MiniCAM Reference

2) S. 2191 Scenario

- This policy scenario uses the same assumptions about technology and international action used in the main policy scenarios in the EPA analyses of S. 280 and S. 1766
  - Bill as written
  - Substantial growth in nuclear power (nuclear power generation increases by ≈150% from 782 bill. kWh in 2005 to 1,982 bill. kWh in 2050) reflecting possible future policies to promote this technology in S. 2191 and elsewhere
  - Widespread international actions by developed and developing countries over the modeled time period. International policy assumptions are based on those used in the recent MIT report, "Assessment of U.S. Cap-and-Trade Proposals"
    - Group 1 countries (Kyoto group less Russia) follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050
    - Group 2 countries (rest of world) adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050

Analytical Scenarios (con't)

In the following scenarios all assumptions are identical to scenario 2 unless specified. These scenarios are drawn from the EPA analysis of S. 280.

3) S. 2191 Scenario with Low International Actions

- This policy scenario uses the same assumptions used in the "low international action" policy scenarios from EPA's analyses of S. 280 and S. 1766
  - Group 2 (developing) countries do not take on GHG emissions targets over the period of the analysis
  - Group 1 countries continue on a "Kyoto Forever" path

4) S. 2191 Scenario Allowing Unlimited Offsets

- This policy scenario uses the same assumptions used in the "Unlimited Offsets" policy scenarios from EPA's analyses of S. 280 and S. 1766
  - Removes the constraint in S. 2191 that limits the usage of domestic offsets to 15% of allowance submissions
  - Removes the constraint in S. 2191 that limits the usage of international credits to 15% of allowance submissions

5) S. 2191 Scenario with No Offsets

- This policy scenario uses the same assumptions used in the "No Offsets" policy scenarios from EPA's analysis of S. 280
  - Assumes offsets and international credits are not allowed so that all reductions must come from covered entities within covered sectors

Analytical Scenarios (con't)

In the following scenarios all assumptions are identical to scenario 2 unless specified. These scenarios are based on the scenarios requested by Senators Inhofe, Voinovich, and Barrasso.

6) S. 2191 Constrained Nuclear & Biomass

- Assumes nuclear power does not exceed reference case growth
- Assumes biomass power does not exceed reference case growth

7) S. 2191 Constrained Nuclear, Biomass, and CCS

- Assumes nuclear power does not exceed reference case growth
- Assumes biomass power does not exceed reference case growth
- Assumes carbon capture and sequestration technology does not become commercially available until 2030

8) S. 2191 Constrained Nuclear, Biomass, and CCS + Beyond Kyoto + Natural Gas Cartel

- Assumes nuclear power does not exceed reference case growth
- Assumes biomass power does not exceed reference case growth
- Assumes carbon capture and sequestration technology does not become commercially available until 2030
- Assumes GHG caps in Group 1 countries are implemented and reduced to 20% below 1990 levels in 2020 and on a trajectory to 80% below 1990 levels in 2050
- Assumes Group 2 countries adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050
- Assumes a functioning natural gas cartel that can extract natural gas prices equivalent to the energy content parity with Low Sulfur Light imported crude

Analytical Scenarios (con't)

The following scenarios are based on the Alternative Reference scenarios from EPA's analysis of the Low Carbon Economy Act of 2007 (S. 2191).

9) Alternative Reference Scenario

- This reference scenario is identical to the 'High Technology Reference Scenario' used in the EPA analysis of S. 1766
  - Does not include any additional climate policies or measures to reduce international GHG emissions
  - For domestic projections, benchmarked to AEO 2006 High Technology Case
  - For international projections, use CCSP Synthesis and Assessment Report 2.1 A MiniCAM Referece

10) S. 2191 Alternative Reference Scenario

- This policy scenario uses the same assumptions about technology and international action used in the High Technology policy scenarios in the EPA analysis of S. 1766
  - Based on Alternative Reference Scenario
  - Bill as written
  - Substantial growth in nuclear power (nuclear power generation increases by ≈150% from 782 bill. kWh in 2005 to 1,982 bill. kWh in 2050) reflecting possible future policies to promote this technology in S. 2191 and elsewhere
  - Widespread international actions by developed and developing countries over the modeled time period. International policy assumptions are based on those used in the recent MIT report, "Assessment of U.S. Cap-and-Trade Proposals"
    - Group 1 countries (Kyoto group less Russia) follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050
    - Group 2 countries (rest of world) adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050

EPA Models and Corresponding GHG Mitigation

S. 280 Sectors		Economy-wide Computable General Equilibrium (CGE) Models		Models Used to Provide Inputs to CGEs				Partial Equilibrium Model (Uses CGE Outputs)
		ADAGE	IGEM	NCGM	FASOM	GTM	MiniCAM	IPM
Domestic	Electricity Generation	All GHGs	All GHGs					CO_2
Domestic	Transportation	All GHGs	All GHGs					
Domestic	Industry	All GHGs	All GHGs	CH_4, N_20, F-gases				
Domestic	Commercial	All GHGs	All GHGs					
Domestic	Agriculture (& Forestry)	All GHGs	All GHGs		CO_2, CH_4, N_20			
Domestic	Residential	All GHGs	All GHGs	CH_4, N_20,				
International Credits*				CH_4, N_20, F-gases		CO_2	CO_2, CH_4, N_20, F-gases	

* International allowance and domestic offset markets were analyzed using EPA's spreadsheet tool which combines results from the NCGM, FASOM, GTM and MiniCAM models.

ADAGE Applied Dynamic Analysis of the Global Economy (Ross, 2007)
IGEM Intertemporal General Equilibrium Model (Jorgenson, 2007)
IPM Integrated Planning Model (EPA, 2007)
NCGM EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH_4, N_2O, and F-gases (EPA, 2005)
FASOMGHG Forest and Agriculture Sector Optimization Model, GHG version (EPA, 2005)
GTM Global Timber Model (Sohngen, 2006)
MiniCAM Mini-Climate Assessment Model (Edmonds, 2005)

Modeling Limitations*

- The Energy Independence and Security Act (EISA) of 2007
  - This analysis of S. 2191 was initiated before the signing of the Energy Independence and Security Act of 2007. The Energy Act is expected to have significant implications for the U.S. Reference Case emissions of greenhouse gases, and is expected to reduce the costs of compliance with S. 2191.
  - EPA is releasing this analysis of S. 2191 based on the EPA Reference Scenario assumptions used for the previously released analyses of S. 280 and S.1766 to facilitate comparison of the three bills.
  - EPA plans to re-analyze S. 2191 using a reference scenario based on the revised *Annual Energy Outlook 2008* which will include the EIA analysis of the 2007 Energy Bill.
  - EPA plans to release the revised analysis including EISA in the reference case in early June, 2008.

* Additional modeling limitations can be found in *Appendix 1: Modeling Approach and Limitations*

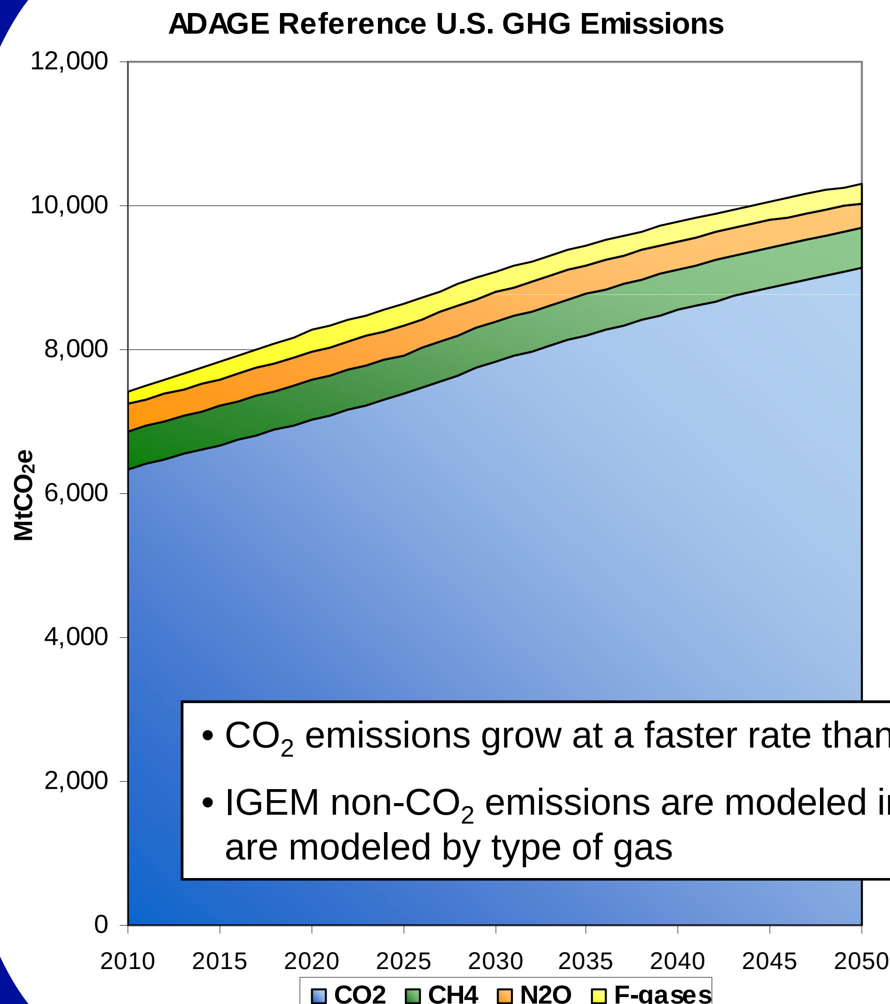
Modeling Limitations (con't)

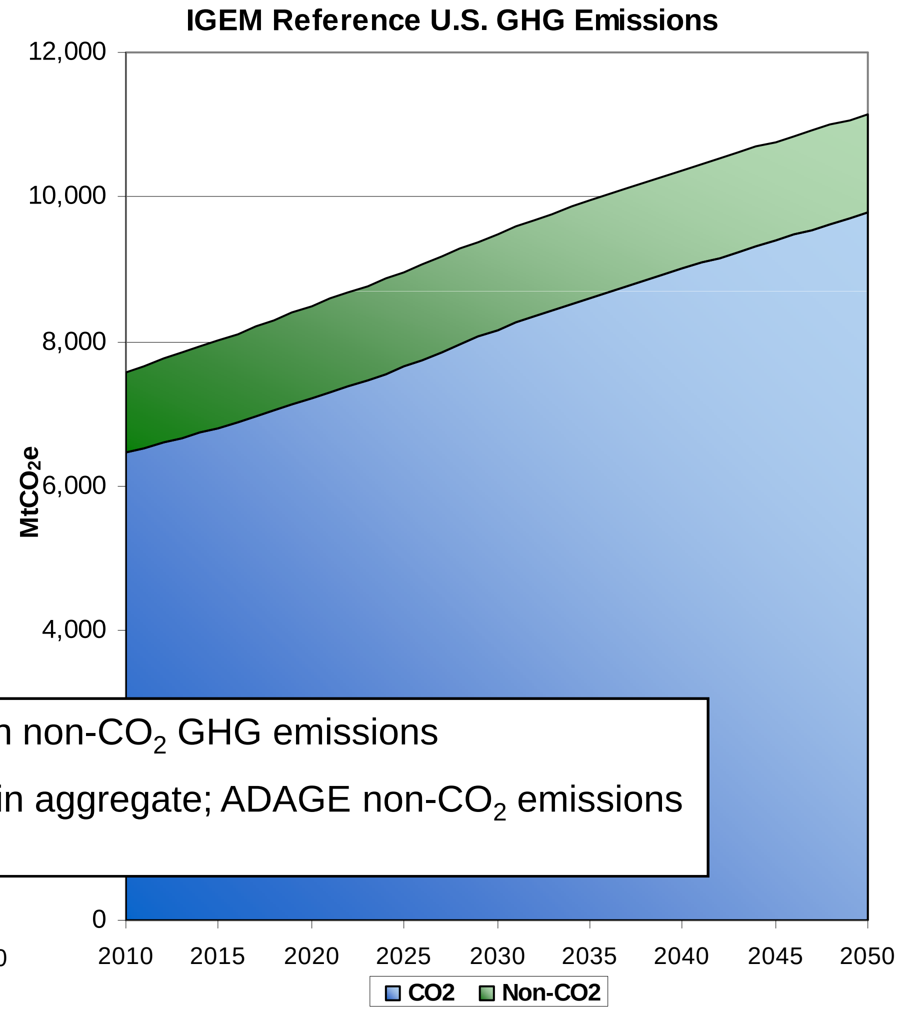
- Alternative Reference Scenario and the preliminary AEO 2008 Reference Case
  - *AEO 2008* forecasts lower CO_2 emissions than the *AEO 2006* Reference case used in EPA's models due to:
    - Slower rate of growth in GDP due to a lower estimate of growth in labor productivity,
    - Higher prices for crude oil and natural gas, and
    - Slower projected growth in energy demand.
  - The *AEO 2006 High Technology Case*, however is closer to the CO_2 emissions in the *AEO 2008*, although for different reasons. The EPA Alternative Reference Scenario is based on the EIA *AEO 2006* High Technology Case.
    - Corporate Average Fuel Economy is assumed to be 9% higher than in the reference case (35.5 MPG for automobiles and 27.1 MPG for light trucks). The Energy Act would require a 25% improvement.
    - Ethanol (Corn or Cellulosic) is not assumed to be consumed on the scale required by the new Renewable Fuels Standard.
    - The AEO High Technology Case assumes improvement in end use energy efficiency in residential, commercial and industrial applications, but EPA does not have the data to compare these to the standards required by the Energy Act.

GHG Emissions Results

Results: Scenario 1 – Reference

U.S. GHG Emissions

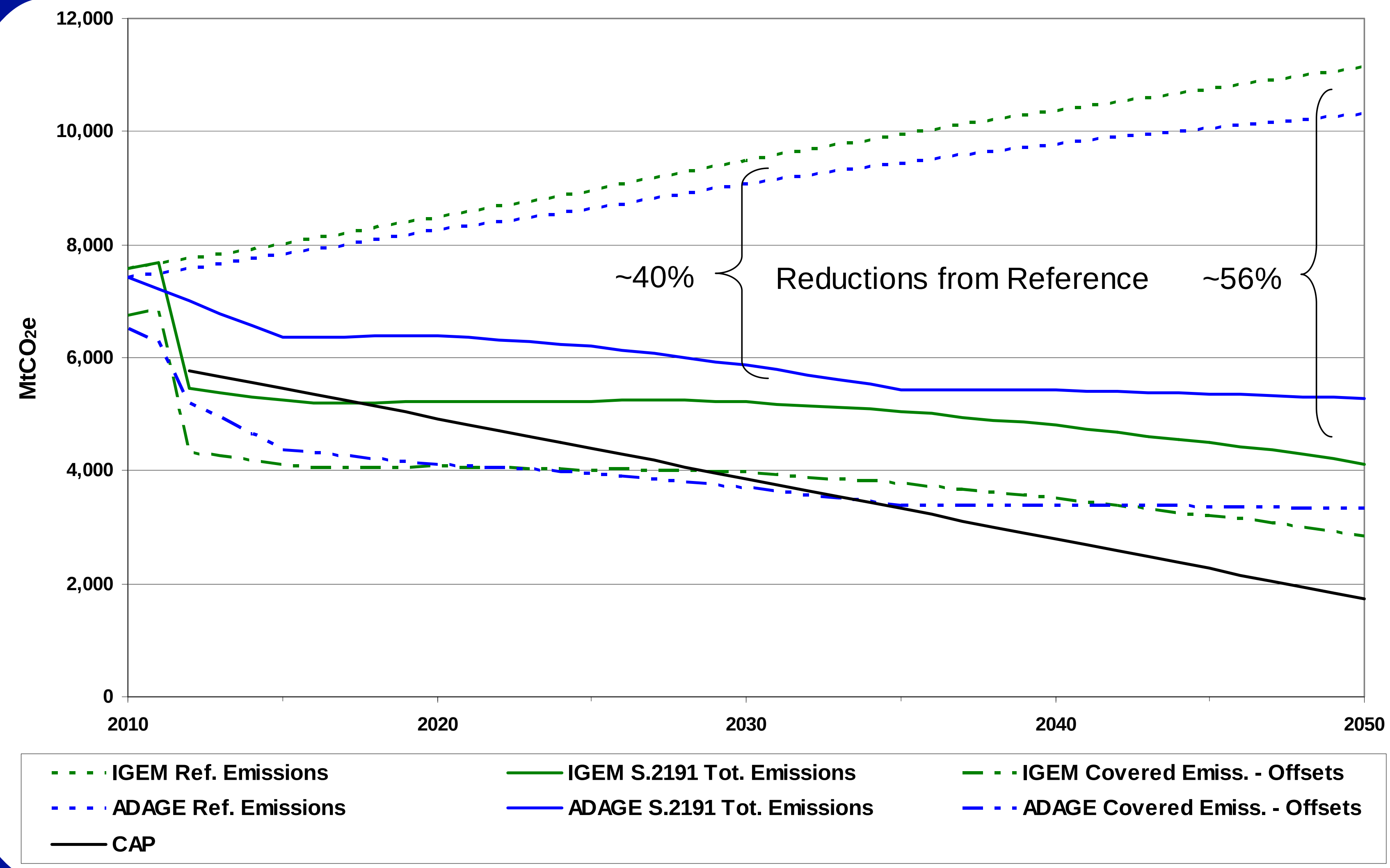




- CO_2 emissions grow at a faster rate than non-CO_2 GHG emissions
- IGEM non-CO_2 emissions are modeled in aggregate; ADAGE non-CO_2 emissions are modeled by type of gas

Results: Scenario 2 - S. 2191

U.S. GHG Emissions



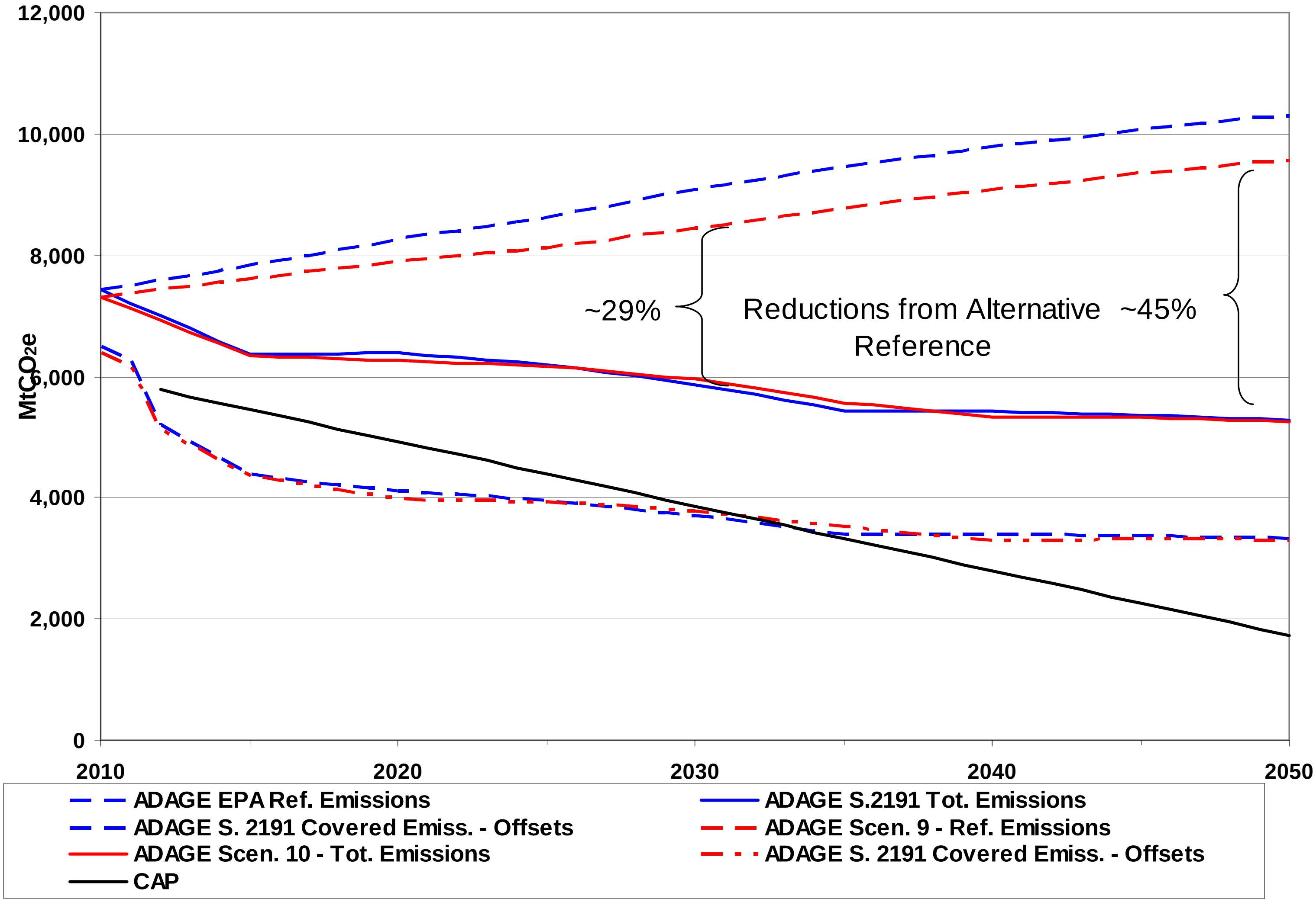
Results: Scenario 2 - S. 2191

U.S. GHG Emissions

- The previous chart shows the emissions results for S. 2191.
- The two dotted lines at the top are the Reference Scenario emissions of IGEM and ADAGE.
- At the bottom of the chart, the black line is the cap on covered sector emissions.
- The dashed blue and green lines show the emissions of covered sectors, taking into account purchases of domestic offsets and international credits.
- The solid blue and green lines show total U.S. emissions under S. 2191. These levels include emissions from non-covered sectors.
  - In 2030, total U.S. emissions under S. 2191 are reduced in IGEM by 4,276 $MtCO_2e$ from the Reference Scenario (45% reduction) and 3,101 $MtCO_2e$ in ADAGE (34% reduction).
  - In 2030, total U.S. emissions under S. 2191 are 16% below 1990 levels in IGEM, and 6% below 1990 levels in ADAGE.
  - In 2050, total U.S. emissions under S. 2191 are 34% below 1990 levels in IGEM, and 15% below 1990 levels in ADAGE.
- Note that the emissions reductions resulting from S. 2191 are larger in IGEM than in ADAGE. This is the result of two factors:
  - While the reference case for both models is tuned to the AEO 2006 forecast, that forecast only runs through 2030, and the tuning process is not exact. The reference case emissions in IGEM are higher than the reference case emissions in ADAGE, so that IGEM requires greater emissions reductions than ADAGE in order to meet the same target.
  - Additionally, the two models use different procedures to model covered versus uncovered emissions, and ADAGE has a larger amount of uncovered emissions. This can be seen in the gap between the 'Covered Emiss. – Offsets' lines and the 'Total Emiss.' lines (noting that similar amounts of offsets are used in both models).
- S. 2191 results in reductions of non-U.S. GHG emissions through U.S. purchases of international credits, so the bill actually reduces global GHG emissions by more than the solid blue and green lines indicate. The bill results in the purchase of 601 $MtCO_2e$ of international credits in 2030, which is approximately six percent of the U.S. Reference Scenario emissions.

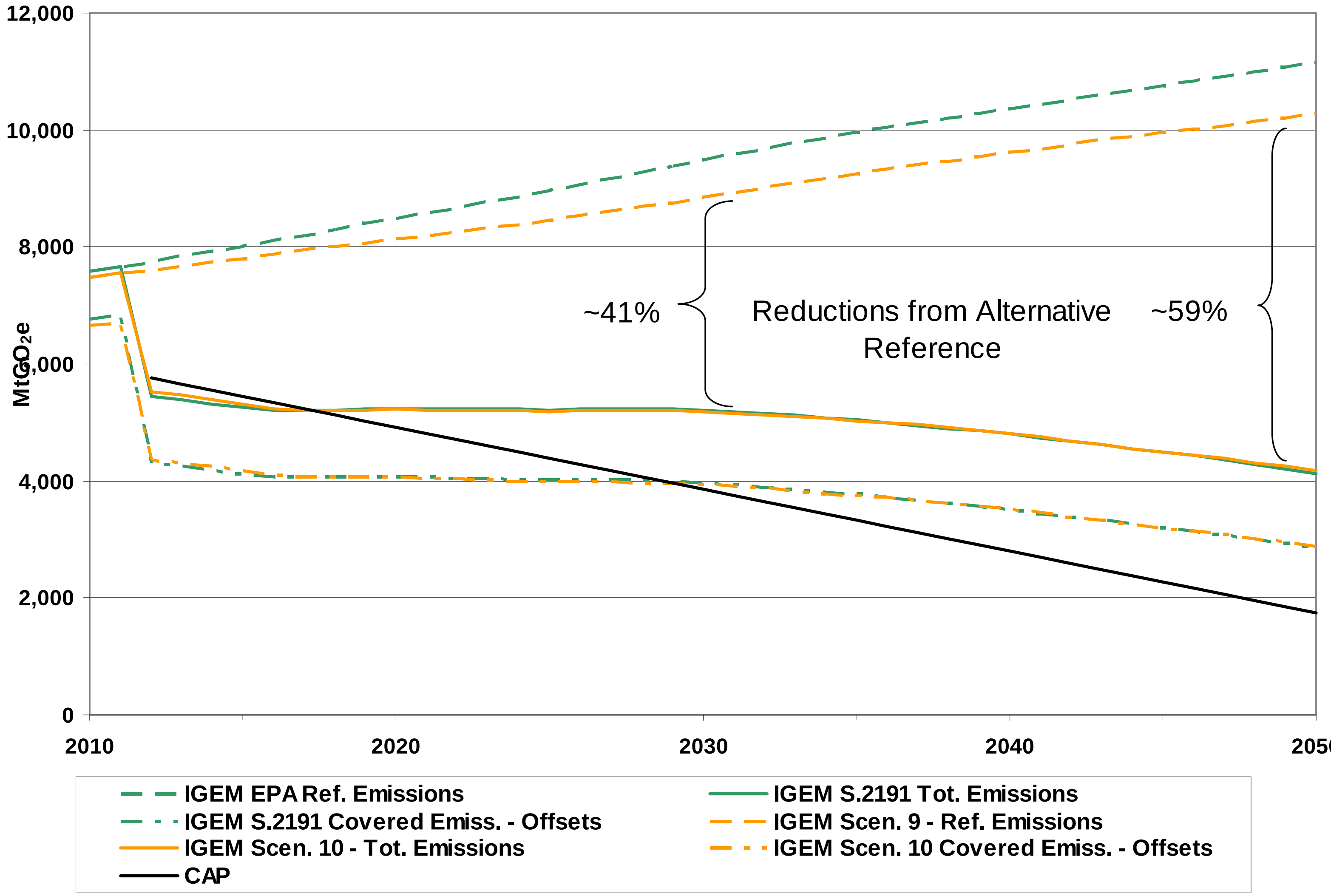
Results: Scenario 10 – S.2191 Alternative Reference

U.S. GHG Emissions (ADAGE)



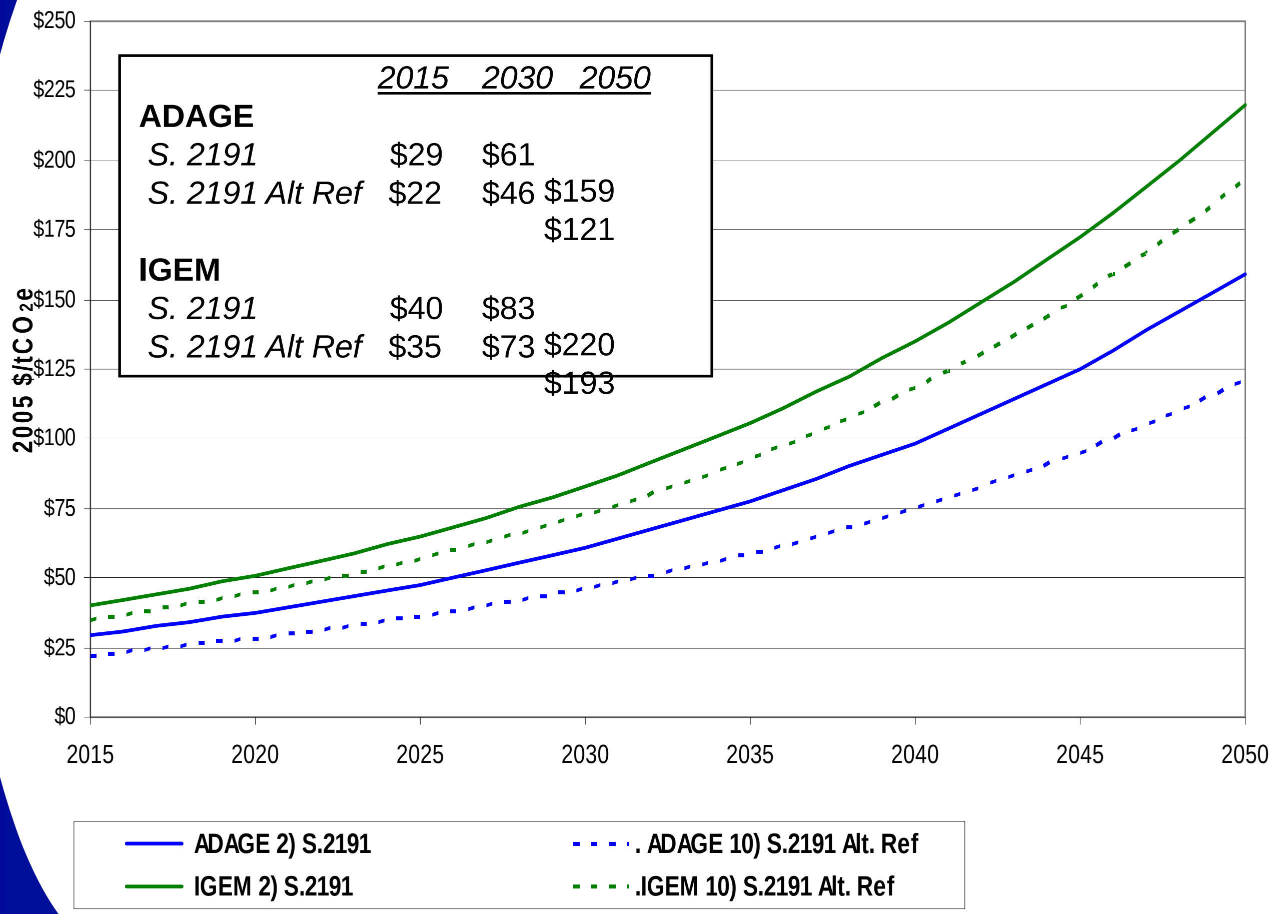
Results: Scenario 10 – S.2191 Alternative Reference

U.S. GHG Emissions (IGEM)



Results: Scenario 2 – S. 2191, Scenario 10 – S. 2191 Alt. Ref.

GHG Allowance Prices



- The $61 - $83 range of 2030 allowance prices only reflects differences in the models and does not reflect other scenarios or additional uncertainties discussed elsewhere.
- Note that although the offset price differs from the allowance price, these prices do reflect the use of offsets and international credits.

Comparison with Other Analyses

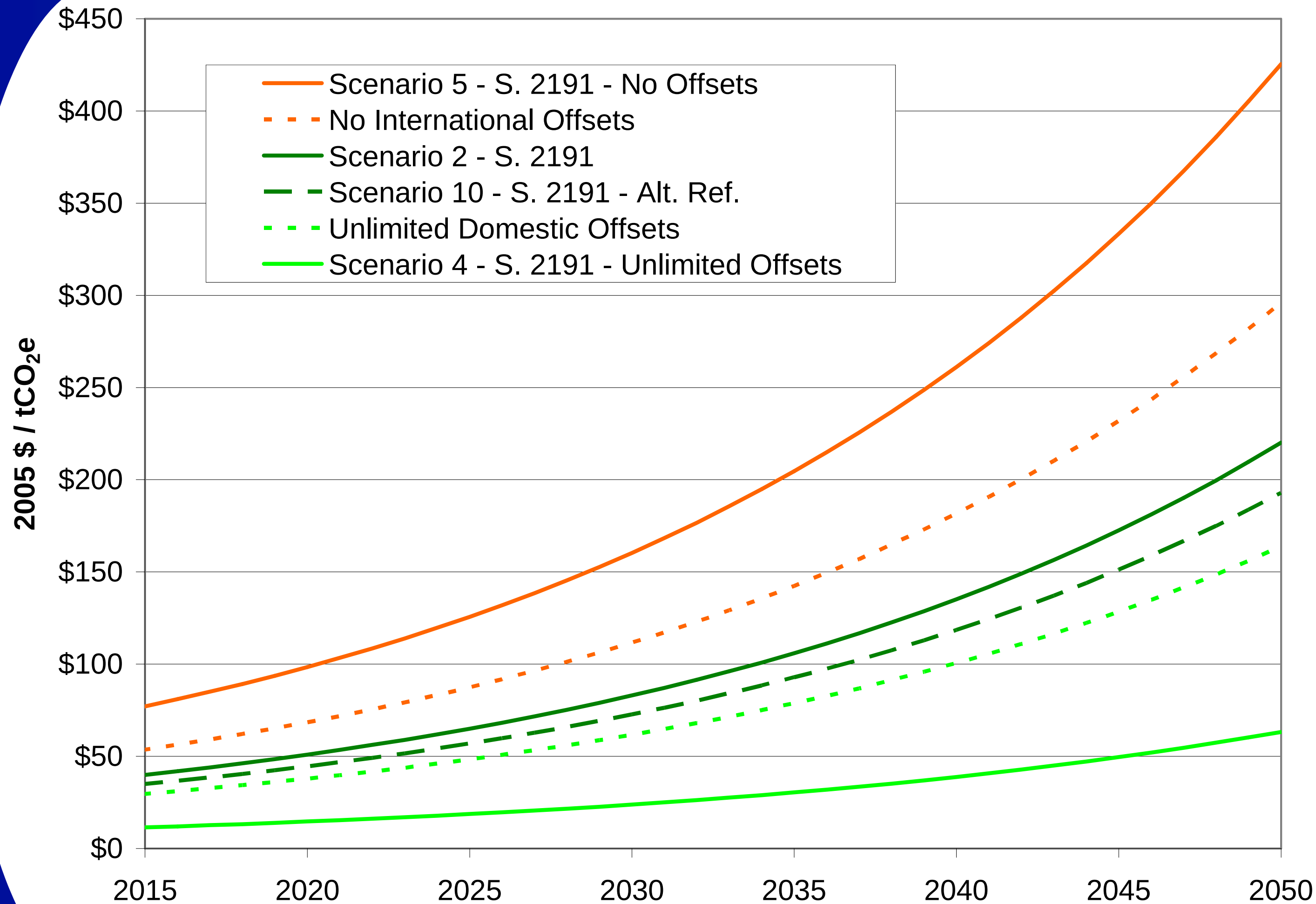
	2015	*2030*	*2050*
MIT*	$48	$86	$189
CRA**	~$50	~$90	~$200

* Paltsev et al., "Assessment of U.S. Cap-and-Trade Proposals – Appendix D: Analysis of the Cap and Trade Features of the Lieberman-Warner Climate Security Act (S. 2191)" 2007. *LW + 15% Credits + CCS Subsidy Scenario*.

** CRA International, "Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model," April, 8 2008.

Scenario Comparison

GHG Allowance Prices (IGEM)

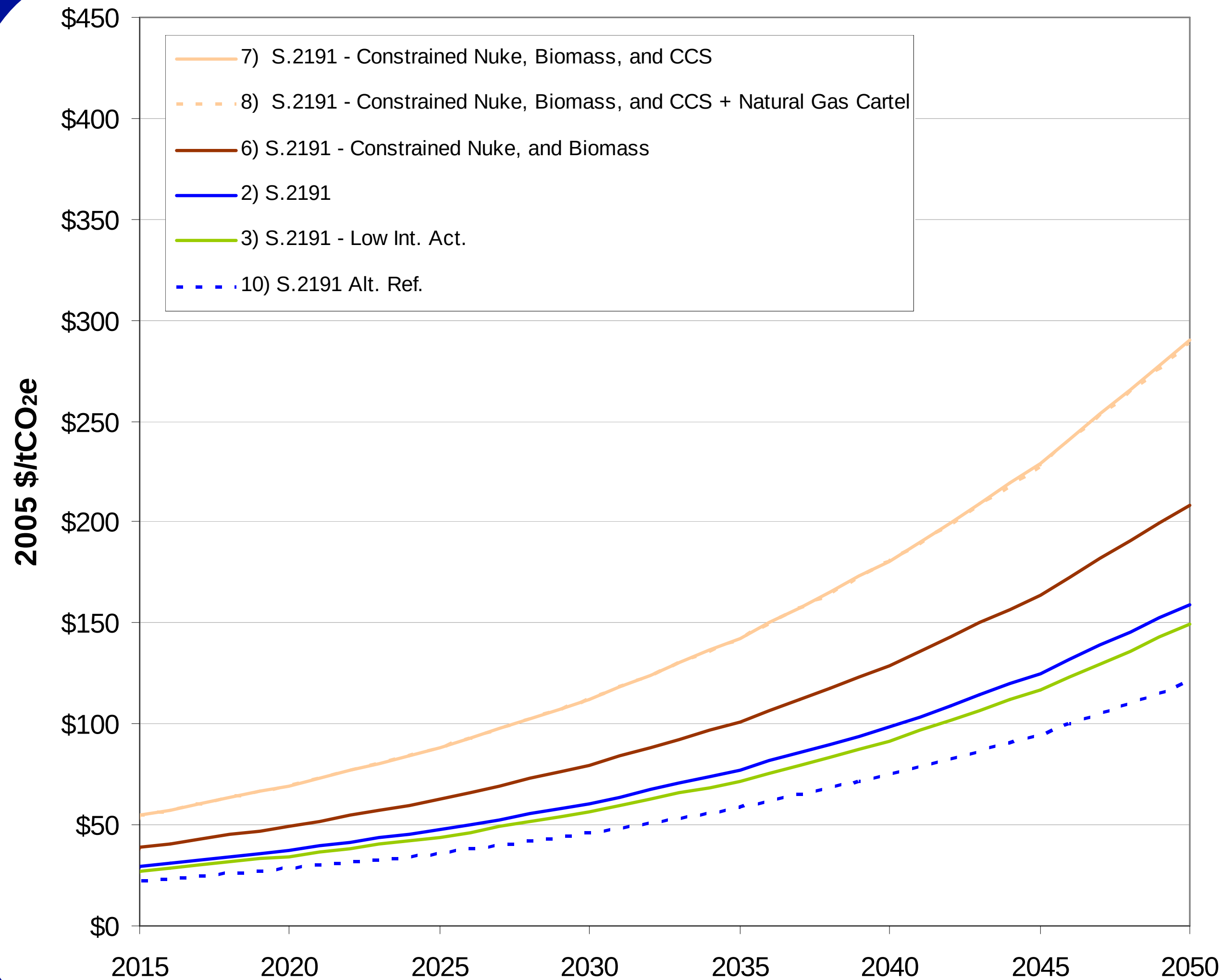


- Compared to the variation in allowance prices between the various alternative technology scenarios, there is a greater variation in allowance prices amongst the alternative offset and international credit scenarios.
- Allowing the unlimited use of domestic offsets and international credits can reduce allowance prices by 71% compared to scenario 2.
- Allowing the unlimited use of just domestic offsets can reduce allowance prices by 26% compared to scenario 2.
- If international credits are not allowed, allowance prices increase by 34% compared to scenario 2.
- If both international credits and domestic offsets are not allowed, allowance prices increase by 93% compared to scenario 2.
- Allowance prices are 12% lower under the alternative reference case compared to scenario 2.

* This slide was updated on 5/508 to correct the units of the Y-axis label.

Scenario Comparison

GHG Allowance Prices (ADAGE)



- Compared to the variation in allowance prices between the various alternative offset and international credit scenarios, there is a smaller variation in allowance prices amongst the alternative technology scenarios.
- Allowance prices are 86% higher in the constrained nuclear, biomass, and CCS scenario compared to scenario 2. The natural gas cartel has minimal influence on the allowance price.
- Allowance prices are 32% higher in the constrained nuclear, and biomass scenario compared to scenario 2.
- Allowance prices are 24% lower under the alternative reference case compared to scenario 2.

Scenario Comparison

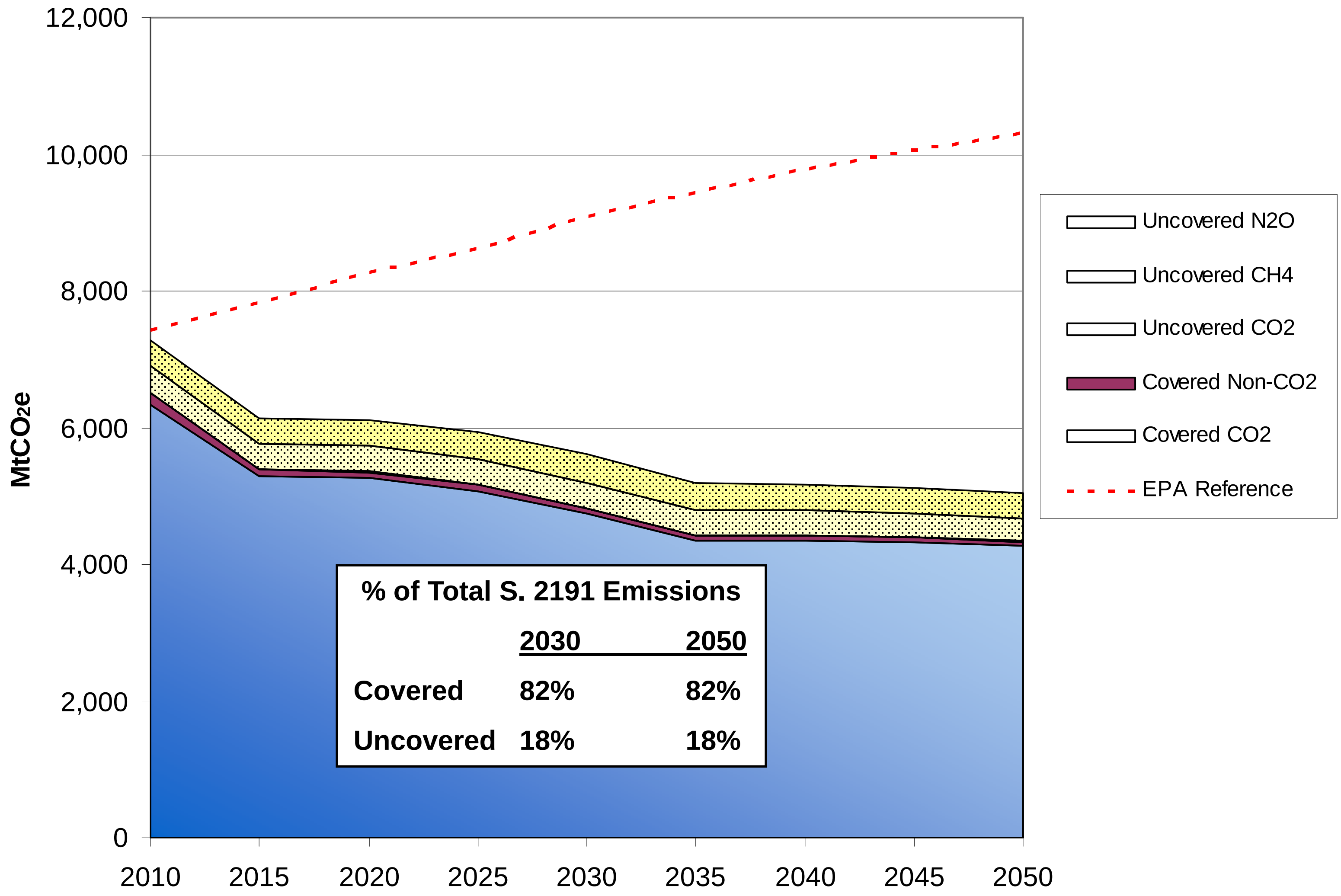
GHG Allowance Prices

Table: Allowance Price Comparison (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	$29	$37	$48	$61	$77	$98	$125	$159
IGEM	$40	$51	$65	$83	$106	$135	$173	$220
3) S.2191 w/ Low International Action								
ADAGE	$27	$35	$44	$56	$72	$92	$117	$149
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S.2191 w/ Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$11	$15	$19	$24	$30	$39	$50	$63
5) S.2191 w/ No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$77	$98	$126	$160	$205	$261	$333	$425
6) S.2191 Constrained Nuclear & Biomass								
ADAGE	$39	$49	$63	$80	$101	$129	$164	$208
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S.2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	$55	$69	$88	$112	$142	$181	$229	$290
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S.2191 Constrained Nuclear & Biomass, and CCS + Beyond Kyoto + Natural Gas Cartel								
ADAGE	$55	$70	$88	$112	$142	$180	$228	$288
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10) S.2191 Alt. Ref.								
ADAGE	$22	$28	$36	$46	$59	$75	$95	$121
IGEM	$35	$45	$57	$73	$93	$118	$151	$193

Results: Scenario 2 - S. 2191

Total U.S. GHG Emissions (ADAGE)

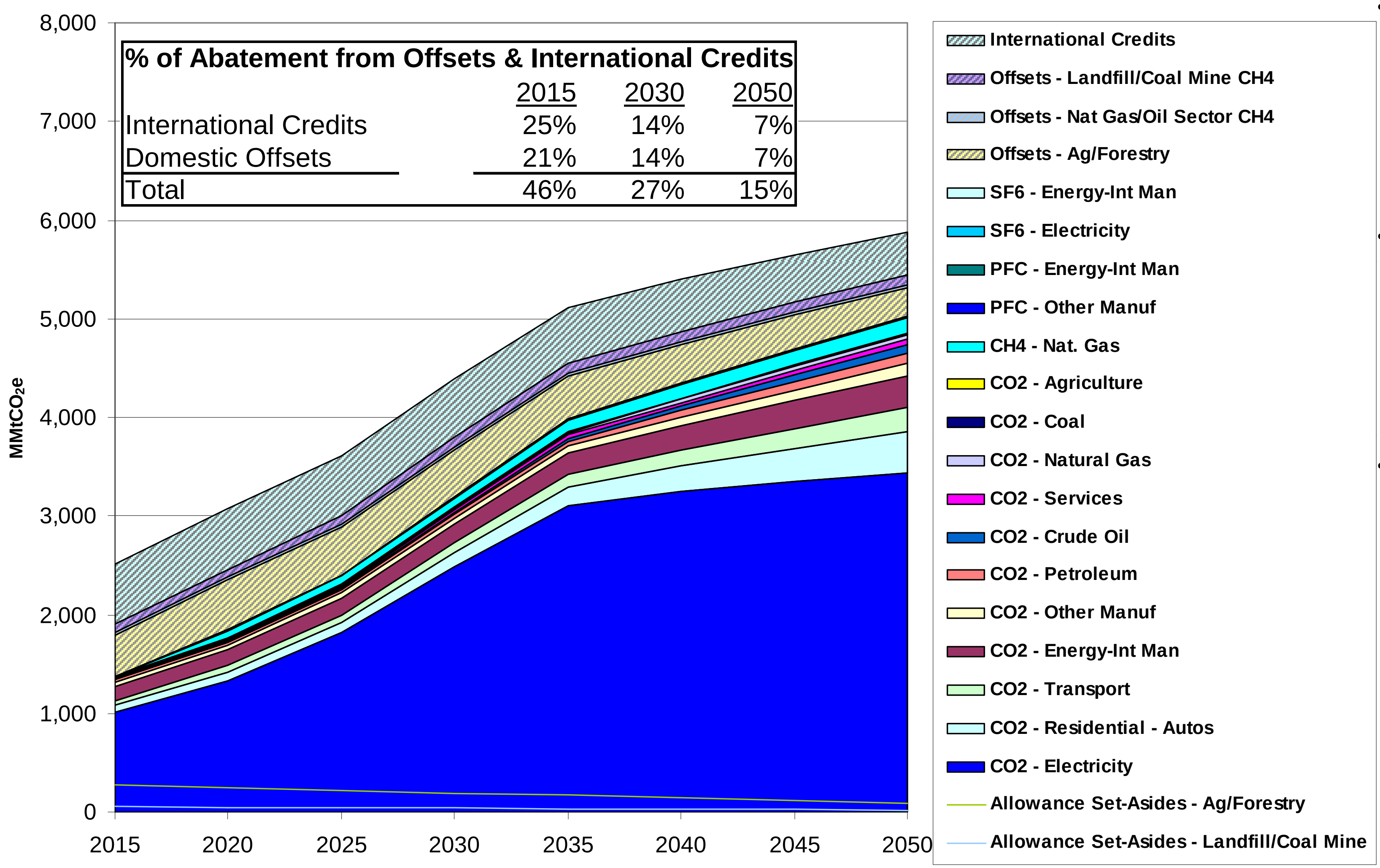


% of Total S. 2191 Emissions

	2030	2050
Covered	82%	82%
Uncovered	18%	18%

Results: Scenario 2 - S. 2191

Sources of GHG Abatement (ADAGE)



% of Abatement from Offsets & International Credits

	2015	2030	2050
International Credits	25%	14%	7%
Domestic Offsets	21%	14%	7%
Total	46%	27%	15%

- S. 2191 allows offsets and international credits to each make up 15% of the total allowance submissions requirement.
- The quantity of offsets and international credits allowed decreases as allowance submissions decrease.
- Since the quantity of offsets allowed is decreasing over time and the quantity of abatement is increasing over time, offsets make up a large fraction of abatement in the early years of the policy, and there contribution to total abatement decreases over time.

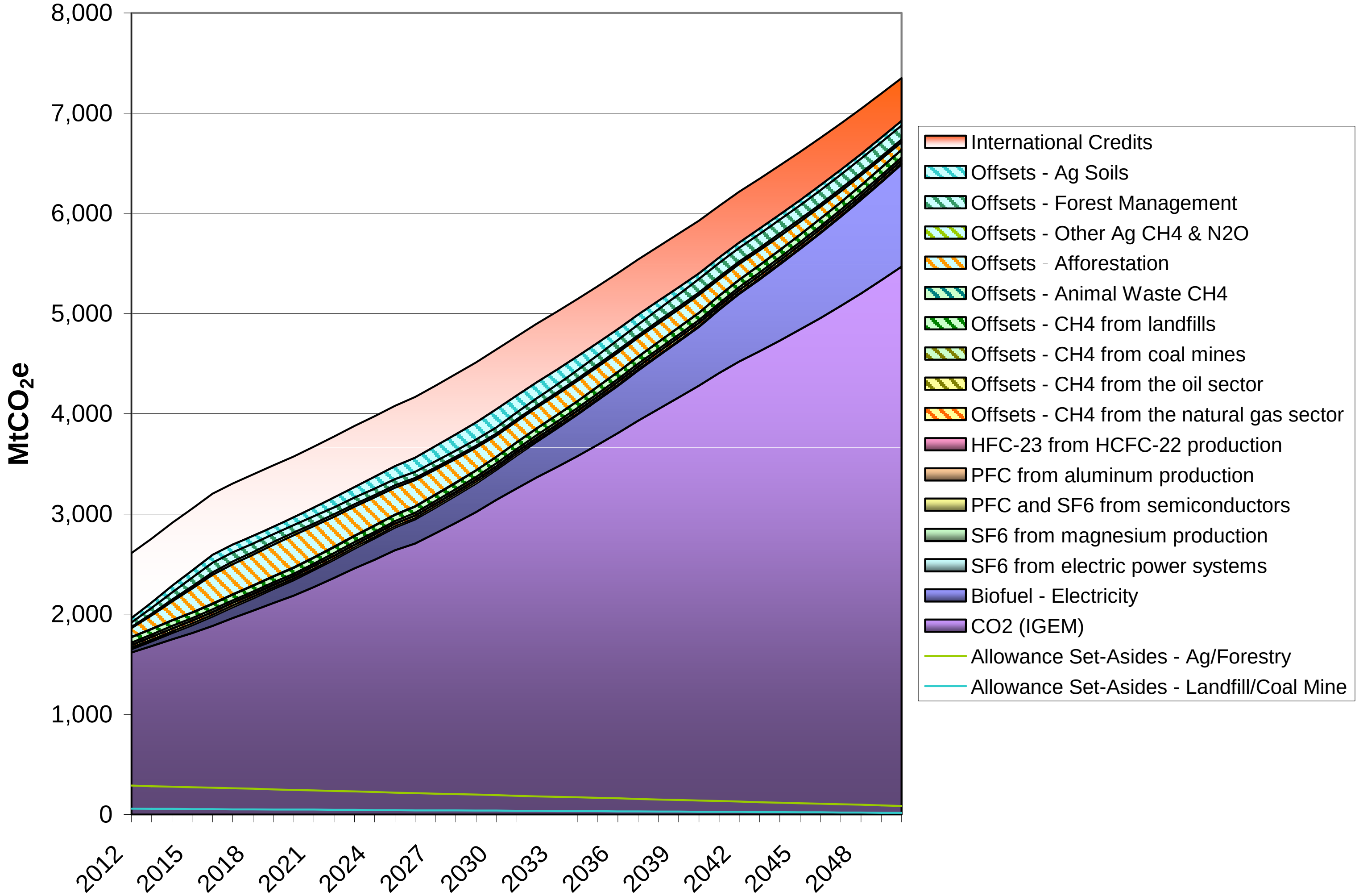
Results: Scenario 2 - S. 2191

Sources of GHG Abatement (ADAGE)

- The previous chart shows the sources by sector of GHG abatement under S. 2191.
- CO_2 emissions from the electricity sector (the blue area at the bottom) represent the largest source of domestic reductions.
- The area toward the top of the chart shaded with hashed lines show emissions reductions from non-covered sectors (offsets) and international credits.
  - International credits (the hashed area at the very top) are limited to make up no more than 15% of compliance in any year. Given this limit, in the early years they make up a larger portion of abatement (25% in 2015), and a smaller portion of abatement in later years (14% in 2030 and 7% in 2050).
    - Note that in the early years when cap level is relatively high compared to reference emissions, and a relatively small amount of abatement is required, offsets and international credits while limited to 15% of compliance, may make up a larger percentage of abatement.
  - Domestic offsets are similarly limited to make up no more than 15% of compliance in any year. Among domestic offsets, the agricultural and forestry sector (the yellow hashed area) supplies the most abatement.
- The light green and blue lines at the bottom represent GHG abatement from allowance set-asides. This abatement is additional to the abatement in covered sectors and offset projects that is used to meet the cap.
- Commercial transportation and personal vehicles ("residential autos") are represented by the solid light blue and green areas above the electricity sector.
  - Note that ADAGE does not explicitly model new developments in transportation technologies – these reductions occur in the model due to the price changes resulting from the imposition of the upstream cap on emissions from the petroleum sector.
- The growth of abatement from CO_2 from the electricity sector drops off sharply after 2035. This occurs because by 2035 advanced coal with carbon capture and storage technology has displaced almost all traditional fossil generation in the model, so further the opportunities for further emissions reductions in the electricity sector are limited.
- Since the electricity sector plays a key role in GHG abatement and the CGE models have a limited representation of technology, we used the IPM model to examine the electricity sector in more detail through 2025.

Results: Scenario 2 - S. 2191

Sources of GHG Abatement (IGEM)



- S. 2191 allows offsets and international credits to each make up 15% of the total allowance submissions requirement.
- The quantity of offsets and international credits allowed decreases as allowance submissions decrease.
- Since the quantity of offsets allowed is decreasing over time and the quantity of abatement is increasing over time, offsets make up a large fraction of abatement in the early years of the policy, and there contribution to total abatement decreases over time.

Results: Scenario 2 - S. 2191

Sources of GHG Abatement (IGEM)

- The previous chart shows, for the IGEM model, the sources of CO_2 and non-CO_2 GHG abatement under S. 2191.
- IGEM does not break out CO_2 emissions by sector, so the bottom purple area represents all energy related CO_2 emissions abatement within IGEM.
  - The other sources of abatement represented here are derived from EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH4, N_2O, and F-gases (NCGM), and the Forest and Agriculture Sector Optimization Model, GHG version (FASOMGHG).
- The areas toward the top of the chart shaded with hashed lines show emissions reductions from domestic offsets and the red shaded area at the very top shows international credits
  - International credits are limited to make up no more than 15% of compliance in any year. Given this limit, in the early years they make up a larger portion of abatement (20% in 2015), and a smaller portion of abatement in later years (13% in 2030 and 6% in 2050).
    - Note that in the early years when cap level is relatively high compared to reference emissions, and a relatively small amount of abatement is required, offsets and international credits while limited to 15% of compliance, may make up a larger percentage of abatement.
  - Domestic offsets are similarly limited to make up no more than 15% of compliance in any year. The majority of domestic offsets come from the agriculture and forestry sectors.
- The light green and blue lines at the bottom represents GHG abatement from allowance set-asides. This abatement is additional to the abatement in covered sectors and offset projects that is used to meet the cap.

Detailed Near-Term Electricity Sector Modeling Results

Detailed Electricity Sector Modeling with IPM

Motivation for Using the Integrated Planning Model (IPM):

- The CGE models used for this analysis do not have detailed technology representations; they are better suited for capturing long-run equilibrium responses than near-term responses.
- Since the electricity sector plays a key role in GHG mitigation, and the near-term response in the electricity sector is of particular interest, we have employed the Integrated Planning Model (IPM) model to shed further light on the near-term impact of S. 2191 on the electricity sector as a complement to the broader picture presented by the CGE models.

Power Sector Modeling (EPA Base Case v3.01 using IPM):

- This version of IPM builds off recently released EPA Base Case v3.0, with the following updates for purposes of modeling carbon policies:
  - Carbon capture and storage (for new plants)
  - Biomass co-firing option
  - Constraints on new nuclear, renewable, and advanced coal (with CCS) capacity

Modeling Approach:

For this analysis, EPA's Base Case v3.01 using IPM was used and incorporated two sets of data from the ADAGE model:

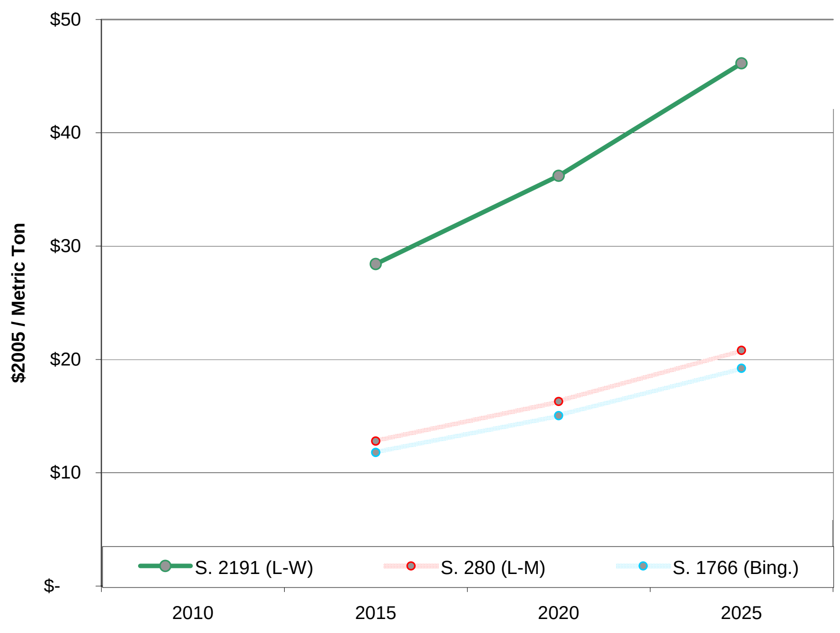
- CO_2 allowance price projections
- Percent change in electricity demand

Key Insights from IPM Results for the Near-Term

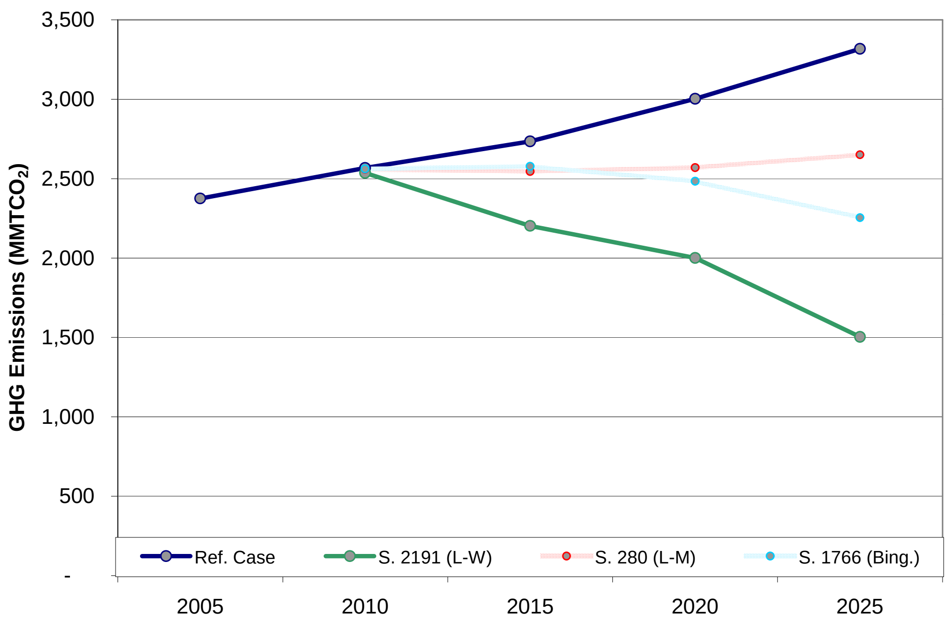
- The reduced electricity demand levels produce the largest share of reductions in the early years (prior to 2020).
- Due to the bonus allowance provision for CCS, GHG allowance prices will be high enough to justify significant penetration of new coal capacity with CCS technology starting in 2015. Further, the carbon price incurred by various emitting technologies (e.g., coal) makes new nuclear plants and renewables more economic to build.
  - Advanced coal with CCS is projected to penetrate at the maximum permissible rate in the model in 2015 and 2025, but not in 2020.
  - A significant number of coal and oil/gas steam units are projected to retire, compared with the reference case.
  - Without the bonus subsidy, IPM projects later penetration of CCS (2025). It also projects less fossil retirement and more renewable penetration.
- Because of considerable uncertainties regarding technology cost, performance, and penetration, as well as uncertainty regarding implementation of complementary measures (such as a Renewable Portfolio Standard (RPS)), it is very difficult to specify bonus allowance ratios to achieve desired deployment of CCS.

CO_2 Allowance Prices and Power Sector CO_2 Emissions (IPM)

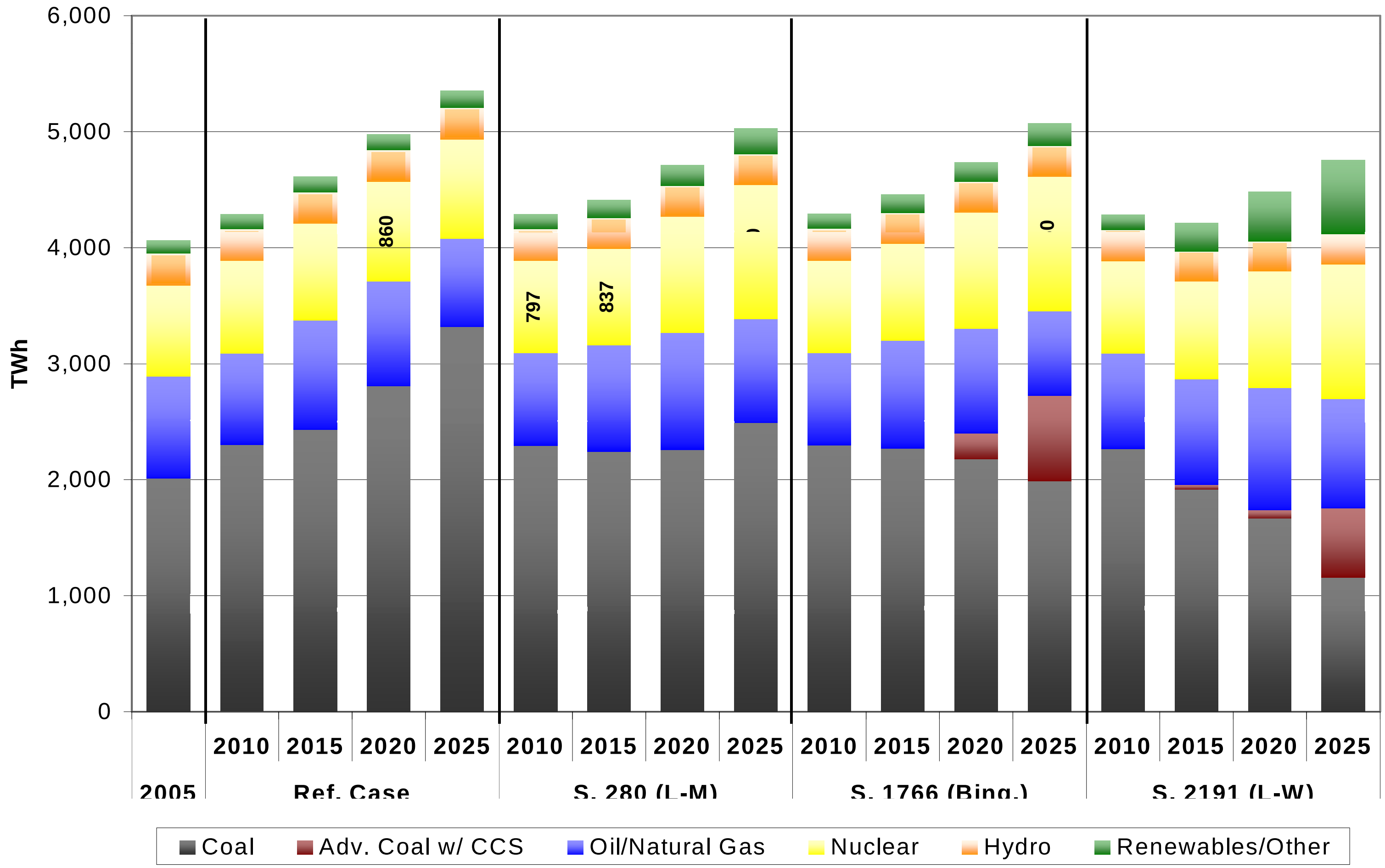
CO_2 Allowance Price (inputs to IPM)



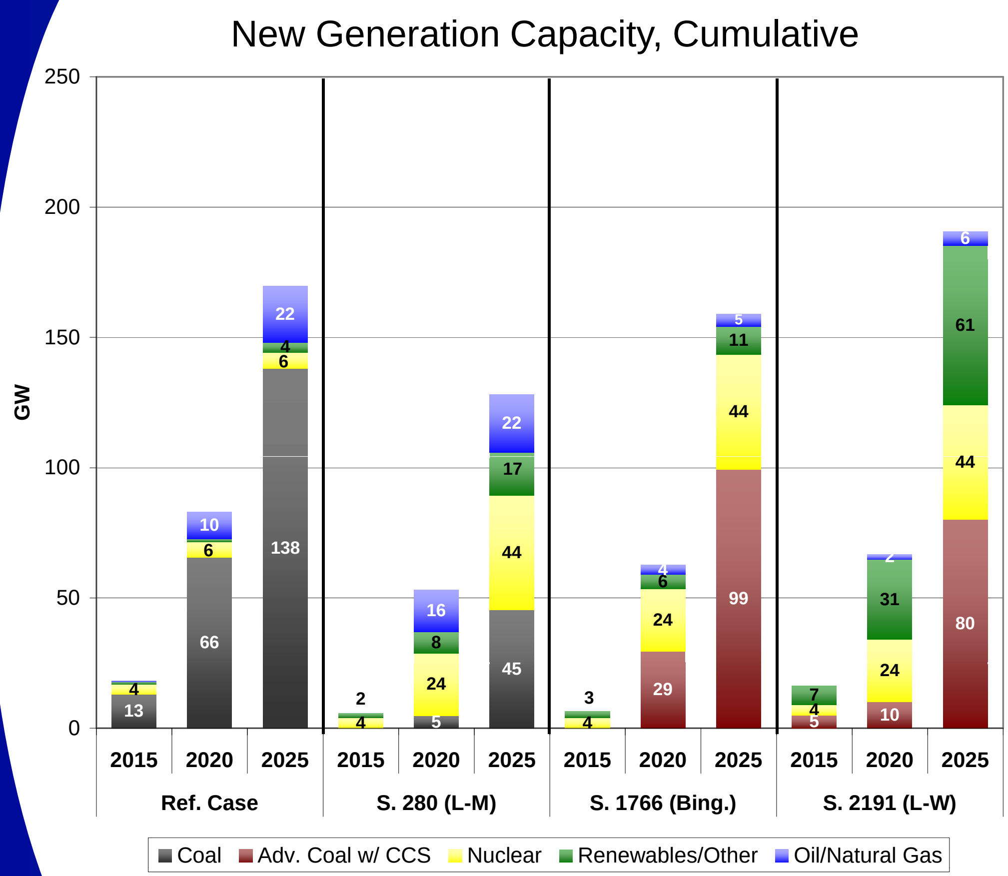
Power Sector CO_2 Emissions



Electricity Generation Mix (IPM)



New Generation Capacity (IPM)



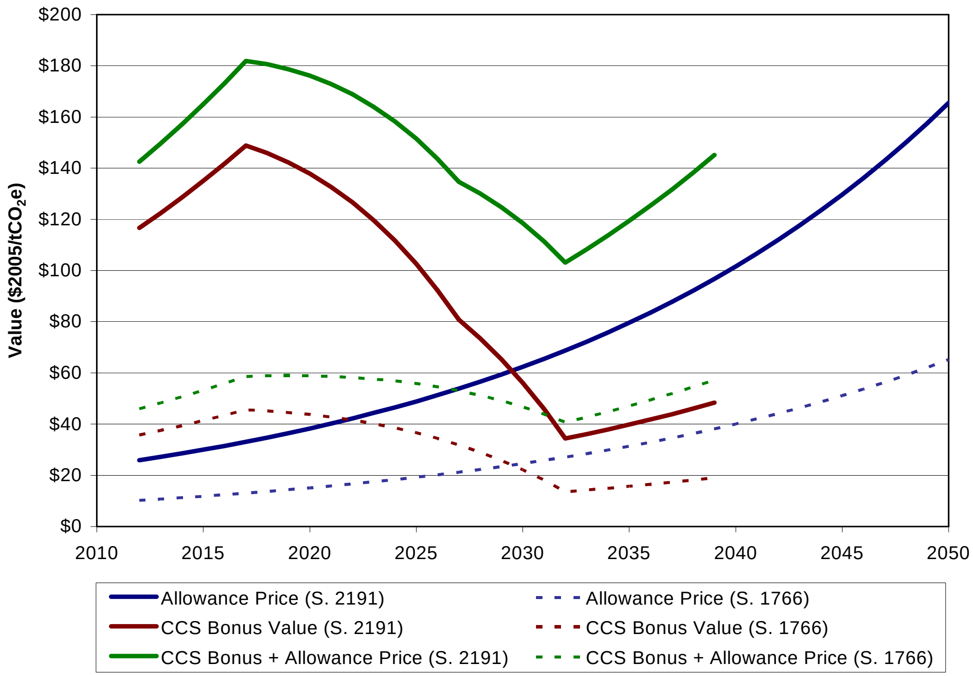
Note: New capacity additions less that 1 GW of capacity are not indicated.

- S. 2191 contains an allowance bonus provision, which is capped, for CO_2 emissions that are captured and sequestered, resulting in significant penetration of new coal capacity with CCS technology (S. 1766 has a similar provision).
  - Bonus allowances go unused in 2015 only, when there is a 5 GW constraint on new adv. coal with CCS (the bonus is used entirely in all years post-2015).
- In 2025, adv. coal with CCS is economic even without the bonus.
- S. 2191 also results in significant penetration of new nuclear and renewable capacity.
- More capacity is built under S. 2191 because a significant amount of the existing fossil fleet is not economic to operate and must be replaced.

New Capacity Limitations in IPM (Incremental/Cumulative)

GW	2010	2015	2020	2025
Nuclear	N/A	4	20 / 24	20 / 44
Adv. Coal w/ CCS	N/A	5	70 / 75	70 / 145
Renewables *(Cumulative Only)*	4	24	44	64

Bonus Allowances for CCS



Year	Bonus Allowance Rate S. 2191	Bonus Allowance Rate S. 1766
2012-2017	4.5	3.5
2018	4.2	3.3
2019	3.9	3.1
2020	3.6	2.9
2021	3.3	2.7
2022	3.0	2.5
2023	2.7	2.3
2024	2.4	2.1
2025	2.1	1.9
2026	1.8	1.7
2027	1.5	1.5
2028	1.3	1.3
2029	1.1	1.1
2030	0.9	0.9
2031	0.7	0.7
2032-2039	0.5	0.5

- **Bonus allowances are distributed to entities that implement geological sequestration projects.**
- **The value of the CCS bonus allowances changes with the allowance price and the bonus allowance rate. The kinks in the CCS bonus value curve are due to the changes in the bonus allowance rate over time.**
- **The benefit to sources that capture and sequester CO_2 is the value of the CCS bonus plus the allowance price.**
- **The bonus allowances allocated in S. 2191 are capped (unlike S. 1766) at 4% of the total, but the bonus allowance rate is higher initially.**
- **The bonus leads to earlier and greater penetration of CCS in both Bills. CCS would be deployed in S. 2191 even without the bonus because of higher allowance prices.**

Bonus Allowances for CCS Cont'd

Although the bonus allowance rate and allowance prices in S. 2191 are greater than S. 1766, the effective incentive is capped and eventually runs out. As a result, the bonus allowances available under S. 1766 are much greater, which leads to more new coal capacity with CCS than under S. 2191, even though allowance prices are lower in S. 1766.

- It should be pointed out that greater builds of new advanced coal with CCS leads to more retirements of existing capacity, mostly less efficient oil/gas steam and coal units.

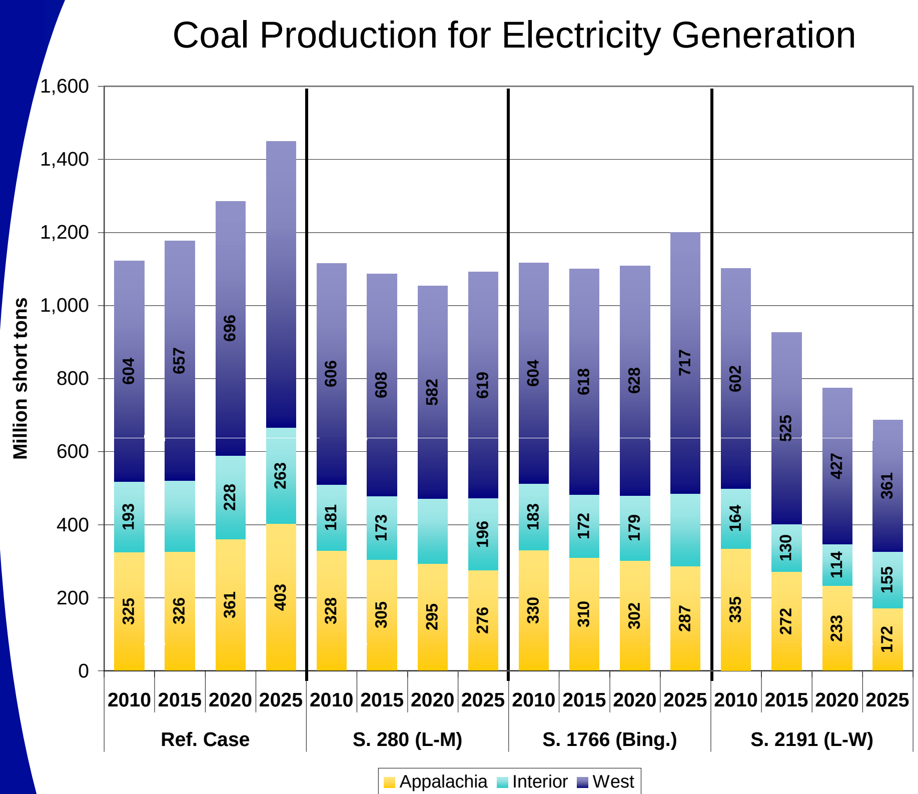
Bonus Allowance Comparison in 2020		
	S. 2191	**S. 1766**
Bonus Rate	3.6 allowances for each ton sequestered, total allocations limited to 4% of total	2.9 allowances for each ton sequestered, unlimited # of projects
Projected Allowance Price ($2005/ton)	$38	$15
Effective Bonus ($/ton sequestered)	$176	$59
Effective Incentive after Limit is Exceeded ($/ton)	$38 (allowance price)	$59 (bonus, no limit)

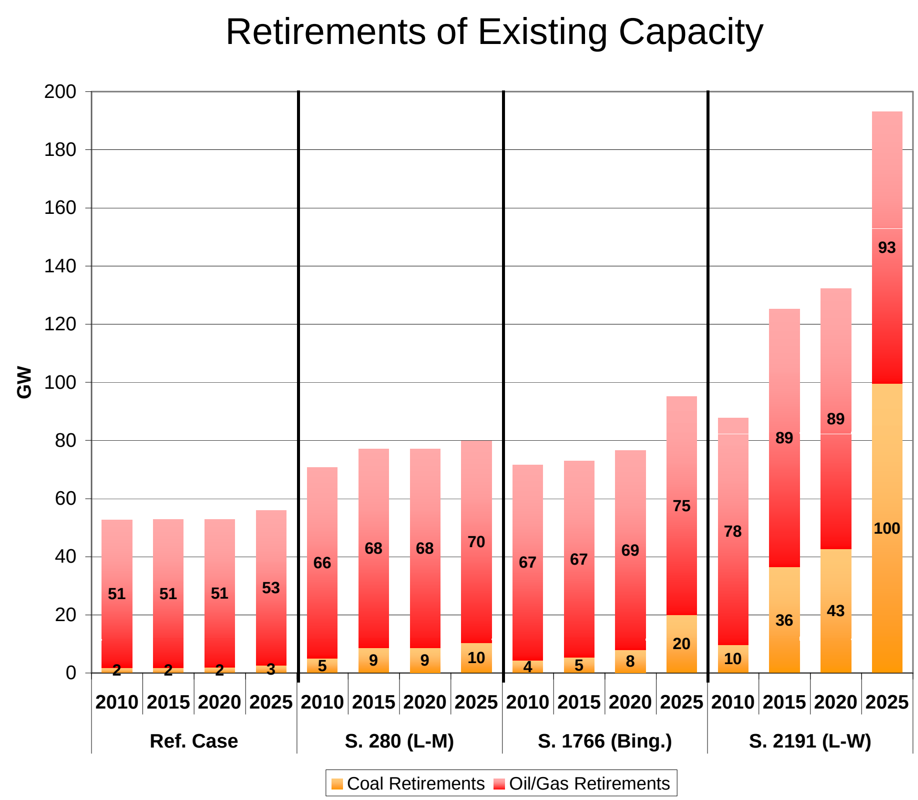
Note: The effective bonus is the product of the allowance prices and the bonus rate, and may not match because of rounding.

Analysis of Bonus Allowances for CCS

- Purpose: To promote greater and/or earlier investment in carbon capture & storage by offering marketable incentives (in the form of allowances) to the power sector.
- Results: Roughly 80 GW of advanced coal with CCS built by 2025 (in 2025 the bonus allowances are exhausted and advanced coal with CCS is economic).
  - In 2015, advanced coal with CCS is only economic with the bonus allowances. The bonus is enough to incentivize more than 5 MW of advanced coal with CCS. Since the model is constrained to build only 5 MW of CCS, that is the amount built
  - In 2020, advanced coal is only economic with the bonus allowances, however only enough allowances are available to build an additional 5 MW of advanced coal with CCS, significantly less than the 70 MW allowed by the model.
- Observations:
  - Investment in CCS is very sensitive in EPA's IPM analysis to the allowance price and bonus allowance ratio because cost assumptions are somewhat uniform.
  - In reality, there is likely to be more variability in risk profiles, capital costs, and transport/storage costs that would result in a wider range of CCS costs than IPM currently reflects.
  - Complementary policies such as a national Renewable Portfolio Standard could dampen allowance prices. Lower prices combined with increased renewables generation would lessen the need for CCS.
  - The incentive for CCS results in earlier retirements of existing coal capacity than might otherwise take place.

Coal Production for Electricity Generation & Retirements of Existing Capacity (IPM)

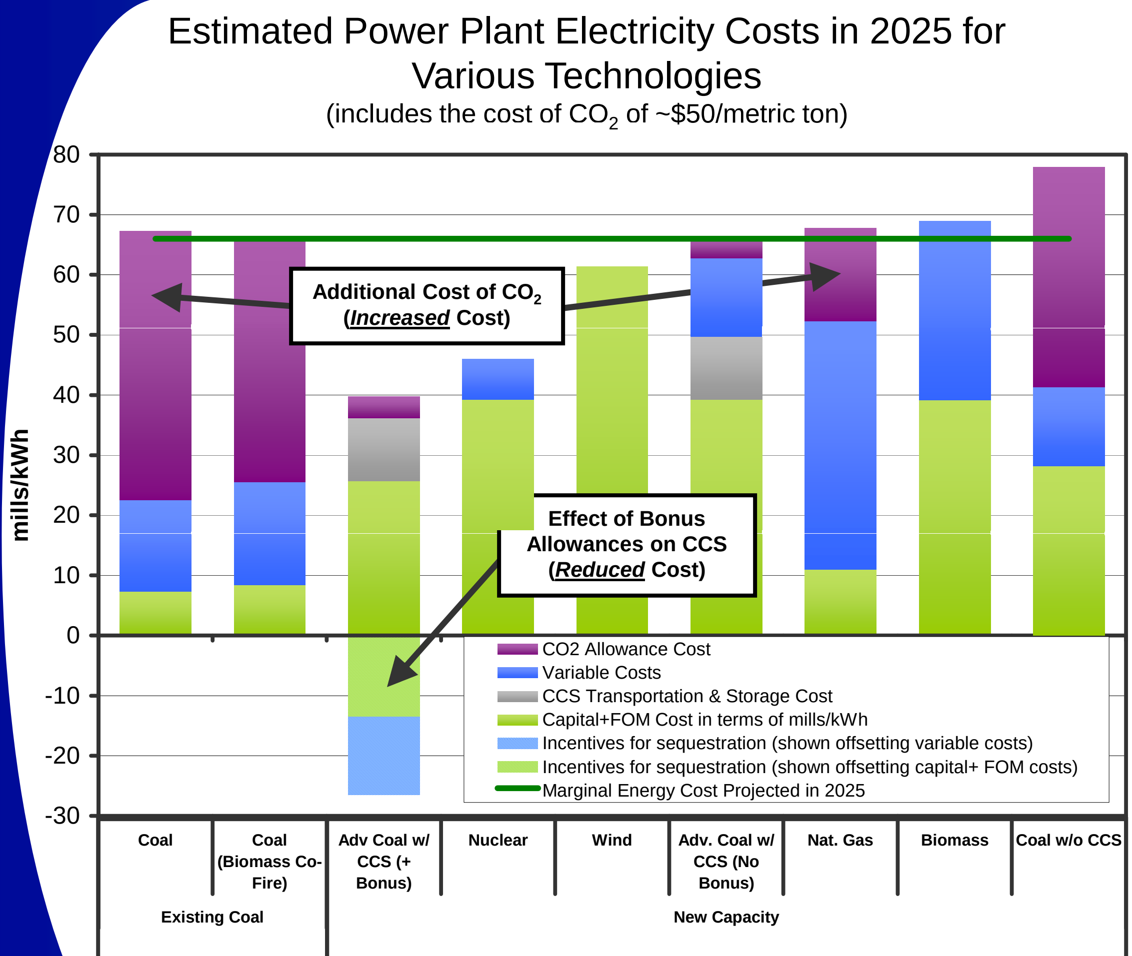




- There are also considerable re-powering of coal to natural gas in the S. 2191 case.

Note: Regional coal production data includes coal production for power generation only.

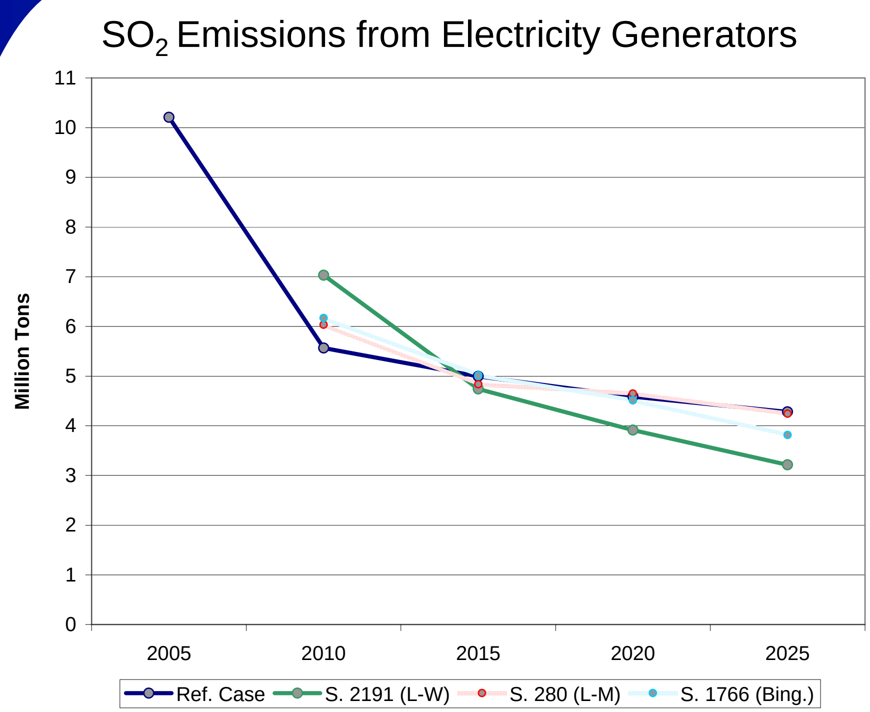
Near-Term Power Plant Economics with CO_2 Allowance Costs

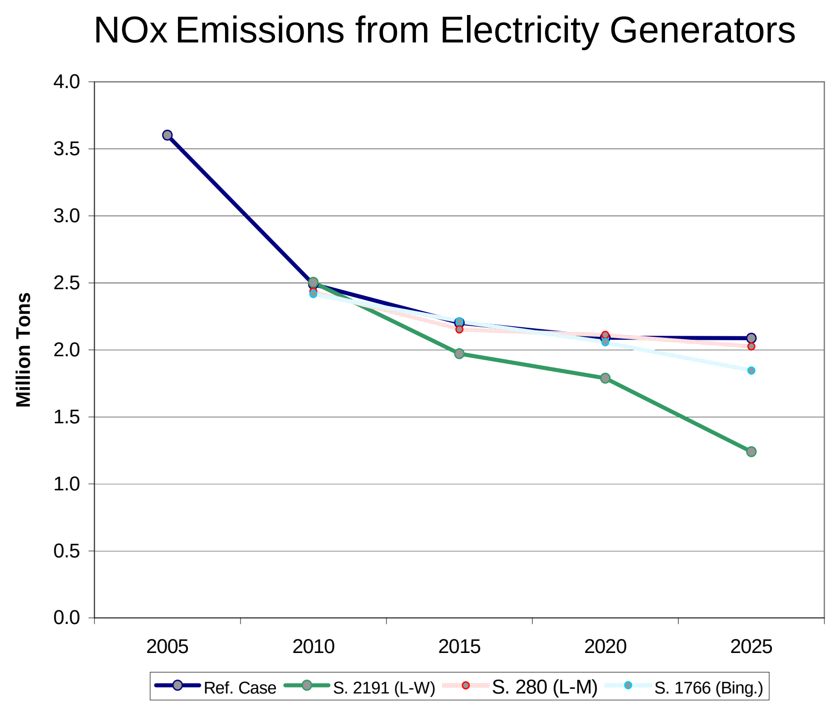


- To illustrate the economics of operating existing and new power technologies, the chart shows the cost of various technologies when the projected CO_2 allowance prices are included.
- Projected CO_2 allowance prices of roughly $50/ton in 2025 increase variable costs of existing plants powered by fossil fuels to the point where many are likely to shut down.
- However, S. 2191 provides significant incentives for CCS technology for coal plants in the form of bonus allowances, resulting in earlier penetration of advanced coal with CCS.

Notes: For the case with bonus allowances, the variable, capital, and fixed O&M costs are actually an aggregate of the solid part and the hashed part but the net cost is only the solid part. For this illustrative calculation, EPA used a conservative efficiency metric for existing coal plants (10,500 Btu/kWh), which most plants currently meet or exceed. The marginal energy cost is defined as the cost of production of the most expensive unit operating in that hour. It includes the cost of fuel, variable O&M cost and the cost of environmental allowances. The capital costs used here are from IPM v3.01, which relies upon EIA capital cost data from AEO 2005. More recently, capital costs have increased with increasing international demand for raw materials. It is not clear how the market will respond to these price increases and whether these increased costs will be sustained over the period of the analysis.

Nationwide Power Sector Emissions (IPM)

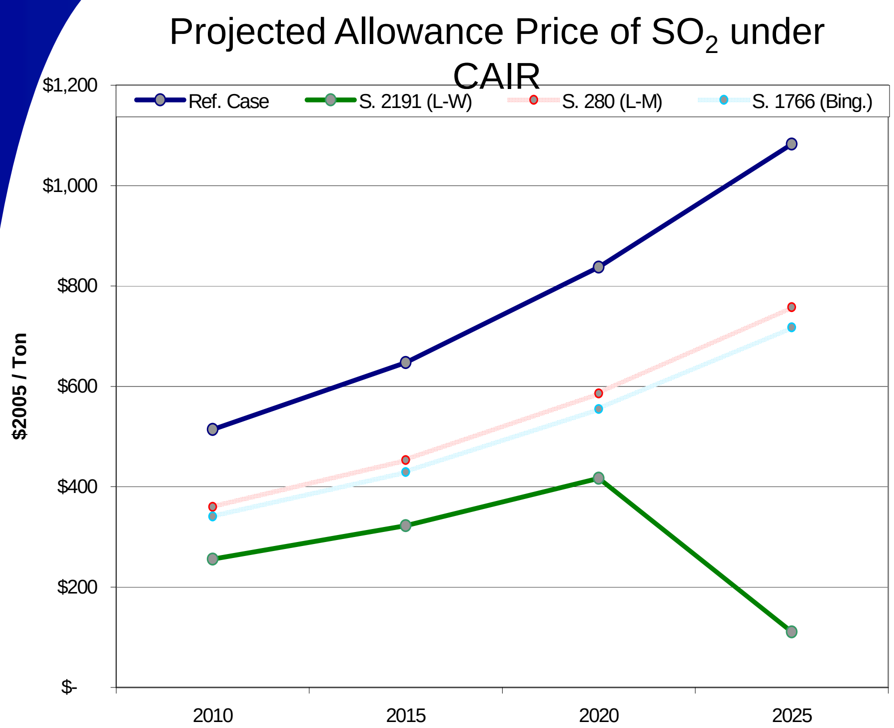


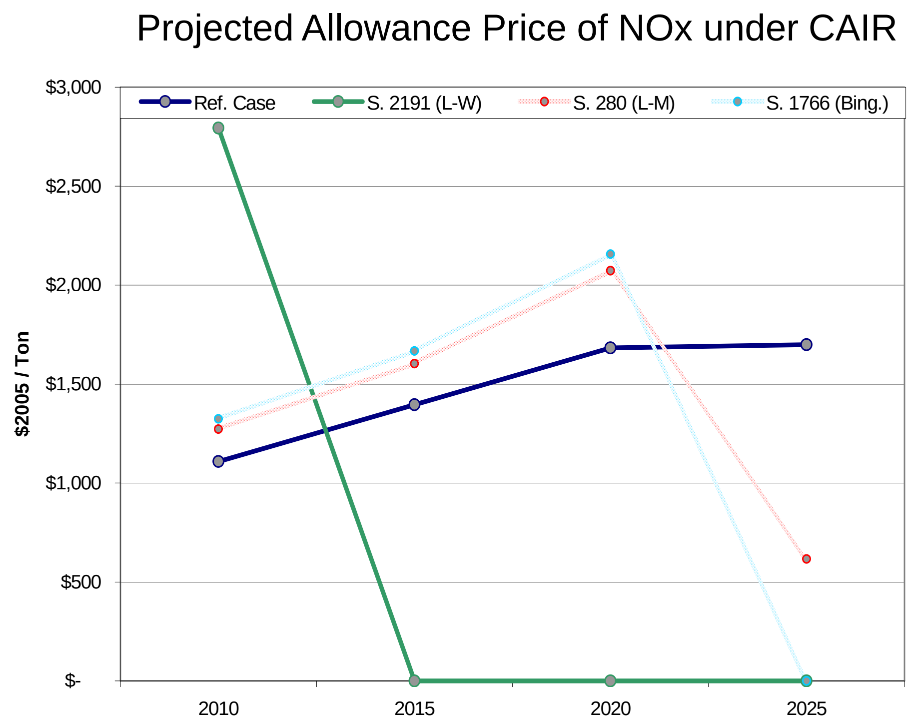


- CO_2 allowance prices projected in S. 2191 influence the timing of SO_2 and NOx emissions because of existing cap and trade programs and emission banking provisions of the CAIR program.
- To a certain extent, short-term changes in emissions (particularly SO_2) are overstated because of the significant number of advanced pollution controls that are currently under construction, which are unlikely to be cancelled.

Note: Emissions generally reflect emissions from affected sources (Acid Rain Program and CAIR), which includes emissions from sources greater than 25 MW in capacity.

SO_2 and NOx Allowance Price Comparisons (IPM)



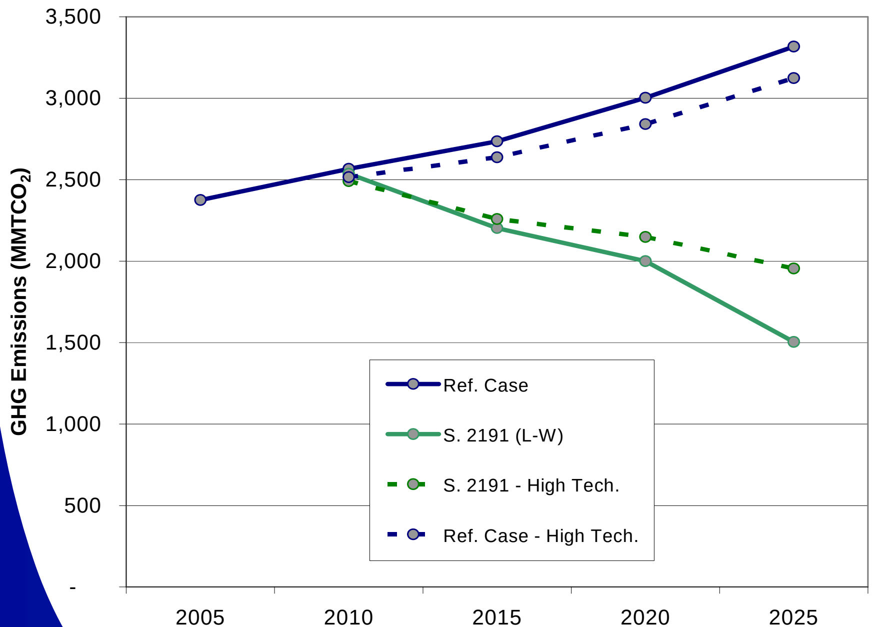


- SO_2 allowance prices are for CAIR affected sources on a $/ton of emissions basis; Title IV allowance prices are not shown separately, but would be a fraction of this amount.
- S. 2191 has an influence on the allowance prices under existing and future cap and trade programs for SO_2 and NOx (the Acid Rain Program and CAIR).
- Generally, any allowance price for CO_2 creates downward pressure on SO_2 markets, and this pressure is amplified with higher CO_2 allowance prices. For NOx, CO_2 allowance prices lead to shorter term price rises in NOx markets as sources rely on less capital-intensive control options for NOx (which are more expensive on the margin, hence the increased allowance price in earlier years), knowing that the higher CO_2 allowance prices in future years will result in lower NOx emissions as an ancillary effect (the NOx market essentially collapses under S. 2191).
- Under S. 2191, there is a large amount of incremental coal retirements in 2025 as the allowance price hits $50/ton. In response, a considerable amount of new nuclear and renewables capacity is built along with new coal with CCS (although not nearly as much coal capacity as is retired) and thus, demand for SO_2 allowances goes down, leading to a kink in 2025.

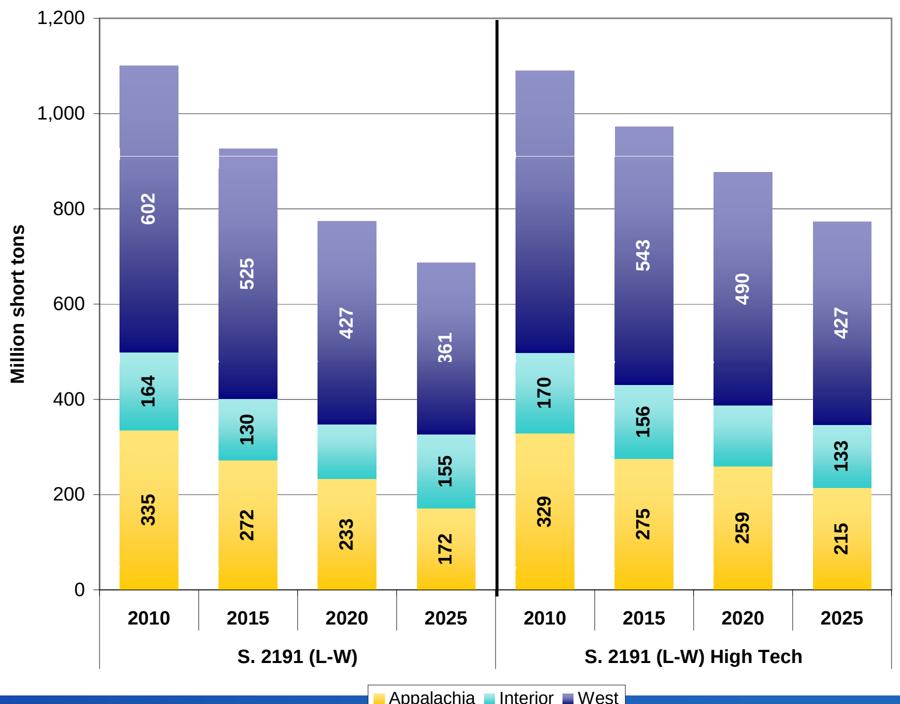
S. 2191 – High Technology Scenario (IPM)

- The high technology scenario is likely to be more similar to EIA's new AEO 2008 with the Energy Bill.
- Power sector CO_2 emissions in the high technology reference scenario are lower than the reference case because of lower electric demand and overall electricity generation. Under the S. 2191 high technology scenario, allowance prices are lower, resulting in greater reliance on coal generation and thus fewer CO_2 reductions compared to the primary S. 2191 case.

Power Sector CO_2 Emissions

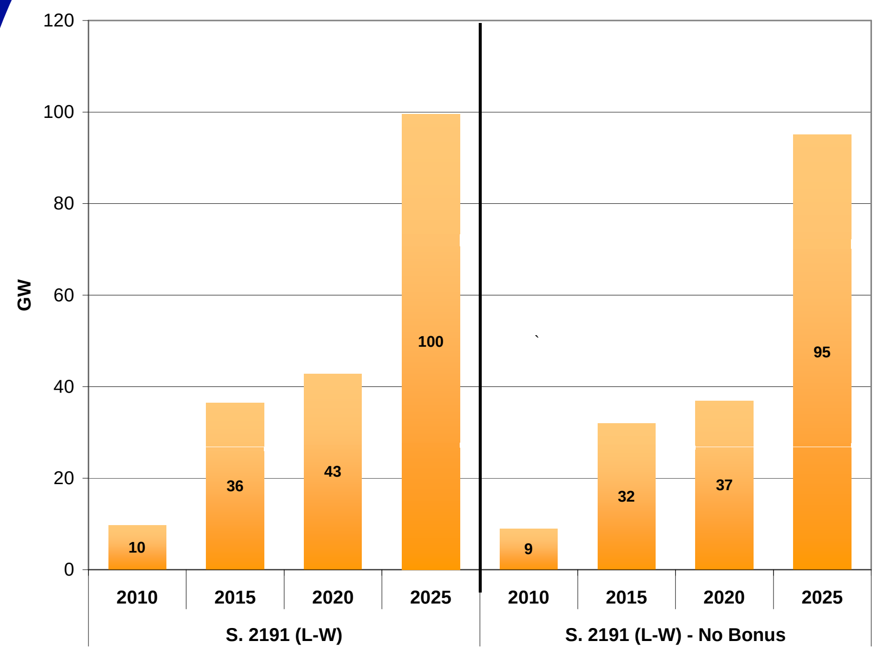


Coal Production for Electricity Generation

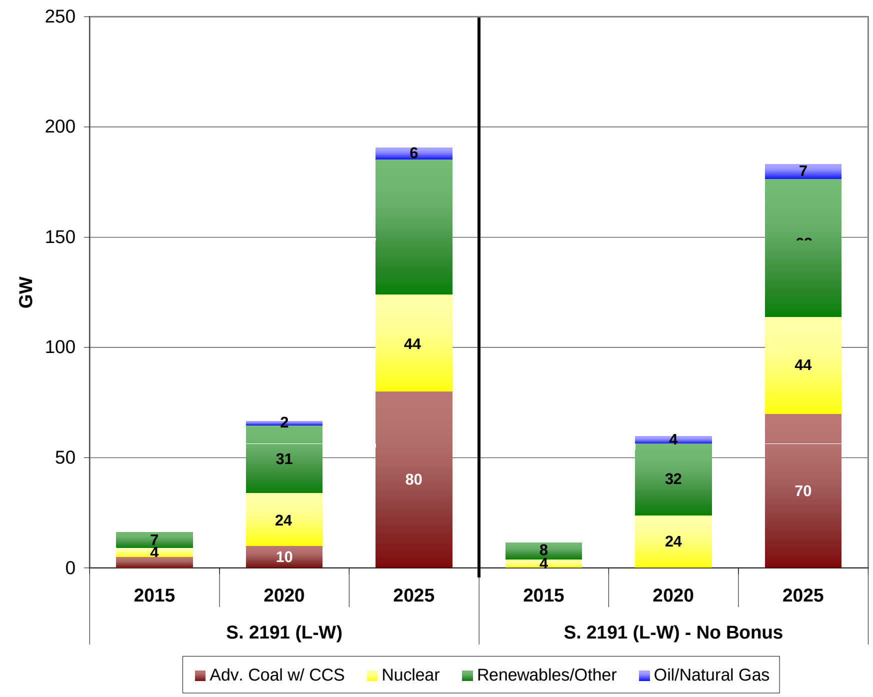


S. 2191 With and Without CCS Bonus Allowances (IPM)

Coal Early Retirements (Cumulative)



New Generation Capacity (Cumulative)



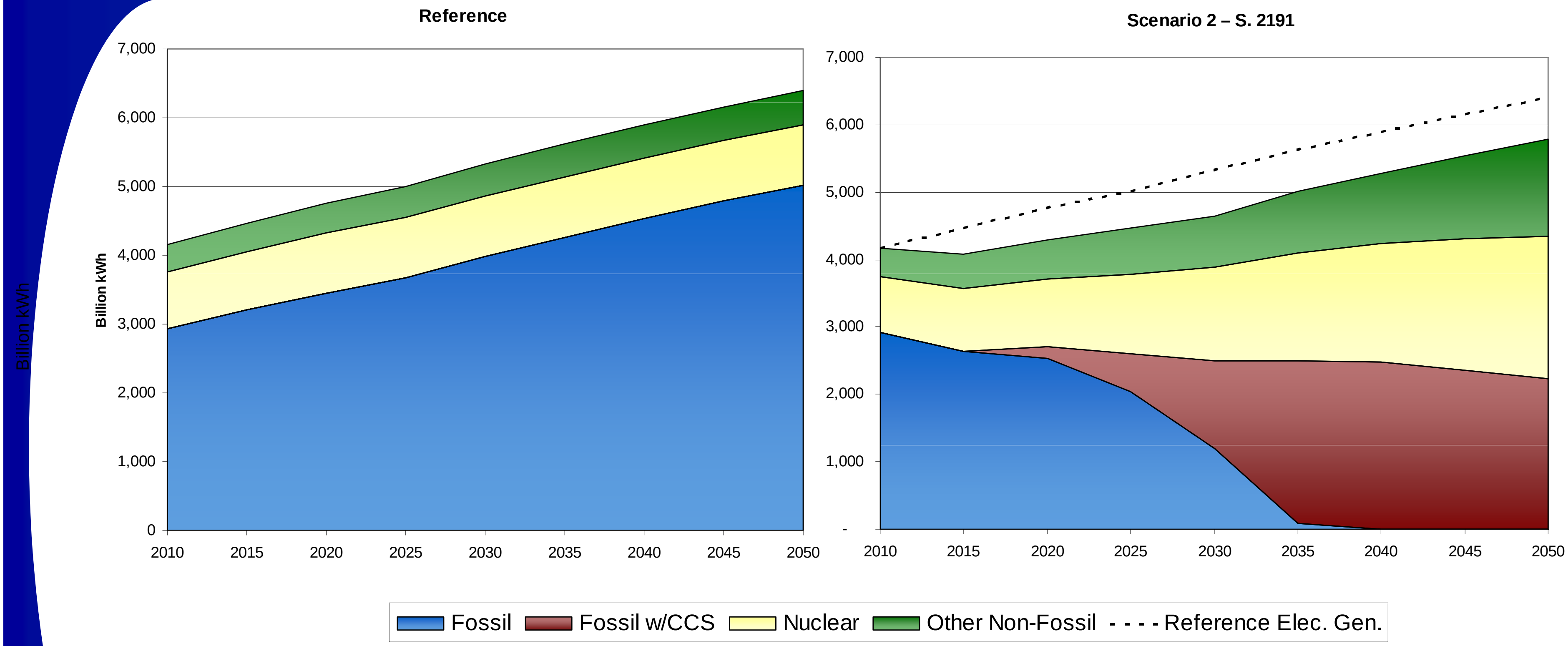
- Slightly fewer coal early retirements occur without the bonus in place, which acts as a subsidy and leads to the building of more CCS than otherwise would have been built.
- Advanced coal with CCS is built under S. 2191 even without the bonus (although later and a slightly lower amount).

IPM Modeling Limitations

- IPM model timeframe only goes through 2025.
  - Model does not see longer term changes in electricity demand and CO_2 allowance prices (due to lowering of the cap post-2025).
  - This can affect projections for new capacity additions and retrofit decisions in later years.
- EPA's Base Case v3.01 does not incorporate several technological innovations that can become available over time (e.g., ultra-supercritical coal, advanced renewables).
- The recent labor/material shortfalls on future construction prices and the timing of power system adjustments have not been modeled.
- Geographic deployment, cost and performance of CCS is highly uncertain.
- Allowance allocation and auctioning are not fully accounted for in the modeling.
- While IPM endogenously builds new capacity, the model places an exogenous constraint on the total amount of new capacity builds.
  - The assumed limitations on new nuclear capacity reflect the recent EPRI analysis "The Power to Reduce CO_2 Emissions: The Full Portfolio" (August 2007) (http://epri-reports.org/DiscussionPaper2007.pdf)
  - There are non-economic considerations for significant expansion of nuclear power capacity which are not reflected in IPM.

Energy Sector Modeling Results from Economy-wide Modeling

Addressing Climate Change Requires Electricity Sector Transformation



- Under S. 2191, both nuclear and renewable electricity generation expands above the reference levels.
- In addition, CCS deployment on fossil-fuel generation begins after 2015. By 2030, 175 GW of new CCS capacity is projected to be built, which is the equivalent of 318 CCS units of 550 MW each. By 2050, 299 GW of new CCS capacity is projected to be built, which is the equivalent of 543 CCS units 550 MW each.
- By 2035, almost all fossil electricity generation is capturing and storing CO_2 emissions. (Note that because ADAGE does not represent peak versus base load generation requirements, the use of CCS technology on almost all fossil fuel generation by 2035 may be overly optimistic).

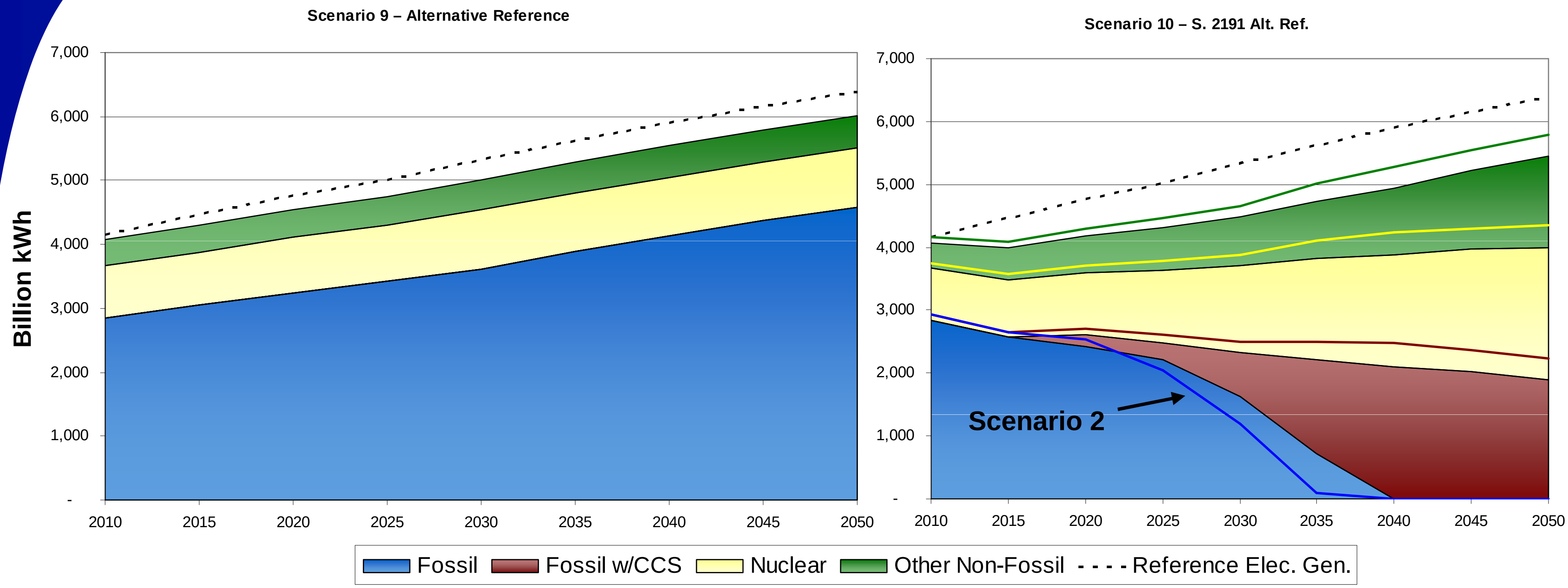
Note: Other non-fossil includes hydro, geothermal, wind, solar, biomass and municipal solid waste.

Electricity Generation with CCS (ADAGE)

- As noted previously, large-scale availability of CCS technology is a key uncertainty in the analysis.
- ADAGE uses EIA data on CCS technology costs and effectiveness (*Assumptions to the Annual Energy Outlook*). Costs are also influenced by fuel prices and any bonus allowances received.
- Maximum penetration rates for CCS in each time period are based on a “learning-by-doing” structure, in which construction in previous years influences future capacity:
  - economic considerations control when CCS initially becomes cost effective in the model.
  - feasible capacity is initially generally based on construction rates for related technologies from AEO forecasts.
  - construction in future years is then controlled by the influence of past decisions on the existing technology base.

Results: Scenario 9 – Alternative Reference; Scenario 10 – S. 2191 Alternative Reference

U.S. Electricity Generation, mid-term results (ADAGE)

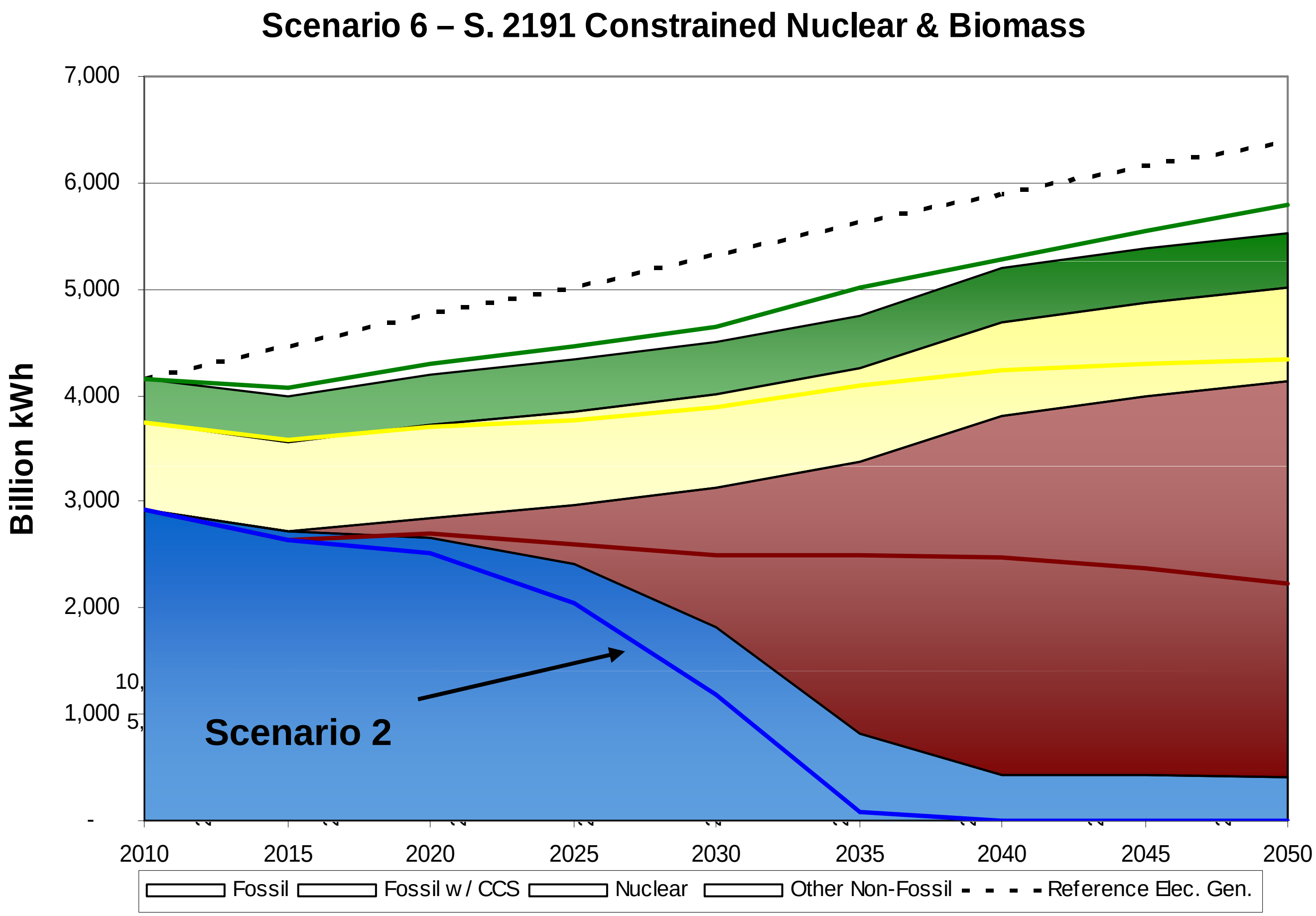


- Under the assumptions of the Alternative Reference Scenario, the economy is more energy efficient and there is lower electricity demand .
- The emissions goals of S. 2191 are achieved with less alteration of the energy infrastructure.
- Electricity demand decreases; nuclear and non-fossil generation increases; but traditional fossil generation continues to be economic for longer in the Alternative case.

Note: Other non-fossil includes hydro, geothermal, wind, solar, biomass and municipal solid waste.

Results: Scenario 6 – S. 2191, Constrained Nuclear & Biomass

U.S. Electricity Generation, mid-term results (ADAGE)

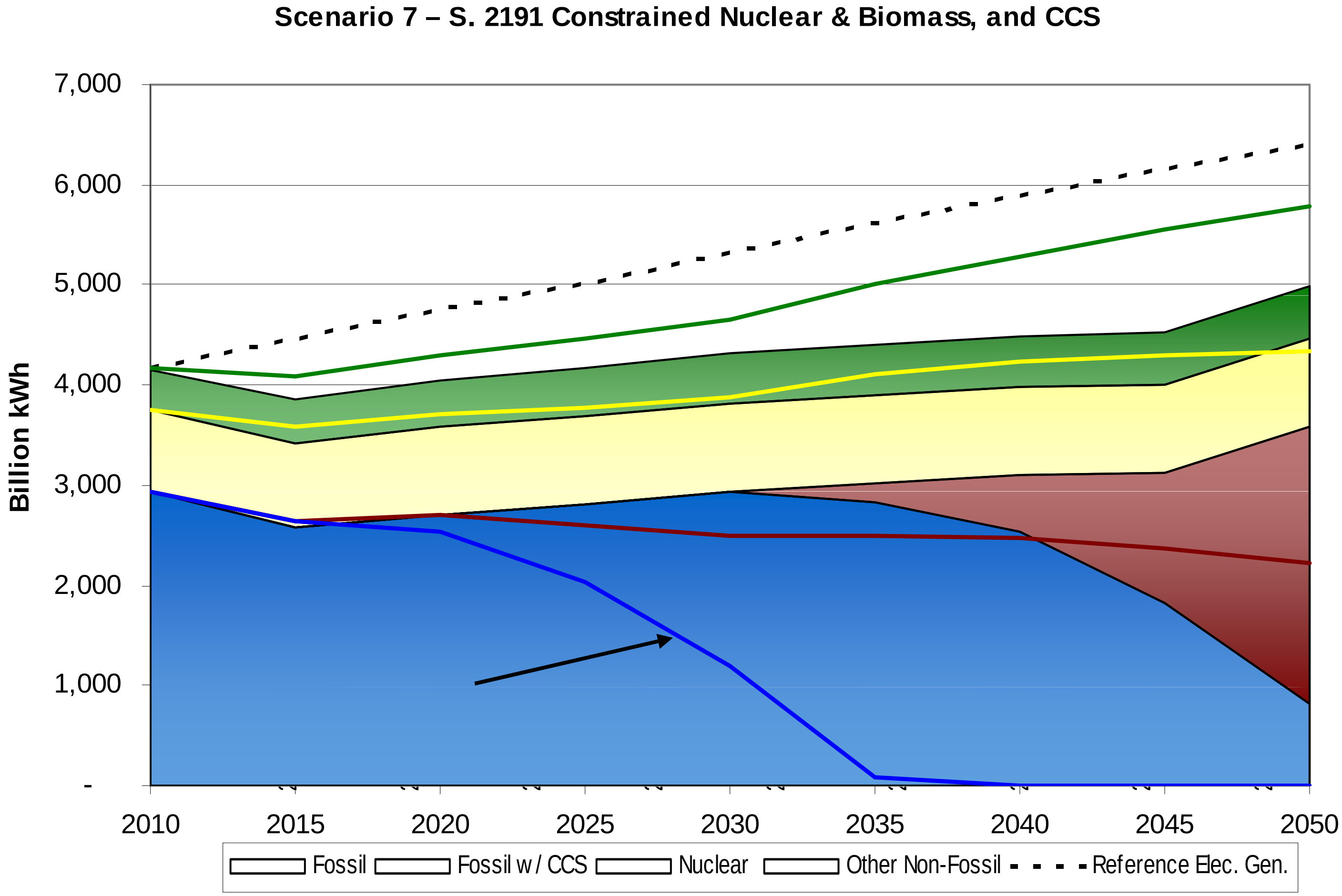


- If nuclear and biomass generation do not grow in response to policy, carbon capture and storage technologies become the dominant source of generation.
- Electricity demand is reduced from the S. 2191 Scenario.
- Traditional fossil continues to be economic for longer than under the S. 2191 Scenario, as CCS reaches it's maximum penetration rate, and nuclear and biomass are not allowed to compete.

Note: Other non-fossil includes hydro, geothermal, wind, solar, biomass and municipal solid waste.

Results: Scenario 7 – S. 2191, Constrained Nuclear & Biomass, and CCS

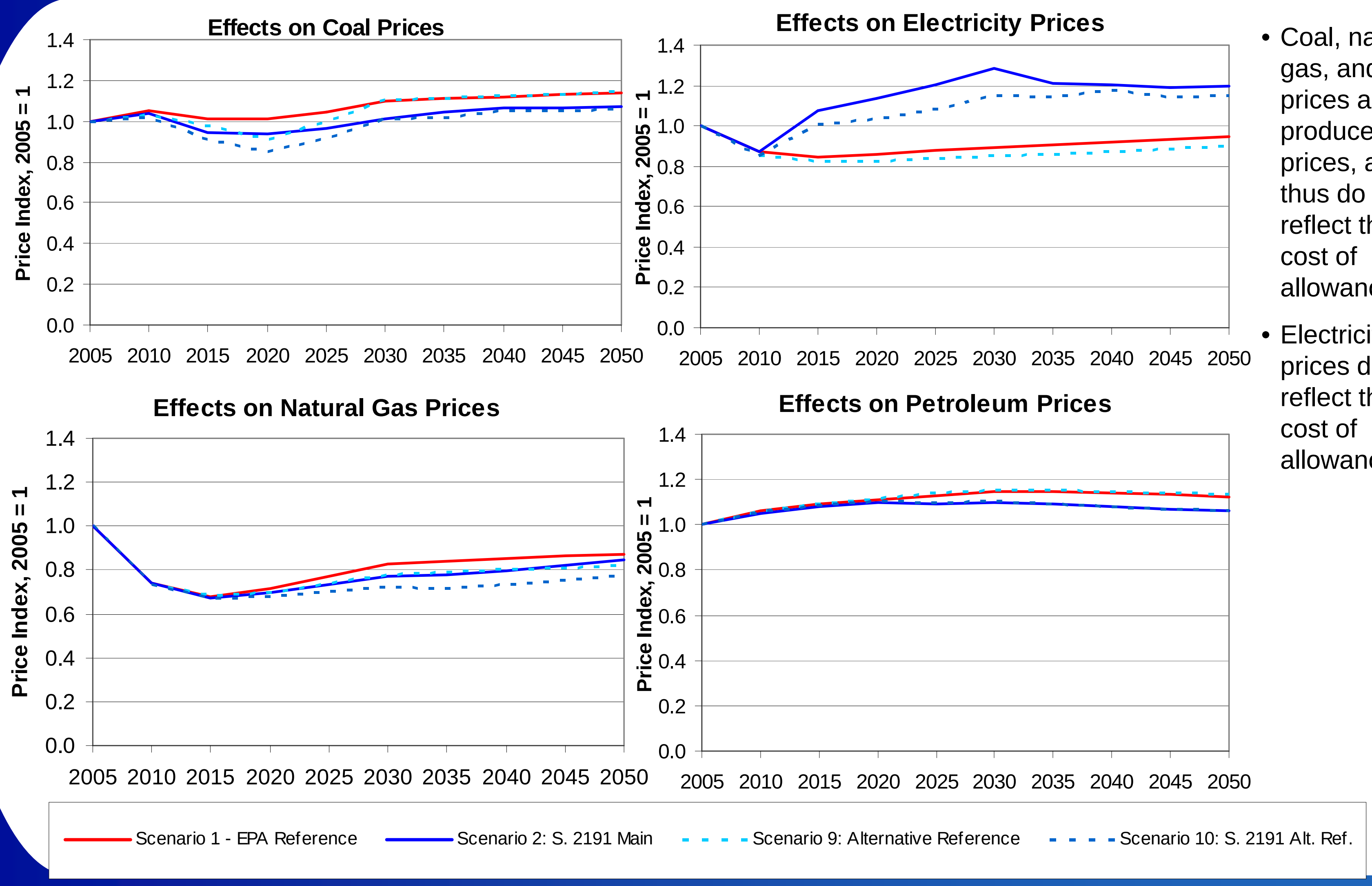
U.S. Electricity Generation, mid-term results (ADAGE)



- If nuclear and biomass generation do not grow in response to policy, and carbon capture and storage technologies are not available before 2030, then demand for electricity is much lower than the S. 2191 Scenario.
- CCS technology reaches its maximum penetration rate, but traditional fossil generation is still supplying electricity by 2050.

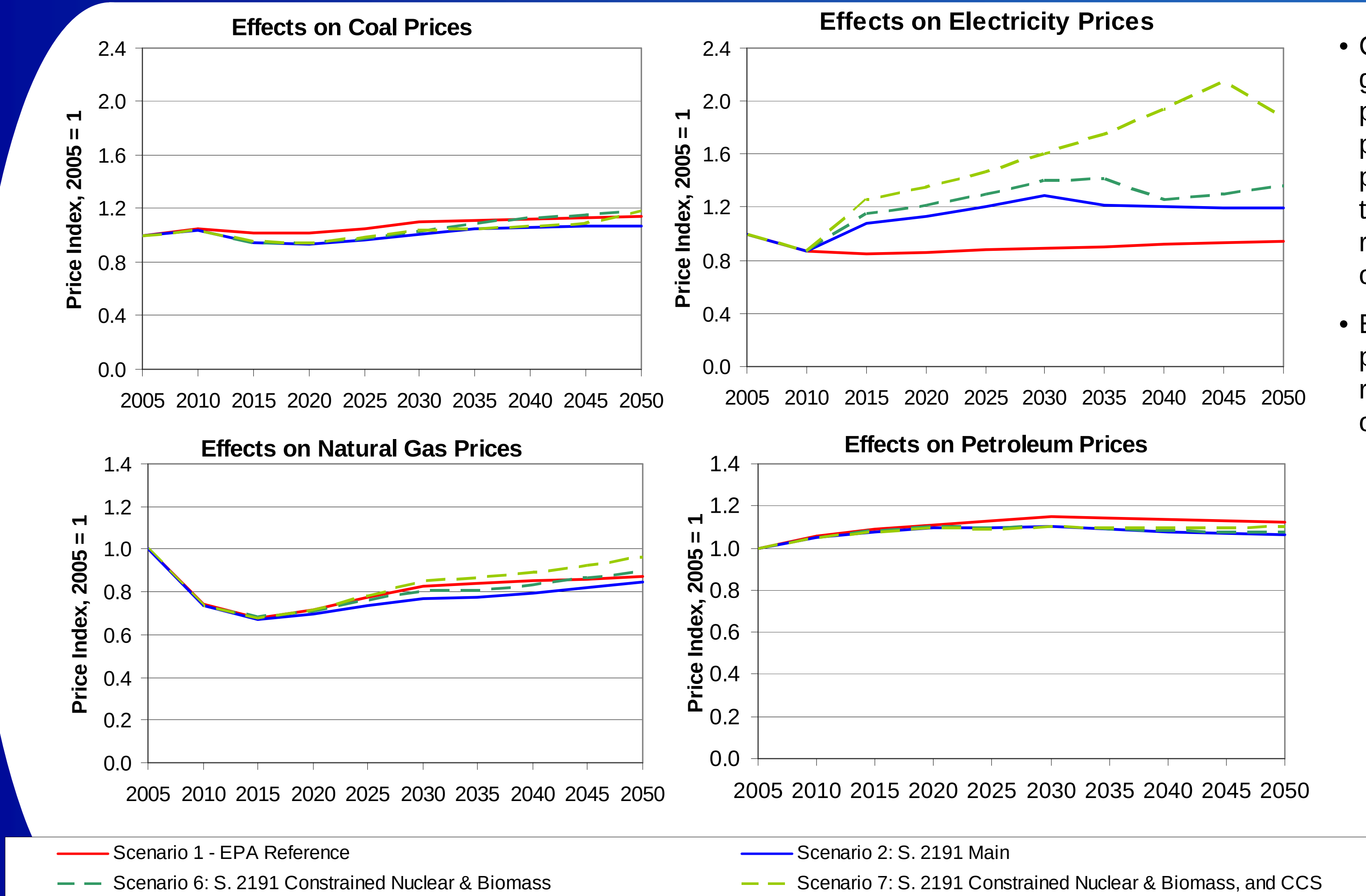
Note: Other non-fossil includes hydro, geothermal, wind, solar, biomass and municipal solid waste.

Results: Scenario 1 – Reference; Scenario 2 – S. 2191; Scenario 9 – Alternative Reference; Scenario 10 – S. 2191 Alt. Ref. Fuel Prices (ADAGE)



- Coal, natural gas, and oil prices are producer prices, and thus do not reflect the cost of allowances
- Electricity prices do reflect the cost of allowances

Results: Scenario 1 – Reference; Scenario 2 – S. 2191; Scenario 6 – S. 2191 Constrained Nuclear & Biomass; Scenario 7 – S. 2191 Constrained Nuclear & Biomass, and CCS
Fuel Prices (ADAGE)



- Coal, natural gas, and oil prices are producer prices, and thus do not reflect the cost of allowances
- Electricity prices do reflect the cost of allowances

Fuel Prices (ADAGE)

- The S. 2191 electricity price reflects the full allowance price the consumer would face.
- S. 2191 electricity prices are 44% higher than in the Reference Scenario in 2030 and 26% higher in 2050, reflecting a shift in fuel mix from coal to gas in the earlier years, the adoption of carbon capture and storage technology in later years, and the increased prices the consumers of coal and gas face due to the price of allowances.
  - Note that capital is more mobile in ADAGE than in IPM and agents in the model have perfect foresight, so the electricity sector responds immediately in the model to the high future allowance prices, this can result in a larger near term increase in the price of electricity in ADAGE than would be shown in IPM.
- Under the Alternative Reference Scenario energy prices are generally lower, due to reduced demand, compared to the reference scenario. Electricity prices in the S. 2191 case under alternative reference assumptions are 35% higher in 2030 and 28% higher in 2050 than the Alternative Reference Scenario prices.
- With assumptions that limit the growth of nuclear, biomass, or carbon capture and storage technologies, meeting the cap becomes more expensive, resulting in larger reductions in demand and increases in the costs of traditional fossil fuels as generators must purchase additional allowances. If all three technologies are constrained, electricity prices in 2030 are 79% higher and 2050 prices are 98% higher than the reference scenario prices.
- For coal, natural gas, and petroleum, the price effect of S. 2191 before adding in the allowance price is shown. This is the price producers of these fuels would face. Electricity prices do include the cost of holding allowances
- Lower demand for fossil fuel drives coal, petroleum and natural gas prices lower than in the Reference Scenario.
  - The impact of S. 2191 on petroleum prices is smaller than the impact on coal and natural gas prices, because fewer options exist in the transportation sector for substituting away from petroleum.
  - Natural gas prices fall further than coal prices, because advanced coal with CCS drives out natural gas fired generation in the electricity sector.
  - In 'Scenario 7 – S. 2191, Constrained Nuclear, Biomass, and CCS' natural gas prices increase, since fuel switching from coal to natural gas is the primary remaining option for the electricity sector to reduce emissions.

Results: Scenario 2 - S. 2191

Fuel Price Adders for 2030 (ADAGE)

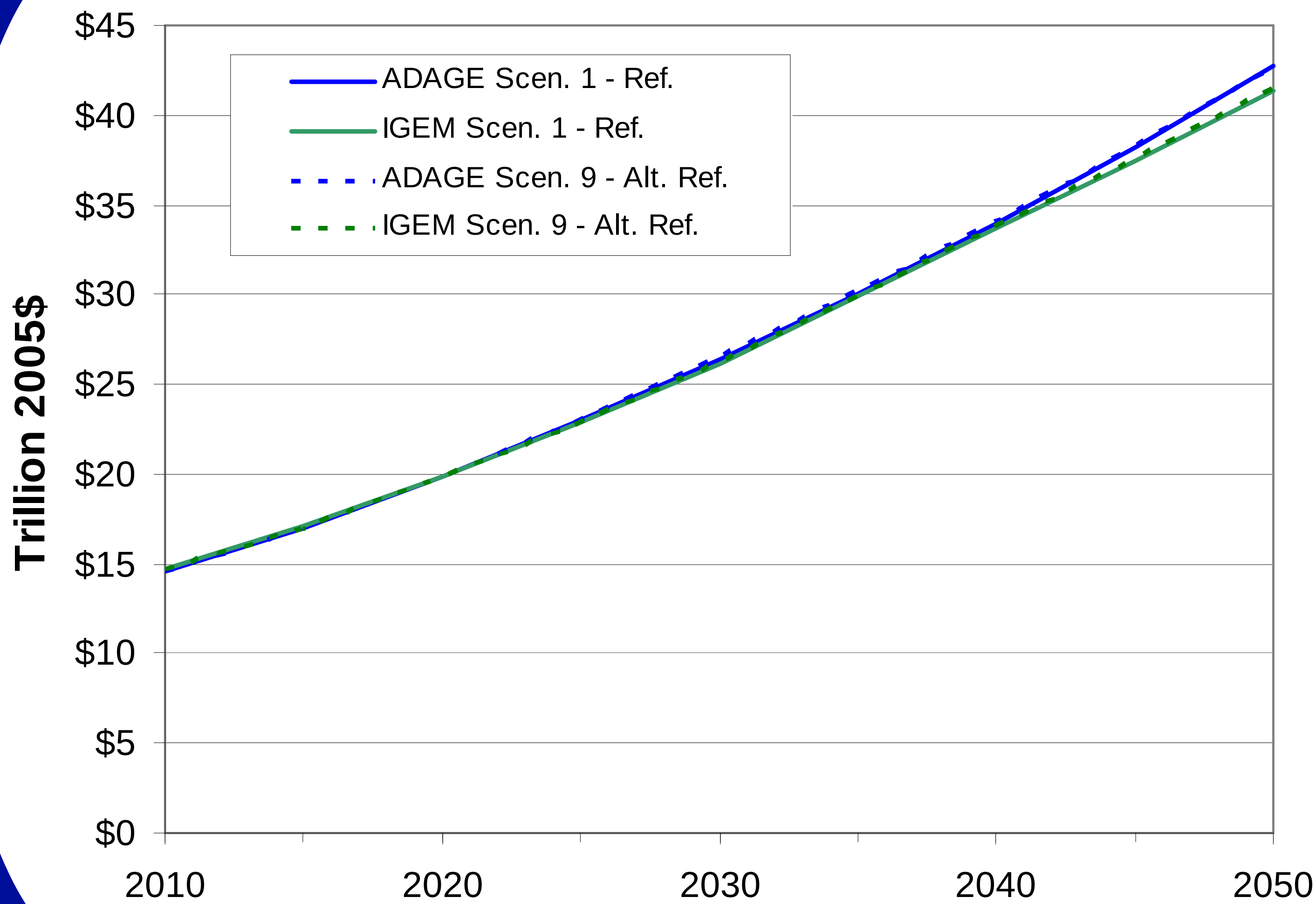
		2030		
	2005 Price	Producer Price	Cost of Carbon Content	End - User Price
Metric Ton of CO_2	n/a		$60.62	
Metric Ton of Carbon	n/a		$222.29	
Barrel of Oil	$50.28	$55.35	$25.95	$81.30
Gallon of Gasoline	$2.34	$2.58	$0.53	$3.11
Short Ton of Coal	$36.79	$37.24	$134.01	$171.25
Short Ton of Coal w/ CCS	$36.79	$37.24	$13.40	$50.64
tCf of Natural Gas	$7.51	$5.79	$3.30	$9.09

- The 2030 producer price is obtained by multiplying the 2030 index price in ADAGE by the 2005 price from EIA's 2006 Monthly Energy Review.
- The cost of carbon content is simply the product of the physical carbon content of the fuel and the allowance price.
- The end-user price is simply the sum of the producer price and the cost of carbon content.
- CCS technology for coal fired power generation captures and stores 90% of carbon emissions, which lowers the cost of carbon content by 90%, and lowers the consumer price accordingly.
- The cost of the carbon content increases the price of gasoline by 21%, increases the price of oil by 47%, increases the price of natural gas by 57%, increases the price of coal by 360%, and increases the price of coal used with CCS by 36%.
- Bonus allowances for CCS are not considered here.

Economy-Wide and Sectoral Modeling Results

Results: Scenario 1 - Reference and Scenario 9 – Alternative Reference

GDP



- GDP growth to 2030 is benchmarked to AEO2006
- Average annual GDP growth from 2010 to 2030 is ~3%.
- Differences in GDP growth in the later years are due to differences in underlying model assumptions
- GDP in the Alternative Reference Scenario is slightly higher than the Reference Scenario

* This slide was updated on 5/508 to correct the bullet describing the annual growth rate of GDP.

Results: Comparing Scenario 2 – S. 2191 with Scenario 10 – S. 2191 Alternative Reference

GDP (Billion 2005$)

Reference Scenario vs. S.2191 Scenario

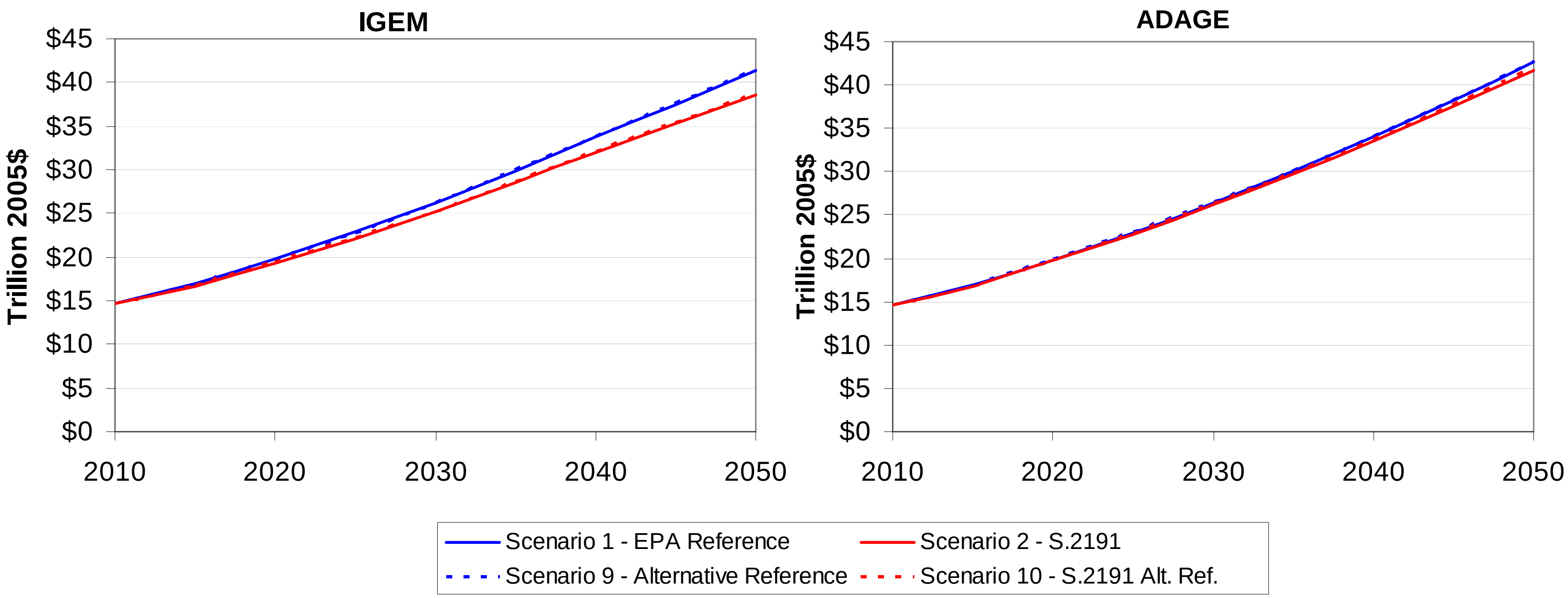
	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 1 - EPA Reference						
ADAGE	$14,620	$19,820	$26,438	$33,958	$42,696	2.72%
IGEM	$14,733	$19,851	$26,173	$33,716	$41,372	2.61%
Scenario 2 - S.2191						
ADAGE	$14,593	$19,683	$26,200	$33,470	$41,684	2.66%
IGEM	$14,595	$19,345	$25,190	$31,964	$38,516	2.46%
Absolute Change						
ADAGE	-$27	-$137	-$238	-$488	-$1,012	*-0.06 Percentage Points*
IGEM	-$138	-$506	-$983	-$1,752	-$2,856	*-0.16 Percentage Points*
% Change						
ADAGE	-0.18%	-0.69%	-0.90%	-1.44%	-2.37%	
IGEM	-0.94%	-2.55%	-3.76%	-5.20%	-6.90%	

Alternative Reference Scenario vs. S.2191 Alt. Ref. Scenario

	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 9 - Alternative Reference Scenario						
ADAGE	$14,638	$19,873	$26,509	$34,019	$42,747	2.72%
IGEM	$14,698	$19,802	$26,220	$33,803	$41,478	2.63%
Scenario 10 - S.2191 Alt. Ref.						
ADAGE	$14,619	$19,775	$26,351	$33,666	$41,993	2.67%
IGEM	$14,602	$19,385	$25,274	$32,103	$38,731	2.47%
Absolute Change						
ADAGE	-$20	-$99	-$158	-$353	-$754	*-0.04 Percentage Points*
IGEM	-$95	-$417	-$947	-$1,700	-$2,747	*-0.16 Percentage Points*
% Change						
ADAGE	-0.13%	-0.50%	-0.60%	-1.04%	-1.76%	
IGEM	-0.65%	-2.10%	-3.61%	-5.03%	-6.62%	

Results: Scenario 2 – S. 2191; and Scenario 10 – S. 2191 Alternative Reference

GDP



Scenario 2 - S. 2191

IGEM

	2010	2020	2030	2040	2050
Absolute Change	-$138	-$506	-$983	-$1,752	-$2,856
% Change	-0.94%	-2.55%	-3.76%	-5.20%	-6.90%

ADAGE

	2010	2020	2030	2040	2050
Absolute Change	-$27	-$137	-$238	-$488	-$1,012
% Change	-0.18%	-0.69%	-0.90%	-1.44%	-2.37%

Scenario 10 - S. 2191 High Technology

	2010	2020	2030	2040	2050
Absolute Change	-$95	-$417	-$947	-$1,700	-$2,747
% Change	-0.65%	-2.10%	-3.61%	-5.03%	-6.62%

	2010	2020	2030	2040	2050
Absolute Change	-$20	-$99	-$158	-$353	-$754
% Change	-0.13%	-0.50%	-0.60%	-1.04%	-1.76%

Results: Scenario 2 – S. 2191 and Scenario 10 – S. 2191 Alternative Reference GDP

- The structure of the IGEM model tends to lead to larger GDP impacts for a given allowance price than the ADAGE model.
  - The elasticity of a household's choice between demand for leisure and demand for goods and services is one of the most important differences between the models that results in the difference in GDP effects (Jorgenson et al. 2000). In ADAGE, this consumption-leisure parameter is adopted from values of related parameters in the empirical literature, while in IGEM this parameter is estimated from historical data. While both models assume that the compensated labor supply elasticity is inelastic, the value used in IGEM is relatively more elastic than the value used in ADAGE. The result of this difference is that similar allowance prices in the two models, result in larger changes in household behavior in IGEM, and thus larger overall economic impacts.
- Additionally, the several other factors lead to a larger difference in GDP impacts than might otherwise be expected.
  - Representation of international GHG policies
    - Since IGEM is a domestic model, world prices are not affected by climate policies in Group 1 and Group 2 countries. As a result of S. 2191, the prices of U.S. exports rise relative to prices in the rest of the world, and export volumes fall. Since exports are price-elastic the volumes fall proportionally more than the price rises and thus the value of exports declines. Imports are reduced in part by the overall reduction in spending associated with the lower levels of consumption. Additionally, commodities directly affected by the emissions cap (e.g. oil) are reduced proportionally more than other imports due to the allowance prices embodied in their cost. Import substitution counterbalances the two forces above. U.S. prices of commodities not directly affected by the policy are relatively higher, which leads to substitution away from domestically produced goods and towards imported goods. To the extent that policies in Group 1 and Group 2 countries increase world prices of affected commodities, the relative price difference between goods produced in the U.S. and goods produced abroad will be lessened. This will reduce impact on exports, and reduce the import substitution effect, both of which are driven by the relative price differential, and subsequently reduce the impact on GDP.
  - Reference case emissions
    - The higher reference case total and covered GHG emissions in IGEM compared to ADAGE lead to higher allowance prices, which in turn lead to higher GDP impacts.
- The GDP impacts found by other models that have analyzed S. 2191 (e.g. MIT* and CRA**) tend to be closer to GDP impacts in ADAGE than GDP impacts in IGEM.
- Changes in consumption may be a better measure of the costs of S. 2191 than changes in GDP since utility (and thus welfare) is a direct function of consumption and not GDP.

* Paltsev et al., "Assessment of U.S. Cap-and-Trade Proposals – Appendix D: Analysis of the Cap and Trade Features of the Lieberman-Warner Climate Security Act (S. 2191)" 2007.

** CRA International, "Economic Modeling of the Lieberman-Warner Bill: S. 2191 as Reported by Senate EPW," January 2008.

Scenario Comparison

GDP Impacts

(Percentage Change from Reference)

Table: GDP Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	-0.7%	-0.7%	-0.7%	-0.9%	-1.1%	-1.4%	-1.9%	-2.4%
IGEM	-2.0%	-2.6%	-3.1%	-3.8%	-4.4%	-5.2%	-6.0%	-6.9%
3) S. 2191 with Low International Actions								
ADAGE	-0.6%	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-2.0%	-2.5%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-1.9%	-2.3%	-2.7%
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-3.3%	-4.1%	-5.0%	-5.9%	-6.9%	-7.9%	-9.0%	-10.1%
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	-0.8%	-0.9%	-0.9%	-1.2%	-1.6%	-2.0%	-2.6%	-3.3%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	-1.1%	-1.5%	-1.8%	-2.3%	-2.6%	-3.1%	-3.8%	-4.4%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel								
ADAGE	-1.1%	-1.4%	-1.6%	-2.1%	-2.4%	-2.9%	-3.6%	-4.3%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	0.1%	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%
IGEM	0.3%	0.2%	0.1%	-0.2%	-0.2%	-0.3%	-0.3%	-0.3%
10) S. 2191 Alternative Reference								
ADAGE	-0.3%	-0.2%	-0.2%	-0.3%	-0.5%	-0.9%	-1.2%	-1.6%
IGEM	-1.5%	-2.1%	-2.8%	-3.6%	-4.3%	-5.0%	-5.8%	-6.6%

Results: Scenario 2 – S. 2191; and Scenario 10 – S. 2191 Alternative Reference

Consumption (Billion 2005$)

Table: **Impact of S. 2191 on U.S. Consumption (Billion 2005 Dollars)**

	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 1 - EPA Reference						
ADAGE	$10,783	$14,638	$19,721	$25,350	$31,887	2.75%
IGEM	$9,222	$12,346	$16,231	$20,921	$25,838	2.61%
Scenario 2 - S.2191						
ADAGE	$10,858	$14,575	$19,541	$24,997	$31,217	2.68%
IGEM	$9,259	$12,265	$15,998	$20,443	$24,995	2.51%
Absolute Change						
ADAGE	$75	-$63	-$180	-$353	-$670	*-0.07 Percentage Points*
IGEM	$36	-$82	-$233	-$478	-$843	*-0.10 Percentage Points*
% Change						
ADAGE	0.69%	-0.43%	-0.91%	-1.39%	-2.10%	
IGEM	0.39%	-0.66%	-1.44%	-2.28%	-3.26%	
Annual Change per Household (2005$)						
ADAGE	$574	-$446	-$1,176	-$2,188	-$3,984	
IGEM	$300	-$608	-$1,574	-$2,943	-$4,771	

	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 9 - Alternative Reference Scenario						
ADAGE	$10,797	$14,673	$19,760	$25,382	$31,914	2.75%
IGEM	$9,223	$12,338	$16,242	$20,968	$25,903	2.62%
Scenario 10 - S.2191 Alt. Ref.						
ADAGE	$10,859	$14,640	$19,643	$25,097	$31,372	2.69%
IGEM	$9,257	$12,277	$16,027	$20,497	$25,083	2.52%
Absolute Change						
ADAGE	$63	-$34	-$118	-$285	-$542	*-0.06 Percentage Points*
IGEM	$34	-$61	-$215	-$471	-$820	*-0.09 Percentage Points*
% Change						
ADAGE	0.58%	-0.23%	-0.60%	-1.12%	-1.70%	
IGEM	0.37%	-0.49%	-1.32%	-2.25%	-3.17%	

Results: Scenario 2 – S. 2191; and Scenario 10 – S. 2191 Alternative Reference

Consumption

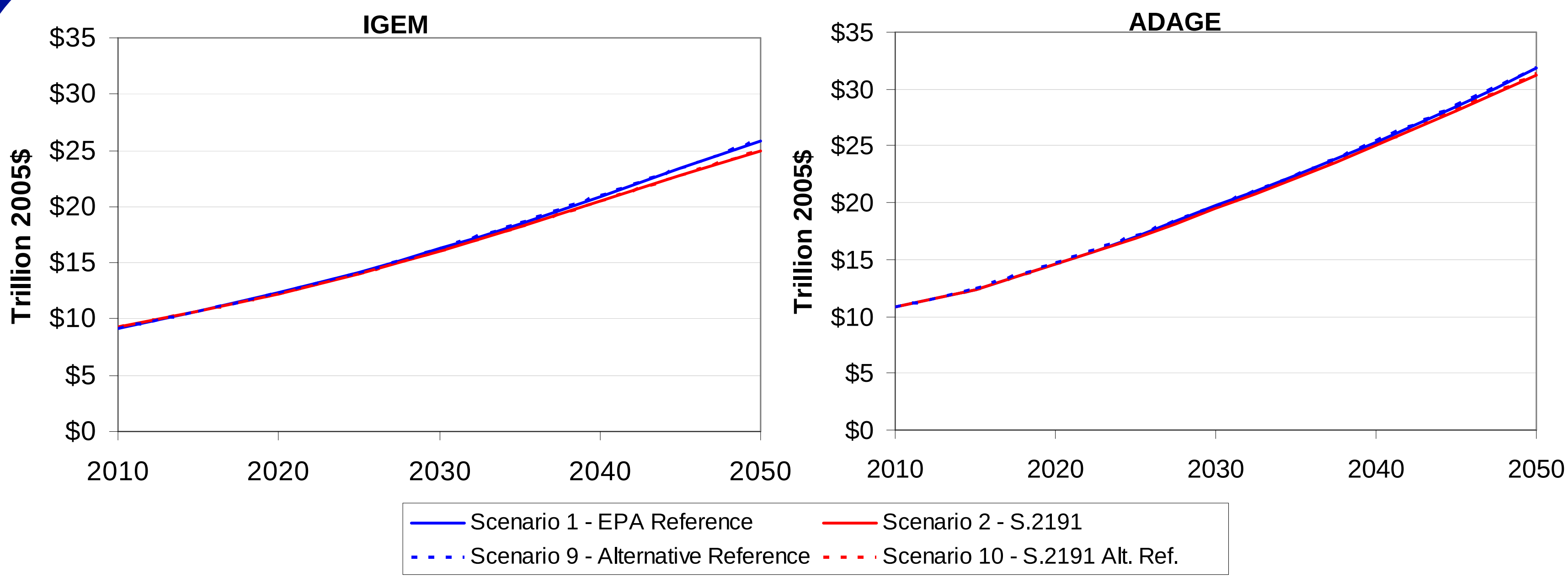


Table: **Impact of S. 2191 on U.S. Consumption (2005 Dollars)**

IGEM

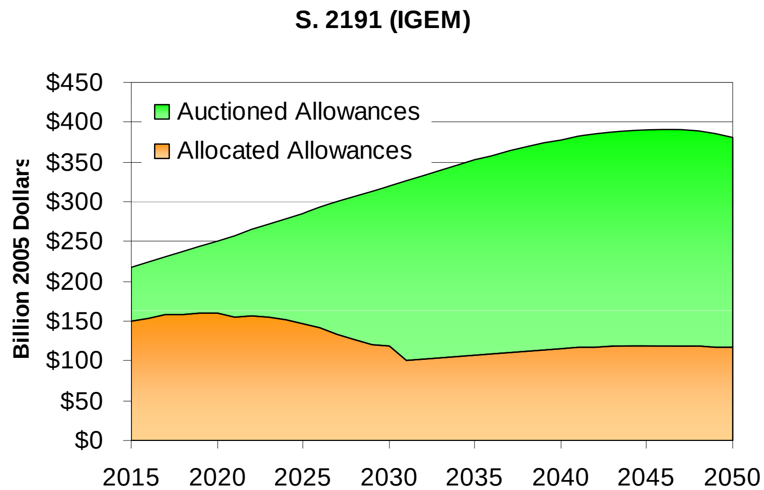
	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Annual Change / HH	$300	-$608	-$1,574	-$2,943	-$4,771
% Change	0.39%	-0.66%	-1.44%	-2.28%	-3.26%
Scenario 10 - S.2191 Alt. Ref.					
Annual Change / HH	$281	-$454	-$1,449	-$2,903	-$4,642
% Change	0.37%	-0.49%	-1.32%	-2.25%	-3.17%

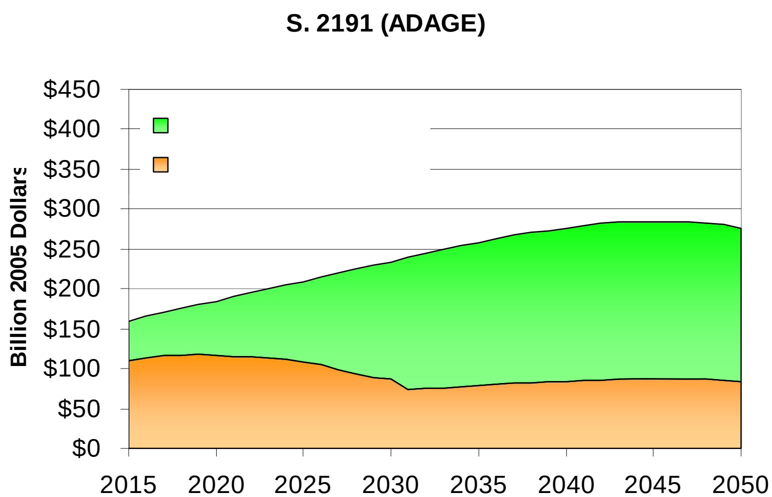
ADAGE

	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Annual Change / HH	$574	-$446	-$1,176	-$2,188	-$3,984
% Change	0.69%	-0.43%	-0.91%	-1.39%	-2.10%
Scenario 10 - S.2191 Alt. Ref.					
Annual Change / HH	$480	-$239	-$768	-$1,765	-$3,222
% Change	0.58%	-0.23%	-0.60%	-1.12%	-1.70%

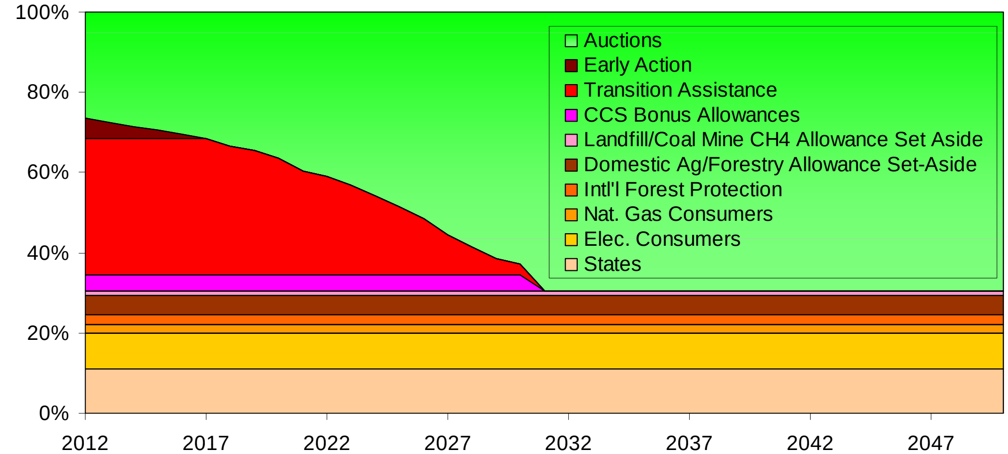
Results: Scenario 2 – S. 2191

Value of Allocated & Auctioned Allowances





- The share of allowances that are auctioned, allocated, or designated for set-aside programs is specified in S. 2191 *Title III – Allocating and Distributing Allowances*.



- Allowance set-asides are treated as allocated allowances.
- In IGEM we assume that the policy is deficit and revenue neutral, which implies that the market outcomes are invariant to the auction / allocation spilt
  - Private sector revenues from allocated allowances accrue to employee-shareholder households, and the government adjusts taxes lump sum to maintain deficit and spending levels.
  - Allowance auction revenues flow to the U.S. government, and are redistributed to households lump sum to the extent that deficit and spending levels are maintained. If auction revenues were directed to special funds instead of returned directly to households as modeled, the reduction in household annual consumption and GDP would likely be greater. If the auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower.
- In IPM the auction / allocation split affects market outcomes because regulated electric utilities, which are explicitly modeled, are allowed to pass on the cost of auctioned allowances to consumers, but are not allowed to pass on the cost of allocated allowances.

Results: Scenario 2 – S. 2191

Value of Allocated & Auctioned Allowances

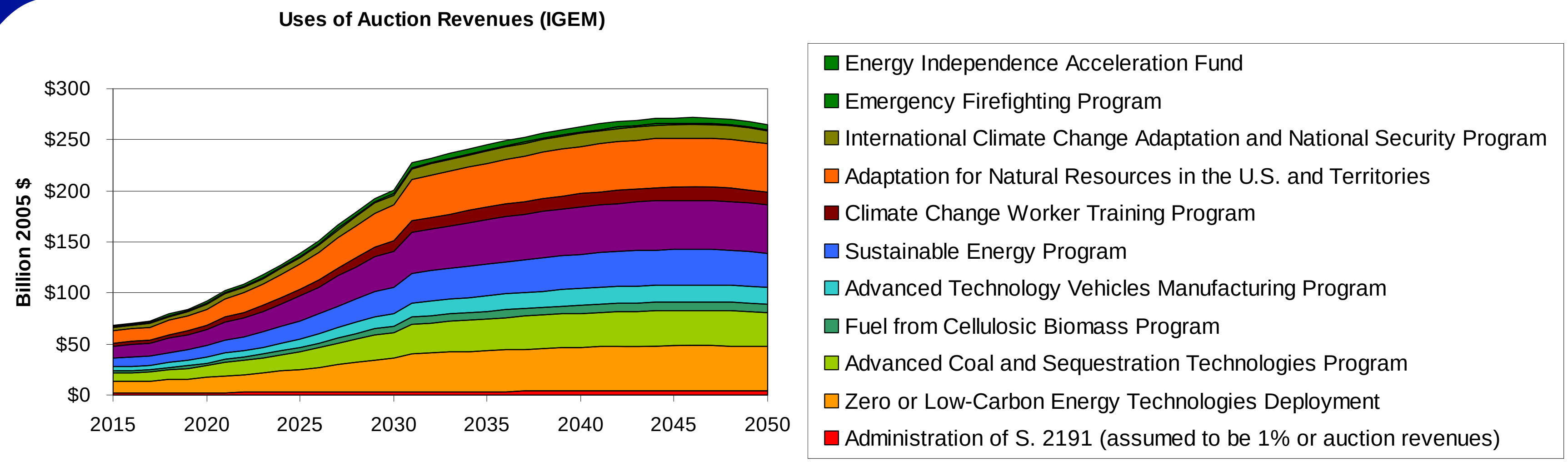
Table: Value of Auctioned and Allocated Allowances (Billion 2005 $)
S. 2191 Title III - Allocating and Distributing Allowances

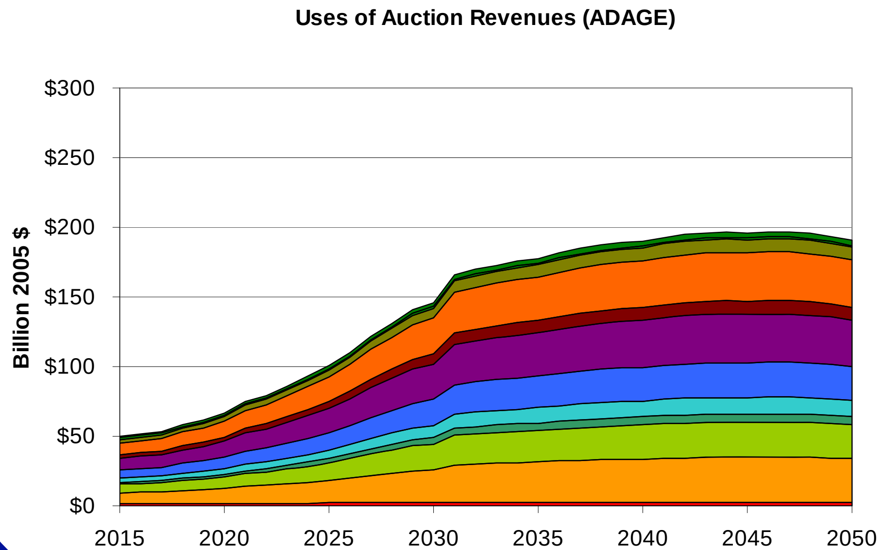
	2015	2020	2025	2030	2035	2040	2045	2050
Subtitle A - Auctions								
ADAGE	$47	$67	$101	$147	$179	$191	$197	$192
IGEM	$64	$92	$139	$201	$245	$263	$272	$265
Subtitle B - Early Action								
ADAGE	$3	$0	$0	$0	$0	$0	$0	$0
IGEM	$4	$0	$0	$0	$0	$0	$0	$0
Subtitle C - States								
ADAGE	$18	$20	$23	$26	$28	$30	$31	$30
IGEM	$24	$28	$31	$35	$39	$42	$43	$42
Subtitle D - Electricity Consumers								
ADAGE	$14	$17	$19	$21	$23	$25	$26	$25
IGEM	$20	$23	$26	$29	$32	$34	$35	$34
Subtitle E - Natural Gas Consumers								
ADAGE	$3	$4	$4	$5	$5	$6	$6	$6
IGEM	$4	$5	$6	$6	$7	$8	$8	$8
Subtitle F - Bonus Allowances for CCS								
ADAGE	$6	$7	$8	$9	$0	$0	$0	$0
IGEM	$9	$10	$11	$13	$0	$0	$0	$0
Subtitle G - Domestic Ag/Forestry								
ADAGE	$8	$9	$10	$12	$13	$14	$14	$14
IGEM	$11	$13	$14	$16	$18	$19	$20	$19
Subtitle H - International Forest Protection								
ADAGE	$4	$5	$5	$6	$6	$7	$7	$7
IGEM	$5	$6	$7	$8	$9	$9	$10	$10
Subtitle I - Transition Assistance								
ADAGE	$54	$53	$36	$6	$0	$0	$0	$0
IGEM	$74	$73	$49	$9	$0	$0	$0	$0
Subtitle J - Landfill / Coal Mine CH4 Allowance Set - Asides								
ADAGE	$2	$2	$2	$2	$3	$3	$3	$3
IGEM	$2	$3	$3	$3	$4	$4	$4	$4

- The percentage of allowances to be allocated for each of these purposes is specified in S. 2191 Title III – Allocating and Distributing Allowances.
- While the values of all the uses of allocated and auctioned allowances are reported here; only the emissions reductions associated with the allowance set asides in *Subtitle G – Domestic Ag/Forestry* and *Subtitle J – Landfill / Coal Mine CH4 Allowance Set – Asides*; and the effect of the subsidy for carbon capture and sequestration technology specified in *Subtitle F – Bonus Allowances for CCS* are explicitly modeled.

Results: Scenario 2 – S. 2191

Value and Uses of Auctioned Allowances





- The percentage of auction revenues to be used for each of these purposes is specified in S. 2191 Title IV – Auctions and Uses of Auction Proceeds.
- While the values of all the uses of auctioned allowances are reported here, the programs specified are not explicitly modeled in this analysis.

Results: Scenario 2 – S. 2191

Value and Uses of Auctioned Allowances

Table: Value and Uses of Auctioned Allowances (Billion 2005 $)

S. 2191 Title IV - Auctions and Uses of Auction Proceeds

	2015	2020	2025	2030	2035	2040	2045	2050
Administration of S. 2191 (assumed to be 1% or auction revenues)								
ADAGE	$1.6	$1.8	$2.1	$2.3	$2.6	$2.8	$2.8	$2.8
IGEM	$2.2	$2.5	$2.9	$3.2	$3.5	$3.8	$3.9	$3.8
Zero or Low-Carbon Energy Technologies Deployment								
ADAGE	$7.8	$10.6	$16.2	$23.7	$29.0	$31.0	$31.9	$31.0
IGEM	$10.9	$14.6	$22.4	$32.7	$40.0	$42.9	$44.3	$43.3
Advanced Coal and Sequestration Technologies Program								
ADAGE	$6.1	$8.3	$12.7	$18.5	$22.6	$24.2	$24.9	$24.3
IGEM	$8.5	$11.4	$17.5	$25.6	$31.2	$33.5	$34.6	$33.8
Fuel from Cellulosic Biomass Program								
ADAGE	$1.5	$2.0	$3.0	$4.4	$5.4	$5.8	$6.0	$5.8
IGEM	$2.0	$2.7	$4.2	$6.1	$7.5	$8.0	$8.3	$8.1
Advanced Technology Vehicles Manufacturing Program								
ADAGE	$2.9	$4.0	$6.1	$8.9	$10.9	$11.6	$12.0	$11.6
IGEM	$4.1	$5.5	$8.4	$12.3	$15.0	$16.1	$16.6	$16.2
Sustainable Energy Program								
ADAGE	$6.1	$8.3	$12.7	$18.5	$22.6	$24.2	$24.9	$24.3
IGEM	$8.5	$11.4	$17.5	$25.6	$31.2	$33.5	$34.6	$33.8
Energy Consumers								
ADAGE	$8.5	$11.4	$17.5	$25.6	$31.3	$33.5	$34.5	$33.6
IGEM	$11.7	$15.8	$24.2	$35.4	$43.2	$46.4	$48.0	$46.8
Climate Change Worker Training Program								
ADAGE	$2.4	$3.2	$4.9	$7.1	$8.7	$9.3	$9.6	$9.3
IGEM	$3.3	$4.4	$6.7	$9.8	$12.0	$12.9	$13.3	$13.0
Adaptation for Natural Resources in the U.S. and Territories								
ADAGE	$8.5	$11.4	$17.5	$25.6	$31.3	$33.5	$34.5	$33.6
IGEM	$11.7	$15.8	$24.2	$35.4	$43.2	$46.4	$48.0	$46.8
International Climate Change Adaptation and National Security Program								
ADAGE	$2.4	$3.2	$4.9	$7.1	$8.7	$9.3	$9.6	$9.3
IGEM	$3.3	$4.4	$6.7	$9.8	$12.0	$12.9	$13.3	$13.0
Emergency Firefighting Program								
ADAGE	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2
IGEM	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2
Energy Independence Acceleration Fund								
ADAGE	$0.9	$1.3	$1.9	$2.8	$3.5	$3.7	$3.8	$3.7
IGEM	$1.3	$1.8	$2.7	$3.9	$4.8	$5.2	$5.3	$5.2

- The percentage of auction revenues to be used for each of these purposes is specified in S. 2191 Title IV – Auctions and Uses of Auction Proceeds.
- While the values of all the uses of auctioned allowances are reported here, the programs specified are not explicitly modeled in this analysis.

Results: Scenario 2 - S. 2191

2030 Selected Sectoral Results (IGEM)

Sector	2007	2030				
		Reference		S.2191 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Personal and business services	4468	8419	88%	8367.2	87%	-1%
Finance, insurance and real estate	2743	6307	130%	6229.7	127%	-1%
Transportation and warehousing	707	1334	89%	1260.3	78%	-5%
Food and kindred products	587	1199	104%	1304.3	122%	9%
Motor vehicles	532	1137	114%	1060.0	99%	-7%
Electric utilities (services)	399	569	43%	460.2	15%	-19%
Petroleum refining	307	403	31%	296.5	-4%	-27%
Gas utilities (services)	52	63	20%	43.4	-17%	-31%
Coal mining	30	42	39%	17.6	-41%	-58%

- Detailed near-term electricity sector modeling in IPM indicates that the decrease in coal usage may be smaller than the decrease shown in the economy-wide models.
- The results for all 35 sectors and for 2050 are available in Appendix 4.

Results: Scenario 10 – S. 2191 Alt. Ref.

2030 Selected Sectoral Results (IGEM)

Sector	2007	2030				
	Alternative Reference			S.2191 Alt. Ref.		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Personal and business services	4468	8503	88%	8373.7	87%	-2%
Finance, insurance and real estate	2743	6377	130%	6234.7	127%	-2%
Transportation and warehousing	707	1340	89%	1267.0	79%	-5%
Food and kindred products	588	1240	104%	1292.3	120%	4%
Motor vehicles	529	1148	114%	1066.3	101%	-7%
Electric utilities (services)	396	540	43%	469.7	19%	-13%
Petroleum refining	305	369	31%	306.2	0%	-17%
Gas utilities (services)	52	61	20%	45.2	-13%	-26%
Coal mining	30	37	39%	18.8	-37%	-48%

- Detailed near-term electricity sector modeling in IPM indicates that the decrease in coal usage may be smaller than the decrease shown in the economy-wide models.
- The results for all 35 sectors and for 2050 are available in Appendix 4.

Results: Scenario 2 – S. 2191

2030 Selected Sectoral Results (IGEM)

- The previous slides shows the impacts of S. 2191 case on the value of output of nine of the 35 IGEM sectors. These sectors correspond roughly to the two digit NAICS classification. (Results for the remaining sectors are presented in the appendix).
- The largest sectors in IGEM (personal and business services and finance, insurance and real estate) account for some fourteen trillion dollars of economic activity in 2030 and are only modestly affected by the policy.
- Transportation (freight and warehousing) and motor vehicle manufacturing do experience reductions in the value of their output, as consumers and other sectors substitute away from energy consumption. The model does not explicitly represent technology, and does not show the possible impact of new transportation technologies.
- In response to S. 2191, the food and kindred products sector is an example in IGEM of a sector which experiences a growth in demand, as consumers substitute away from other goods which may be more energy intensive.
- The energy production and transformation sectors experience reduction in output as other industries and consumers substitute capital, labor, and non-energy inputs.[1]
- Under the assumptions of the Alternative case, impacts on energy industries are less significant than under the reference case assumptions.

[1] Note that the coal industry shows large declines in output by 2030. Most domestic coal is consumed by the electricity sector, and IGEM does not explicitly represent generation technologies such as carbon capture and sequestration. The ADAGE model does represent generation technologies, and also shows that coal output decreases by 2030, but after 2030, all fossil generation is eventually replaced by coal fired integrated combined cycle and gasification plants with carbon capture and sequestration technologies, and coal output increases. See slide in Appendix on Primary Energy Use from ADAGE.

Results: Scenario 2 – S. 2191
Total Abatement Cost

Table: Total Abatement Cost Calculations
Scenario 2 - S.2191

	2015	2020	2025	2030	2035	2040	2045	2050
Domestic Covered Abatement and Allowance Set-Asides (MtCO2e)								
ADAGE	1,785	2,157	2,681	3,446	4,204	4,520	4,832	5,128
IGEM	2,234	2,648	3,139	3,680	4,340	5,042	5,787	6,600
Domestic Offset Abatement (MtCO2e)								
ADAGE	392	619	596	558	511	512	508	501
IGEM	529	611	602	596	566	526	481	427
International Credits (MtCO2e)								
ADAGE	624	619	596	558	511	512	508	501
IGEM	619	611	602	596	566	526	481	427
Allowance Price ($/tCO2e)								
ADAGE	$29	$37	$48	$61	$77	$98	$125	$159
IGEM	$40	$51	$65	$83	$106	$135	$173	$220
Offset Price ($/tCO2e)								
ADAGE	$29	$30	$27	$23	$24	$28	$29	$31
IGEM	$40	$29	$27	$24	$27	$29	$28	$26
International Credit Price ($/tCO2e)								
ADAGE	$9	$12	$15	$20	$25	$32	$41	$52
IGEM	$9	$12	$15	$20	$25	$32	$41	$52
Domestic Covered Abatement Cost (Billion 2005 Dollars)								
ADAGE	$26	$40	$64	$104	$162	$222	$302	$408
IGEM	$45	$67	$102	$153	$230	$341	$499	$727
Domestic Offset Abatement Cost (Billion 2005 Dollars)								
ADAGE	$6	$9	$8	$6	$6	$7	$7	$8
IGEM	$11	$9	$8	$7	$8	$8	$7	$6
International Credit Payments (Billion 2005 Dollars)								
ADAGE	$6	$7	$9	$11	$13	$16	$21	$26
IGEM	$6	$7	$9	$12	$14	$17	$20	$22
Total Abatement Cost (Billion 2005 Dollars)								
ADAGE	$38	$57	$81	$122	$181	$246	$331	$442
IGEM	$61	$84	$119	$172	$251	$365	$526	$754

* This slide was updated on 5/508 to correct the ADAGE values for domestic covered abatement and subsequent calculations.

- The allowance price is equal to the marginal cost of abatement.
- The offset price is the marginal cost of abatement for uncovered sectors and entities in the U.S.
- The international credit price is the marginal cost of abatement outside of the U.S.
- Domestic covered abatement cost is approximated for each model as the product of domestic covered GHG emissions abatement and the allowance price divided by two.
  - Division by 2 is assumed to represent the fact that most reduction measures are not implemented at the marginal allowance price but at lower prices. In most cases, the relationship between emission reduction and the marginal price is a concave curve – which implies a value larger than 2. The value of 2, used here for simplicity leads to an overestimation of abatement costs.
- Domestic offset abatement cost is approximated for each model as the product of domestic offset abatement and the offset price divided by two.
- International credit payments are calculated for each model as the product of the amount of international credits purchased and the international credit price.
  - Unlike the abatement costs associated with domestic covered abatement and domestic offsets, there is no need for dividing by two when calculating the costs of international credits as all international credits are purchased at the full price of international allowances and those payments are sent abroad.
- Total abatement cost is simply the sum of domestic covered abatement cost, domestic offset abatement cost, and payments for international credits.

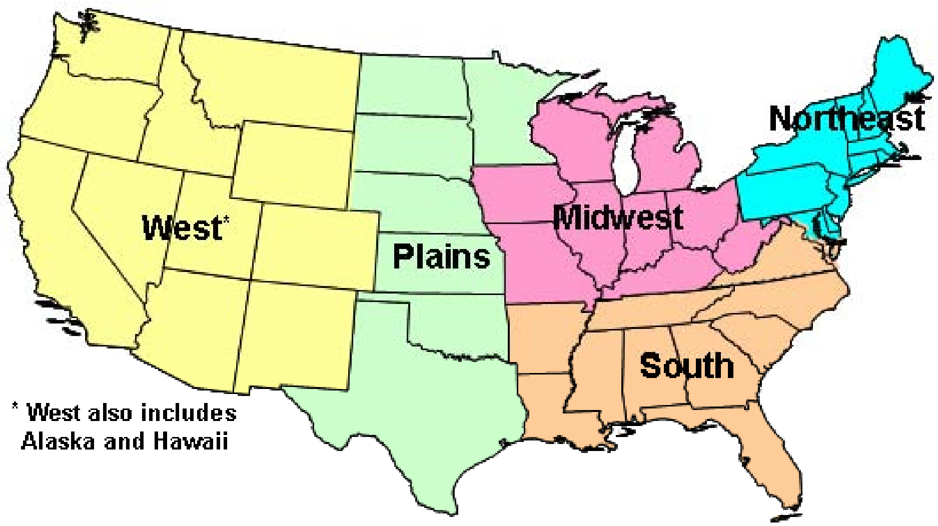
Regional Modeling Results

Introduction to Regional Results

(ADAGE)

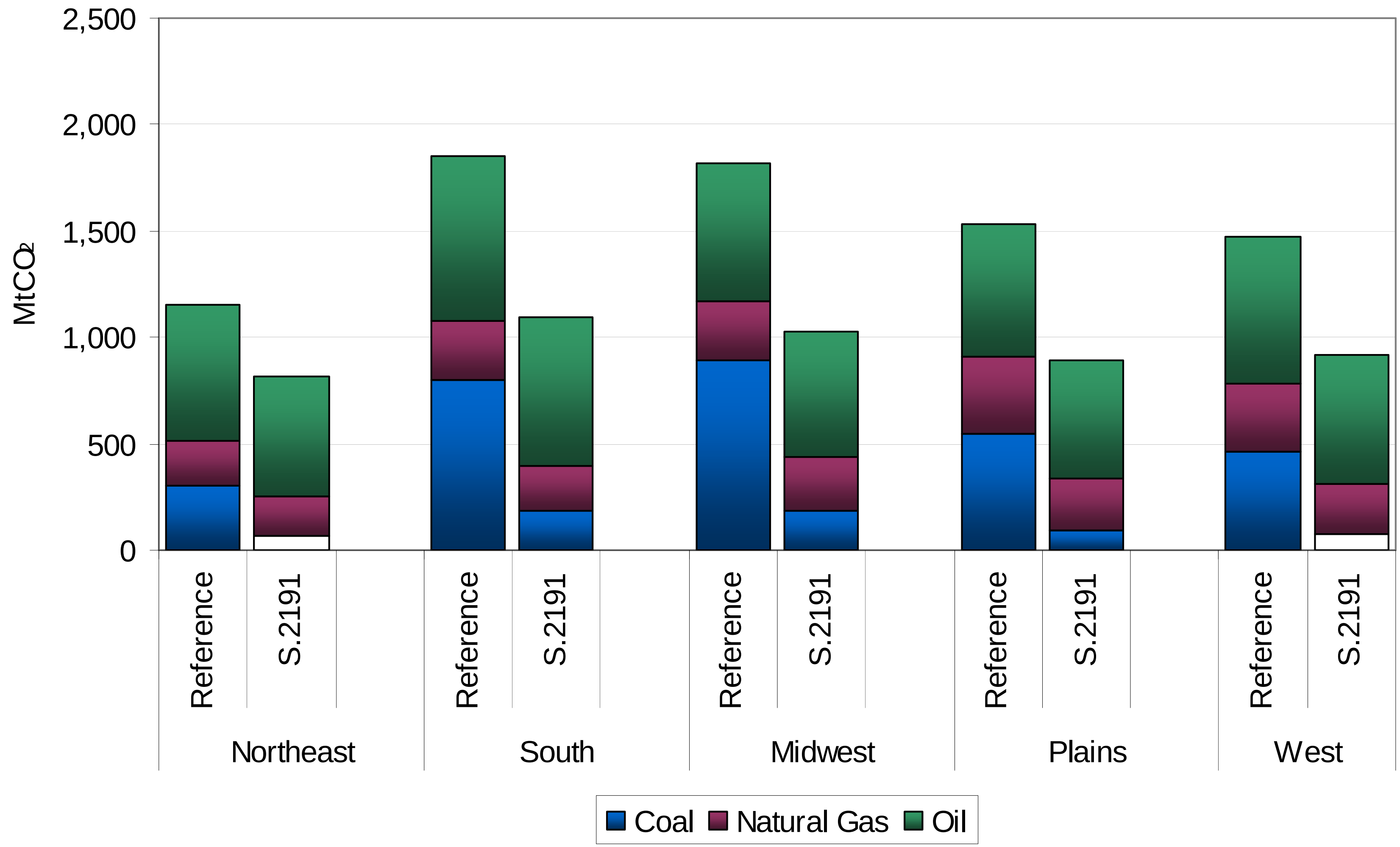
- ADAGE models 5 regions in the U.S.
  - West, Plains, Midwest, South and Northeast

- Difference in regional results can be attributed to a variety of factors:
  - Economic Base
    - Energy industry composition
    - Manufacturing industry composition
  - Energy Use
    - Efficiency and types of manufacturing
    - Household heating and cooling needs
    - Transportation systems and average distances traveled
  - Electricity Generation
    - Existing fossil fuel capacity
  - Allowance Allocation
    - Allocation impacts regional consumption, income, and GDP



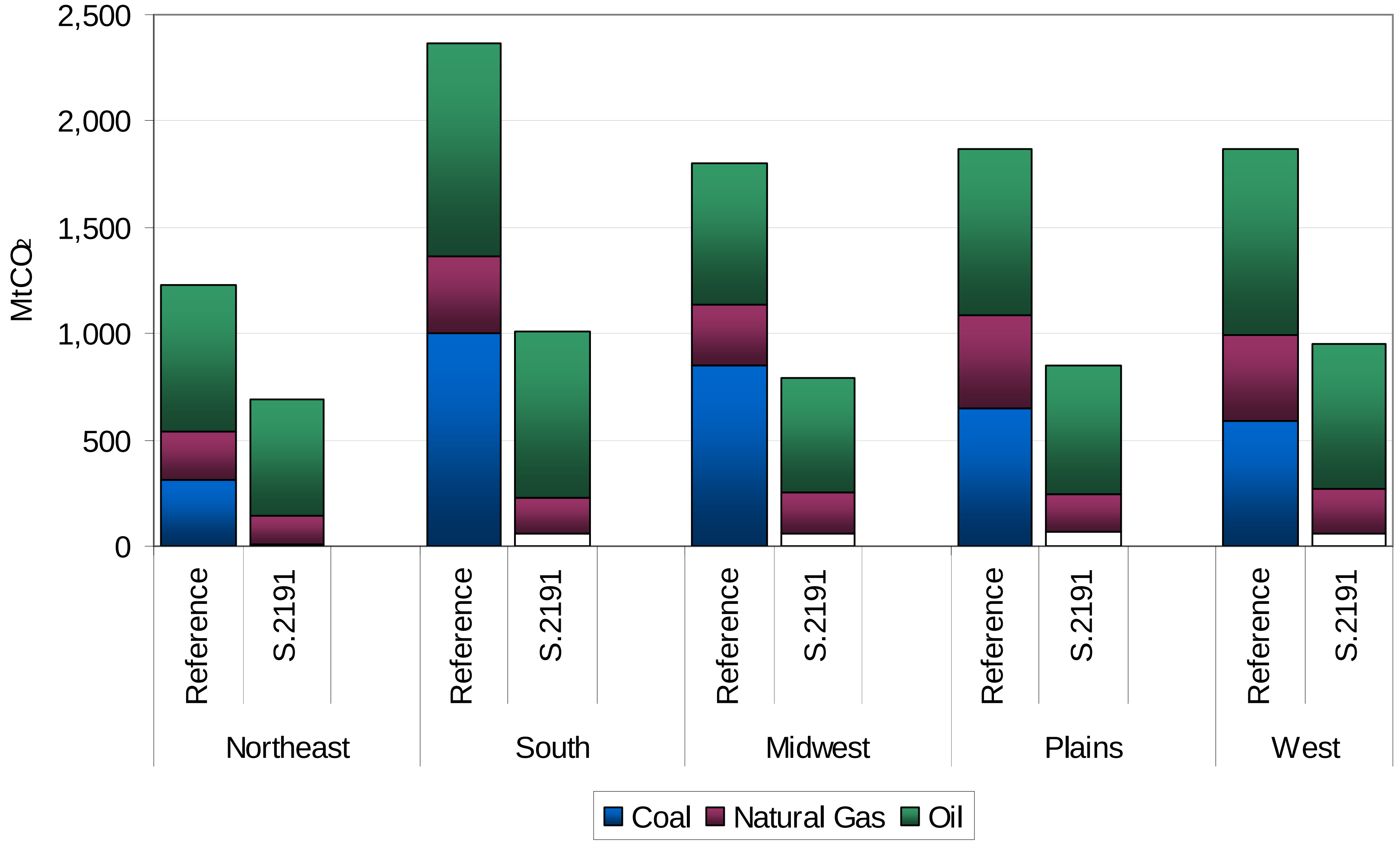
Results: Scenario 2 - S. 2191

Regional CO_2 from Energy Use - **2030** (ADAGE)



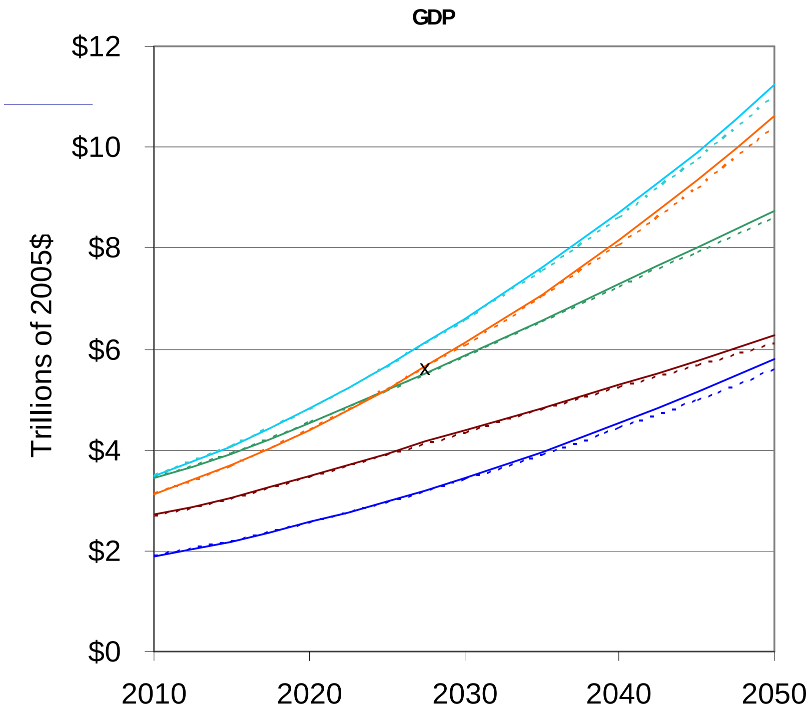
Results: Scenario 2 - S. 2191

Regional CO_2 from Energy Use - **2050** (ADAGE)



Results: Scenario 2 - S. 2191

Regional GDP and Consumption (ADAGE)



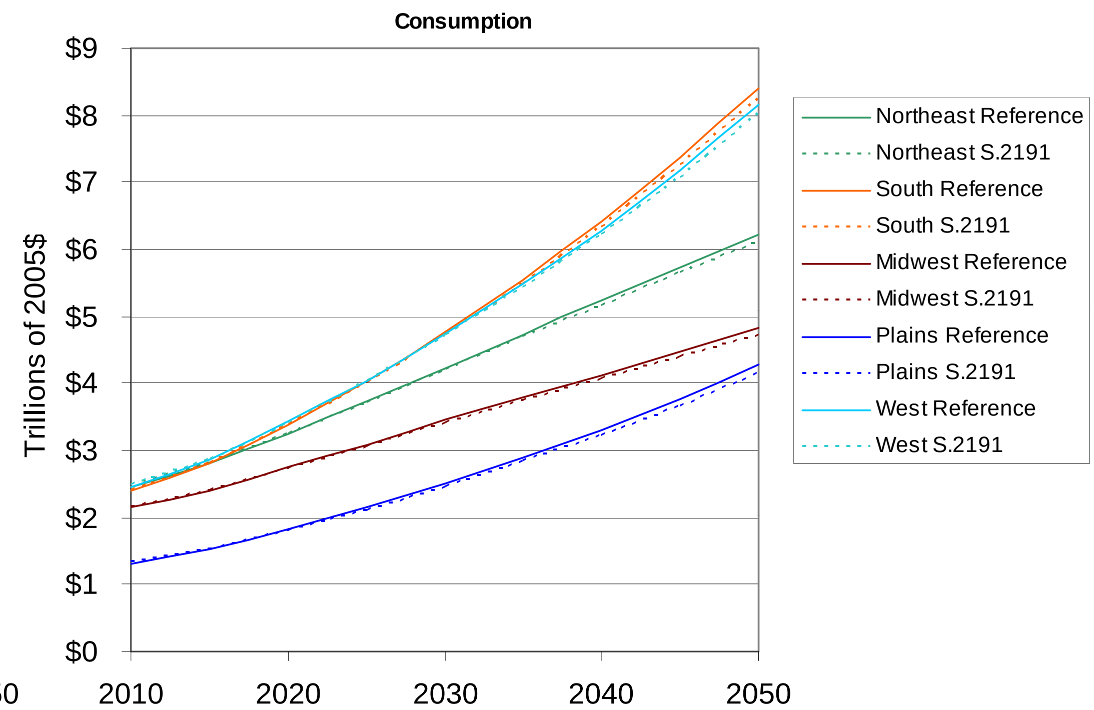


Table: % Change in Regional GDP Scenario 2 - S.2191

	2010	2020	2030	2040	2050
Northeast	-0.1%	-0.5%	-0.6%	-1.1%	-1.9%
South	-0.2%	-0.6%	-0.7%	-1.3%	-2.2%
Midwest	-0.2%	-0.8%	-1.1%	-1.6%	-2.8%
Plains	-0.2%	-1.3%	-1.8%	-2.6%	-3.8%
West	-0.2%	-0.6%	-0.7%	-1.3%	-2.2%

Table: % Change in Regional Consumption Scenario 2 - S.2191

	2010	2020	2030	2040	2050
Northeast	0.8%	-0.2%	-0.7%	-1.3%	-1.9%
South	0.8%	-0.3%	-0.7%	-1.1%	-1.8%
Midwest	0.8%	-0.5%	-1.1%	-1.6%	-2.6%
Plains	0.2%	-1.4%	-2.0%	-2.5%	-3.4%
West	0.7%	-0.2%	-0.7%	-1.1%	-1.8%

* This slide was updated on 5/508 to correct the sign of the values in the % Change in Regional Consumption Table.

Results: Scenario 2 - S. 2191

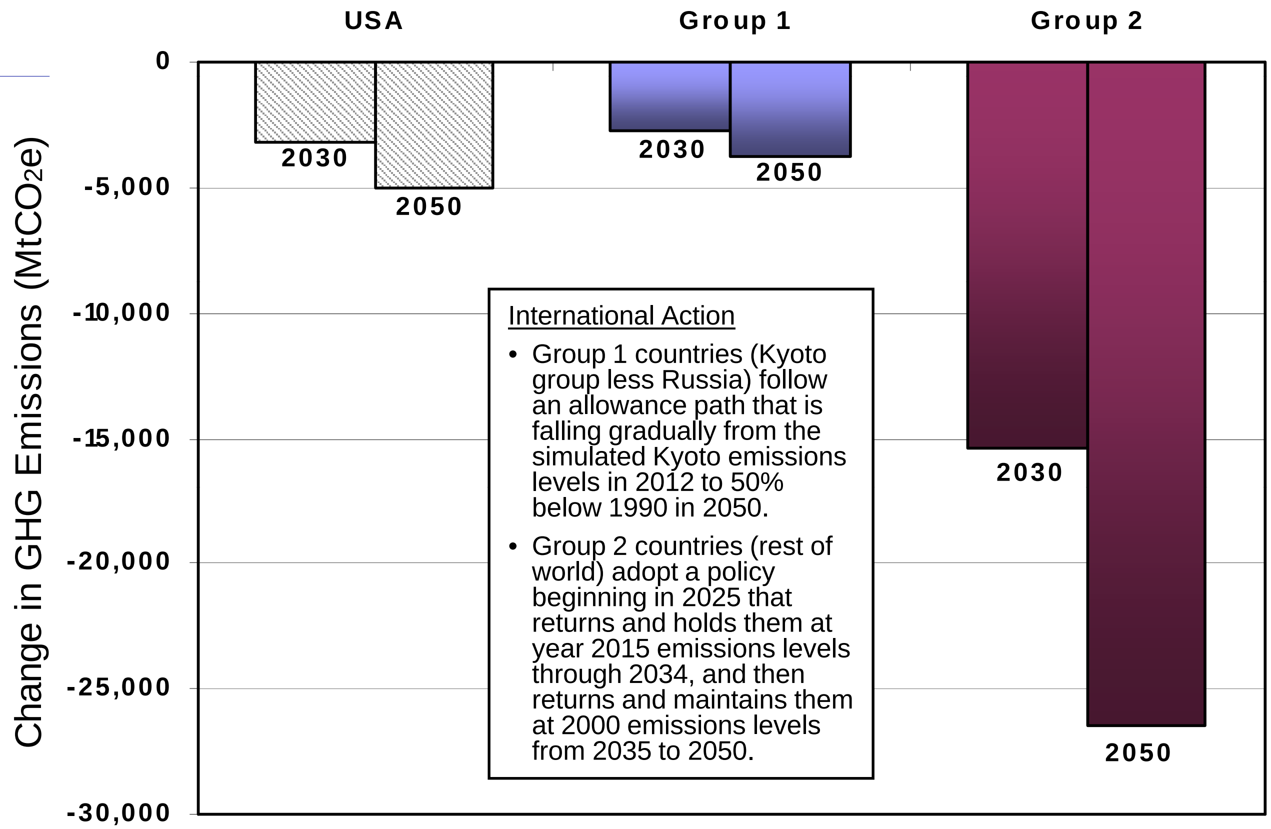
Regional Results Discussion (ADAGE)

- Reference CO_2 emissions are highest in the South and Midwest regions, largely stemming from coal use by electric utilities.
- The most significant reductions in CO_2 across all regions are from coal:
  - By 2030, electric utilities are reducing coal and switching to natural gas.
  - By 2050, coal use by utilities has rebounded as Advanced Coal + CCS technologies penetrate the market.
  - Emissions from coal continue to decline through 2050 through use of these advanced CCS options.
- The decline in CO_2 emissions from petroleum is more modest across all ions.
- Although natural gas consumption remains relatively steady through 2030 to meet higher demand from utilities, these emissions also decline by 2050.
- The largest reductions, in both GDP and consumption, are seen in the Plains region.
- Percent changes in GDP and consumption are less than 3% throughout the time frame in all other regions.
- All other regions (Northeast, South, Midwest, West) see an initial increase in consumption, followed by a decrease by 2015.

Global Results:
Emissions Leakage and
Alternative International Action Sensitivities

Results: Scenario 2 – S. 2191

International GHG Emissions Leakage (ADAGE)

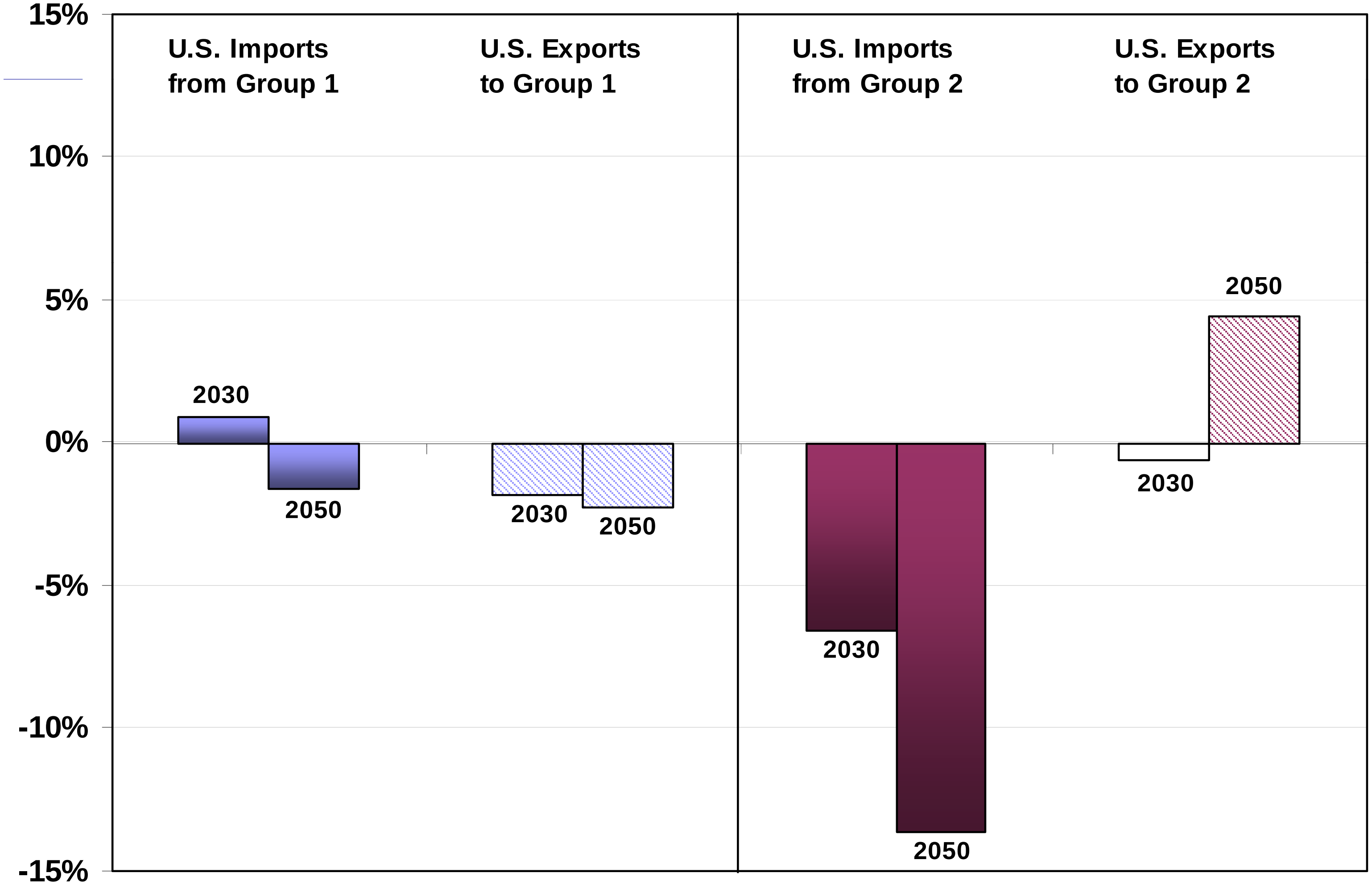


- Emissions leakage occurs when a domestic GHG policy causes a relative price differential between domestically produced goods and imported goods, which causes production of goods that domestically would have GHG allowance prices embodied in their cost to shift abroad, and thus causes an increase in GHG emissions in other countries.
- Under the Scenario 2 - S. 2191 international assumptions, no international emissions leakage occurs.
- Emissions in Group 2 fall by over 26,000 $MtCO_2e$ as they adopt emission targets beginning in 2025.
- Emission reductions are greater in 2050 than in 2030 for all regions as they face more stringent targets.

* This slide was updated on 5/508 to correct the description of the Group 1 emissions cap in 2050.

Results: Scenario 2 – S. 2191

International Trade Leakage for Energy-Intensive Manufacturing (ADAGE)

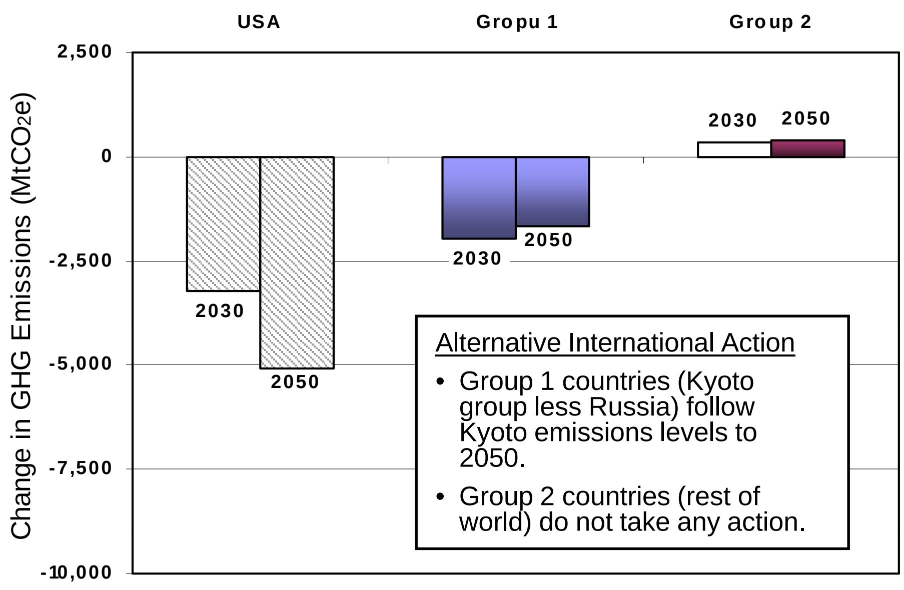


- Under Scenario 2 – S. 2191, imports of energy-intensive manufacturing goods from Group 2 to the U.S. fall as Group 2 takes on emission targets.
- The U.S. exports more energy-intensive manufacturing goods to Group 2, particularly in 2050 as Group 2 is meeting a stable emission target from 2035 to 2050.
- Trade of energy-intensive manufactured goods with Group 1 countries falls somewhat as both groups face emissions targets.

Results: Scenario 3 - S. 2191, Alternative International Action

International GHG Emissions Leakage (ADAGE)

- Emissions leakage occurs when a domestic GHG policy causes a relative price differential between domestically produced and imported goods. This causes domestic production, which embodies the GHG allowance price to shift abroad, and thus an increase in GHG emissions in other countries. Additionally, emissions leakage not associated with trade effects may occur when a GHG policy reduces domestic consumption of oil, lower demand for oil lowers the world oil price, which increases oil consumption in countries without a GHG policy thus increasing emissions.
- As a result of S. 2191, the prices of U.S. exports rise relative to prices in the rest of the world, and export volumes fall. Since exports are price-elastic the volumes fall proportionally more than the price rises and thus the value of exports declines. Imports are reduced in part by the overall reduction in spending associated with the lower levels of consumption. Additionally, commodities directly effected by the emissions cap (e.g. oil) are reduced proportionally more than other imports due to the allowance prices embodied in their cost. Import substitution counterbalances the above two forces. U.S. prices of commodities not directly affected by the policy are relatively higher, which leads to substitution away from domestically produced goods and towards imported goods.
- In Scenario 3 – S. 2191, Alternative International Action , the International Reserve Allowance Requirement is assumed to be triggered, due to inaction in Group 2 countries.
- Group 2 emissions rise by 350 $MtCO_2e$ in 2030, and 385 $MtCO_2e$ in 2050, since developing countries do not take any action. This is a less than 1% increase in Group 2 emissions from the reference levels, and is equivalent to U.S. emissions leakage rates of approximately 11% in 2030 and 8% in 2050.
- While Group 2 is not taking any action in this scenario, their emissions are somewhat limited by demand from the U.S. and Group 1 for offset credits from Group 2. This results in smaller amounts of leakage than may otherwise be expected.*
- The sensitivity case without the International Reserve Allowance Requirement results in a minimal effect on emissions leakage, with an increase in Group 2 emissions of 361 $MtCO_2e$ in 2030, and an increase of 412 $MtCO_2e$ in 2050 without the requirement included.
- Group 1 emissions fall by a lesser amount in 2050 than in 2030 as Group 1 follows a "Kyoto forever" constant emissions target, and greater emission reductions are needed in the earlier years to meet these targets.

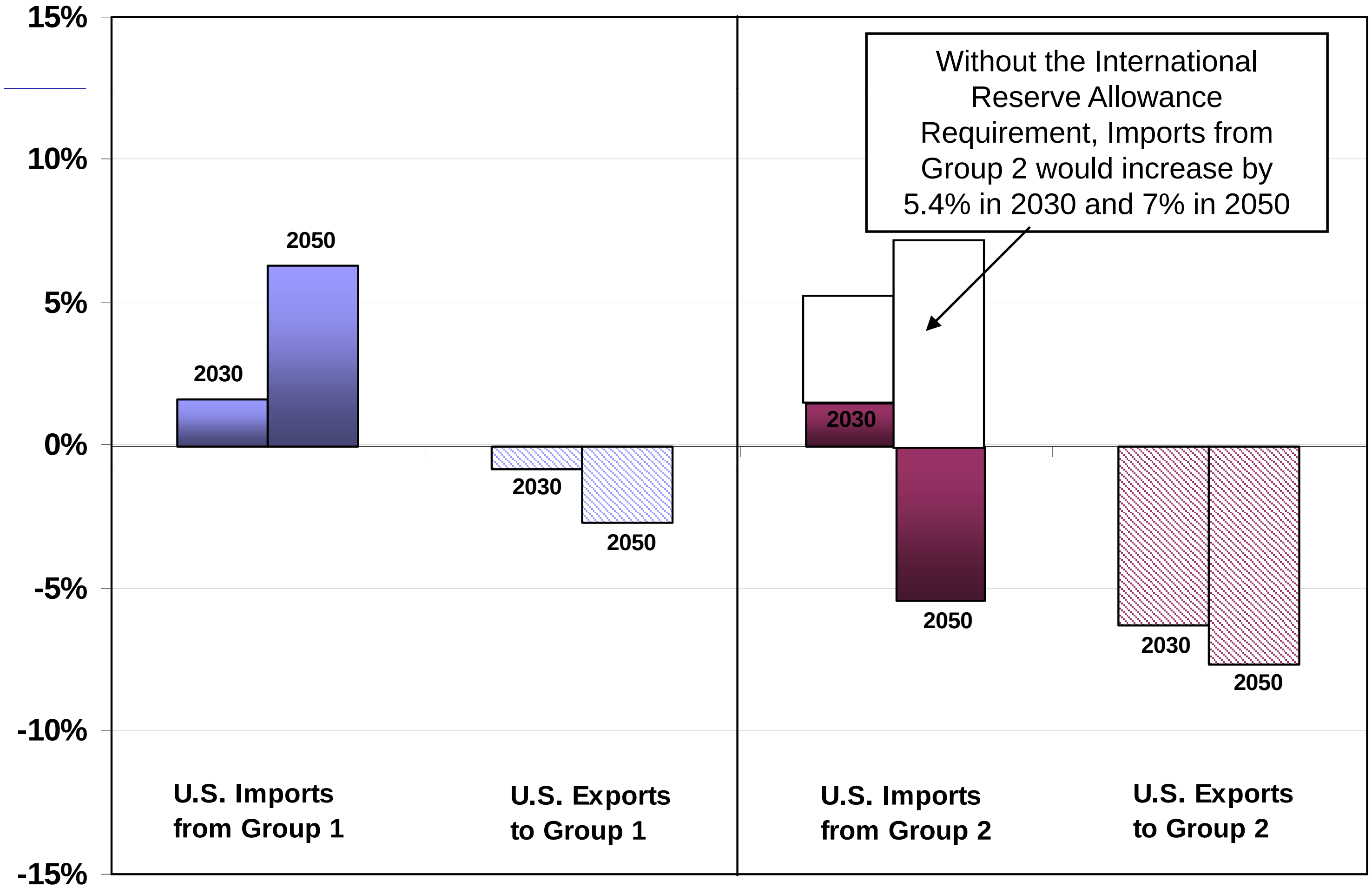


* For example Paltsev (2001) indicates that in a policy limited to industrialized countries, leakage rates can range from 5% - 34% for individual countries, although international trading may reduce that by half. One important difference between Paltsev (2001) and this analysis is that S. 2191 requires greater emissions reductions than those modeled in Paltsev (2001). This means that economic activity is reduced more under S. 2191, which results in greater reductions in overall consumption and imports. Counterbalancing this effect is the greater relative price differential, which causes a larger import substitution effect.

Paltsev, Sergey V. "The Kyoto Protocol: Regional and Sectoral Contributions to the Carbon Leakage." *The Energy Journal*, 2001, volume 22, number 4, pages 53-79.

Results: Scenario 3 - S. 2191, Alternative International Action

International Trade Leakage for Energy-Intensive Manufacturing (ADAGE)



- Under Scenario 2 – S. 2191, Alternative International Action, imports of energy-intensive manufacturing goods from Group 2 countries to the U.S. rise in 2030 since Group 2 countries are not taking any emissions action.
- The International Reserve Allowance Requirement limits the imports from Group 2.
  - The International Reserve Allowance Requirement has no effect on GDP in 2030, and increases GDP impacts by $34 billion (or 0.08 percentage points) in 2050.
- The U.S. is exporting less energy-intensive manufacturing goods to Group 2, as Group 2 uses more of their domestic energy-intensive manufacturing, resulting in increased emissions in Group 2.
- Trade of energy-intensive manufactured goods with Group 1 countries is a mixed story as policies in all regions, as well as the International Reserve Allowance Requirement, interact in 2030 & 2050.

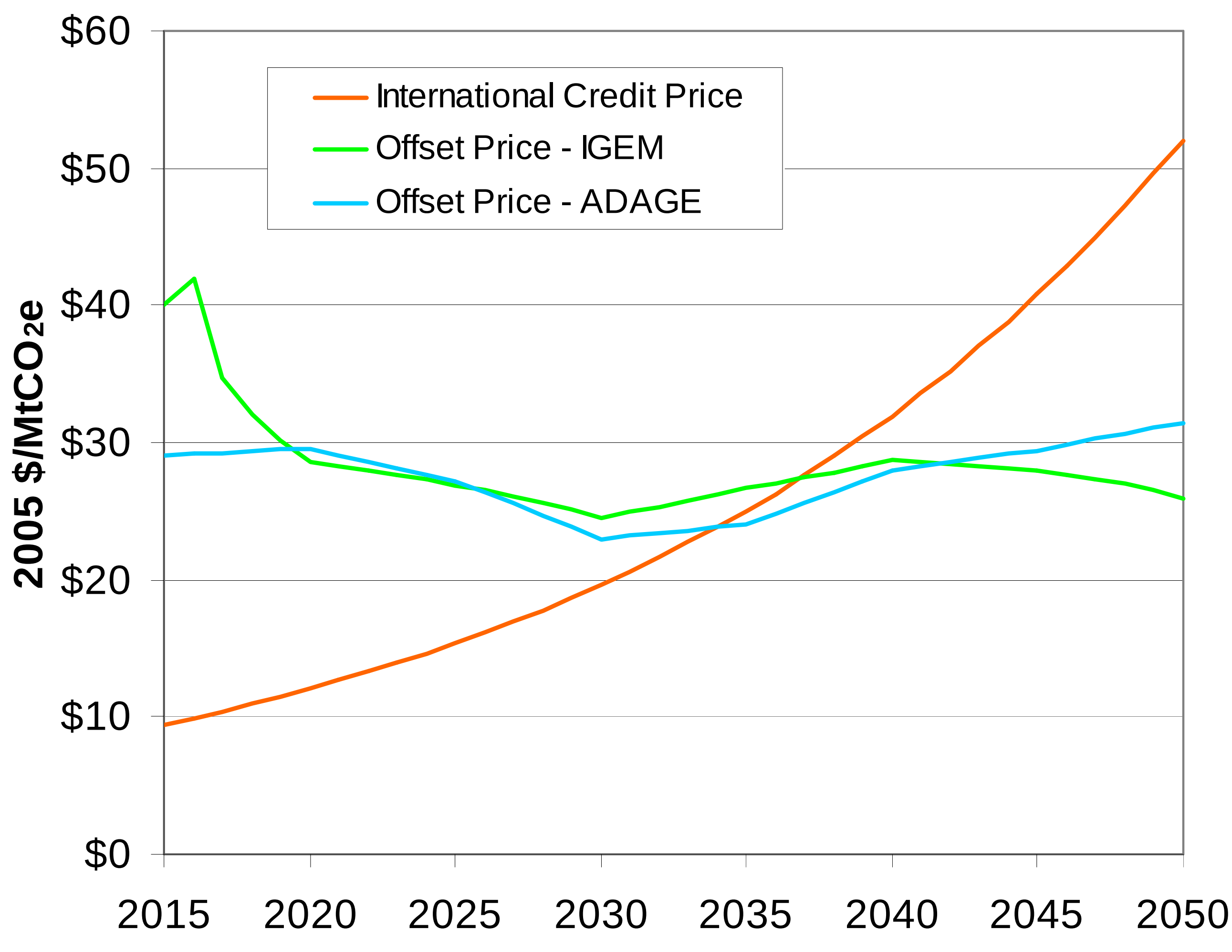
Offsets and International Credits

Domestic Offsets & International Credits Methodology Highlights

- EPA developed mitigation cost schedules for 24 offset mitigation categories, covering the following mitigation types:
  - Domestic non-CO_2 GHG emissions reductions
  - International non-CO_2 GHG emissions reductions
  - Domestic and international increases in terrestrial carbon sinks (soil and plant carbon stocks)
  - International energy-related CO_2 mitigation
- EPA evaluated individual mitigation options to determine potential eligibility and feasibility over time for a future mitigation program
  - – Based on EPA's emissions inventory & mitigation program expertise
    - Considered a broad set of factors, including existing and emerging programs/protocols/tools, monitoring, measurement & verification (MMV), magnitude of potential, additionality, permanence, leakage, and co-effects
  - – Options evaluated both domestically, internationally (by region group), and over time
  - – Captured responses to rising carbon prices
    - Modeled rising carbon price pathways (vs. constant) to capture investment behavior
    - Applied in three mitigation categories: Domestic agriculture & forestry, international forestry, and international energy-related CO_2
  - – Capped sector non-CO_2 and bio-energy emissions reductions are also modeled.
  - – For the individual mitigation options that were determined to be eligible, no further discounting was assumed.

Results: Scenario 2 - S. 2191

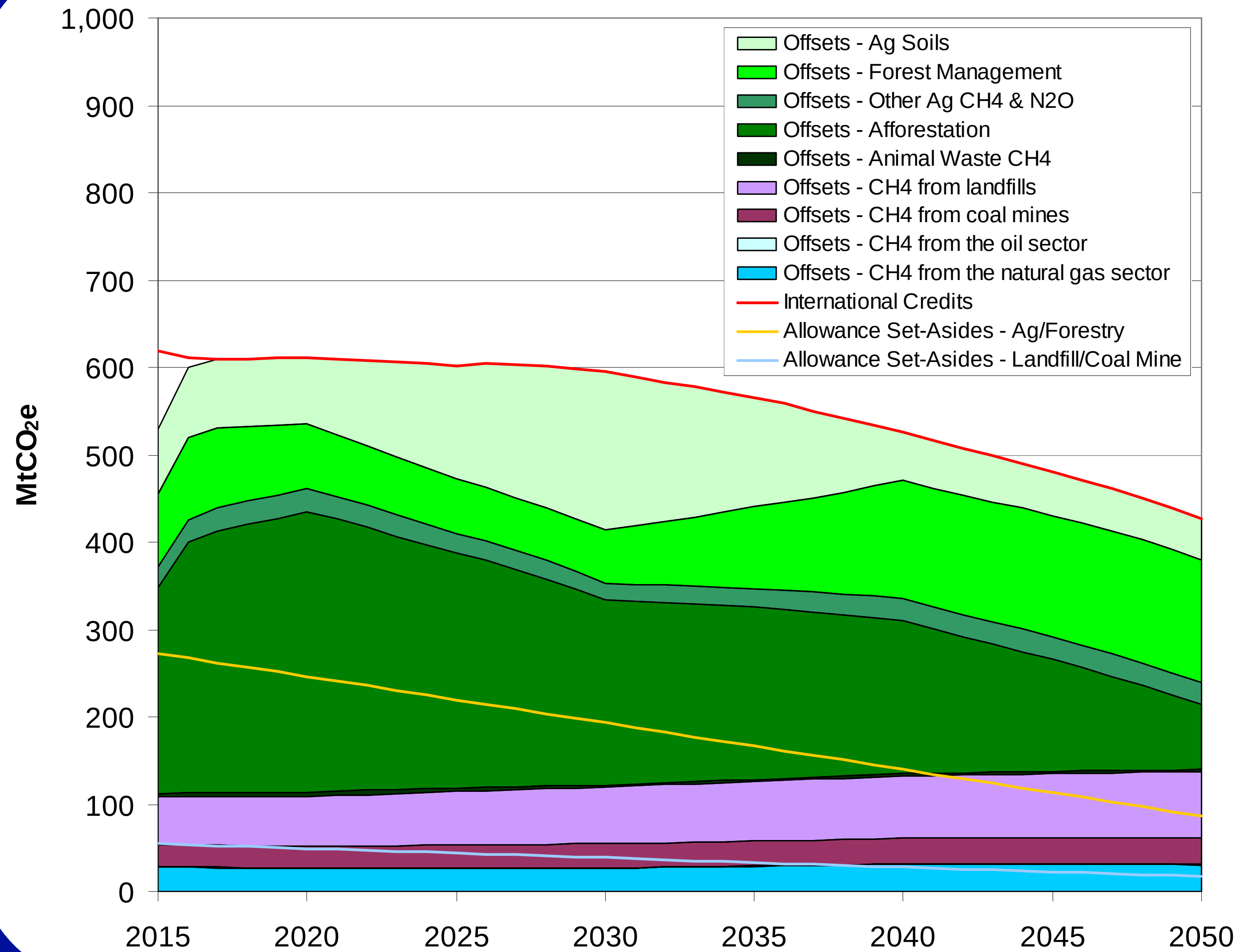
Offset and International Credit Prices



- S. 2191 limits the use of offsets and international credits to 15% of allowance submissions.
- The 15% limit on the use of domestic offsets is binding in IGEM starting in 2017, and in ADAGE starting in 2015.
- In IGEM, the offset price is equal to the GHG allowance price before 2017 when the 15% limit is not binding.
- Starting in 2017 in IGEM, and 2015 in ADAGE, when the 15% limit is binding, the offset price is lower than the GHG allowance price.
- The international credit price is driven by the international demand and supply of GHG abatement.
- This scenario assumes that offsets are not discounted, if offsets were discounted, the offset price would be expected to rise.

Results: Scenario 2 - S. 2191

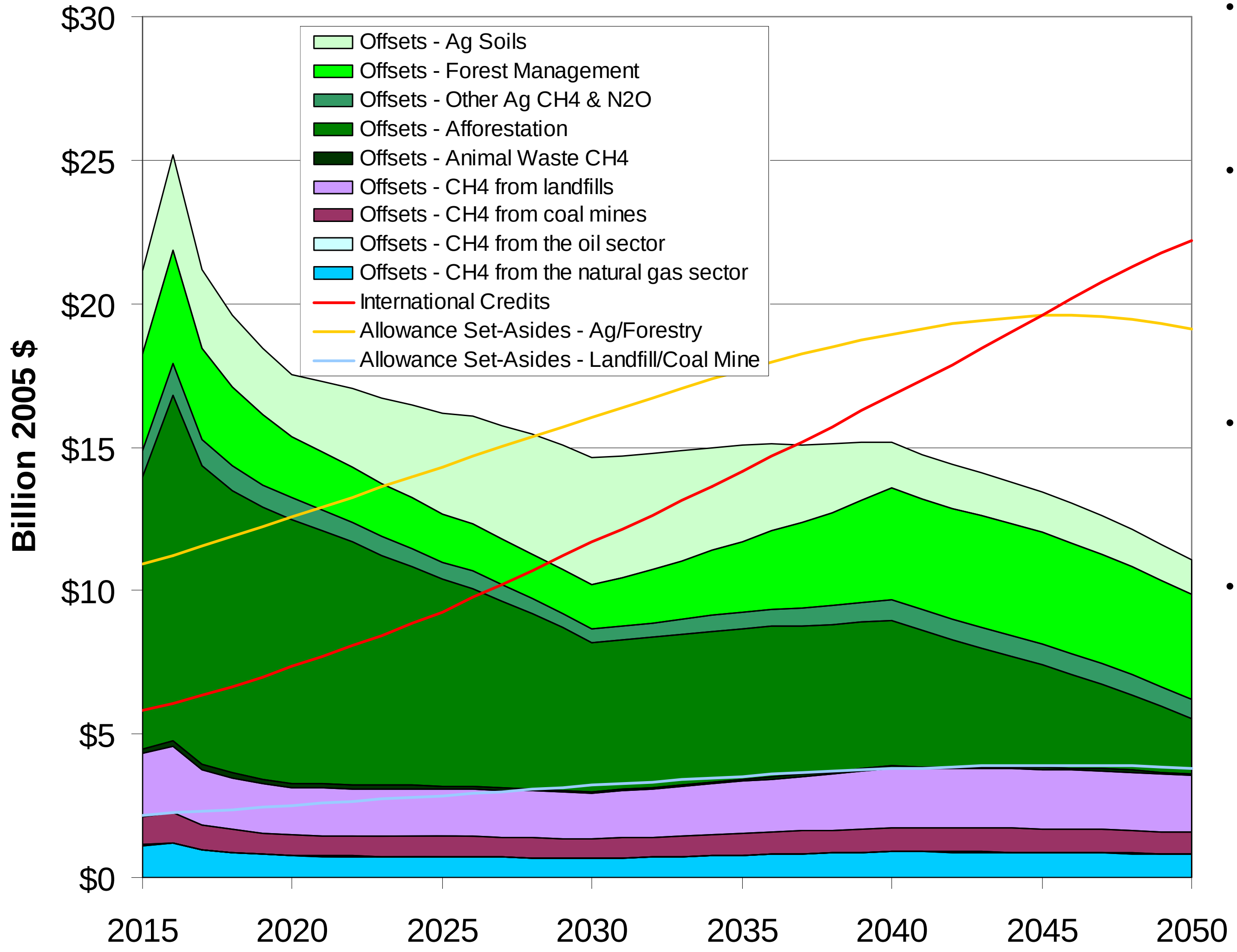
Allowance Set-Aside, Offset, and International Credit Abatement (IGEM)



- The total quantity of abatement from domestic offsets is limited to 15% of allowance submissions in each year.
- The quantity of abatement from international credits is similarly limited to 15% of allowance submissions in each year.
- The quantity of abatement from allowance set-asides is proscribed by the bill, 4% of allowances in each year are set aside for Ag/Forestry abatement projects, and 1% are set aside for landfill and coal mine CH_4 abatement projects.
- Because the offset price is lower than the GHG allowance price, projects that are eligible for both allowance set-asides and offsets would prefer to be in the allowance set-aside program.

Results: Scenario 2 - S. 2191

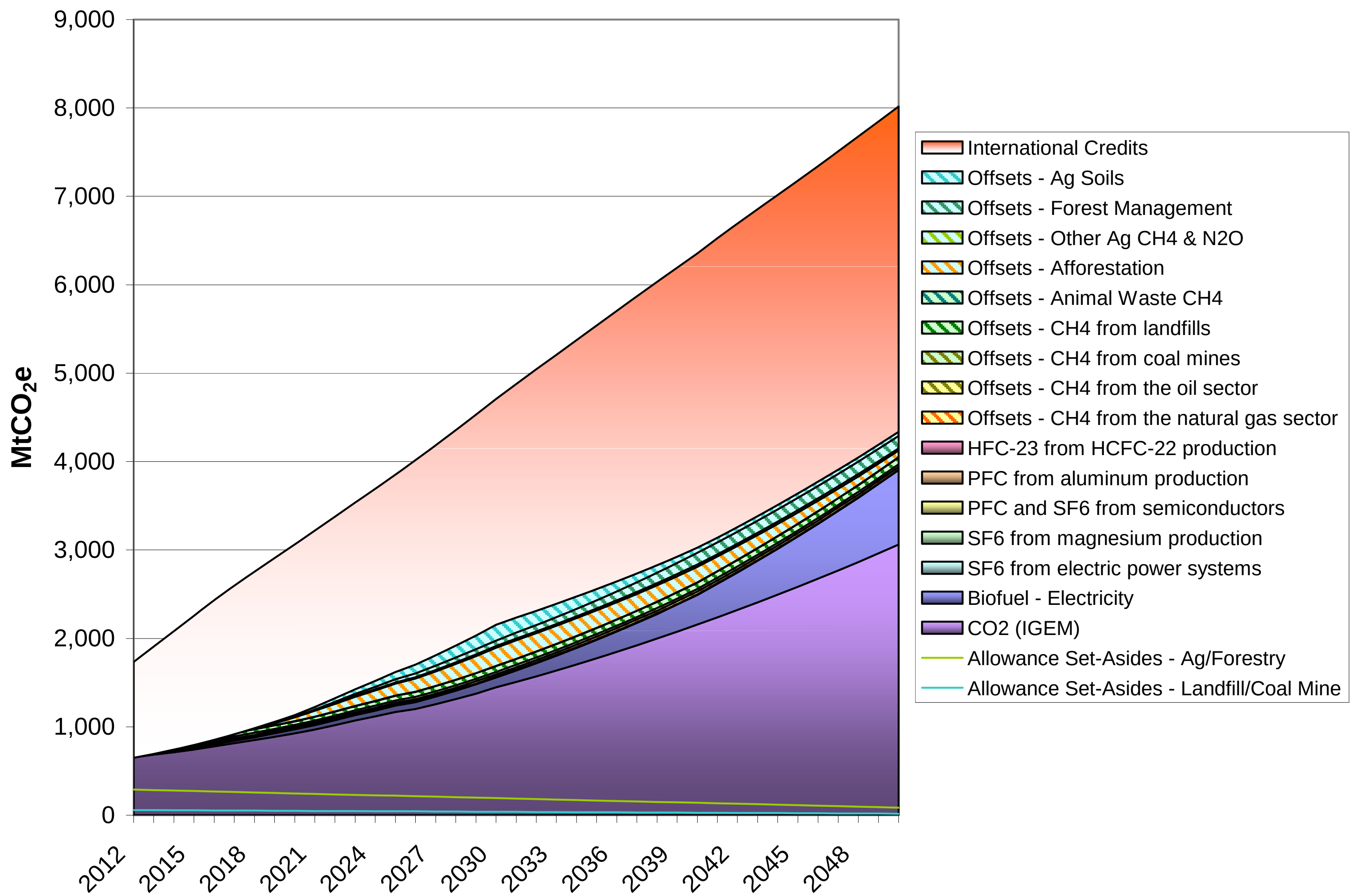
Allowance Set-Aside, Offset, and International Credit Payments (IGEM)



- Payments for offsets are simply determined by multiplying the offset price by the quantity of offsets supplied from each source.
- Before 2017, offset payments are considerably higher than in later years. This is driven by the high offset prices in these early years when the 15% limit on the use of offsets is not binding, and the offset price is thus equal to the price of GHG allowances.
- Payments for international credits are simply the product of the international credit price and the quantity of international credits purchased.
- Similarly, the value of the allowance set-asides is the product of the GHG allowance price and the quantity of abatement associated with the allowance set-aside programs.

Results: Scenario 4 - S. 2191, Unlimited Offsets

Sources of GHG Abatement (IGEM)



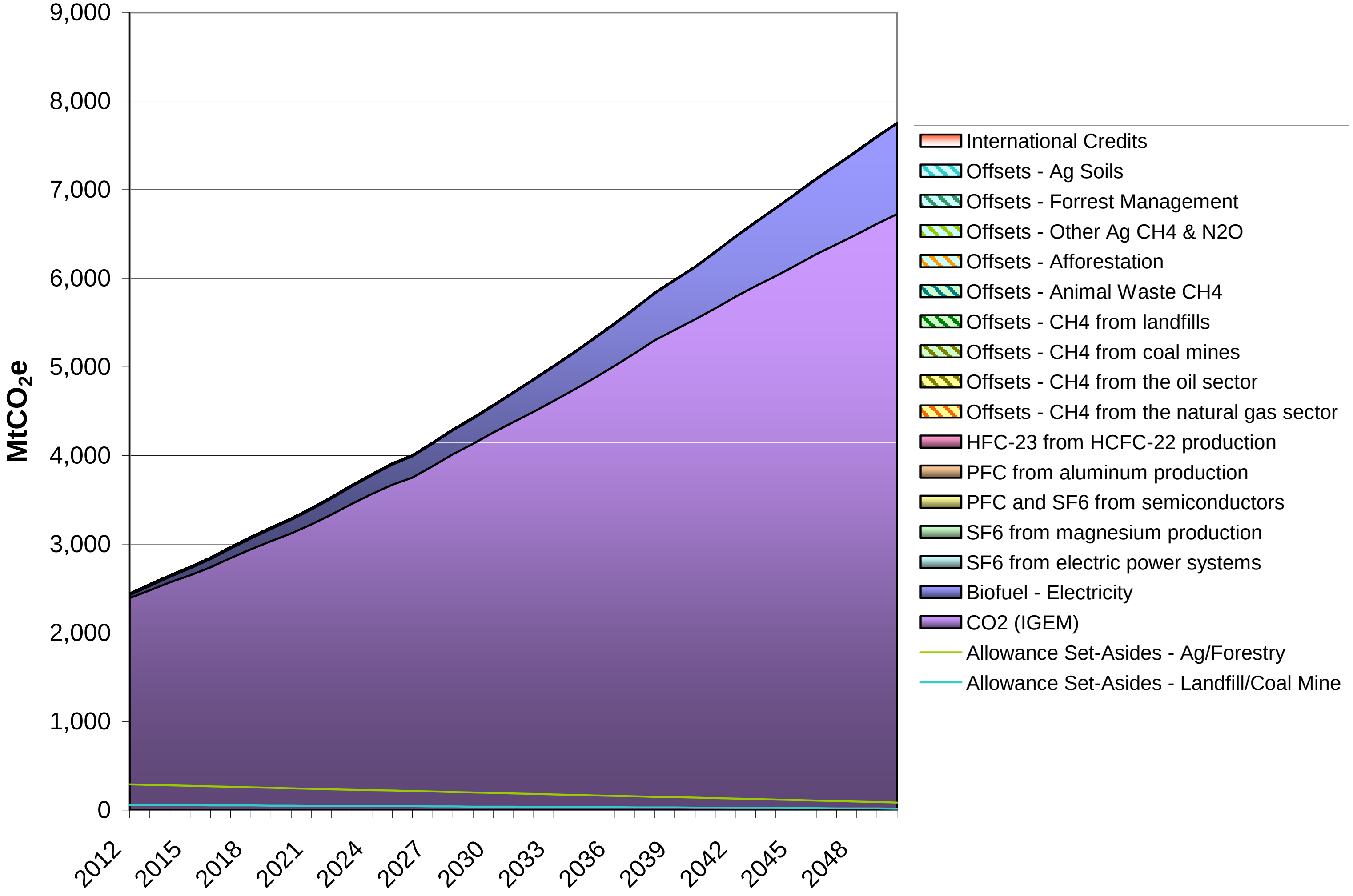
Results: Scenario 4 - S. 2191, Unlimited Offsets

Sources of GHG Abatement (IGEM)

- The previous chart shows, for the IGEM model, the sources of CO_2 and non-CO_2 GHG abatement under S. 2191 with unlimited offsets.
- IGEM does not break out CO_2 emissions by sector, so the bottom purple area represents all energy related CO_2 emissions abatement within IGEM.
  - The other sources of abatement represented here are derived from EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH_4, N_2O, and F-gases (NCGM), and the Forest and Agriculture Sector Optimization Model, GHG version (FASOMGHG).
- The areas toward the top of the chart shaded with hashed lines show emissions reductions from domestic offsets and the red shaded area at the very top shows international credits
  - International credits make up the largest portion of abatement in all years. 52% of abatement comes from international credits in 2030, and 45% in 2050.
    - Note that In terms of compliance obligation (which is limited to 15% for international credits in the bill as written) 65% comes from international credits in 2030, and 169% comes from international credits in 2050. It is possible for greater than100% of compliance obligation to come from international credits when the quantity of international credits purchased is greater than the level of emissions less offsets and international credits that is required to meet the cap.
  - Domestic offsets make up a smaller portion of abatement than in Scenario 2 where offsets are limited. This is because the allowance price in the unlimited case is lower than the domestic offset price in the limited case, so fewer domestic offsets are supplied.
- The light green and blue lines at the bottom represent GHG abatement from allowance set-asides. This abatement is additional to the abatement in covered sectors and offset projects that is used to meet the cap.

Results: Scenario 5 - S. 2191, No Offsets

Sources of GHG Abatement (IGEM)



Results: Scenario 5 - S. 2191, No Offsets

Sources of GHG Abatement (IGEM)

- The previous chart shows, for the IGEM model, the sources of CO_2 and non-CO_2 GHG abatement under S. 2191 with no offsets.
- IGEM does not break out CO_2 emissions by sector, so the bottom purple area represents all energy related CO_2 emissions abatement within IGEM.
  - The other sources of abatement represented here are derived from EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH_4, N_2O, and F-gases (NCGM), and the Forest and Agriculture Sector Optimization Model, GHG version (FASOMGHG).
- Without offsets as an option, all abatement must come from capped sectors, which dramatically increases the allowance price.
- The light green and blue lines at the bottom represents GHG abatement from allowance set-asides. This abatement is additional to the abatement in covered sectors and offset projects that is used to meet the cap.

Results: International Offsets Sensitivity Scenarios (4, 5, and 10)

GDP and Consumption (IGEM)

Table: GDP Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
2) S. 2191								
IGEM	-2.0%	-2.6%	-3.1%	-3.8%	-4.4%	-5.2%	-6.0%	-6.9%
4) S. 2191 Unlimited Offsets								
IGEM	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-1.9%	-2.3%	-2.7%
5) S. 2191 No Offsets								
IGEM	-3.3%	-4.1%	-5.0%	-5.9%	-6.9%	-7.9%	-9.0%	-10.1%
10) S. 2191 High Technology								
IGEM	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-1.9%	-2.3%	-2.7%

Table: Consumption Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
2) S. 2191								
IGEM	-0.2%	-0.7%	-1.1%	-1.4%	-1.9%	-2.3%	-2.7%	-3.3%
4) S. 2191 Unlimited Offsets								
IGEM	0.0%	-0.2%	-0.4%	-0.5%	-0.7%	-0.8%	-1.0%	-1.2%
5) S. 2191 No Offsets								
IGEM	-0.3%	-1.2%	-1.8%	-2.5%	-3.2%	-3.9%	-4.5%	-5.3%
10) S. 2191 High Technology								
IGEM	0.0%	-0.2%	-0.4%	-0.5%	-0.7%	-0.8%	-1.0%	-1.2%

Additional Qualitative Considerations

Allowance Allocation & Revenue Recycling in ADAGE and IGEM

- In the models used for this analysis, households are represented by a single representative consumer. Since the behavior of employee-shareholders do not vary by industry, the initial allocation of allowances to different industries does not affect estimated model outcomes.
- In this analysis we assume that the policy is deficit and revenue neutral, which implies that the market outcomes are invariant to the auction / allocation spilt
  - Private sector revenues from allocated allowances accrue to employee-shareholder households, and the government adjusts taxes lump sum to maintain deficit and spending levels.
  - Allowance auction revenues flow to the U.S. government, and are redistributed to households lump sum to the extent that deficit and spending levels are maintained. If auction revenues were directed to special funds instead of returned directly to households as modeled, the impact on household annual consumption and GDP would be greater. If the auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower.

Revenue Recycling Issues

- The use of the revenue generated by auctioning permits can affect the cost of the policy.
- Compared to returning auction revenues to consumers in a lump sum fashion that maintains revenue and deficit neutrality, other uses of auction revenues for other purposes can positively or negatively impact the cost of the policy.
  - Using auction revenues to lower distortionary taxes can lower the cost of the policy.
    - This possibility is known as the “double dividend” and has been widely discussed in the economics literature (e.g. Goulder et al. 1999, Parry et al. 1999, Parry and Oates 2000, and Parry and Bento 2000, CBO 2007).
    - One study (Parry and Bento 2000) finds that different methods of revenue recycling under a cap-and-trade system that reduces emissions by 10 percent can lead to economy-wide costs that differ by a factor of three.
  - Directing auction revenues to special funds or creating subsidies to specific technologies can raise the overall costs of a policy due to the need to finance these policies with increases in distortionary taxes (the converse of the “double dividend” benefit of reducing distortionary taxes discussed above).
    - However, substantial cost savings could be achieved by combining direct emissions policies (e.g. cap-and-trade or carbon tax) with technology push policies (e.g. technology and R&D incentives) that correct for the market failure associated with the fact that the inventor of a new technology can not appropriate all of the associated social benefits (Fischer and Newell 2005; Schneider and Goulder 1997).

Allowance Allocation Issues

- Since emissions allowances are valuable assets, differing allowance allocation schemes can have differing equity implications.
- Equity considerations can justify allocating allowances to (or directing allowance auction revenue to) those who ultimately bear the cost of abatement.
- Who bears the ultimate burden of the costs of abatement is not determined by who is required to hold allowances (or who performs the abatement), but by the complex interaction of markets.
  - (Harberger 1962 provides the first general equilibrium model of tax incidence, Kotlikoff and Summers 1987 provides a useful review of the subsequent literature, CBO 2007 discusses the issue in the context of a cap-and-trade program).
- Freely allocating allowances to the entities required to hold allowances can create a windfall gain for those entities as they receive a valuable asset and pass the costs associated with abatement downstream to consumers.
  - Freely allocating less than a fifth of allowances to U.S. fossil fuel suppliers may be sufficient to prevent their profits from falling, and freely allocating a greater share of allowances could lead to increased profits (Bovenberg and Goulder 2001).
- Similar to creating subsidies, allocating allowances in a non lump sum fashion has a distortionary effect that raises costs.
  - E.g. allocating allowances based on the average number of production employees employed at a facility acts as a distortionary subsidy for labor.

Tax Interaction Effects

- Distortions may also occur with tax interaction effects with labor, indirectly reducing the labor supply by increasing the distortionary effect of income taxes. (See Murray, Thurman, and Keeler, 2000)
  - Burtraw et al (2001) discuss three alternative allocation mechanisms and their resulting distributional impacts on consumers and producers. They demonstrate that allocation based on a generation performance standard acts as a generation subsidy and increases overall costs compared with allocation through auction.
  - Fischer, Kerr, and Toman (1998) discuss the types of risk associated with different allocation systems. They note that "external" risk (e.g. changes in caps due to international agreements or improved climate science) should be borne by the emitter while "internal" risk (e.g. political or revenue based motivations for changing caps) should be eliminated to the extent possible. They also address tax effects of different allocation systems and note that there are tax distortion effects in both grandfathering and auction systems (encouraging too much and too little banking, respectively) and that eliminating these effects would require a broad overhaul of the capital gains tax system.
  - Neuhoff, Grubb, and Keats (2005) demonstrate that the potential for future updating of the emissions allocation baseline in Europe creates distortionary incentives in operation and investment.
  - Burtraw, Kahn, and Palmer (2005) examine the proposed Regional Greenhouse Gas Initiative effort by nine NE/mid-Atlantic states and discuss the implications for individual firms' profits. They find that allocation mechanism impacts the price of electricity, consumption, and mix of production technologies. Additionally, they show that the regional nature of the system will allow for leakage, creating profit for firms outside the region.

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U.S. Environmental Protection Agency
Office of Atmospheric Programs

EPA Analysis of the Lieberman-Warner Climate Security Act of 2008

S. 2191 in 110th Congress

Appendix

March 14, 2008

Appendix 1: Modeling Approach and Limitations

EPA Models Used for Different Analytical Scenarios

Table: Models Used for Different Scenarios

Scenario					
1) EPA Reference	ADAGE	IGEM	IPM	MiniCAM	
2) S. 2191	ADAGE	IGEM	IPM	MiniCAM	NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
3) S. 2191 with Low International Actions	ADAGE				NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
4) S. 2191 Unlimited Offsets		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
5) S. 2191 No Offsets		IGEM			
6) S. 2191 Constrained Nuclear & Biomass	ADAGE				
7) S. 2191 Constrained Nuclear & Biomass, and CCS	ADAGE				
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel	ADAGE				
9) Alternative Reference	ADAGE	IGEM	IPM		
10) S. 2191 Alternative Reference	ADAGE	IGEM	IPM		NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool

ADAGE Applied Dynamic Analysis of the Global Economy (Ross, 2007)
IGEM Intertemporal General Equilibrium Model (Jorgenson, 2007)
IPM Integrated Planning Model (EPA, 2007)
NCGM EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH_4, N_2O, and F-gases (EPA, 2005)
FASOMGHG Forest and Agriculture Sector Optimization Model, GHG version (EPA, 2005)
GTM Global Timber Model (Sohngen, 2006)
MiniCAM Mini-Climate Assessment Model (Edmonds, 2005)

Note: International allowance and domestic offset markets were analyzed using EPA's spreadsheet tool which combines results from the NCGM, FASOM, GTM and MiniCAM models.

Modeling Approach

- For the purpose of this analysis, we have chosen to use two separate computable general equilibrium (CGE) models: IGEM and ADAGE.
- CGE models are structural models.
  - They build up their representation of the whole economy through the interactions of multiple agents (e.g. households and firms), whose decisions are based upon optimizing economic behavior.
  - The models simulate a market economy, where in response to a new policy, prices and quantities adjust so that all markets clear.
- These models are best suited for capturing long-run equilibrium responses, and unique characteristics of specific sectors of the economy.
- The general equilibrium framework of these models allows us to examine both the direct and indirect economic effects of the proposed legislation, as well as the dynamics of how the economy adjusts in the long run in response to S. 2191.
- The NCGM, FASOM, GTM, and MiniCAM models are used to provide information on abatement options that fall outside of the scope of the CGE models.
  - These models generate mitigation cost schedules for various abatement options.
- Additionally, the IPM model gives a detailed picture of the electricity sector in the short-run (through 2025), which complements the long-run (through 2050) equilibrium response represented in the CGE models.

Modeling Approach (con't)

Several updates were made in the S. 1766 analysis as compared with the S. 280 analysis. These updates have also been included in the S. 2191 analysis:

- Assumptions
  - The renewables assumptions in ADAGE were updated in the S. 1766 analysis to include a biomass response curve for electricity generation from the FASOM model. These updated assumptions are also used in the S. 2191 analysis.
- Results reported
  - As in the S. 1766 analysis, we are reporting regional impacts form the ADAGE model in the S. 2191 analysis.
  - As in the S. 1766 analysis, we are also reporting international leakage from ADAGE in the S. 2191 analysis.

Modeling Limitations

- The models used in this analysis do not formally represent uncertainty.
  - Confidence intervals cannot be presented for any of the results in this analysis.
  - Very few CGE models are capable of computing confidence intervals, so this limitation is currently shared with virtually all CGE models.
  - The use of two CGE models provides a range for many of the key results of this analysis; however, this range should not be interpreted as a confidence interval.
  - Alternate scenarios are presented to provided sensitivities on a few of the key determinants of the modeled costs of S. 2191.
- The CGE modeling approach generally does not allow for a detailed representation of technologies.
  - While ADAGE does represent different generation technologies within the electricity sector, it does not represent peak and base load generation requirements.
  - Since the electricity sector plays a vital role in the abatement of CO_2 emissions, we have supplemented the results from our CGE models with results from the Integrated Planning Model (IPM), which is bottom-up model of the electricity sector.
  - The CGE models do not explicitly model new developments in transportation technologies. These reductions occur as households alter their demand for motor gasoline and through broad representations of improvements in motor vehicle fuel efficiency.
- The time horizon of the CGE models, while long from an economic perspective, is short from a climate perspective.
- CGE models represent emissions of GHGs, but cannot capture the impact that changes in emissions have on global GHG concentrations.
  - In order to provide information on how S. 2191 affects CO_2 concentrations throughout the 21st century, we have used the Mini-Climate Assessment Model (MiniCAM) to supplement our results.
- None of the models used in this analysis currently represent the benefits of GHG abatement.
  - While the models do not represent benefits, it can be said that as the abatement of GHG emissions increases over time, so do the benefits of the abatement.

Modeling Limitations (con't)

- The models used in this analysis do not incorporate benefit-side effects of reductions in conventional pollutants (SO_2, NOx , and Hg) , such as labor productivity improvements from gains in public health.
  - While this is an important limitation of the models, the impact on modeled costs of the policy is small because S. 2191 does not impact overall emissions of conventional pollutants covered by existing cap and trade programs due to the existence caps which instead allow allowance prices for conventional pollutants to fall.
- The costs of administering S. 2191 (e.g. monitoring and enforcement) are not captured in this analysis.
- Household effects are not disaggregated.
- Both of the CGE models used in this analysis are full employment models.
  - The models do not represent effects on unemployment.
  - The models do represent the choice between labor and leisure, and thus labor supply changes are represented in the models.
- While ADAGE does include capital adjustment costs, capital in IGEM moves without cost.
- IGEM is a domestic model; ADAGE has the capability of representing regions outside of the U.S., which were used to incorporate interactions between the U.S. and Group 1 & 2 countries. For consistency across analyses, international abatement options were generated in the following fashion:
  - We used the MiniCAM model to generate the supply and demand of GHG emissions abatement internationally.
  - For Group 2 countries that are assumed to not have a cap on GHG emissions before 2025, and thus supply mitigation only through certified emissions reductions resulting from project activities, the potential energy related CO_2 mitigation supply is reduced by 90% though 2015, and by 75% between 2015 and 2025.
  - Combining the international demand for abatement from MiniCAM, the domestic demand for offsets determined by the 30% limit on offsets, and the mitigation cost schedules for the various sources of offsets generated by the NCGM, FASOM, GTM, and MiniCAM models, allows us to find market equilibrium price and quantity of offsets and international credits.

Modeling Limitations (con't)

- Since international abatement occurs outside of IGEM, the model does not capture emissions leakage.*
  - Since IGEM is a domestic model, world prices are not affected by climate policies in Group 1 and Group 2 countries. As a result of S. 2191, the prices of U.S. exports rise relative to prices in the rest of the world, and export volumes fall. Since exports are price-elastic the volumes fall proportionally more than the price rises and thus the value of exports declines. Imports are reduced in part by the overall reduction in spending associated with the lower levels of consumption. Additionally, commodities directly affected by the emissions cap (e.g. oil) are reduced proportionally more than other imports due to the allowance prices embodied in their cost. Import substitution counterbalances the two forces above. U.S. prices of commodities not directly affected by the policy are relatively higher, which leads to substitution away from domestically produced goods and towards imported goods. To the extent that policies in Group 1 and Group 2 countries increase world prices of affected commodities, the relative price difference between goods produced in the U.S. and goods produced abroad will be lessened. This will reduce impact on exports, and reduce the import substitution effect, both of which are driven by the relative price differential.
- ADAGE is a global model which does represent the emissions leakage associated with S. 2191.
  - The assumed climate policies in Group 1 and Group 2 countries are explicitly represented in ADAGE, and thus affect world prices. As a result the relative price differences between goods produced domestically and abroad are smaller than the differences in IGEM, and thus the relative price driven changes in imports and exports are smaller in ADAGE than in IGEM.

* Emissions leakage occurs when a domestic GHG policy causes a relative price differential between domestically produced and imported goods. This causes domestic production, which embodies the GHG allowance price to shift abroad, and thus an increase in GHG emissions in other countries. Additionally, emissions leakage not associated with trade effects may occur when a GHG policy reduces domestic consumption of oil, lower demand for oil lowers the world oil price, which increases oil consumption in countries without a GHG policy thus increasing emissions.

Modeling Limitations (con't)

S. 2191 Title III – Allocating and Distributing Allowances

- Not all of the specified uses of allocated allowances are explicitly modeled.
  - Explicitly modeled:
    - CCS Bonus allowances specified in *Title III – Subtitle F – Bonus Allowances for Carbon Capture and Geological Sequestration.*
    - Emissions reductions associated with allowance set-asides in *Title III – Subtitle G – Domestic Agriculture and Forestry*
    - Emissions reductions associated with allowance set-asides in *Title III – Subtitle J – Reducing Methane Emissions From Landfills and Coal Mines*.
  - Not explicitly modeled (although the value of allowances allocated for each of these purposes is reported):
    - Allocation for early action specified in *Title III – Subtitle B – Early Action*
    - Allocation to states for energy savings and programs that exceed federal emissions reductions targets specified in *Title III – Subtitle C - States*.
    - Allocation to load serving entities for the purpose of energy efficiency programs and mitigation of impacts on low and middle-income energy consumers specified in *Title III – Subtitle D – Electricity Consumers.*
    - Allocation to natural gas distributors for the purpose of energy efficiency programs and mitigation of impacts on low and middle-income energy consumers specified in *Title III – Subtitle E – Natural Gas Consumers.*
    - Allocation to for use in carrying out forest carbon activities in countries other than the United States specified in *Title III – Subtitle H – International Forest Protection.*
    - Allocation to fossil fuel-fired electric power generating facilities, rural electric power cooperatives, owners and operators of energy intensive manufacturing facilities, facilities that produce or import petroleum based fuels, and HFC producers and importers specified in *Title III – Subtitle I – Transition Assistance.*
- While not all of the uses of allocated allowances are explicitly modeled, the value of allowances allocated for each of the specified uses is reported.

Modeling Limitations (con't)

S. 2191 Title IV – Auctions and Uses of Auction Proceeds

- The specified uses of the revenues associated with auctioned allowances are not explicitly modeled. Sections of note that are not modeled include:
  - *Title IV – Subtitle C – Auctions* (such percentage that the Administrator deems sufficient may be used for the efficient and effective administration of this act)
  - *Title IV – Subtitle D – Energy Technology Deployment* (52% of remaining auction revenues)
    - *Sec. 4402. Zero- or Low-Carbon Energy Technologies Deployment* (32% *Title IV - Subtitle D* funds)
    - *Sec. 4403. Advanced Coal and Sequestration Technologies Program* (25% *Title IV - Subtitle D* funds)
    - *Sec. 4404. Fuel from Cellulosic Biomass* (6% *Title IV - Subtitle D* funds)
    - *Sec. 4405. Advanced Technologies Vehicle Manufacturing Incentive Program* (12% *Title IV - Subtitle D* funds)
    - *Sec. 4406. Sustainable Energy Program* (25% *Title IV - Subtitle D* funds)
  - *Title IV – Subtitle E – Energy Consumers* (18% of remaining auction revenues)
  - *Title IV – Subtitle F – Climate Change Worker Training Program* (5% of remaining auction revenues)
  - *Title IV – Subtitle G – Adaptation for Natural Resources in the U.S. and Territories* (18% of remaining auction revenues)
  - *Title IV – Subtitle H – International Climate Change Adaptation and National Security Program* (5% of remaining auction revenues)
  - *Title IV – Subtitle I – Emergency Firefighting Program* ($1.2 billion annually)
  - *Energy Independence Acceleration Fund* (2% or remaining auction revenues)
- While the uses of the auction revenues are not modeled, the amount of auction revenue available for each of these purposes is reported.

Modeling Limitations (con't)

S. 2191 Title III – Allocating and Distributing Allowances and Title IV – Auctions and Uses of Auction Proceeds

- In IGEM we assume that the policy is deficit and revenue neutral, which implies that the market outcomes are invariant to the auction / allocation spilt
  - Allowance auction revenues flow to the U.S. government, and are redistributed to households lump sum to the extent that deficit and spending levels are maintained. If auction revenues were directed to special funds instead of returned directly to households as modeled, the reduction in household annual consumption and GDP would likely be greater. If the auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower.
  - Private sector revenues from allocated allowances accrue to employee-shareholder households, and the government adjusts taxes lump sum to maintain deficit and spending levels.
- The use of the revenue generated by auctioning permits can affect the cost of the policy.
- Compared to returning auction revenues to consumers in a lump sum fashion that maintains revenue and deficit neutrality, other uses of auction revenues for other purposes can positively or negatively impact the cost of the policy.
  - Using auction revenues to lower distortionary taxes can lower the cost of the policy.
    - This possibility is known as the "double dividend" and has been widely discussed in the economics literature (e.g. Goulder et al. 1999, Parry et al. 1999, Parry and Oates 2000, and Parry and Bento 2000, CBO 2007).
    - One study (Parry and Bento 2000) finds that different methods of revenue recycling under a cap-and-trade system that reduces emissions by 10 percent can lead to economy-wide costs that differ by a factor of three.
  - Directing auction revenues to special funds or creating subsidies to specific technologies can raise the overall costs of a policy due to the need to finance these policies with increases in distortionary taxes (the converse of the "double dividend" benefit of reducing distortionary taxes discussed above).
    - However, substantial cost savings could be achieved by combining direct emissions policies (e.g. cap-and-trade or carbon tax) with technology push policies (e.g. technology and R&D incentives) that correct for the market failure associated with the fact that the inventor of a new technology can not appropriate all of the associated social benefits (Fischer and Newell 2005; Schneider and Goulder 1997).

Modeling Limitations (con't)

S. 2191 Title V – Energy Efficiency and Title II – Subtitle F – Carbon Market Efficiency Board

- The energy efficiency standards specified in *Title V – Subtitle A – Appliance Efficiency* and *Title V – Subtitle B – Building Efficiency* are not included in this analysis.
- The Carbon Market Efficiency Board (CMEB), established under *Title II – Managing and Containing Costs Efficiently – Subtitle F – Carbon Market Efficiency Board* is not explicitly modeled in this analysis.
  - Several of the powers of the CMEB involve expanding or altering the provisions for borrowing allowances (*Sec. 2604 – Powers – (a)(1)(A),(B),(C),* and *(F)*). The models used for this analysis make a standard economic assumption of perfect foresight, and as a result the price of allowances rise at a predictable rate without any volatility. Without any allowance price volatility, firms bank allowances in the early years and draw down that bank in the later years without any need for borrowing; hence, an expansion of the borrowing provisions would not affect firms in the models used in this analysis. In the absence of perfect information, price volatility would likely lead to the use of borrowing in some years, and the CMEB's powers to alter the terms of borrowing would affect the amount of borrowing and thus the amount of price volatility.
  - The CMEB also is granted the power to increase the quantity of allowances that may be obtained from foreign GHG emissions trading markets (*Sec. 2604 – Powers – (a)(1)(D)*) and domestic offset markets (*Sec. 2604 – Powers – (a)(1)(E)*). While this is not explicitly modeled in this analysis; two alternative scenarios do explore the affects of allowing unlimited offsets and allowing no offsets. These alternative scenarios show the maximum extent that altering the offset and international credit limitations can affect costs, given a specific set of assumptions about international actions to reduce GHG emissions.

Modeling Limitations (con't)

Title II – Subtitle D – Sections 2402 & 2404 (Offsets Discounting)

- There are sections within Title II - Subtitle D of S. 2191 that deal with discounting offsets.
  - Title II - Subtitle D - Section 2402 (b)(3)(D) requires that regulations promulgated to authorize the issuance and certification of offset allowances shall include provisions that, "establish procedures to monitor, quantify, and discount reductions in greenhouse gas emissions or increases in biological sequestration in accordance with subsections (d) through (g) of section 2404."
  - Title II - Subtitle D - Section 2404 (g)(3) states the minimum requirements for the standardized methods for determining the discount for leakage.
  - Title II - Subtitle D - Section 2404 (h) requires the development of standardized methods for use in determining and discounting for uncertainty for each offset project type.
- The discounting of offsets has the potential to raise the price of offsets, which would increase the costs of implementing S. 2191.
- However, none of these provisions provide enough detail about how offsets would be discounted for us to include them in our economic modeling of S. 2191.
- Furthermore, because the 15% limit on the use of offsets is a binding constraint in our analysis, any small change in the offset supply curves due to discounting would have a negligible impact on the analysis outside of the offset market (i.e. the offset price would increase and offset payments would increase, but the allowance price would remain unchanged, and the economy wide economic impacts would be essentially the same).
  - However, if the discounting were great enough to significantly change the offset supply curves to the point that the 15% limit on the use of offsets were no longer binding, then allowance prices would be expected to rise, and the economy wide impacts would increase.

Appendix 2: Scenario Comparison Tables

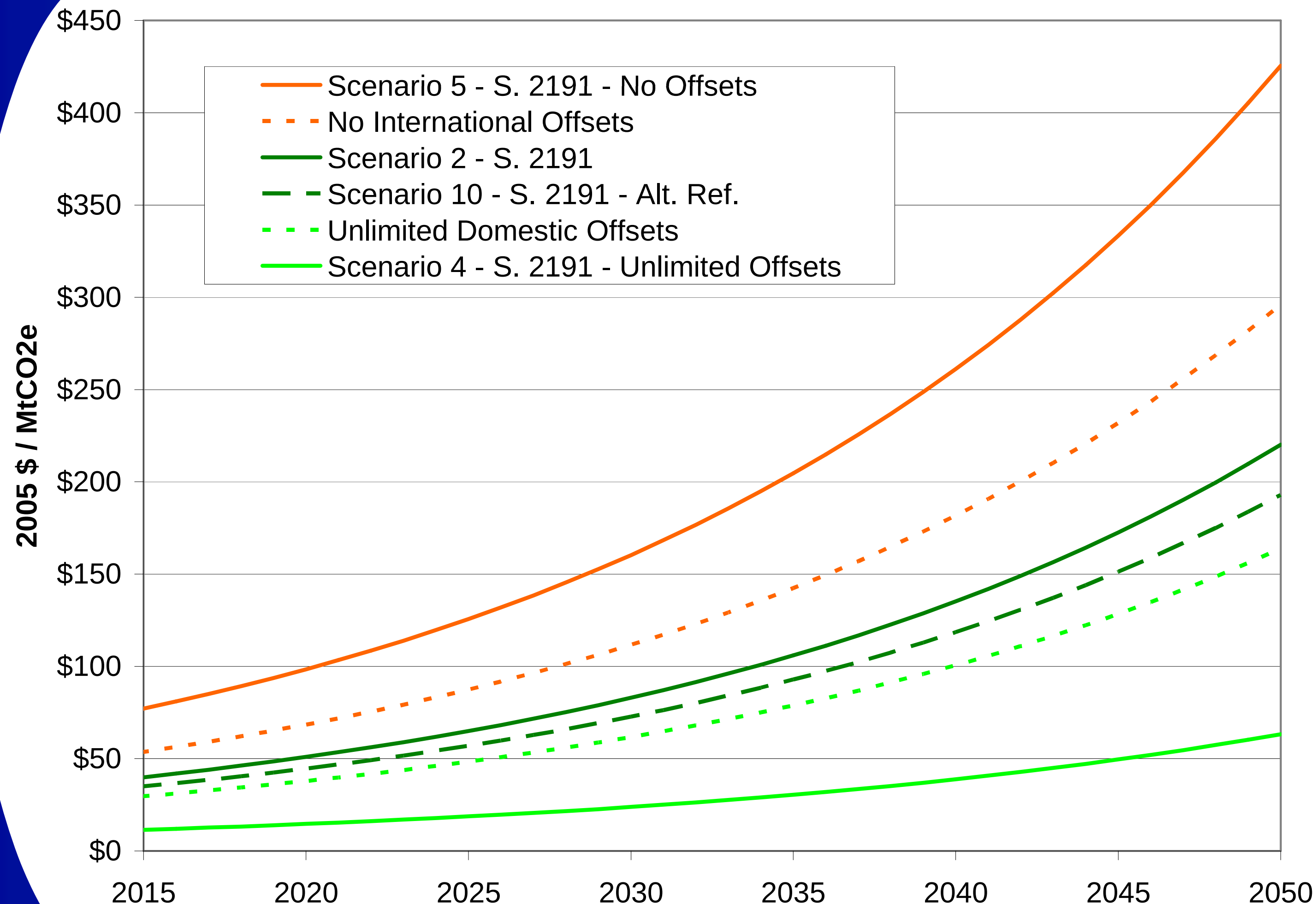
Analytical Scenarios (con't)

Table: Scenario Definitions

	Ref	International Action	Domestic Offsets	International Offsets	Biomass	CCS	Nuclear	Natural Gas Cartel
1) EPA Reference								
	Standard	None	n/a	n/a	Ref	n/a	Ref	No
2) S. 2191								
	Standard	MIT	15%	15%	Unrestricted	Unrestricted	150% Increase	No
3) S. 2191 with Low International Actions								
	Standard	Alternative	15%	15%	Unrestricted	Unrestricted	150% Increase	No
4) S. 2191 Unlimited Offsets								
	Standard	MIT	Unlimited	Unlimited	Unrestricted	Unrestricted	150% Increase	No
5) S. 2191 No Offsets								
	Standard	MIT	None	None	Unrestricted	Unrestricted	150% Increase	No
6) S. 2191 Constrained Nuclear & Biomass								
	Standard	MIT	15%	15%	Ref	Unrestricted	Ref	No
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
	Standard	MIT	15%	15%	Ref	After 2030	Ref	No
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel								
	Standard	Inhofe	15%	15%	Ref	After 2030	Ref	No
9) Alternative Reference								
	High Tech	None	n/a	n/a	High Tech Re	n/a	High Tech Ref	No
10) S. 2191 Alternative Reference								
	High Tech	MIT	15%	15%	Unrestricted	Unrestricted	150% Increase	No

Scenario Comparison

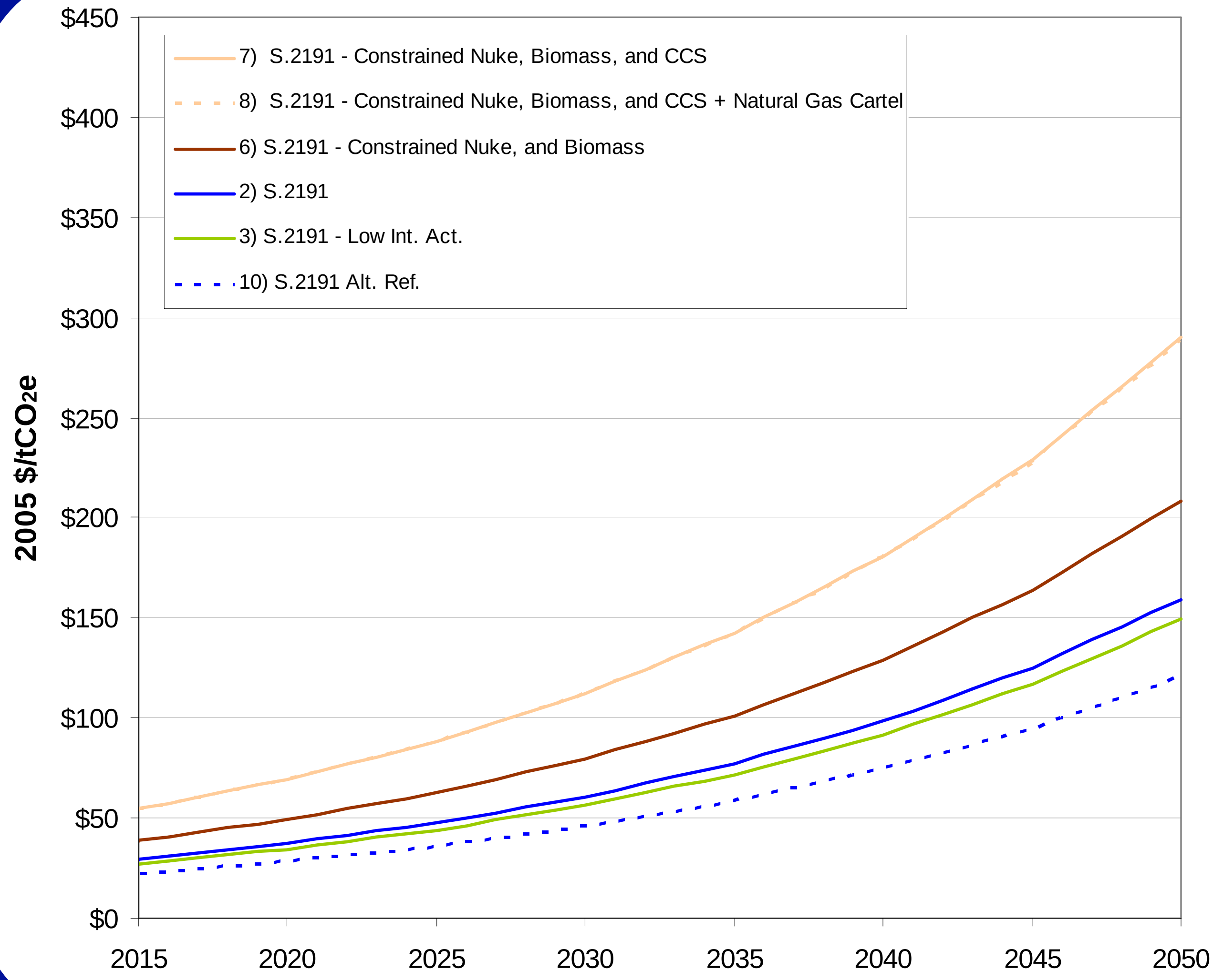
GHG Allowance Prices (IGEM)



- Compared to the variation in allowance prices between the various alternative technology scenarios, there is a greater variation in allowance prices amongst the alternative offset and international credit scenarios.
- Allowing the unlimited use of domestic offsets and international credits can reduce allowance prices by 71% compared to scenario 2.
- Allowing the unlimited use of just domestic offsets can reduce allowance prices by 26% compared to scenario 2.
- If international credits are not allowed, allowance prices increase by 34% compared to scenario 2.
- If both international credits and domestic offsets are not allowed, allowance prices increase by 93% compared to scenario 2.
- Allowance prices are 12% lower under the alternative reference case compared to scenario 2.

Scenario Comparison

GHG Allowance Prices (ADAGE)



- Compared to the variation in allowance prices between the various alternative offset and international credit scenarios, there is a smaller variation in allowance prices amongst the alternative technology scenarios.
- Allowance prices are 86% higher in the constrained nuclear, biomass, and CCS scenario compared to scenario 2. The natural gas cartel has minimal influence on the allowance price.
- Allowance prices are 32% higher in the constrained nuclear, and biomass scenario compared to scenario 2.
- Allowance prices are 24% lower under the alternative reference case compared to scenario 2.

Scenario Comparison

GHG Allowance Prices

Table: Allowance Price Comparison (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	$29	$37	$48	$61	$77	$98	$125	$159
IGEM	$40	$51	$65	$83	$106	$135	$173	$220
3) S.2191 w/ Low International Action								
ADAGE	$27	$35	$44	$56	$72	$92	$117	$149
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S.2191 w/ Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$11	$15	$19	$24	$30	$39	$50	$63
5) S.2191 w/ No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$77	$98	$126	$160	$205	$261	$333	$425
6) S.2191 Constrained Nuclear & Biomass								
ADAGE	$39	$49	$63	$80	$101	$129	$164	$208
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S.2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	$55	$69	$88	$112	$142	$181	$229	$290
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S.2191 Constrained Nuclear & Biomass, and CCS + Beyond Kyoto + Natural Gas Cartel								
ADAGE	$55	$70	$88	$112	$142	$180	$228	$288
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10) S.2191 Alt. Ref.								
ADAGE	$22	$28	$36	$46	$59	$75	$95	$121
IGEM	$35	$45	$57	$73	$93	$118	$151	$193

Scenario Comparison

GDP Impacts

(Percentage Change from Reference)

Table: GDP Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	-0.7%	-0.7%	-0.7%	-0.9%	-1.1%	-1.4%	-1.9%	-2.4%
IGEM	-2.0%	-2.6%	-3.1%	-3.8%	-4.4%	-5.2%	-6.0%	-6.9%
3) S. 2191 with Low International Actions								
ADAGE	-0.6%	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-2.0%	-2.5%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-0.7%	-0.9%	-1.1%	-1.3%	-1.6%	-1.9%	-2.3%	-2.7%
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-3.3%	-4.1%	-5.0%	-5.9%	-6.9%	-7.9%	-9.0%	-10.1%
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	-0.8%	-0.9%	-0.9%	-1.2%	-1.6%	-2.0%	-2.6%	-3.3%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	-1.1%	-1.5%	-1.8%	-2.3%	-2.6%	-3.1%	-3.8%	-4.4%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel								
ADAGE	-1.1%	-1.4%	-1.6%	-2.1%	-2.4%	-2.9%	-3.6%	-4.3%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	0.1%	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%
IGEM	0.3%	0.2%	0.1%	-0.2%	-0.2%	-0.3%	-0.3%	-0.3%
10) S. 2191 Alternative Reference								
ADAGE	-0.3%	-0.2%	-0.2%	-0.3%	-0.5%	-0.9%	-1.2%	-1.6%
IGEM	-1.5%	-2.1%	-2.8%	-3.6%	-4.3%	-5.0%	-5.8%	-6.6%

Scenario Comparison

GDP Impacts

(Billion 2005$, Change from Reference)

Table: GDP Comparisons (Billion 2005 $ Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	-$110	-$137	-$162	-$238	-$322	-$488	-$711	-$1,012
IGEM	-$340	-$506	-$715	-$983	-$1,326	-$1,752	-$2,258	-$2,856
3) S. 2191 with Low International Actions								
ADAGE	-$108	-$148	-$210	-$300	-$393	-$555	-$767	-$1,049
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-$111	-$173	-$250	-$350	-$486	-$654	-$865	-$1,134
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-$557	-$820	-$1,142	-$1,542	-$2,049	-$2,657	-$3,365	-$4,185
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	-$141	-$170	-$212	-$323	-$479	-$672	-$983	-$1,390
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	-$191	-$293	-$404	-$603	-$776	-$1,052	-$1,459	-$1,892
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel								
ADAGE	-$188	-$276	-$370	-$560	-$724	-$991	-$1,393	-$1,835
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	$24	$54	$64	$71	$67	$61	$55	$51
IGEM	$50	$49	$17	-$47	-$74	-$87	-$98	-$106
10) S. 2191 Alternative Reference								
ADAGE	-$58	-$45	-$45	-$88	-$158	-$292	-$463	-$703
IGEM	-$262	-$417	-$638	-$947	-$1,292	-$1,700	-$2,179	-$2,747

Scenario Comparison

Consumption Impacts
(Percentage Change from Reference)

Table: Consumption Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	-0.3%	-0.4%	-0.6%	-0.9%	-1.1%	-1.4%	-1.7%	-2.1%
IGEM	-0.2%	-0.7%	-1.1%	-1.4%	-1.9%	-2.3%	-2.7%	-3.3%
3) S. 2191 with Low International Actions								
ADAGE	-0.6%	-0.7%	-0.9%	-1.1%	-1.1%	-1.3%	-1.5%	-1.7%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	0.0%	-0.2%	-0.4%	-0.5%	-0.7%	-0.8%	-1.0%	-1.2%
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-0.3%	-1.2%	-1.8%	-2.5%	-3.2%	-3.9%	-4.5%	-5.3%
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	-0.5%	-0.7%	-1.0%	-1.4%	-1.7%	-1.9%	-2.3%	-2.8%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	-0.8%	-1.0%	-1.4%	-1.9%	-2.5%	-3.1%	-3.8%	-4.2%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & B + Beyond Kyoto + Natural Gas Cartel								
ADAGE	-0.5%	-0.8%	-1.2%	-1.8%	-2.4%	-3.2%	-4.0%	-4.4%
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	0.1%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%
IGEM	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.2%	-0.2%	-0.3%
10) S. 2191 Alternative Reference								
ADAGE	-0.1%	-0.2%	-0.4%	-0.6%	-0.8%	-1.1%	9.7%	-1.7%
IGEM	-0.1%	-0.5%	-0.9%	-1.3%	-1.8%	-2.3%	-2.7%	-3.2%

Scenario Comparison

Consumption Impacts

(Billion 2005$, Change from Reference)

Table: Consumption Comparisons (Billion 2005 $ Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	-$37	-$63	-$104	-$180	-$243	-$353	-$488	-$670
IGEM	-$19	-$82	-$149	-$233	-$346	-$478	-$641	-$843
3) S. 2191 with Low International Actions								
ADAGE	-$71	-$107	-$153	-$216	-$258	-$330	-$418	-$536
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-$4	-$25	-$51	-$81	-$124	-$173	-$237	-$318
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	-$33	-$144	-$262	-$404	-$591	-$806	-$1,062	-$1,369
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	-$68	-$109	-$167	-$268	-$378	-$476	-$667	-$908
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	-$94	-$152	-$236	-$374	-$555	-$791	-$1,093	-$1,336
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & B + Beyond Kyoto + Natural Gas Cartel								
ADAGE	-$66	-$120	-$203	-$349	-$543	-$799	-$1,129	-$1,410
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	$16	$36	$39	$40	$36	$32	$29	$27
IGEM	$6	$9	$3	-$11	-$32	-$47	-$57	-$66
10) S. 2191 Alternative Reference								
ADAGE	-$19	-$34	-$61	-$118	-$182	-$285	$2,761	-$542
IGEM	-$7	-$61	-$126	-$215	-$337	-$471	-$630	-$820

Scenario Comparison

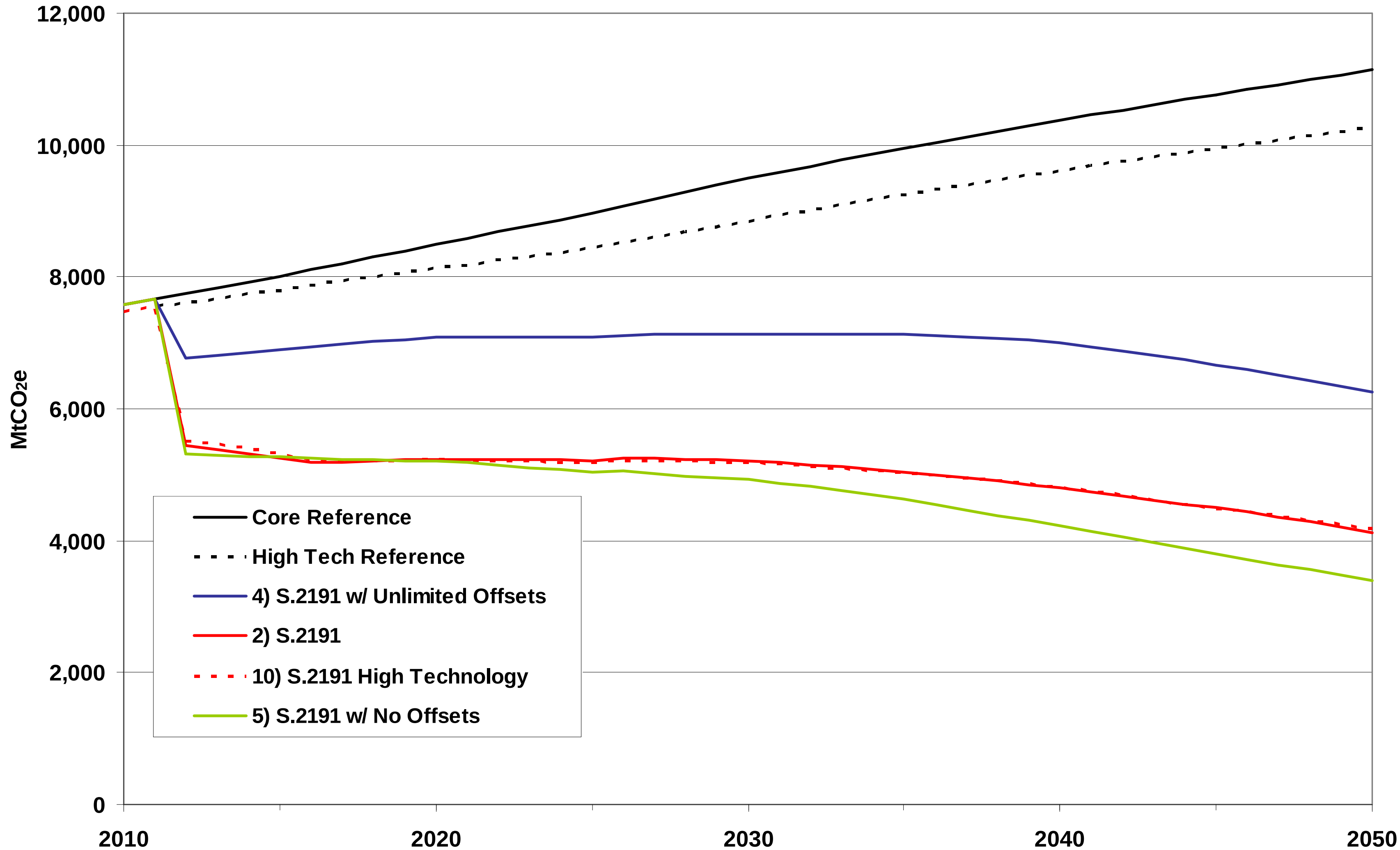
Total U.S. GHG Emissions ($MtCO_2e$)

Table: Total U.S. Greenhouse Gas Emissions

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	7,830	8,264	8,626	9,089	9,452	9,786	10,068	10,312
IGEM	8,011	8,494	8,958	9,493	9,954	10,370	10,765	11,148
2) S. 2191								
ADAGE	6,362	6,388	6,201	5,867	5,439	5,424	5,362	5,279
IGEM	5,249	5,236	5,217	5,217	5,048	4,801	4,496	4,121
3) S. 2191 with Low International Actions								
ADAGE	6,409	6,433	6,198	5,852	5,405	5,379	5,334	5,239
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	6,900	7,079	7,088	7,124	7,127	7,005	6,671	6,253
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	5,267	5,205	5,047	4,924	4,629	4,237	3,806	3,395
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	6,244	6,298	6,218	5,996	5,580	5,430	5,368	5,260
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	5,949	6,061	6,120	6,176	6,044	5,816	5,409	4,946
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & Biomass + Beyond Kyoto + Natural Gas Cartel								
ADAGE	5,955	6,068	6,143	6,201	6,076	5,852	5,445	4,984
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	7,618	7,896	8,121	8,442	8,779	9,088	9,349	9,576
IGEM	7,804	8,129	8,451	8,850	9,255	9,615	9,953	10,279
10) S. 2191 Alternative Reference								
ADAGE	6,347	6,256	6,176	5,953	5,568	5,321	5,316	5,263
IGEM	5,315	5,221	5,193	5,185	5,035	4,808	4,490	4,178

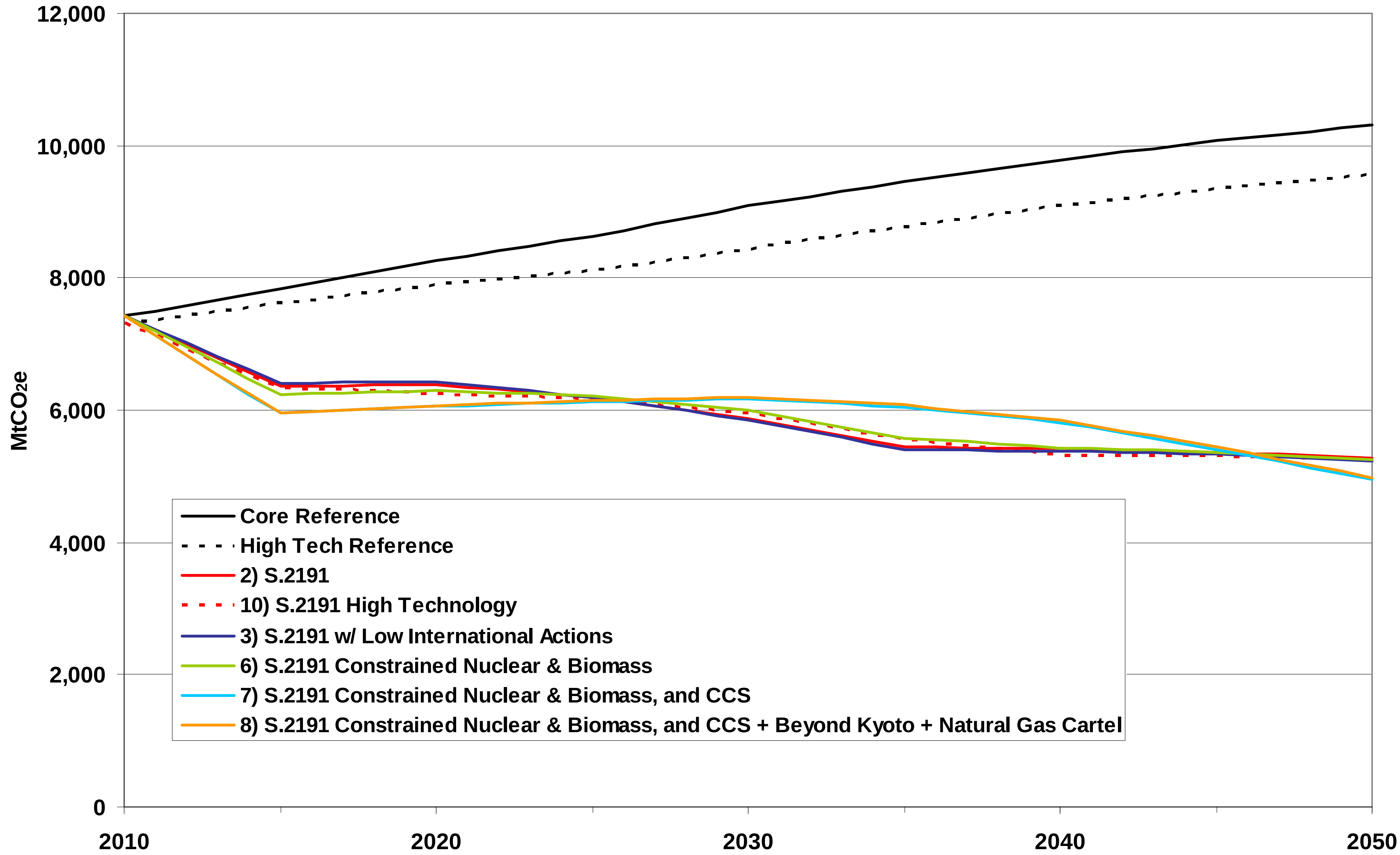
Scenario Comparison

Total U.S. GHG Emissions ($MtCO_2e$) (IGEM)



Scenario Comparison

Total U.S. GHG Emissions ($MtCO_2e$) (ADAGE)



Scenario Comparison

Covered GHG Emissions – Offsets ($MtCO_2e$)

Table: Covered GHG Emissions - Offsets

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	4,378	4,112	3,963	3,706	3,395	3,401	3,374	3,329
IGEM	4,124	4,073	4,014	3,971	3,771	3,510	3,207	2,845
3) S. 2191 with Low International Actions								
ADAGE	4,424	4,155	3,968	3,702	3,372	3,369	3,361	3,307
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S. 2191 Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	4,952	4,634	4,320	4,029	3,561	3,054	2,486	1,921
5) S. 2191 No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	4,434	4,358	4,182	4,042	3,717	3,304	2,862	2,442
6) S. 2191 Constrained Nuclear & Biomass								
ADAGE	4,264	4,025	3,984	3,840	3,541	3,411	3,385	3,318
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S. 2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	3,975	3,796	3,892	4,026	4,012	3,806	3,436	3,011
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S. 2191 Constrained Nuclear & B + Beyond Kyoto + Natural Gas Cartel								
ADAGE	3,980	3,802	3,909	4,045	4,038	3,834	3,463	3,039
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10) S. 2191 Alternative Reference								
ADAGE	4,360	3,975	3,933	3,786	3,518	3,292	3,322	3,307
IGEM	4,179	4,058	3,990	3,939	3,754	3,511	3,196	2,890

Scenario Comparison

Electricity: Fossil Fuel Generation (Billion kWh)

(ADAGE)

Table: **Electricity Generation (billion kWh) (ADAGE)**

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
Fossil	3208	3449	3676	3981	4265	4536	4787	5017
Fossil w/CCS	0	0	0	0	0	0	0	0
Nuclear	837	879	879	879	879	879	879	879
Other Non-Fossil	414	433	452	470	477	484	491	499
2) S.2191								
Fossil	2646	2526	2043	1189	92	0	0	0
Fossil w/CCS	0	186	558	1303	2405	2474	2365	2226
Nuclear	932	995	1174	1387	1603	1766	1939	2118
Other Non-Fossil	500	592	684	769	905	1040	1242	1444
3) S.2191 w/ Low International Action								
Fossil	2670	2551	2065	1216	103	1	0	0
Fossil w/CCS	0	186	558	1303	2406	2480	2384	2249
Nuclear	930	992	1171	1383	1600	1765	1936	2116
Other Non-Fossil	499	591	683	769	905	1040	1242	1444
6) S.2191 Constrained Nuclear & Biomass								
Fossil	2715	2669	2417	1827	828	431	423	410
Fossil w/CCS	0	186	558	1303	2548	3383	3566	3726
Nuclear	837	879	879	879	879	879	879	879
Other Non-Fossil	435	459	485	499	504	509	515	521
7) S.2191 Constrained Nuclear & Biomass, and CCS								
Fossil	2579	2697	2800	2930	2839	2536	1824	813
Fossil w/CCS	0	0	0	0	186	558	1303	2765
Nuclear	837	879	879	879	879	879	879	879
Other Non-Fossil	442	465	485	499	504	510	516	522
8) S.2191 Constrained Nuclear & Biomass, and CCS + Beyond Kyoto + Natural Gas Cartel								
Fossil	2582	2700	2805	2935	2846	2543	1832	815
Fossil w/CCS	0	0	0	0	186	558	1303	2766
Nuclear	837	879	879	879	879	879	879	879
Other Non-Fossil	442	465	485	499	504	510	516	522
9) Alternative Reference								
Fossil	3061	3244	3431	3621	3886	4138	4372	4587
Fossil w/CCS	0	0	0	0	0	0	0	0
Nuclear	814	864	864	916	916	916	916	916
Other Non-Fossil	417	441	456	480	486	493	499	507
10) S.2191 Alt. Ref.								
Fossil	2566	2416	2221	1634	718	0	0	0
Fossil w/CCS	0	186	257	699	1501	2099	2032	1890
Nuclear	924	987	1164	1375	1602	1775	1934	2103
Other Non-Fossil	499	593	680	778	918	1054	1256	1454

Appendix 3:Comparison to EPA's Analyses of S. 280 and S. 1766

"Lieberman-Warner Climate Security Act of 2008" (S. 2191) Bill Summary

- Economy-wide coverage:
  - Upstream on petroleum, natural gas, as well as manufacturers of F-gases and N_2O
  - Downstream on coal facilities (that use over 5,000 tons of coal per year)
- GHG emission targets for covered sectors (targets decline in each calendar year):

  2012: 5,775 $MtCO_2e$
  2020: 4,924 $MtCO_2e$
  2030: 3,860 $MtCO_2e$
  2050: 1,732 $MtCO_2e$ (70% below 2005 emissions levels from covered facilities)

- Establishes a market-driven system of tradable emission allowances
- Establishes a separate cap and trade system for HFCs

- Domestic offsets may be used to meet 15% of compliance obligation
- International credits may be used to meet 15% of compliance obligation

- Establishes a Carbon Market Efficiency Board

- Set-asides for agriculture and forestry sequestration as well as landfill and coal mine methane
- Bonus allowances for CCS similar to provisions in S. 1766
- International reserve allowance requirement similar to provisions in S. 1766

Lieberman-McCain "Climate Stewardship and Innovation Act" (S. 280) Bill Summary

- Economy-wide coverage:
  - Transportation (upstream on fuels)
  - Electricity, Industrial, and Commercial sectors (downstream on emissions)
- Extensive GHG coverage: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6
- GHG emission targets for covered sectors:

  2012: 2004 emission level, then adjusted for non-covered entities

  2020: 1990 emission level, then adjusted

  2050: 60% below 1990 emission level, then adjusted
- Establishes a market-driven system of tradable emission allowances
- Caps are placed on covered Entities that emit 10,000 tons CO_2e or more emissions per year
- Domestic offsets & international credits can be used to meet up to 30% of the emission cap level
  - S. 280 provides the EPA Administrator, in coordination with the Secretaries of Commerce, Energy, and Agriculture, discretion for setting standards for domestic and international mitigation activities

Bingaman-Specter "Low Carbon Economy Act" (S. 1766) Bill Summary

- Economy-wide coverage:
  - Upstream on petroleum, natural gas, as well as manufacturers of F-gases and N_2O
  - Downstream on coal facilities (that use over 5,000 tons of coal per year)
- GHG emission targets for covered sectors (targets decline in each calendar year):

  2012: 6,652 $MtCO_2e$

  2020: 6,188 $MtCO_2e$ (approximately 2006 emissions levels)

  2050: 1,732 $MtCO_2e$ (equal to 1990 emissions levels)

  The President may set 2050 emission targets of at least 60% below 2006 levels, if the 5 largest trading partners of the U.S. are taking comparable action. According to the core international assumptions used in this analysis, both developed and developing countries take on GHG reduction targets, and thus this reduction is assumed to be enacted.

- Establishes a market-driven system of tradable emission allowances
- Technology Accelerator Payment (TAP) of $12/$tCO_2e$ rising at real rate of 5 percent per year
- Unlimited specified domestic offsets can be used to meet the emission cap level
  - Specified offset project categories include CH_4 from landfills, coal mines, and animal waste, and SF_6 from electric power systems
    - For other offset project categories, the President may distribute less than 1 credit for each ton of greenhouse gas emissions reduced or sequestered.
    - This analysis assumes that only offsets from specified project categories are allowed.
  - The President can implement an international offset program, allowing not more than 10% of compliance to be met through this program
- Set-asides for agriculture sequestration and bonus allowances for CCS
- Ensures comparable action from major trading partners through a specified approach of incentives (i.e., for technology deployment) and countervailing trade measures

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

Major Provisions

- Coverage of US GHG Emissions (based on 2005 GHG inventory)
  - S. 280: ~73%
  - S. 1766: ~83%
  - S. 2191: ~87%
- Cap rate of decline
  - S. 280: Step down decrease every 10 years
  - S. 1766: Annual decrease
  - S. 2191: Annual decrease
- Safety valve
  - S. 280: no safety valve
  - S. 1766: $12/ton of CO_2e in 2012 rising at a real rate of 5%
  - S. 2191: no safety valve
- Use of offsets
  - S. 280: 30% of compliance from domestic offsets and international credits
  - S. 1766: Unlimited specified domestic offsets can be used to meet the emission cap level
    - Specified offset project categories include CH_4 from landfills, coal mines, and animal waste, and SF_6 from electric power systems
    - The President can implement an international offset program, allowing not more than 10% of compliance to be met through this program
  - S. 2191: 15% of compliance from domestic offsets; and 15% of compliance from international credits

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

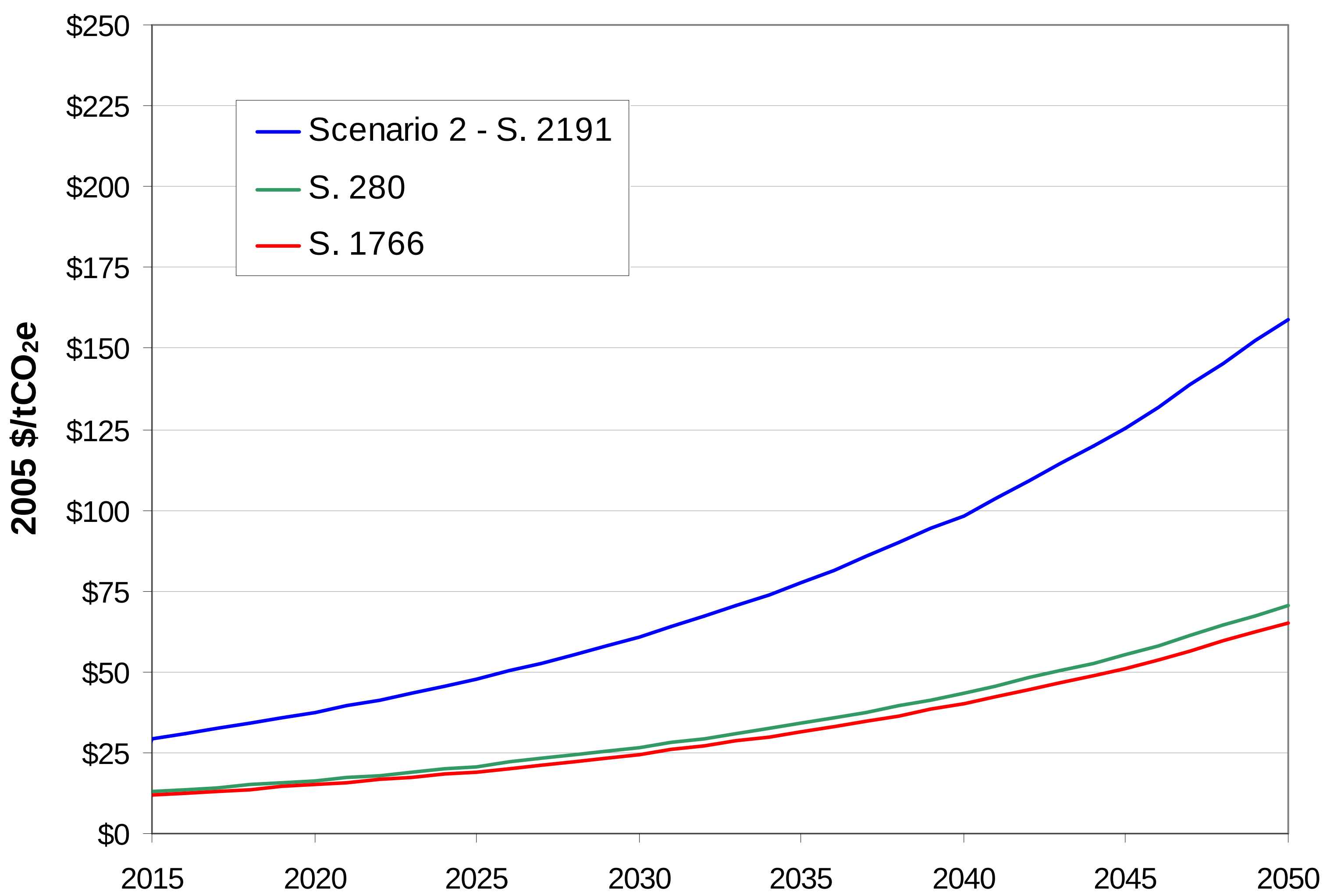
Scenarios from Previous Analyses

- The results presented in this appendix compare three bills analyzed by EPA:
  - S. 280
    - Lieberman-McCain, "Climate Stewardship and Innovation Act of 2007"
    - EPA analysis released July 16, 2007
    - www.epa.gov/climatechange/economics/economicanalyses.html#s280
    - Scenario 2 – S. 280 Senate Scenario
  - S. 1766
    - Bingaman-Specter, "Low Carbon Economy Act of 2007"
    - EPA analysis released January 15, 2008
    - www.epa.gov/climatechange/economics/economicanalyses.html#s1766
    - Scenario 2 – S. 1766
  - S. 2191
    - "Lieberman-Warner Climate Security Act of 2008"
    - EPA analysis contained in this document
    - www.epa.gov/climatechange/economics/economicanalyses.html#s2191
    - Scenario 2 – S. 2191
- The same reference case was used in each of the analyses described above

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

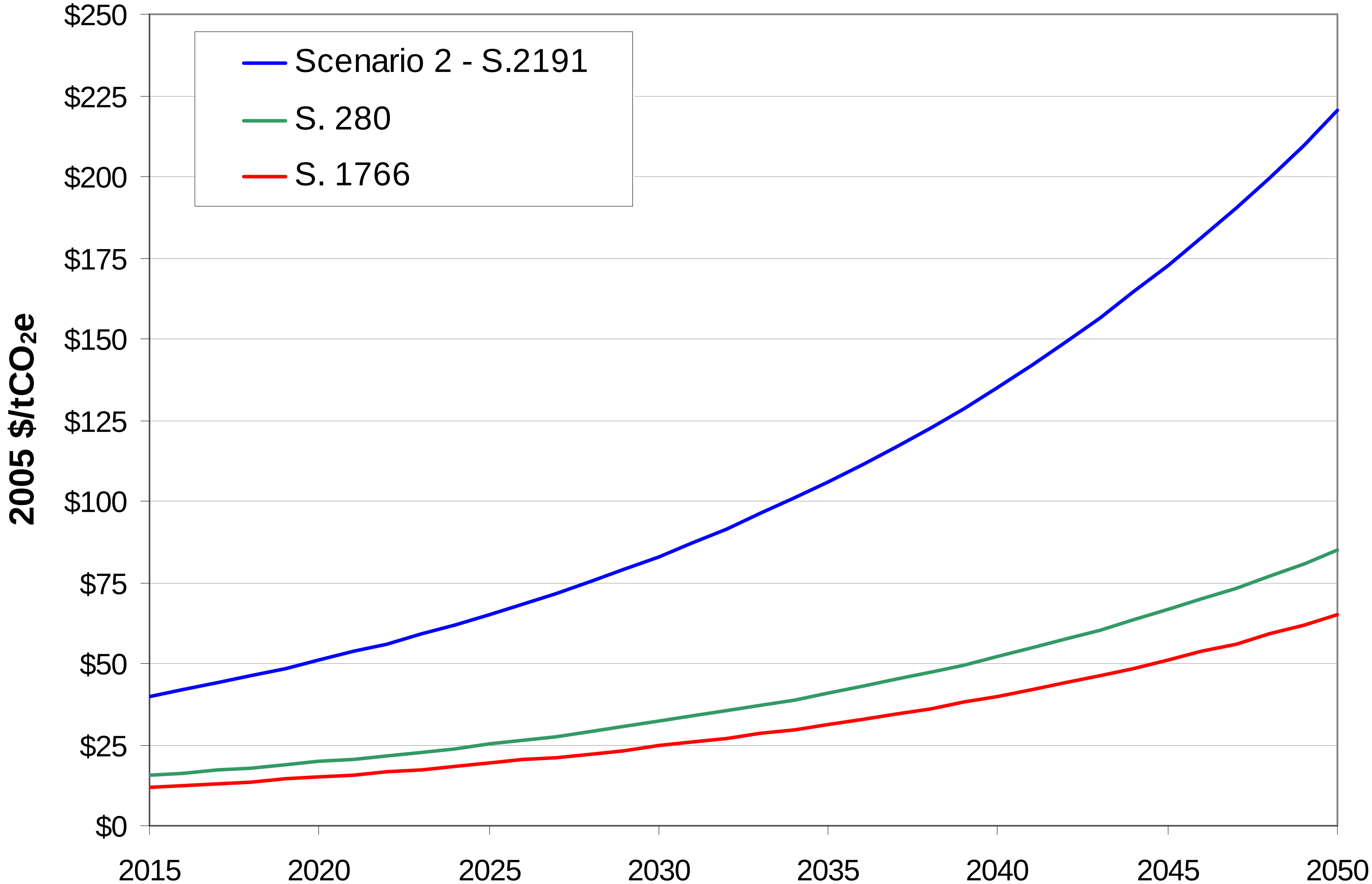
GHG Allowance Prices (IGEM)



Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

GHG Allowance Prices (ADAGE)



Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

GHG Allowance Prices (2005$/t$CO_2$e)

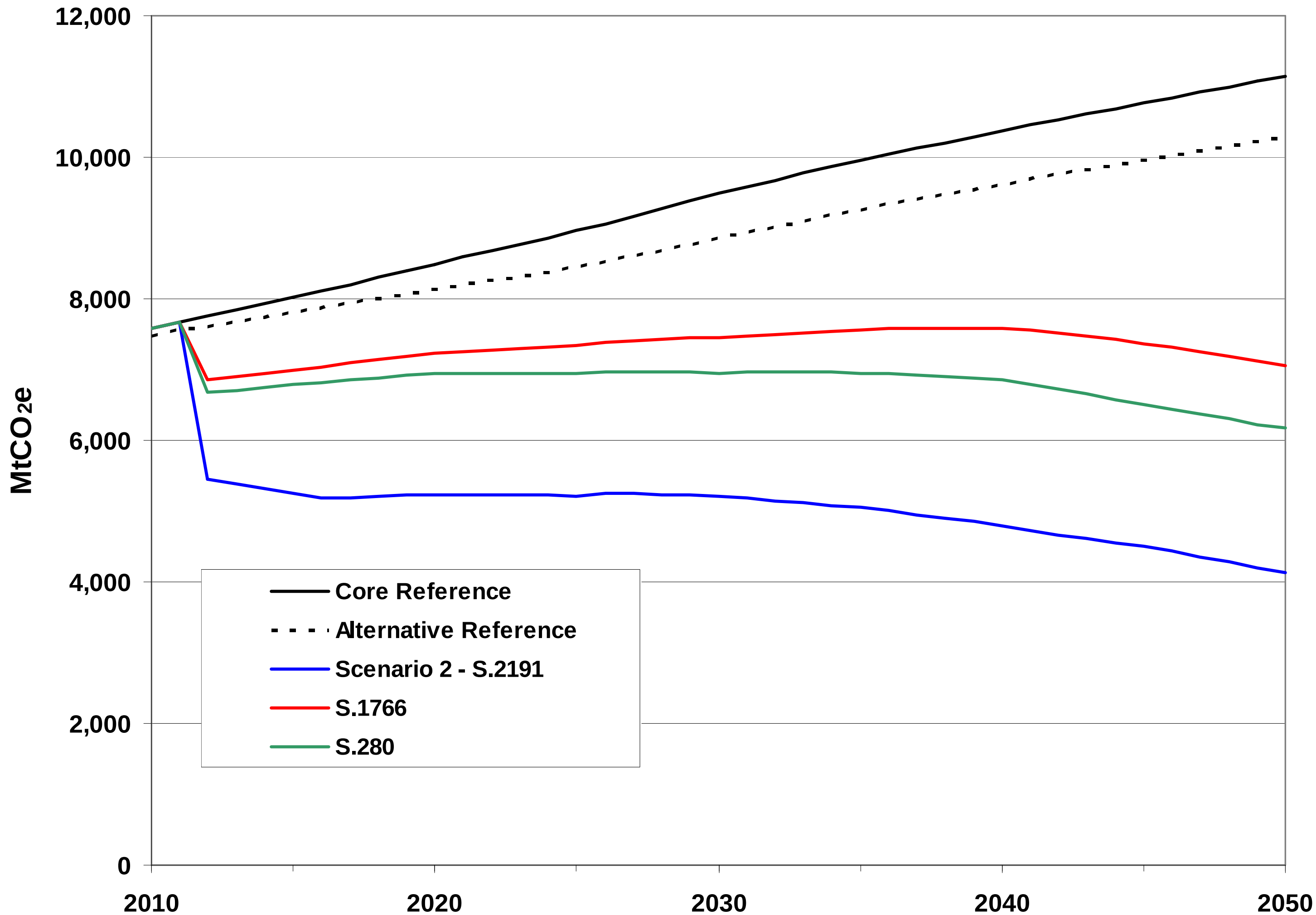
Table: Allowance Price Comparisons (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Scenario 2 - S. 2191								
ADAGE	$29	$37	$48	$61	$77	$98	$125	$159
IGEM	$40	$51	$65	$83	$106	$135	$173	$220
S. 1766								
ADAGE	$12	$15	$19	$25	$31	$40	$51	$65
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
S. 280								
ADAGE	$13	$16	$21	$27	$34	$43	$55	$70
IGEM	$15	$20	$25	$32	$41	$52	$67	$85

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

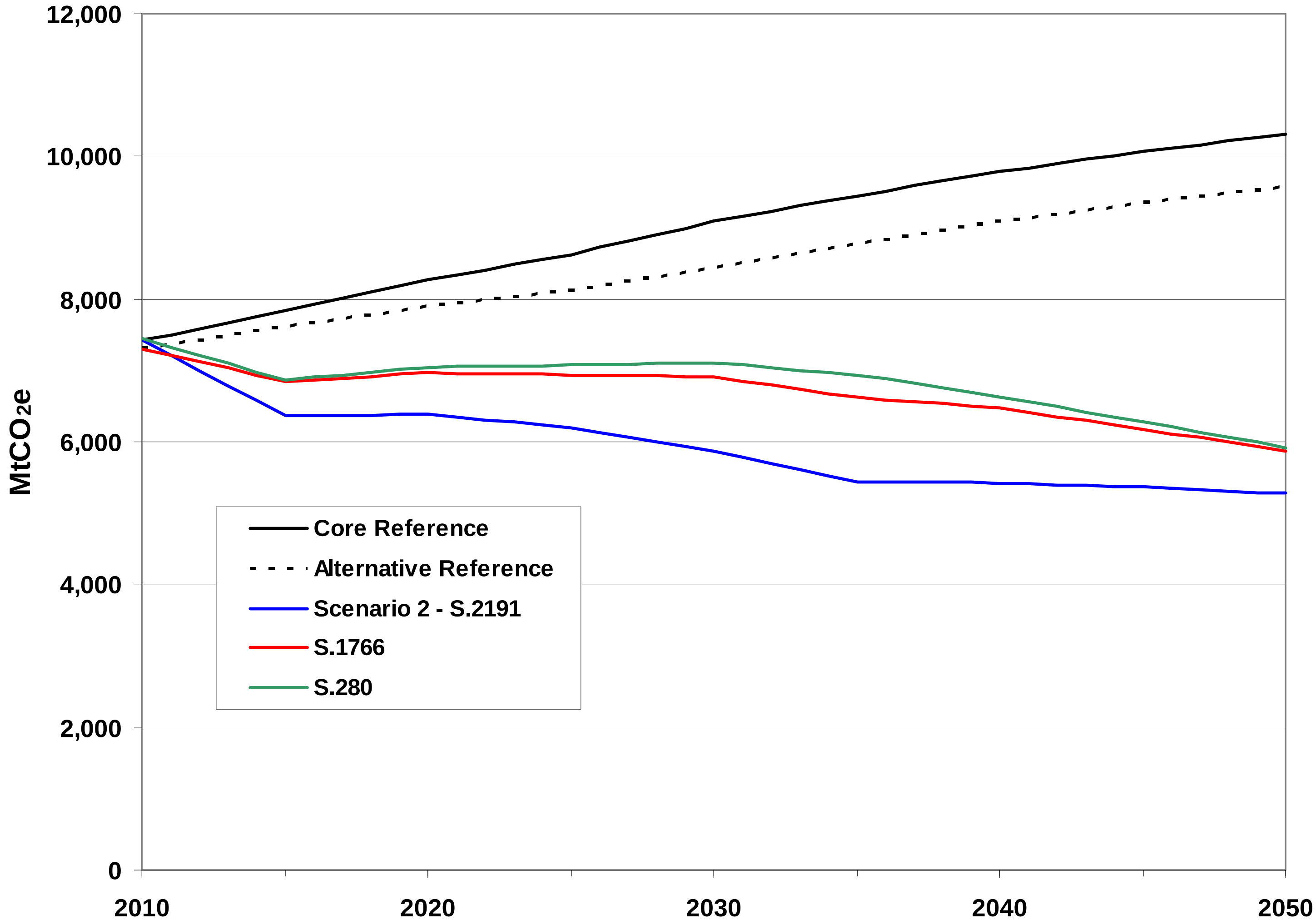
Total U.S. GHG Emissions ($MtCO_2e$) (IGEM)



Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

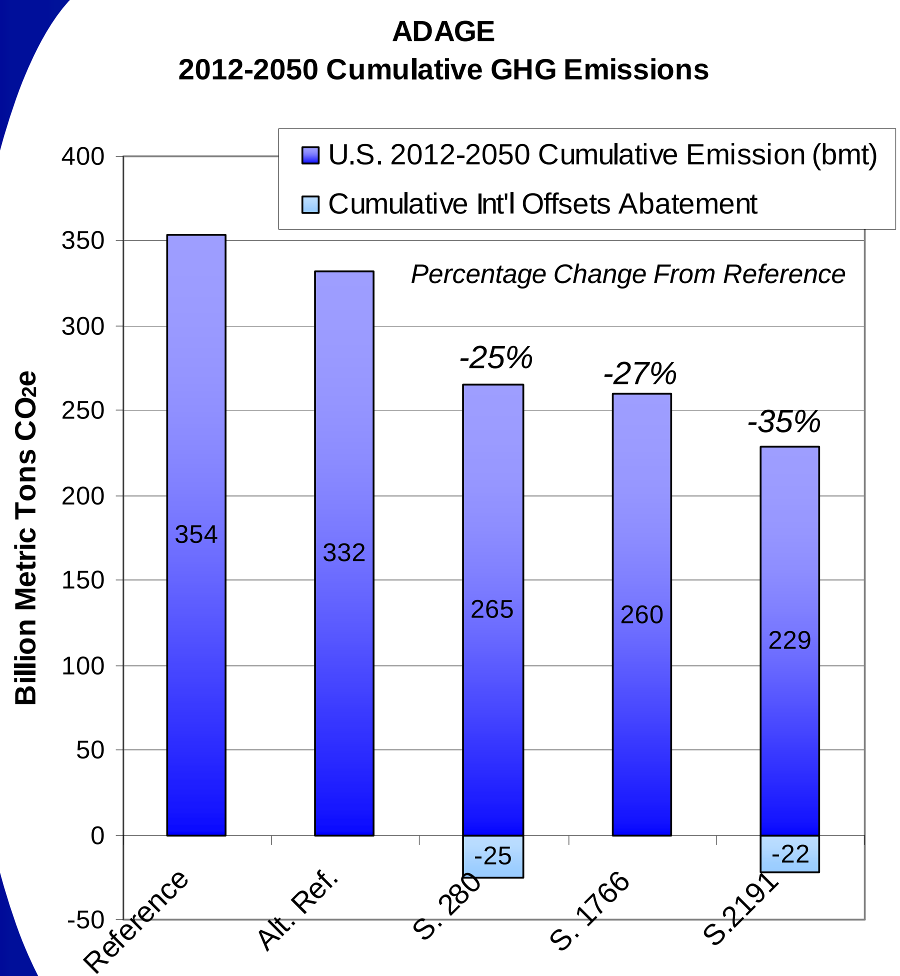
Total U.S. GHG Emissions ($MtCO_2e$) (ADAGE)

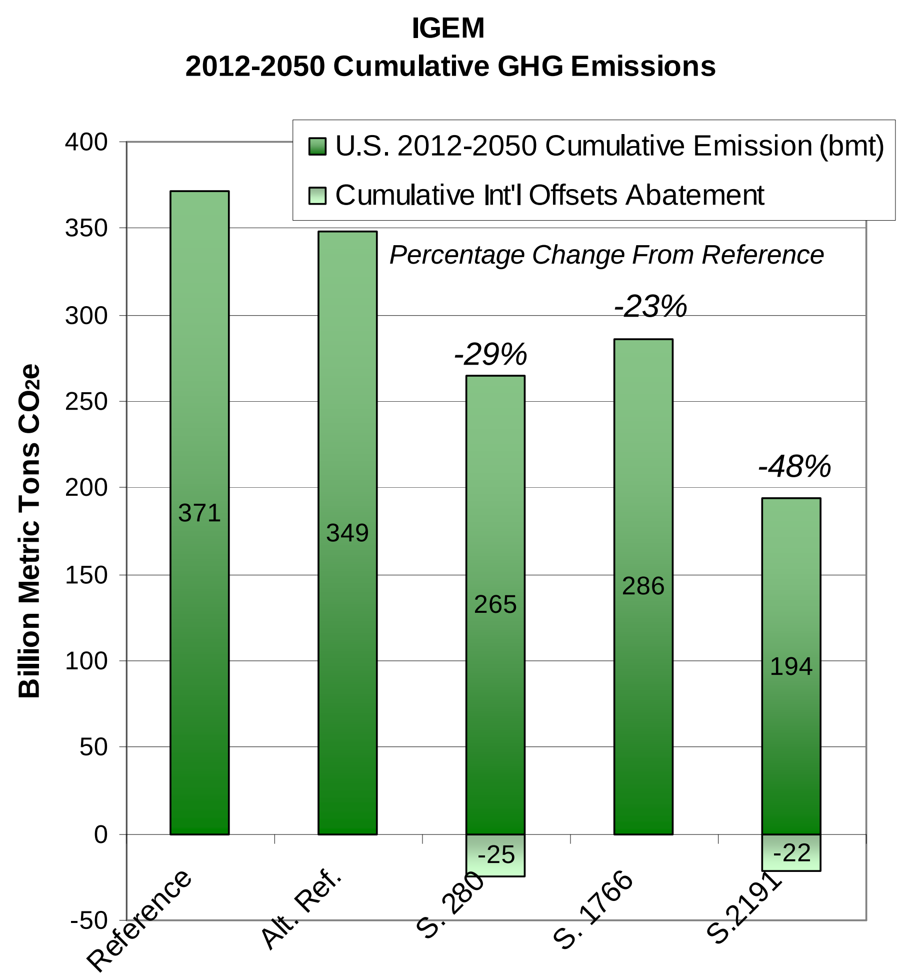


Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

2012 – 2050 Cumulative U.S. GHG Emissions (Billion Metric Tons CO_2e)

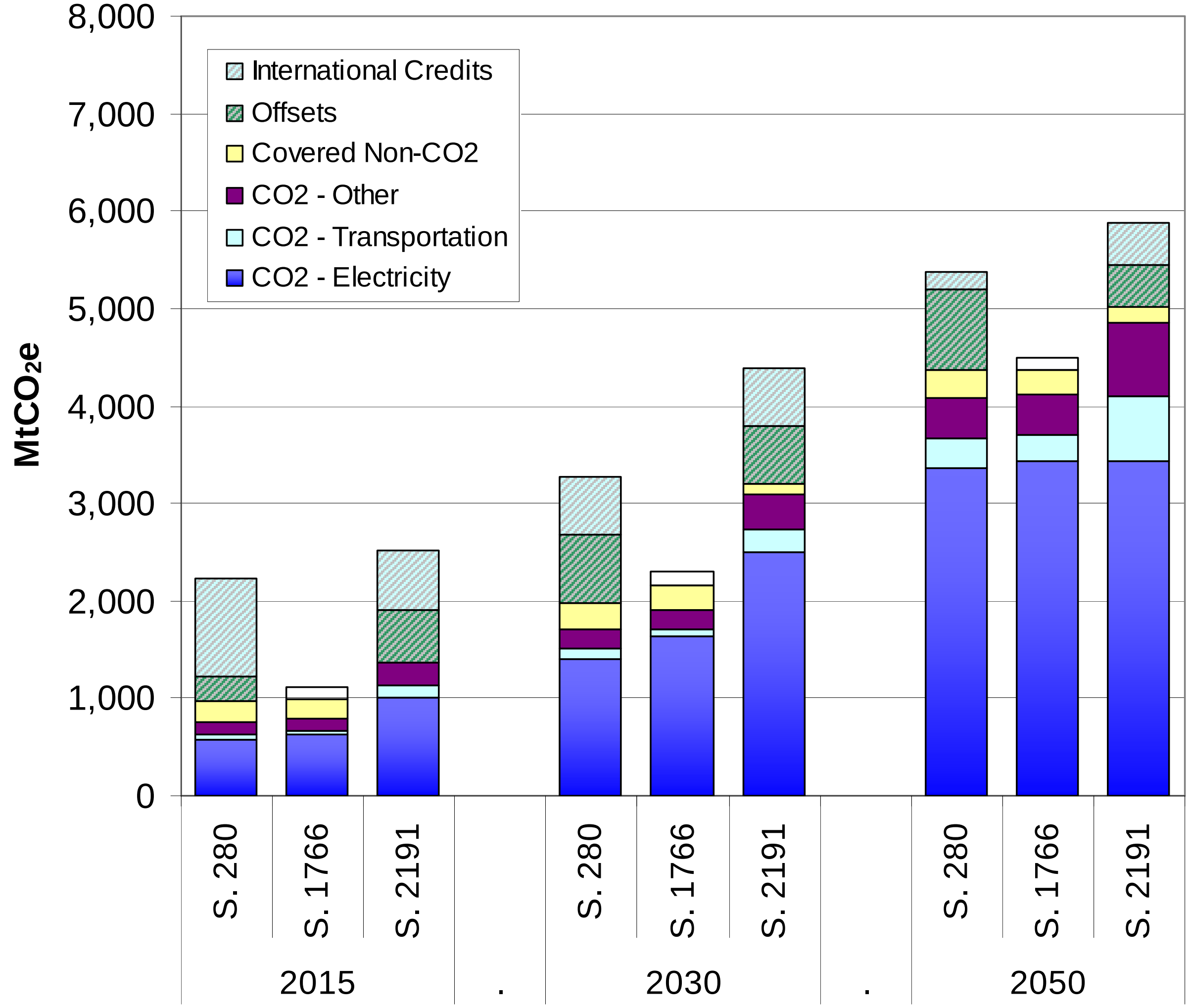




Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

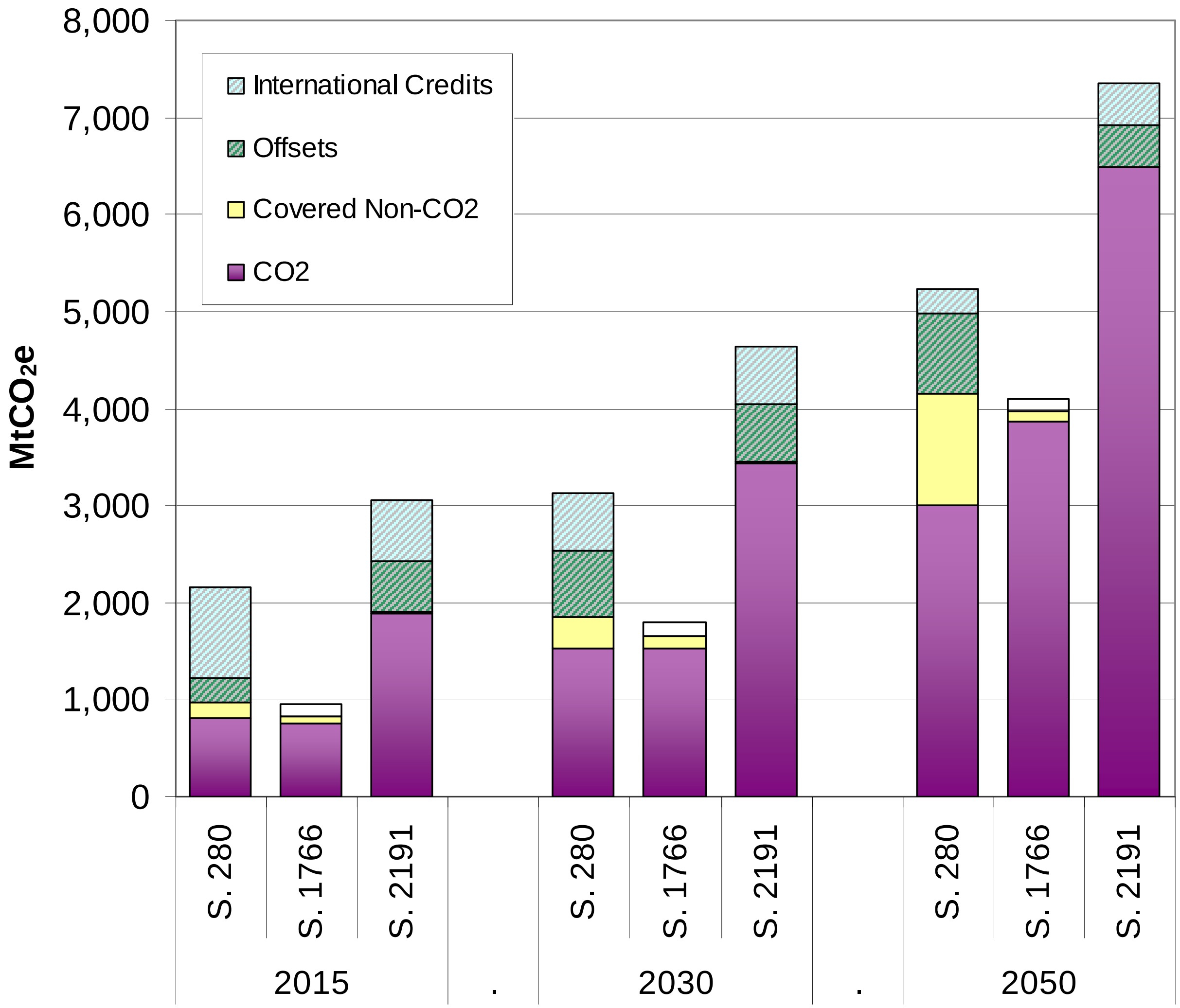
Sources of GHG Abatement (ADAGE)



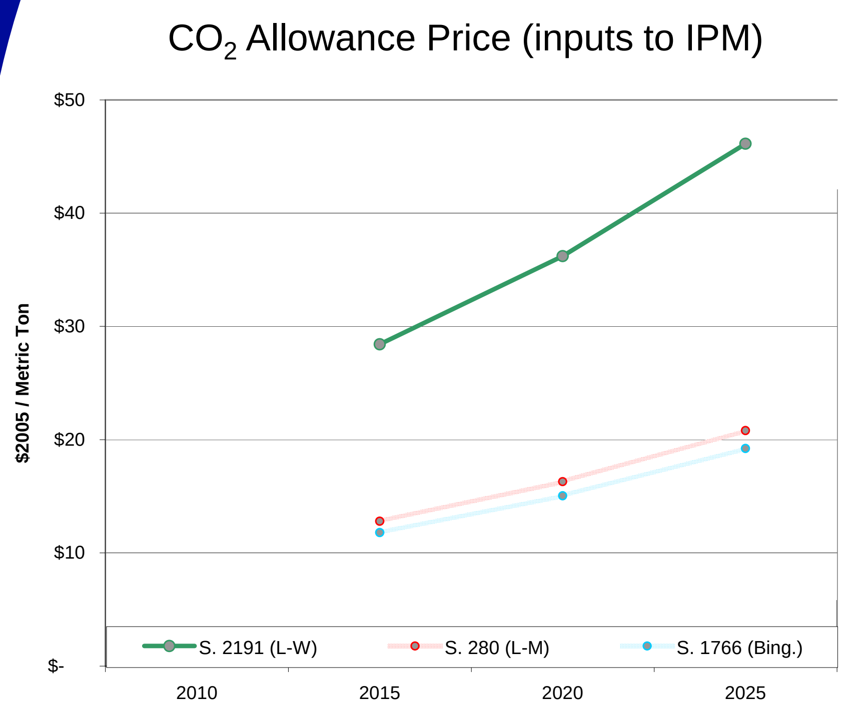
Policy Comparison:

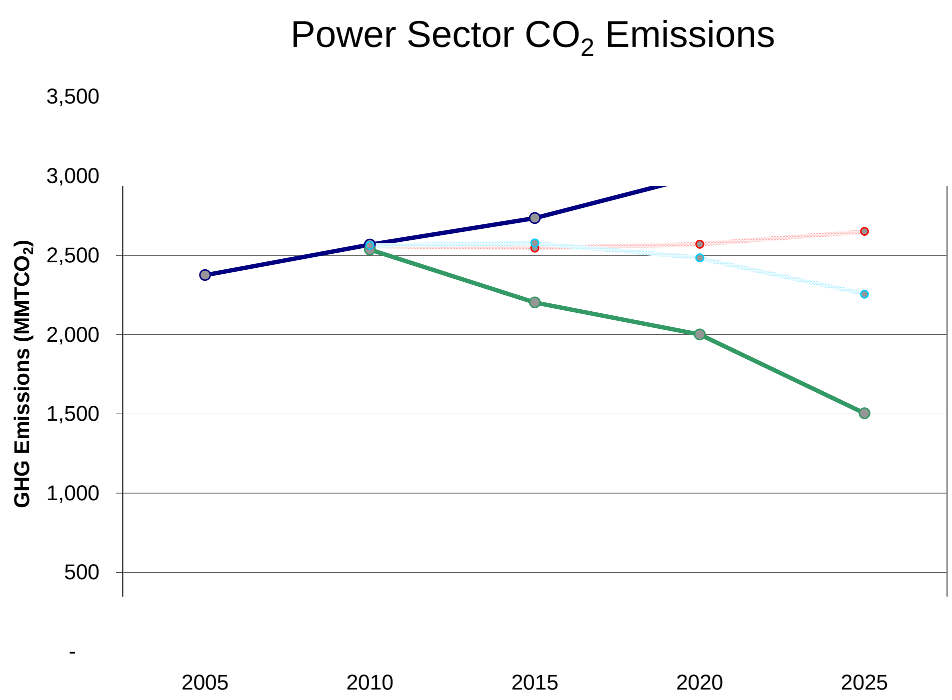
Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

Sources of GHG Abatement (IGEM)



Policy Comparison:
Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)
CO_2 Allowance Prices and Power Sector CO_2 Emissions (IPM)

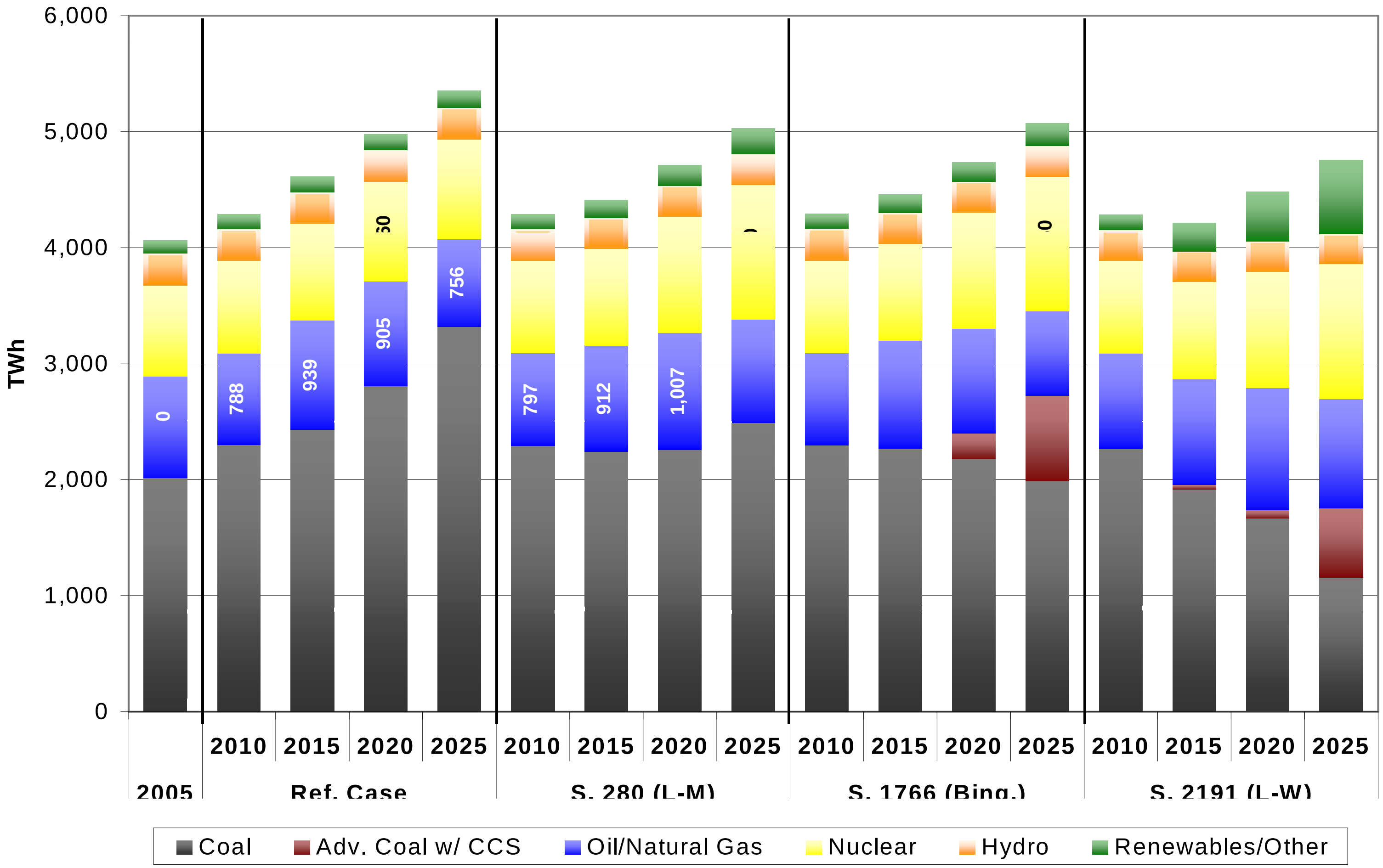




Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

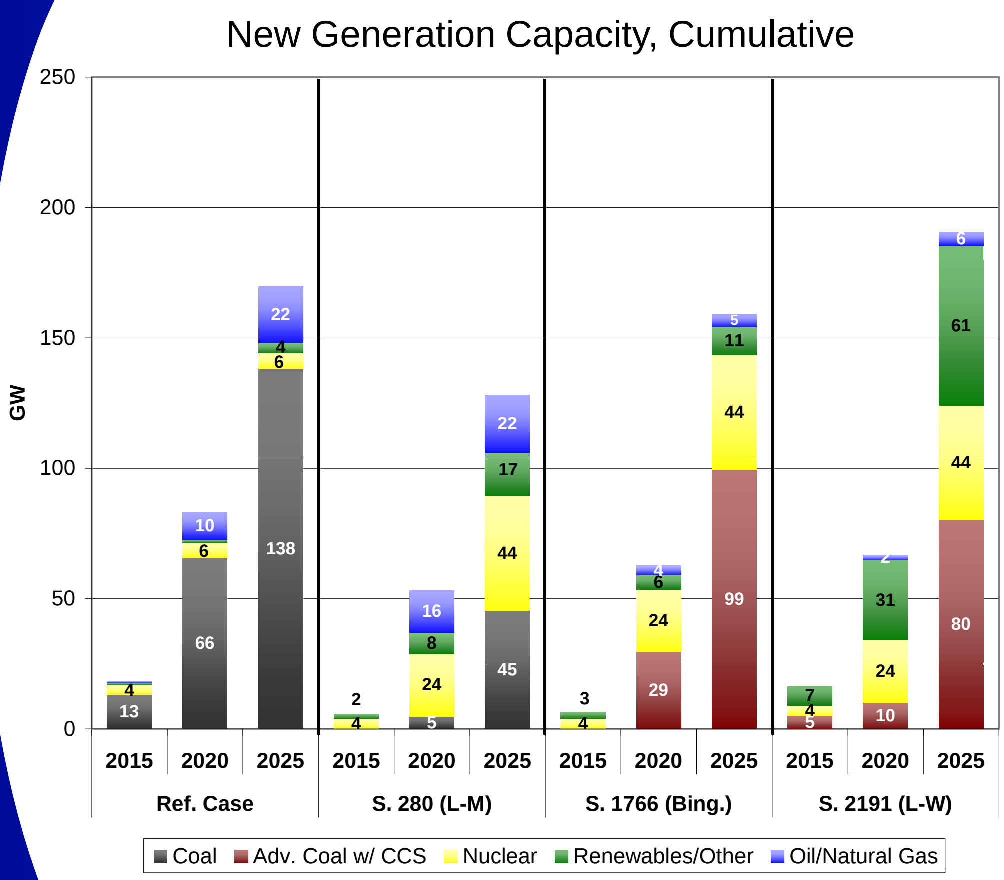
Electricity Generation Mix (IPM)



Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

New Generation Capacity (IPM)



Note: New capacity additions less that 1 GW of capacity are not indicated.

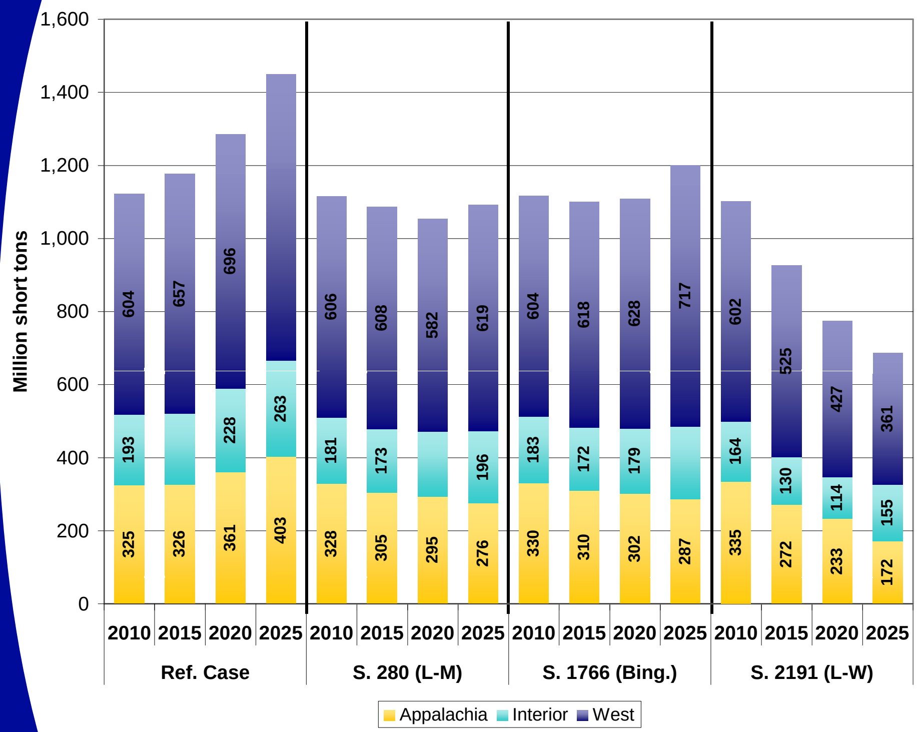
- S. 2191 contains an allowance bonus provision, which is capped, for CO_2 emissions that are captured and sequestered, resulting in significant penetration of new coal capacity with CCS technology (S. 1766 has a similar provision).
  - Bonus allowances go unused in 2015 only, when there is a 5 GW constraint on new adv. coal with CCS (the bonus is used entirely in all years post-2015).
- In 2025, adv. coal with CCS is economic even without the bonus.
- S. 2191 also results in significant penetration of new nuclear and renewable capacity.
- More capacity is built under S. 2191 because a significant amount of the existing fossil fleet is not economic to operate and must be replaced.

New Capacity Limitations in IPM (Incremental/Cumulative)

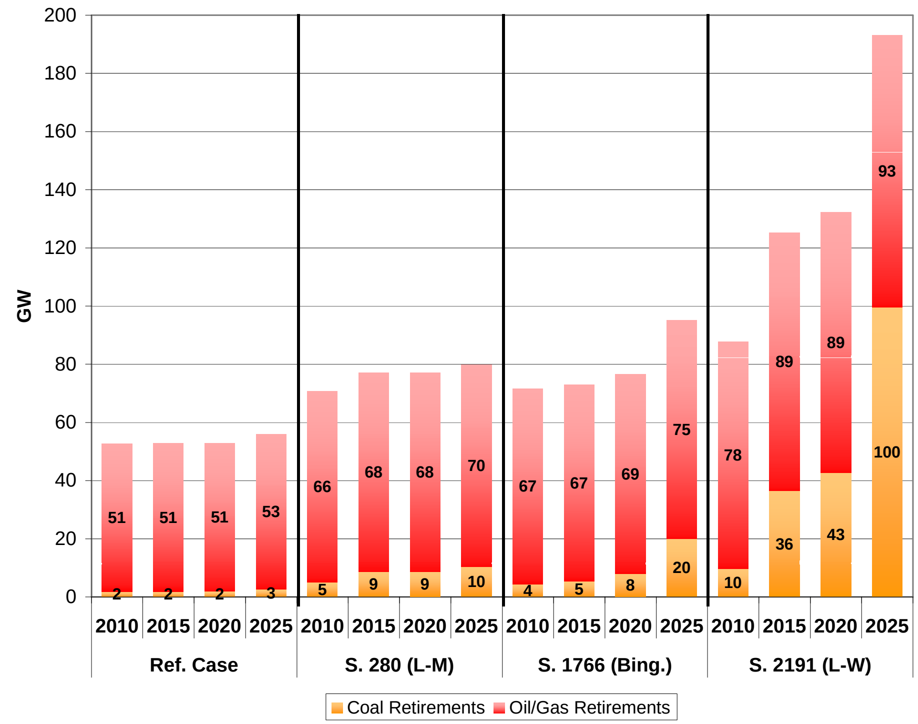
GW	2010	2015	2020	2025
Nuclear	N/A	4	20 / 24	20 / 44
Adv. Coal w/ CCS	N/A	5	70 / 75	70 / 145
Renewables *(Cumulative Only)*	4	24	44	64

Coal Production for Electricity Generation & Retirements of Existing Capacity (IPM)

Coal Production for Electricity Generation



Retirements of Existing Capacity



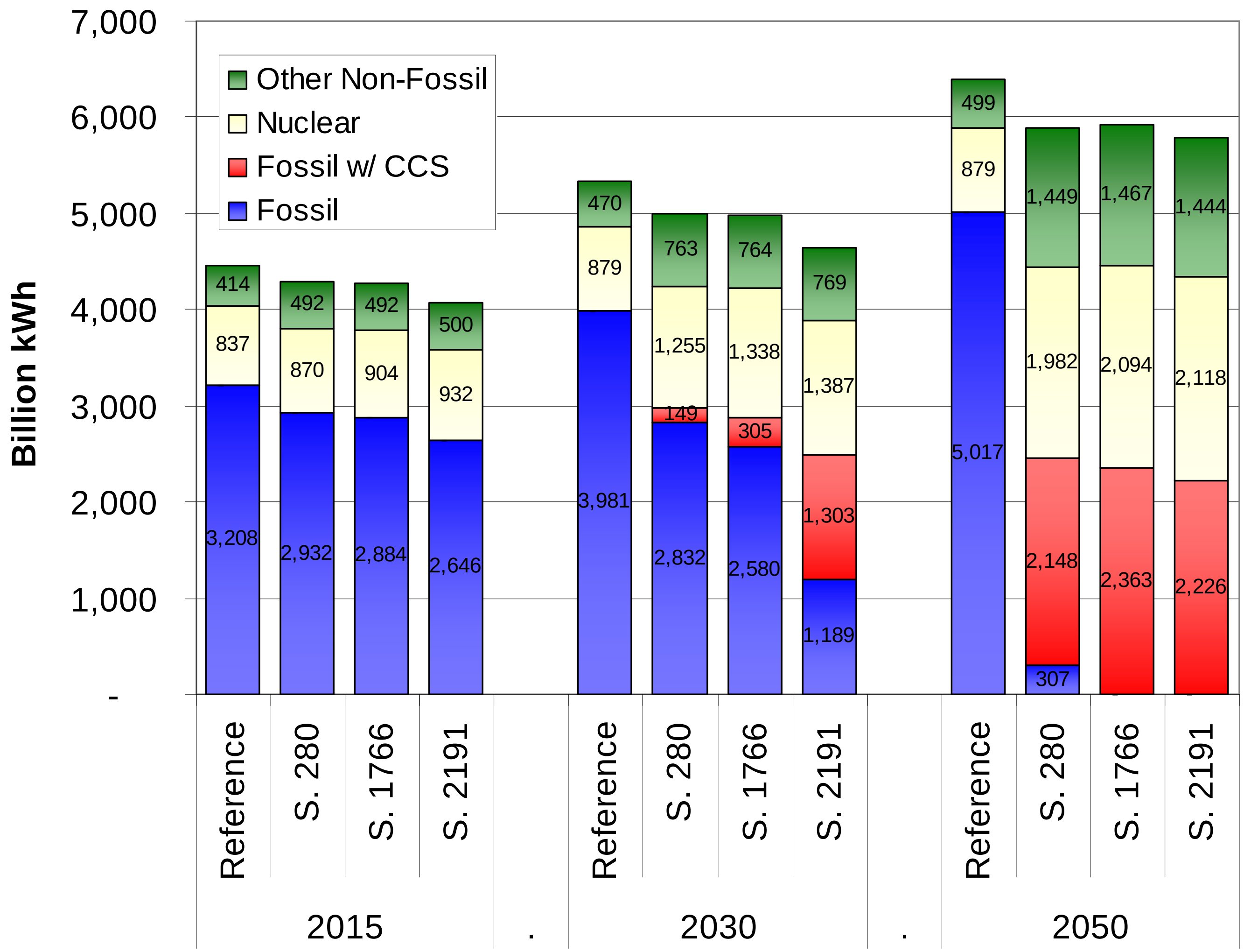
- There is are also considerable re-powering of coal to natural gas in the S. 2191 case.

Note: Regional coal production data includes coal production for power generation only.

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

Electricity Generation (Billion kWh) (ADAGE)



S. 280 Other Non-Fossil Generation Sensitivity

(ADAGE)

- The representation of renewable energy in ADAGE changed between the S. 280 analysis and the S. 1766 and S. 2191 analyses.
- For the S. 280 analysis, much of the non-fossil electricity generation in ADAGE was exogenously fixed, so the analysis showed very little increase in renewable energy compared to the reference case.
- For this analyses of S. 1766 and S. 2191, ADAGE augmented its representation of other non-fossil generation with the response curves for biomass electricity generation from the FASOM model.
- The following results show the impact of including this updated representation of biomass electricity generation on the ADAGE 'S. 280 Senate Scenario' from EPA's analysis of S. 280.
    - Other non-fossil electricity generation grows by ~250% from 2010 to 2050. In comparison, the original S. 280 analysis showed growth of ~30% over the same time period.
    - With increased renewable electricity generation, less fossil with CCS generation is required.
    - Allowance prices start at ~ $1.8 lower in 2015 than in EPA's original S. 280 analysis. The allowance price is $23.0 in 2030, and $60.8 /t$CO_2$e in 2050. In comparison, the original S. 280 analysis yielded allowance prices of $26.6 in 2030, and $70.3 /t$CO_2$e in 2050.
    - GDP impacts are slightly smaller (-0.51% in 2030, and -1.06% in 2050). Under the original S. 280 analysis, GDP impacts were -0.55% in 2030, and -1.07% in 2050.

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

GDP

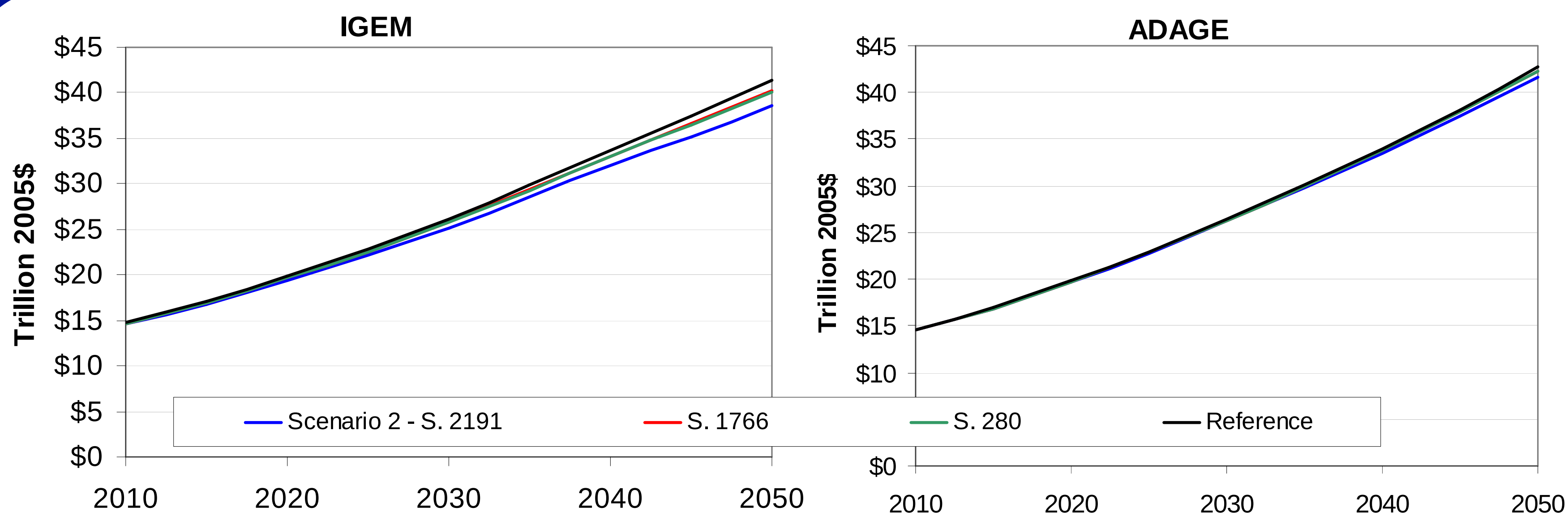


Table: **Impact of S. 280, S.1766, and S. 2191 on U.S. GDP (Billion 2005 Dollars)**

IGEM

	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Absolute Change	-$138	-$506	-$983	-$1,752	-$2,856
% Change	-0.94%	-2.55%	-3.76%	-5.20%	-6.90%
S. 1766					
Absolute Change	-$51	-$182	-$369	-$690	-$1,196
% Change	-0.34%	-0.92%	-1.41%	-2.05%	-2.89%
S. 280					
Absolute Change	-$55	-$206	-$419	-$775	-$1,328
% Change	-0.37%	-1.04%	-1.60%	-2.30%	-3.21%

ADAGE

	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Absolute Change	-$27	-$137	-$238	-$488	-$1,012
% Change	-0.18%	-0.69%	-0.90%	-1.44%	-2.37%
S. 1766					
Absolute Change	-$17	-$78	-$124	-$200	-$401
% Change	-0.12%	-0.39%	-0.47%	-0.59%	-0.94%
S. 280					
Absolute Change	-$15	-$71	-$133	-$208	-$430
% Change	-0.10%	-0.36%	-0.50%	-0.61%	-1.01%

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

Consumption

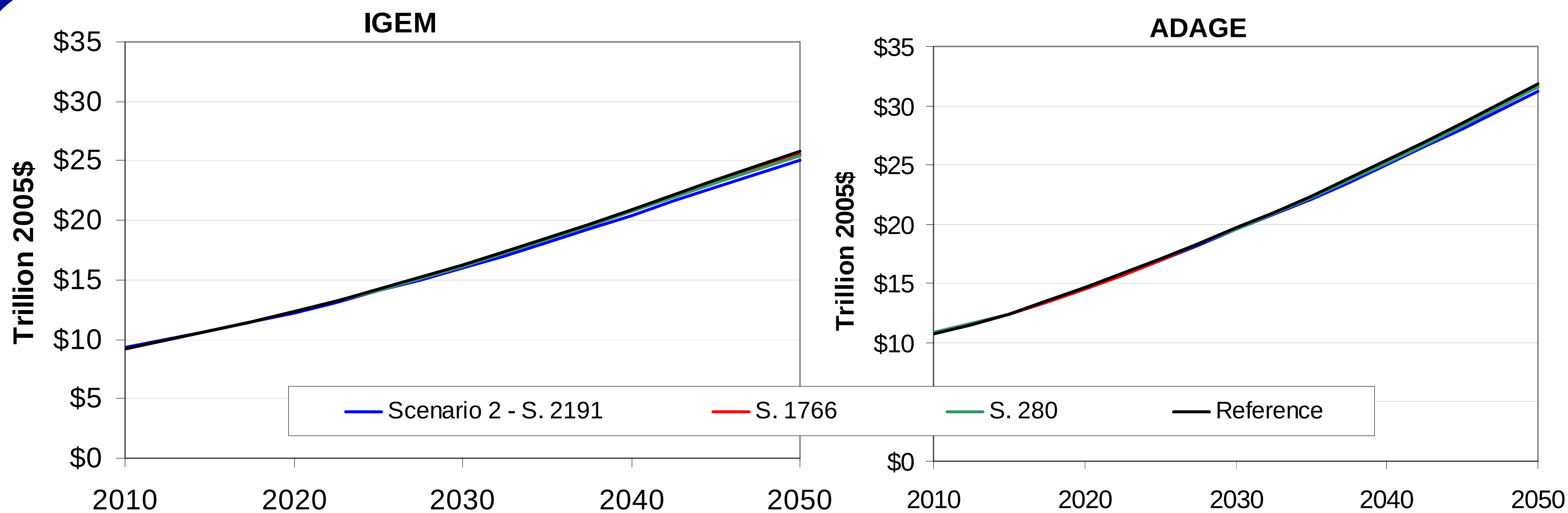


Table: **Impact of S. 280, S.1766, and S. 2191 on U.S. Consumption (2005 Dollars)**

IGEM

	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Change Per HH	$300	-$608	-$1,574	-$2,943	-$4,771
% Change	0.39%	-0.66%	-1.44%	-2.28%	-3.26%
S. 1766					
Change Per HH	$110	-$176	-$511	-$989	-$1,656
% Change	0.14%	-0.19%	-0.47%	-0.77%	-1.13%
S. 280					
Change Per HH	$115	-$230	-$625	-$1,211	-$1,990
% Change	0.15%	-0.25%	-0.57%	-0.94%	-1.36%

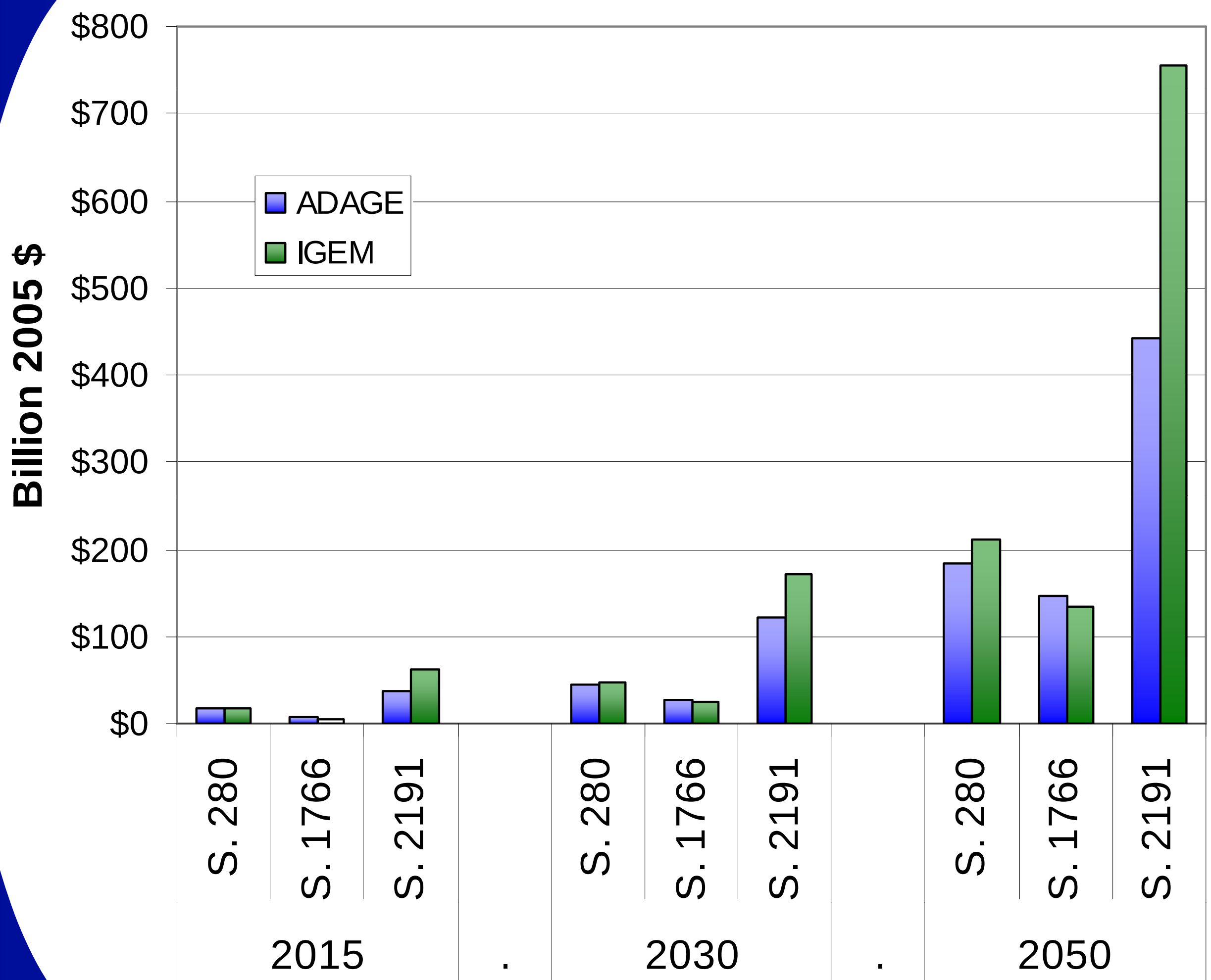
ADAGE

	2010	2020	2030	2040	2050
Scenario 2 - S. 2191					
Change Per HH	$574	-$446	-$1,176	-$2,188	-$3,984
% Change	0.69%	-0.43%	-0.91%	-1.39%	-2.10%
S. 1766					
Change Per HH	$214	-$333	-$459	-$785	-$1,590
% Change	0.26%	-0.32%	-0.36%	-0.50%	-0.84%
S. 280					
Change Per HH	$391	-$53	-$483	-$1,093	-$1,876
% Change	0.47%	-0.05%	-0.38%	-0.70%	-0.99%

Policy Comparison:

Lieberman-Warner (S. 2191) – Bingaman-Specter (S. 1766) – Lieberman-McCain (S. 280)

Total Abatement Cost



- Total abatement cost is simply the sum of domestic covered abatement cost, domestic offset abatement cost, and payments for international credits.
- Domestic covered abatement cost is approximated for each model as the product of domestic covered GHG emissions abatement and the allowance price divided by two.
  - Division by 2 is assumed to represent the fact that most reduction measures are not implemented at the marginal allowance price but at lower prices. In most cases, the relationship between emission reduction and the marginal price is a concave curve – which implies a value larger than 2. The value of 2, used here for simplicity leads to an overestimation of abatement costs.
- Domestic offset abatement cost is approximated for each model as the product of domestic offset abatement and the offset price divided by two.
- International credit payments are calculated for each model as the product of the amount of international credits purchased and the international credit price.
  - Unlike the abatement costs associated with domestic covered abatement and domestic offsets, there is no need for dividing by two when calculating the costs of international credits as all international credits are purchased at the full price of international allowances and those payments are sent abroad.

Appendix 4: Additional Information

Results: Scenario 2 - S. 2191

Fuel Price Adders for 2050 (ADAGE)

	2005 Price	2050 Producer Price	2050 Cost of Carbon Content	2050 End - User Price
Metric Ton of CO_2	n/a		$159.13	
Metric Ton of Carbon	n/a		$583.48	
Barrel of Oil	$50.28	$53.52	$68.11	$121.64
Gallon of Gasoline	$2.34	$2.49	$1.40	$3.89
Short Ton of Coal	$36.79	$39.40	$351.76	$391.16
Short Ton of Coal w/ CCS	$36.79	$39.40	$35.18	$74.58
tCf of Natural Gas	$7.51	$6.37	$8.65	$15.02

- The 2030 producer price is obtained by multiplying the 2030 index price in ADAGE by the 2005 price from EIA's 2006 Monthly Energy Review.
- The cost of carbon content is simply the product of the physical carbon content of the fuel and the allowance price.
- The end-user price is simply the sum of the producer price and the cost of carbon content.
- CCS technology for coal fired power generation captures and stores 90% of carbon emissions, which lowers the cost of carbon content by 90%, and lowers the consumer price accordingly.
- The cost of the carbon content increases the price of gasoline by 21%, increases the price of oil by 47%, increases the price of natural gas by 57%, increases the price of coal by 360%, and increases the price of coal used with CCS by 36%.
- Bonus allowances for CCS are not considered here.

Results: Scenario 7 - S. 2191 Constrained Nuclear, Biomass, and CCS

Fuel Price Adders for 2030 (ADAGE)

		2030		
	2005 Price	**Producer Price**	**Cost of Carbon Content**	**End - User Price**
Metric Ton of CO_2	n/a		$112.15	
Metric Ton of Carbon	n/a		$411.21	
Barrel of Oil	$50.28	$55.55	$48.00	$103.55
Gallon of Gasoline	$2.34	$2.59	$0.99	$3.57
Short Ton of Coal	$36.79	$38.20	$247.90	$286.10
Short Ton of Coal w/ CCS	$36.79	$38.20	$24.79	$62.99
tCf of Natural Gas	$7.51	$6.39	$6.10	$12.49

- The 2030 producer price is obtained by multiplying the 2030 index price in ADAGE by the 2005 price from EIA's 2006 Monthly Energy Review.
- The cost of carbon content is simply the product of the physical carbon content of the fuel and the allowance price.
- The end-user price is simply the sum of the producer price and the cost of carbon content.
- CCS technology for coal fired power generation captures and stores 90% of carbon emissions, which lowers the cost of carbon content by 90%, and lowers the consumer price accordingly.
- The cost of the carbon content increases the price of gasoline by 21%, increases the price of oil by 47%, increases the price of natural gas by 57%, increases the price of coal by 360%, and increases the price of coal used with CCS by 36%.
- Bonus allowances for CCS are not considered here.

* This slide was updated on 5/508 to correct the producer price values which were erroneously taken from Scenario 2.

Results: Scenario 7 - S. 2191 Constrained Nuclear, Biomass, and CCS

Fuel Price Adders for 2050 (ADAGE)

		2050		
	2005 Price	Producer Price	Cost of Carbon Content	End - User Price
Metric Ton of CO_2	n/a		$290.14	
Metric Ton of Carbon	n/a		$1,063.83	
Barrel of Oil	$50.28	$55.47	$124.19	$179.66
Gallon of Gasoline	$2.34	$2.58	$2.56	$5.14
Short Ton of Coal	$36.79	$43.41	$641.35	$684.76
Short Ton of Coal w/ CCS	$36.79	$43.41	$64.13	$107.55
tCf of Natural Gas	$7.51	$7.23	$15.78	$23.01

- The 2030 producer price is obtained by multiplying the 2030 index price in ADAGE by the 2005 price from EIA's 2006 Monthly Energy Review.
- The cost of carbon content is simply the product of the physical carbon content of the fuel and the allowance price.
- The end-user price is simply the sum of the producer price and the cost of carbon content.
- CCS technology for coal fired power generation captures and stores 90% of carbon emissions, which lowers the cost of carbon content by 90%, and lowers the consumer price accordingly.
- The cost of the carbon content increases the price of gasoline by 21%, increases the price of oil by 47%, increases the price of natural gas by 57%, increases the price of coal by 360%, and increases the price of coal used with CCS by 36%.
- Bonus allowances for CCS are not considered here.

* This slide was updated on 5/508 to correct the producer price values which were erroneously taken from Scenario 2.

Results: Scenario 2 – S. 2191

2030 Sectoral Results (Sectors 1 – 18) (IGEM)

Sector	2007	2030				
		Reference		S.2191 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Agriculture, forestry, fisheries	511	1029	101%	1115	118%	8%
Metal mining	83	165	98%	149	80%	-9%
Coal mining	30	42	39%	18	-41%	-58%
Crude oil and gas extraction	165	241	46%	207	26%	-14%
Non-metallic mineral mining	17	15	-11%	13	-20%	-10%
Construction	1195	1639	37%	1561	31%	-5%
Food and kindred products	587	1199	104%	1304	122%	9%
Tobacco manufactures	34	60	79%	68	104%	14%
Textile mill products	86	239	178%	217	153%	-9%
Apparel and other textile products	81	226	180%	218	170%	-4%
Lumber and wood products	153	344	124%	316	106%	-8%
Furniture and fixtures	104	234	125%	219	111%	-6%
Paper and allied products	225	577	156%	541	140%	-6%
Printing and publishing	253	457	81%	445	76%	-3%
Chemicals and allied products	535	1453	172%	1274	138%	-12%
Petroleum refining	307	403	31%	297	-4%	-27%
Rubber and plastic products	226	571	152%	526	132%	-8%
Leather and leather products	13	35	167%	34	155%	-4%

Results: Scenario 2 – S. 2191
2030 Sectoral Results (Sectors 19 – 35) (IGEM)

Sector	2007	2030				
		Reference		S.2191 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Stone, clay and glass products	121	259	114%	247	104%	-5%
Primary metals	213	465	119%	409	92%	-12%
Fabricated metal products	329	649	97%	598	82%	-8%
Non-electrical machinery	655	2478	278%	2296	250%	-7%
Electrical machinery	465	3401	631%	3161	580%	-7%
Motor vehicles	532	1137	114%	1060	99%	-7%
Other transportation equipment	227	436	92%	418	84%	-4%
Instruments	261	587	125%	562	115%	-4%
Miscellaneous manufacturing	69	182	166%	174	154%	-4%
Transportation and warehousing	707	1334	89%	1260	78%	-5%
Communications	537	1181	120%	1175	119%	0%
Electric utilities (services)	399	569	43%	460	15%	-19%
Gas utilities (services)	52	63	20%	43	-17%	-31%
Wholesale and retail trade	2590	4883	89%	4657	80%	-5%
Finance, insurance and real estate	2743	6307	130%	6230	127%	-1%
Personal and business services	4468	8419	88%	8367	87%	-1%
Government enterprises	467	874	87%	847	81%	-3%

Results: Scenario 2 – S. 2191

2050 Sectoral Results (Sectors 1 – 18) (IGEM)

Sector	2007	2050				
		Reference		S.2191 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Agriculture, forestry, fisheries	511	1515	197%	1688	231%	11%
Metal mining	83	256	208%	217	161%	-15%
Coal mining	30	53	77%	13	-56%	-75%
Crude oil and gas extraction	165	325	97%	235	43%	-28%
Non-metallic mineral mining	17	19	15%	16	-2%	-15%
Construction	1195	2272	90%	2100	76%	-8%
Food and kindred products	587	1857	216%	2214	277%	19%
Tobacco manufactures	34	95	183%	125	273%	32%
Textile mill products	86	409	377%	355	314%	-13%
Apparel and other textile products	81	412	411%	384	375%	-7%
Lumber and wood products	153	633	313%	549	258%	-13%
Furniture and fixtures	104	352	239%	316	204%	-10%
Paper and allied products	225	1010	348%	897	298%	-11%
Printing and publishing	253	713	182%	675	167%	-5%
Chemicals and allied products	535	2626	391%	2091	291%	-20%
Petroleum refining	307	478	55%	250	-19%	-48%
Rubber and plastic products	226	901	298%	776	243%	-14%
Leather and leather products	13	62	367%	56	324%	-9%

Results: Scenario 2 – S. 2191

2050 Sectoral Results (Sectors 19 – 35) (IGEM)

Sector	2007	2050				
		Reference		S.2191 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Stone, clay and glass products	121	468	287%	454	276%	-3%
Primary metals	213	768	261%	612	188%	-20%
Fabricated metal products	329	1023	211%	892	171%	-13%
Non-electrical machinery	655	4636	608%	4076	522%	-12%
Electrical machinery	465	7752	1567%	6833	1370%	-12%
Motor vehicles	532	1888	255%	1684	216%	-11%
Other transportation equipment	227	702	210%	654	188%	-7%
Instruments	261	894	242%	835	220%	-7%
Miscellaneous manufacturing	69	329	379%	304	342%	-8%
Transportation and warehousing	707	2006	184%	1808	156%	-10%
Communications	537	1920	258%	1913	256%	0%
Electric utilities (services)	399	731	83%	479	20%	-35%
Gas utilities (services)	52	67	27%	31	-41%	-54%
Wholesale and retail trade	2590	7293	182%	6713	159%	-8%
Finance, insurance and real estate	2743	10257	274%	10085	268%	-2%
Personal and business services	4468	12694	184%	12603	182%	-1%
Government enterprises	467	1297	178%	1223	162%	-6%

Results: Scenario 10 – S. 2191 Alt. Ref.

2030 Sectoral Results (Sectors 1 – 18) (IGEM)

Sector	2007	2030				
		Alternative Reference			S.2191 Alt. Ref.	
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Agriculture, forestry, fisheries	510	1049	106%	1103	116%	5%
Metal mining	83	165	100%	151	83%	-9%
Coal mining	30	37	22%	19	-37%	-48%
Crude oil and gas extraction	165	243	47%	210	28%	-13%
Non-metallic mineral mining	16	15	-12%	13	-19%	-8%
Construction	1190	1645	38%	1566	32%	-5%
Food and kindred products	588	1240	111%	1292	120%	4%
Tobacco manufactures	34	63	87%	68	101%	7%
Textile mill products	86	238	179%	219	156%	-8%
Apparel and other textile products	81	227	181%	219	171%	-3%
Lumber and wood products	153	346	126%	319	109%	-8%
Furniture and fixtures	103	235	127%	220	114%	-6%
Paper and allied products	225	579	157%	544	142%	-6%
Printing and publishing	252	460	82%	446	77%	-3%
Chemicals and allied products	533	1455	173%	1292	142%	-11%
Petroleum refining	305	369	21%	306	0%	-17%
Rubber and plastic products	225	574	155%	530	135%	-8%
Leather and leather products	13	35	168%	34	157%	-4%

Results: Scenario 10 – S. 2191 Alt. Ref.

2030 Sectoral Results (Sectors 19 – 35) (IGEM)

Sector	2007	2030				
		Alternative Reference		S.2191 Alt. Ref.		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Stone, clay and glass products	120	261	117%	247	105%	-5%
Primary metals	211	466	120%	414	96%	-11%
Fabricated metal products	328	652	99%	602	84%	-8%
Non-electrical machinery	652	2498	283%	2311	255%	-7%
Electrical machinery	463	3429	641%	3181	588%	-7%
Motor vehicles	529	1148	117%	1066	101%	-7%
Other transportation equipment	226	439	94%	419	85%	-5%
Instruments	260	590	127%	564	117%	-4%
Miscellaneous manufacturing	68	183	168%	175	156%	-5%
Transportation and warehousing	707	1340	90%	1267	79%	-5%
Communications	537	1196	123%	1176	119%	-2%
Electric utilities (services)	396	540	36%	470	19%	-13%
Gas utilities (services)	52	61	18%	45	-13%	-26%
Wholesale and retail trade	2583	4894	90%	4677	81%	-4%
Finance, insurance and real estate	2743	6377	133%	6235	127%	-2%
Personal and business services	4468	8503	90%	8374	87%	-2%
Government enterprises	466	878	88%	849	82%	-3%

Results: Scenario 10 – S. 2191 Alt. Ref.

2050 Sectoral Results (Sectors 1 – 18) (IGEM)

Sector	2007	2050				
		Alternative Reference			S.2191 Alt. Ref.	
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Agriculture, forestry, fisheries	510	1551	204%	1663	226%	7%
Metal mining	83	256	211%	219	166%	-14%
Coal mining	30	46	54%	14	-52%	-69%
Crude oil and gas extraction	165	328	99%	242	47%	-26%
Non-metallic mineral mining	16	19	15%	16	0%	-13%
Construction	1190	2279	92%	2111	77%	-7%
Food and kindred products	588	1933	229%	2179	271%	13%
Tobacco manufactures	34	101	200%	122	264%	21%
Textile mill products	86	408	377%	361	321%	-12%
Apparel and other textile products	81	413	412%	386	379%	-6%
Lumber and wood products	153	636	316%	555	264%	-13%
Furniture and fixtures	103	352	241%	318	208%	-10%
Paper and allied products	225	1014	351%	905	303%	-11%
Printing and publishing	252	717	184%	678	169%	-6%
Chemicals and allied products	533	2628	393%	2137	301%	-19%
Petroleum refining	305	433	42%	265	-13%	-39%
Rubber and plastic products	225	906	302%	786	249%	-13%
Leather and leather products	13	62	368%	57	329%	-8%

Results: Scenario 10 – S. 2191 Alt. Ref.

2050 Sectoral Results (Sectors 19 – 35) (IGEM)

Sector	2007	2050				
		Alternative Reference			S.2191 Alt. Ref.	
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Stone, clay and glass products	120	474	294%	454	277%	-4%
Primary metals	211	768	263%	623	195%	-19%
Fabricated metal products	328	1027	213%	901	175%	-12%
Non-electrical machinery	652	4672	617%	4114	531%	-12%
Electrical machinery	463	7819	1590%	6896	1390%	-12%
Motor vehicles	529	1904	260%	1698	221%	-11%
Other transportation equipment	226	707	213%	657	191%	-7%
Instruments	260	897	245%	838	222%	-7%
Miscellaneous manufacturing	68	331	383%	306	347%	-8%
Transportation and warehousing	707	2018	186%	1824	158%	-10%
Communications	537	1946	263%	1913	256%	-2%
Electric utilities (services)	396	687	74%	497	25%	-28%
Gas utilities (services)	52	64	24%	33	-36%	-48%
Wholesale and retail trade	2583	7301	183%	6757	162%	-7%
Finance, insurance and real estate	2743	10389	279%	10090	268%	-3%
Personal and business services	4468	12831	187%	12611	182%	-2%
Government enterprises	466	1302	179%	1229	164%	-6%

Results: Scenario 2 – S. 2191
International Trade Leakage – All Sectors (ADAGE)

Change in Trade Quantities		2010	2020	2030	2040	2050
		Scenario 2 - S.2191				
Agriculture	U.S. Imports from Group 1	-2.5%	-3.5%	-2.4%	-3.4%	-5.6%
	U.S. Exports to Group 1	4.1%	5.2%	5.3%	7.6%	8.9%
	U.S. Imports from Group 2	2.7%	6.2%	-4.0%	-5.7%	-7.8%
	U.S. Exports to Group 2	-5.4%	-10.4%	-5.4%	-6.1%	-5.4%
Energy-Intensive Manufacturing	U.S. Imports from Group 1	-0.1%	0.2%	0.9%	-0.1%	-1.6%
	U.S. Exports to Group 1	1.1%	1.0%	-1.8%	-1.9%	-2.3%
	U.S. Imports from Group 2	4.7%	8.7%	-6.6%	-12.0%	-13.6%
	U.S. Exports to Group 2	-5.0%	-9.4%	-0.6%	2.2%	4.4%
Other Manufacturing	U.S. Imports from Group 1	1.8%	2.6%	3.7%	3.8%	3.7%
	U.S. Exports to Group 1	-1.1%	0.3%	-0.5%	-0.7%	-1.6%
	U.S. Imports from Group 2	3.4%	4.5%	0.3%	-2.6%	-2.9%
	U.S. Exports to Group 2	-4.5%	-7.9%	-7.0%	-6.4%	-4.9%
Services	U.S. Imports from Group 1	1.6%	1.1%	2.1%	2.4%	2.5%
	U.S. Exports to Group 1	-0.3%	0.1%	0.8%	0.6%	0.2%
	U.S. Imports from Group 2	3.3%	4.0%	3.0%	0.4%	-0.7%
	U.S. Exports to Group 2	-4.5%	-6.5%	-9.8%	-9.1%	-7.9%
Transportation Services	U.S. Imports from Group 1	-0.9%	3.8%	4.7%	6.6%	9.9%
	U.S. Exports to Group 1	2.5%	-3.8%	-6.4%	-9.1%	-12.6%
	U.S. Imports from Group 2	6.0%	13.5%	1.3%	-3.1%	-4.8%
	U.S. Exports to Group 2	-4.9%	-14.4%	-12.3%	-13.0%	-11.5%

* This slide was updated on 5/508 to correct the sign of the changes in trade quantities.

Results: Scenario 3 – S. 2191, Alternative International Action
International Trade Leakage – All Sectors (ADAGE)

Change in Trade Quantities		Scenario 3 - Alternative International Action 2010	2020	2030	2040	2050
Agriculture	U.S. Imports from Group 1	-1.7%	-1.0%	-0.9%	1.9%	5.5%
	U.S. Exports to Group 1	2.4%	1.4%	1.5%	0.0%	-2.2%
	U.S. Imports from Group 2	1.6%	3.7%	4.7%	6.5%	9.3%
	U.S. Exports to Group 2	-3.2%	-5.6%	-6.8%	-7.5%	-8.8%
Energy-Intensive Manufacturing	U.S. Imports from Group 1	-0.3%	1.0%	1.7%	3.4%	6.3%
	U.S. Exports to Group 1	0.7%	-0.6%	-0.8%	-1.5%	-2.7%
	U.S. Imports from Group 2	3.0%	3.7%	1.5%	-2.2%	-5.5%
	U.S. Exports to Group 2	-3.1%	-5.3%	-6.3%	-6.7%	-7.7%
Other Manufacturing	U.S. Imports from Group 1	0.6%	0.8%	1.3%	1.8%	3.4%
	U.S. Exports to Group 1	-0.8%	-1.3%	-1.6%	-1.6%	-1.9%
	U.S. Imports from Group 2	2.1%	2.4%	2.4%	1.9%	2.3%
	U.S. Exports to Group 2	-2.4%	-3.5%	-4.4%	-4.9%	-5.4%
Services	U.S. Imports from Group 1	1.0%	0.3%	0.5%	0.3%	0.8%
	U.S. Exports to Group 1	-0.2%	-0.3%	-0.6%	-0.4%	-0.4%
	U.S. Imports from Group 2	1.7%	1.5%	1.9%	1.9%	2.3%
	U.S. Exports to Group 2	-2.8%	-3.3%	-3.9%	-4.2%	-4.5%
Transportation Services	U.S. Imports from Group 1	0.0%	5.3%	4.3%	8.1%	15.6%
	U.S. Exports to Group 1	1.5%	-5.4%	-9.2%	-13.7%	-18.4%
	U.S. Imports from Group 2	4.0%	9.9%	10.4%	13.6%	20.0%
	U.S. Exports to Group 2	-2.9%	-10.5%	-15.2%	-19.3%	-23.4%

* This slide was updated on 5/508 to correct the sign of the changes in trade quantities.

Results: Scenario 8 – S. 2191, Constrained Nuclear, Biomass and CCS + Beyond Kyoto + Natural Gas Cartel

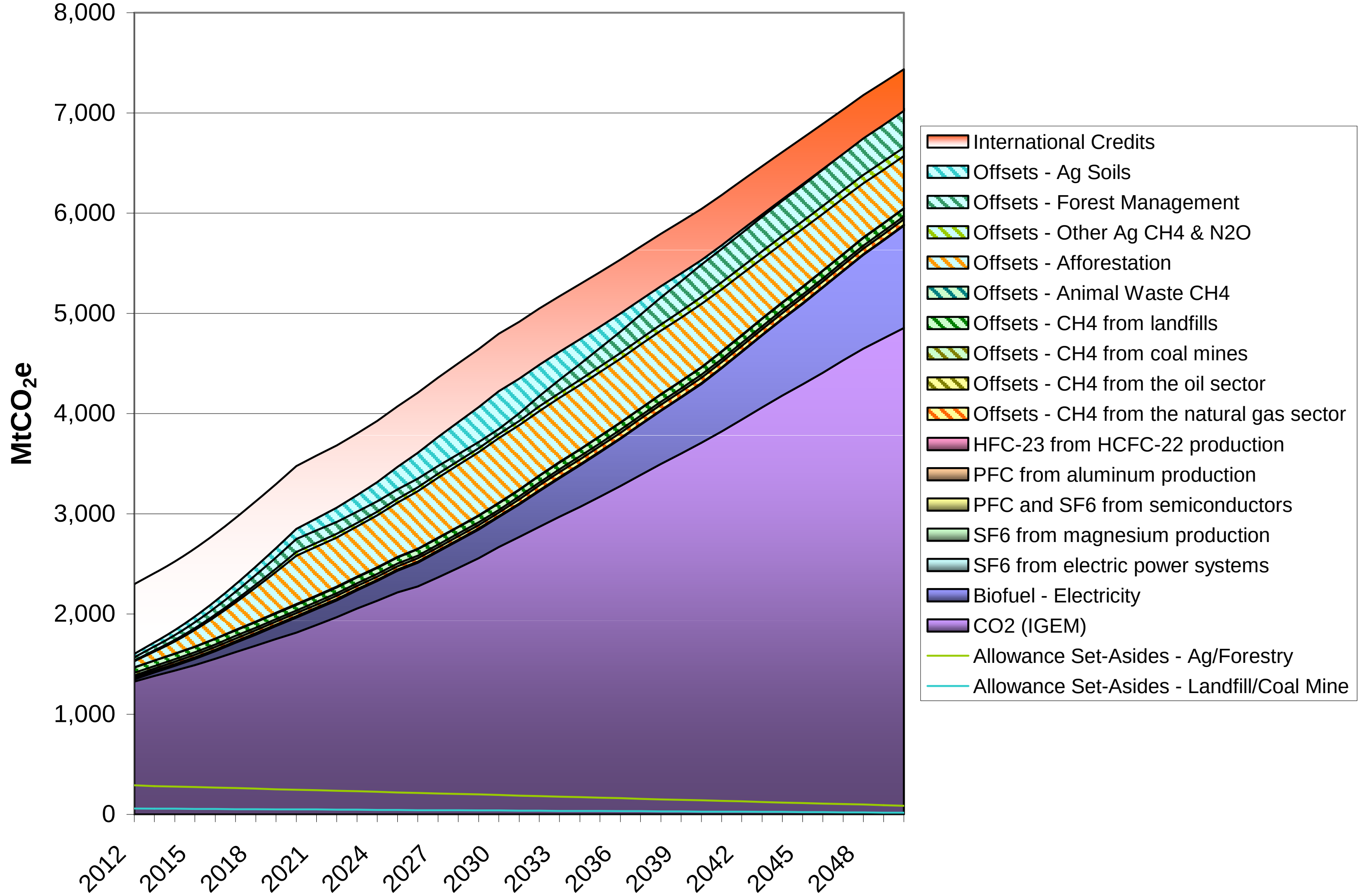
International Trade Leakage – All Sectors (ADAGE)

Scenario 8 - S. 2191 Constrain Nuclear, Biomass, CCS, Beyond Kyoto, and Natural Gas Cartel						
Change in Trade Quantities		**2010**	**2020**	**2030**	**2040**	**2050**
Agriculture	U.S. Imports from Group 1	-3.9%	-6.3%	-6.2%	-8.3%	-10.7%
	U.S. Exports to Group 1	5.1%	6.3%	6.8%	9.6%	11.9%
	U.S. Imports from Group 2	2.9%	6.3%	-8.3%	-11.0%	-13.7%
	U.S. Exports to Group 2	-6.6%	-13.2%	-5.9%	-6.9%	-7.1%
Energy-Intensive Manufacturing	U.S. Imports from Group 1	-0.7%	-0.2%	0.3%	-0.4%	-1.0%
	U.S. Exports to Group 1	1.4%	0.6%	-2.8%	-3.9%	-5.2%
	U.S. Imports from Group 2	5.8%	11.5%	-8.3%	-14.2%	-19.2%
	U.S. Exports to Group 2	-6.1%	-12.7%	-1.6%	1.3%	4.3%
Other Manufacturing	U.S. Imports from Group 1	2.0%	2.7%	3.9%	4.6%	5.8%
	U.S. Exports to Group 1	-1.7%	0.1%	-0.5%	-1.6%	-3.3%
	U.S. Imports from Group 2	3.8%	5.0%	-0.6%	-3.6%	-5.5%
	U.S. Exports to Group 2	-5.7%	-10.8%	-9.9%	-9.0%	-7.8%
Services	U.S. Imports from Group 1	2.0%	0.7%	1.6%	2.1%	3.3%
	U.S. Exports to Group 1	-0.8%	-0.4%	0.8%	0.3%	-0.9%
	U.S. Imports from Group 2	4.3%	4.8%	3.2%	0.4%	-2.4%
	U.S. Exports to Group 2	-5.4%	-8.5%	-13.0%	-12.6%	-11.3%
Transportation Services	U.S. Imports from Group 1	-1.6%	7.2%	11.5%	16.0%	21.1%
	U.S. Exports to Group 1	2.8%	-8.1%	-10.8%	-15.4%	-22.2%
	U.S. Imports from Group 2	6.9%	20.1%	6.3%	2.9%	-1.5%
	U.S. Exports to Group 2	-6.0%	-21.0%	-17.4%	-19.0%	-21.1%

* This slide was updated on 5/508 to correct the sign of the changes in trade quantities.

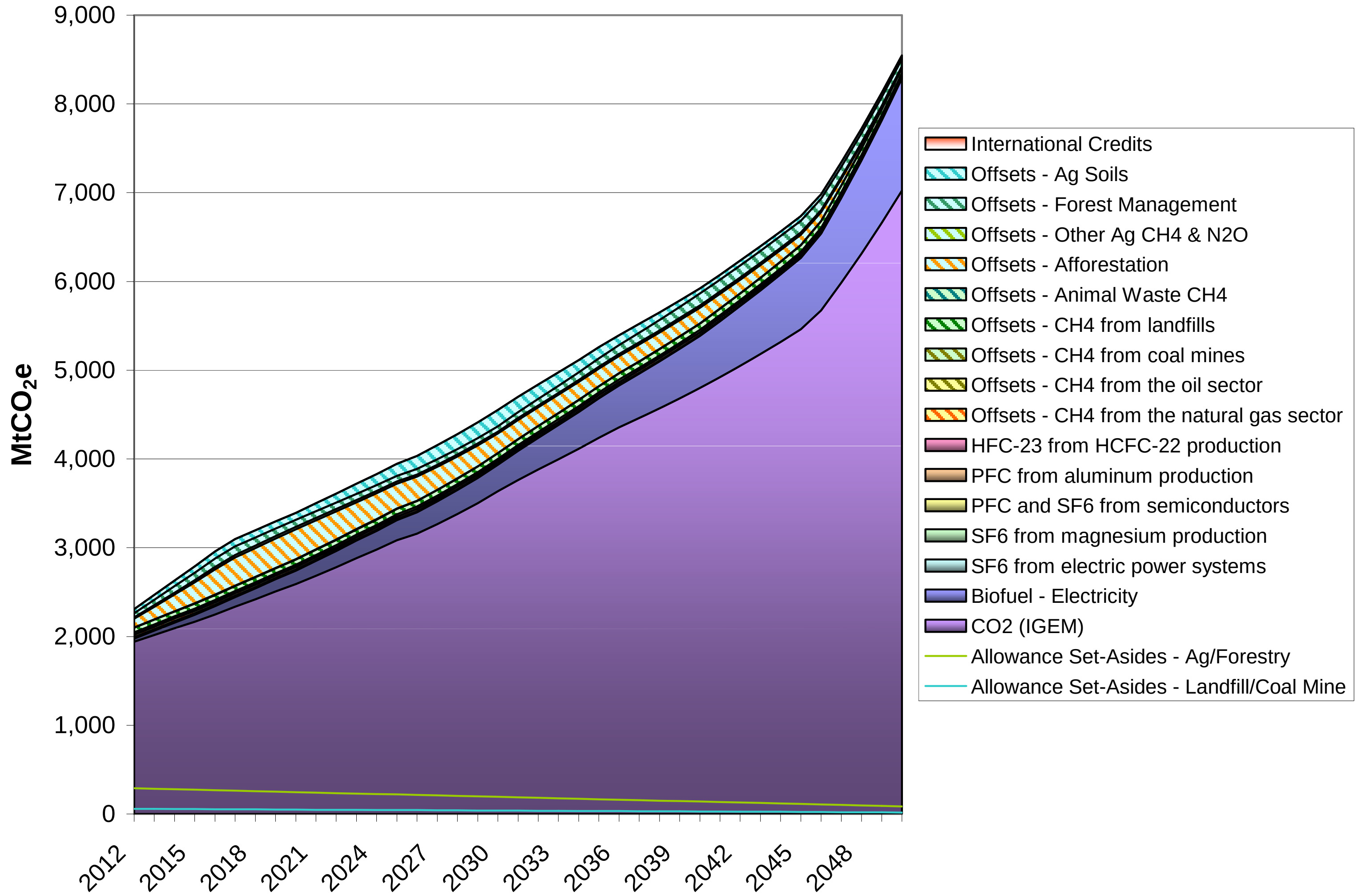
Results: S. 2191 – Unlimited Domestic Offsets, Limited Int'l Credits

Sources of GHG Abatement (IGEM)



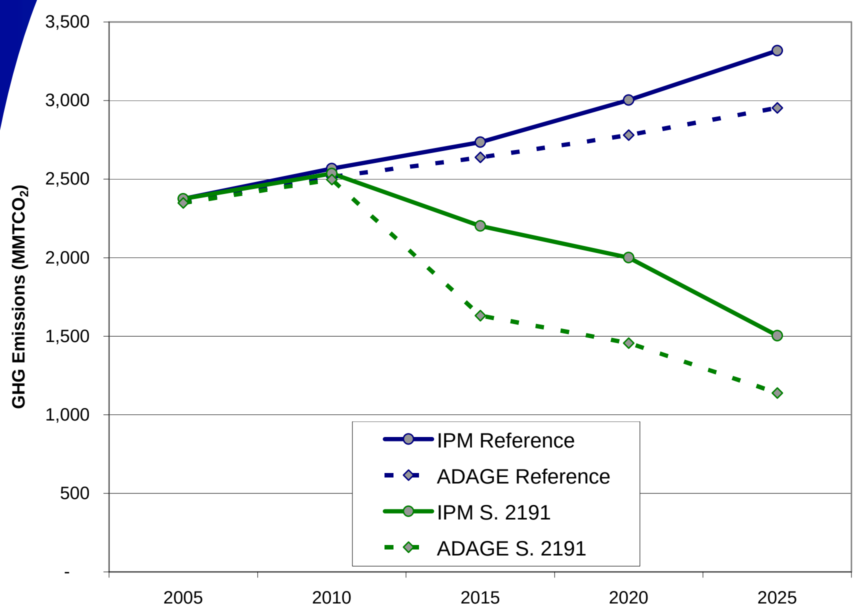
Results: S. 2191 – Limited Domestic Offsets, No Int'l Credits

Sources of GHG Abatement (IGEM)

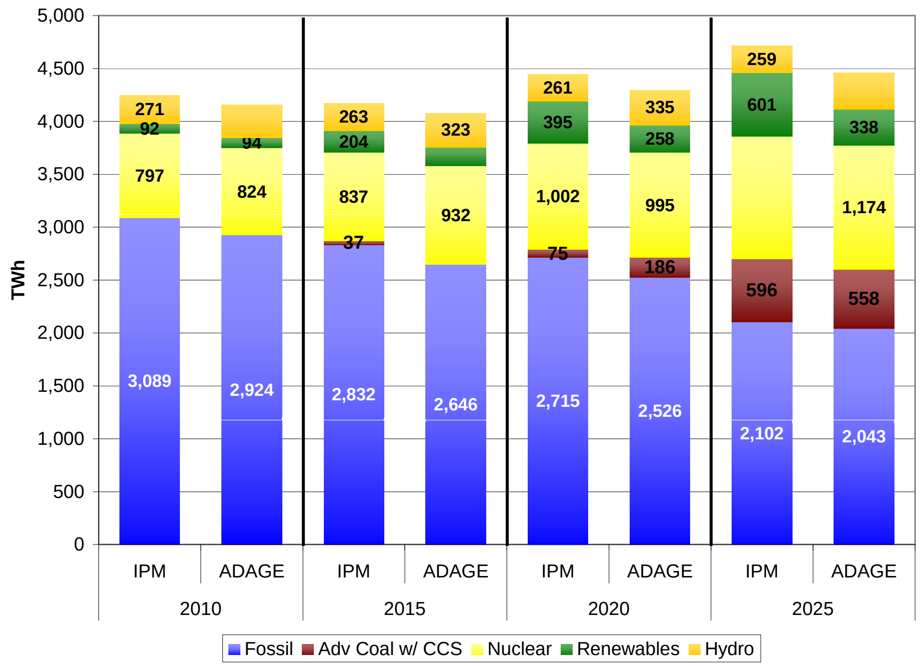


ADAGE & IPM Comparison of Power Sector Results

Power Sector CO_2 Emissions



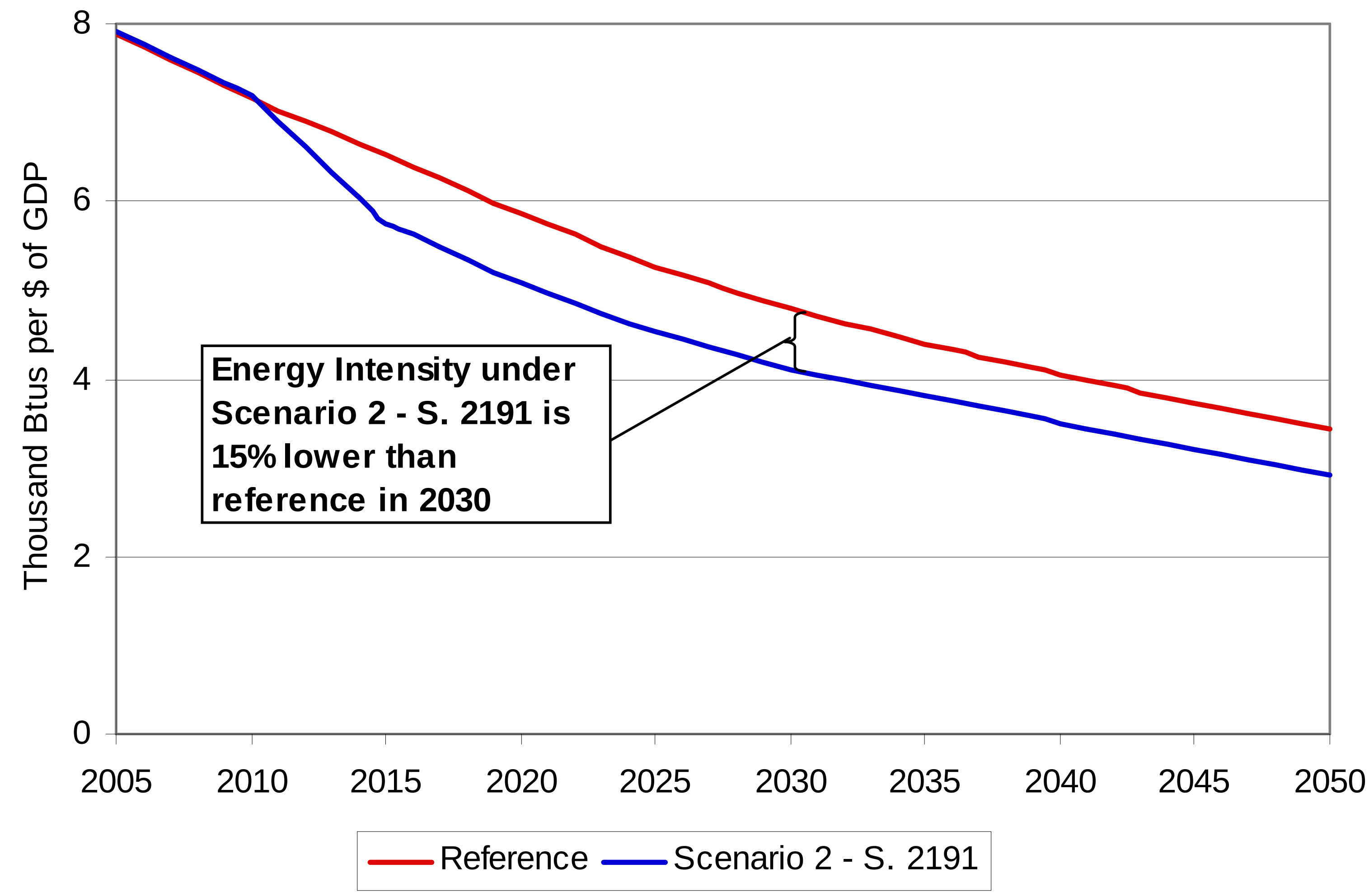
S. 2191 Scenario Electricity Generation Mix



- The ADAGE reference emissions are somewhat lower than IPM, and emission reductions under S. 2191 are greater prior to 2025.
- Electricity generation mix projections are similar, with slightly lower overall electricity demand in ADAGE compared to IPM and lower renewable generation.

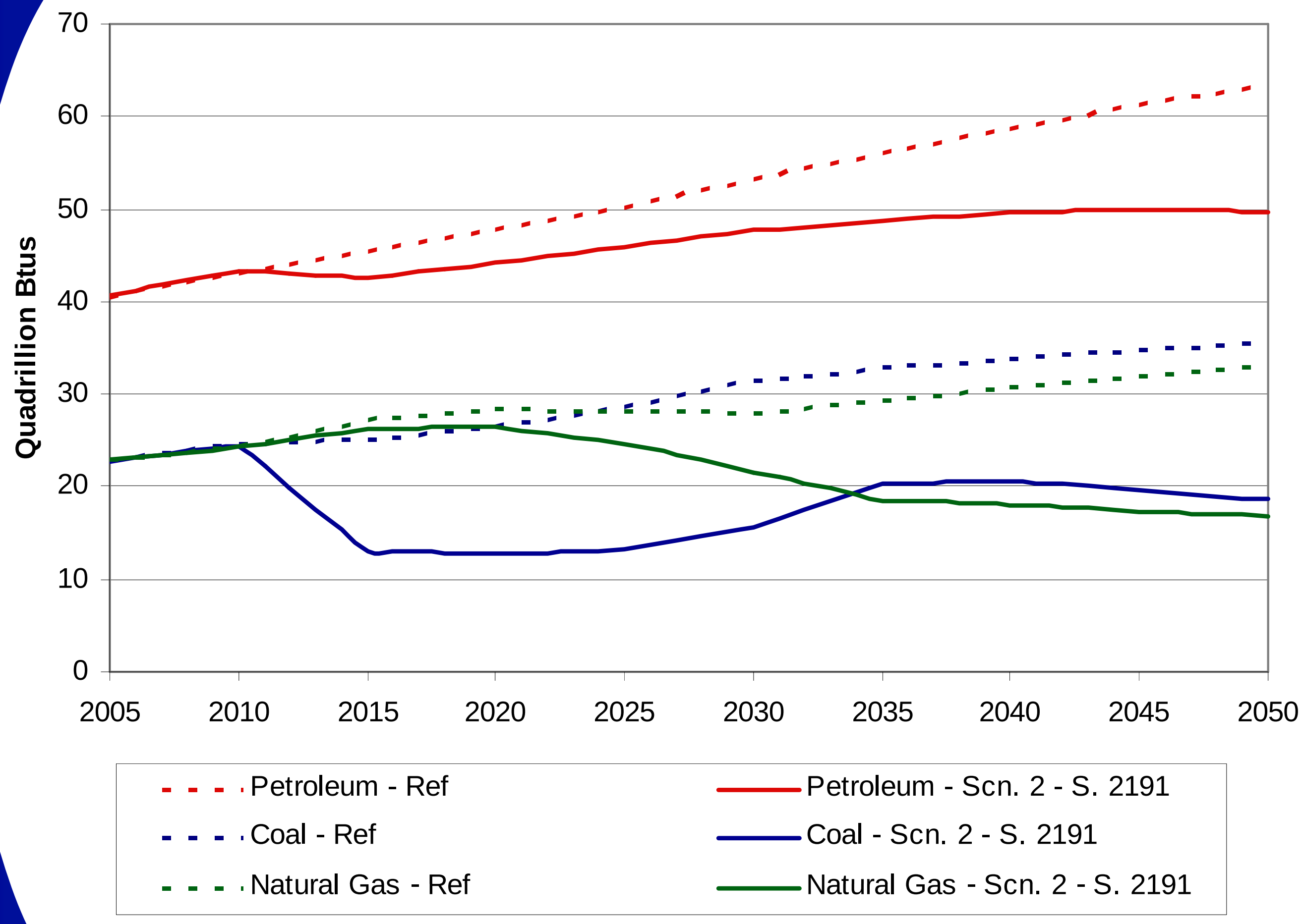
Results: Scenario 2 – S. 2191

Energy Intensity (ADAGE)



Results: Scenario 2 – S. 2191

Primary Energy Use (ADAGE)



- Growth in petroleum use is less under S. 2191 than in the Reference Scenario.
- Coal use falls as S. 2191 is implemented and fuel-switching to natural gas occurs, then rises again in the later years as advanced coal plants with CCS are deployed.
  - Note that the IPM analysis shows a much smaller impact on near-term coal usage.
- The natural gas use trend follows an opposite path to the coal use trend. Natural gas use increases in the earlier years as fuel-switching occurs, and then falls in the later years as CCS is deployed.

Appendix 5: Request Letters

Request for EPA Analysis

United States Senate
WASHINGTON, DC 20510

November 9, 2007

The Honorable Stephen L. Johnson
Administrator
Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Dear Administrator Johnson:

We are writing to request that EPA estimate the economic, greenhouse-gas emissions, and atmospheric greenhouse-gas concentration impacts of S.2191, America's Climate Security Act of 2007. A similar request is being sent to the Energy Information Administration.

We ask that EPA begin this process by meeting with our staff as soon as possible to discuss the parameters, methods, and duration of the analysis. Please call David McIntosh in Senator Lieberman's office at (202) 224-5016 or Chelsea Maxwell in Senator Warner's office at (202) 224-6283.

Thank you for your assistance with this analysis.

Sincerely,

Joseph I. Lieberman
UNITED STATES SENATOR

John Warner
UNITED STATES SENATOR

- On November 9, 2007 Senators Lieberman and Warner requested that EPA estimate the economic impacts of the S. 2191, the 'Climate Security Act of 2007' (now the 'Lieberman-Warner Climate Security Act of 2008').
- This document constitutes EPA's analysis in response to this request. The analysis is available online at:

www.epa.gov/climatechange/economics/economicanalyses.html

- The analysis was conducted by EPA's Office of Atmospheric Programs. Contact: Francisco de la Chesnaye. Tel: 202-343-9010. Email: delachesnaye.francisco@epa.gov.

United States Senate

WASHINGTON, DC 20510

October 5, 2007

The Honorable Stephen L. Johnson
Administrator
Environmental Protection Agency
Areil Rios Federal Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Dear Mr. Johnson:

As Congress considers policies to address global climate change, the need for robust, objective, and well-grounded technical analysis of the impacts those policies will have on the American economy is imperative. We applaud the Environmental Protection Agency (EPA) for providing credible historical analyses over the years. However, we are concerned that, in its current forecasts, EPA is not considering realistic scenarios of our nation's energy future, and as a result, is not providing an accurate picture of the potential consequences arising from mandatory greenhouse gas emission controls.

As you are well aware, concern about climate change has reinforced opposition in some quarters against certain types of energy production. This seems to be especially true of coal, as the prospects for building new coal-fired power plants look increasingly dire.

The same seems to be true of natural gas, particularly whether producers will have access to domestic supplies. Moreover, opposition to construction of new liquefied natural gas terminals and expansion of domestic production and pipelines, international greenhouse gas mandates, and geopolitical instability also present serious risks for U.S. natural gas supplies. For example, talks of additional carbon reductions beyond those required by the Kyoto Protocol could severely constrain the global natural gas market, while recent news of a possible natural gas cartel between Russia and Iran greatly complicates an already bleak future for U.S. natural gas imports.

In addition, concern about climate change has sparked a renewed interest in nuclear power as a viable alternative to fossil fuels. Yet despite greater acceptance of this important, emissions-free energy resource, nuclear power still faces a host of obstacles and uncertainties that, if unresolved, could inhibit its expansion and prevent the construction of new plants.

These issues raise serious questions as to whether and how this country will meet growing energy demand while complying with constraints on carbon emissions. As such, we are requesting that your agency reanalyze S. 280, "The Climate Stewardship and Innovation Act of 2007," by taking these realities into account. Moreover, we are requesting that your agency factor these realities into *all future analyses of mandatory climate change legislation you undertake.*

Specifically, the reanalysis of S. 280 and all future analyses of climate legislation — including S. 1766, the Low Carbon Economy Act, which I understand you are analyzing now – must include an assessment of the factors outlined in the three following scenarios:

An Alternative Policy Case assuming:

- Nuclear power does not exceed AEO 2007 Reference Case growth through 2030 (increase of 12.5 GWe);
- Biomass power does not exceed AEO 2007 Reference Case growth through 2030 (increase of 64 Billion KWhrs).

Please refer to this alternative policy case as: Reference Nuclear and Biomass Power.

An Alternative Policy Case assuming the Reference Nuclear and Biomass Power case above and assuming:

- Carbon capture and sequestration technology does not become commercially available until 2030;

Please refer to this alternative policy analysis as: Constrained CCS.

An Alternative Policy Case assuming all of the above (Reference Nuclear and Biomass Power and Constrained CCS) and assuming:

- That GHG caps are implemented for all Kyoto Protocol Annex 1 signatory countries and are reduced to 20% below 1990 levels in 2020 and to 80% below 1990 levels in 2050; and
- A functioning natural gas cartel, using the same basic modeling approach used in EIA's assessments of the Organization of the Petroleum Exporting Countries (OPEC) operations.

Please refer to this alternative policy analysis as: Beyond Kyoto Plus Natural Gas Cartel.

The July 2007 EPA analysis of S. 280, the Climate Stewardship and Innovation Act of 2007, identified a number of concerns and key assumptions as well as a number of different models used.

Please provide a description of the model or models that EPA uses to:

1. Determine the marginal abatement curves for greenhouse gases, including CO2;
2. The domestic supply and prices of natural gas;
3. The global supply and prices of natural gas;
4. The deployment of technologies, including advanced coal technologies and carbon capture and storage;
5. The economic impact of policy options at the regional and local level; and
6. The economic impact of policy options out to 2050.

For the documentation above please provide information on the compliance of any model used with the EPA's guidelines under Federal Data Quality Guidelines, including model validation by comparing past natural gas forecasts with real data. Also, provide appropriate documentation on these models prepared by EPA's Council for Regulatory Environmental Modeling.

Please provide a detailed comparison between EPA's reference case and EIA's AEO 2007 Reference Case. If EPA has run its models for any constrained natural gas supply case, e.g. comparable to the AEO 2007 Low LNG Case, please provide the data.

Finally, in the recent EIA analysis of S 280 there was reference to use of analysis by MIT. Please explain the extent to which EPA used MIT analysis in providing support for the EIA analysis.

An expedited process would be greatly appreciated as a credible analysis is critical to a well-informed debate concerning climate change and related energy policy choices now before Congress. Either Todd Johnston (202-224-9325), or John Shanahan (202-224-6176), is available to work with you to clarify any issues. Thank you for your attention to this.

Sincerely,

James M. Inhofe
United States Senator

George V. Voinovich
United States Senator

John Barrasso
United States Senator

United States Senate
WASHINGTON, DC 20510

November 16, 2007

The Honorable Stephen L. Johnson
Administrator
Environmental Protection Agency
Ariel Rios Federal Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Dear Mr. Johnson:

This is a supplemental request to our letter of October 5, 2007 requesting additional analysis of S. 280. We are anxious to receive your response to that letter.

Another proposal to limit greenhouse gas emissions, S. 2191, has been introduced. We understand that Senators Lieberman and Warner requested EPA analysis of their bill and we wanted to assure that your evaluation addressed all interests, and is as comprehensive as possible.

Therefore, in addition to the alternative scenarios outlined in our previous correspondence, we are requesting that your agency provide analysis of S. 2191 using some of the assumptions in your analysis of S. 280. The assumptions are as follows:

Non-Policy Cases:

Reference: Reference case used in the S 280 analysis.

Low LNG Case and Global Carbon Constraint:

- LNG import terminals are limited to those operational by the end of 2008,
- GHG caps are implemented for ALL Kyoto Protocol Annex 1 signatory countries and are reduced to 20% below 1990 levels in 2020 and on a trajectory to 80% below 1990 levels in 2050; and
- A functioning natural gas cartel that can extract natural gas prices equivalent to the energy content parity with Low Sulfur Light imported crude.

Policy Cases:

- The policy cases should include the Core S. 2191 case, the no international offsets case, and the 30 percent fixed offset case patterned after your S 280 analysis.

Alternative Policy Cases:

Your analysis of S. 2191 should include an assessment of the factors outlined in the two following scenarios:

An Alternative Policy Case assuming:

- Nuclear power does not exceed AEO 2007 Reference Case growth through 2030; and
- Biomass power does not exceed AEO 2007 Reference Case growth through 2030.

Please refer to this alternative policy case as: Reference Nuclear and Biomass Power (RefNB).

An Alternative Policy Case assuming the Reference Nuclear and Biomass Power case above and assuming:

- Carbon capture and sequestration technology does not become commercially available until 2030;

Please refer to this alternative policy analysis as: Constrained CCS (RefNB+noCCS).

We have attached a table that summarizes these cases.

In addition, since the costs of greenhouse gas controls escalate over time, an accurate account for the impacts between 2030 and 2050 is required. Therefore, in your analysis of S. 2191, please provide estimates of the economic impacts for the period 2030-2050 including the aggregate loss of GDP for the periods 2008-2030, 2030-2050, and 2008-2050.

EPA should also provide natural gas, electricity, and economic impact data at the state and regional level.

Letter to Administrator Stephen Johnson
November 16, 2007
Page 3

An expedited process of this request is appreciated; we expect the results to be released in conjunction with the information provided in response to the request of Senators Lieberman and Warner. Todd Johnston (202-224-9325) and John Shanahan (202-224-8072) are available to work with you to clarify any issues. Thank you for your prompt attention to our request.

Sincerely,

James M. Inhofe
United States Senator

George V. Voinovich
United States Senator

John Barrasso
United States Senator

Appendix 6: Model Descriptions

Intertemporal General Equilibrium Model (IGEM)

- IGEM is a model of the U.S. economy with an emphasis on the energy and environmental aspects.
- It is a dynamic model, which depicts growth of the economy due to capital accumulation, technical change and population change.
- It is a detailed multi-sector model covering 35 industries.
- It also depicts changes in consumption patterns due to demographic changes, price and income effects.
- The model is designed to simulate the effects of policy changes, external shocks and demographic changes on the prices, production and consumption of energy, and the emissions of pollutants.
- The main driver of economic growth in this model is capital accumulation and technological change. It also includes official projections of the population, giving us activity levels in both level and per-capita terms.
- Capital accumulation arises from savings of a household that is modeled as an economic actor with "perfect foresight."

- This model is implemented econometrically which means that the parameters governing the behavior of producers and consumers are statistically estimated over a time series dataset that is constructed specifically for this purpose.
- This is in contrast to many other multi-sector models that are calibrated to the economy of one particular year.
- These data are based on a system of national accounts developed by Jorgenson (1980) that integrates the capital accounts with the National Income Accounts.
- These capital accounts include an equation linking the price of investment goods to the stream of future rental flows, a link that is essential to modeling the dynamics of growth.

- The model is developed and run by Dale Jorgenson Associates for EPA.
- Model Homepage: http://post.economics.harvard.edu/faculty/jorgenson/papers/papers.html

Applied Dynamic Analysis of the Global Economy (ADAGE)

- ADAGE is a dynamic computable general equilibrium (CGE) model capable of examining many types of economic, energy, environmental, climate-change mitigation, and trade policies at the international, national, U.S. regional, and U.S. state levels.
- To investigate policy effects, the CGE model combines a consistent theoretical structure with economic data covering all interactions among businesses and households.
- A classical Arrow-Debreu general equilibrium framework is used to describe economic behaviors of these agents.

- ADAGE has three distinct modules: International, U.S. Regional, and Single Country.
- Each module relies on different data sources and has a different geographic scope, but all have the same theoretical structure.
- This internally consistent, integrated framework allows its components to use relevant policy findings from other modules with broader geographic coverage, thus obtaining detailed regional and state-level results that incorporate international impacts of policies.
- Economic data in ADAGE come from the GTAP and IMPLAN databases, and energy data and various growth forecasts come from the International Energy Agency and Energy Information Administration of the U.S. Department of Energy.
- Emissions estimates and associated abatement costs for six types of greenhouse gases (GHGs) are also included in the model.

- The model is developed and run by RTI International for EPA.
- Model Homepage: http://www.rti.org/adage

Non-CO_2 GHG Models

- EPA develops and houses projections and economic analyses of emission abatement through the use of extensive bottom-up, spreadsheet models.
- These are engineering–economic models capturing the relevant cost and performance data on over 15 sectors emitting the non-CO_2 GHGs.
- For the emissions inventory and projections, all anthropogenic sources are covered. For mitigation of methane, the sources evaluated include coal mining, natural gas systems, oil production, and solid waste management.
- For mitigation of HFC, PFC, and SF6, the sources evaluated include over 12 industrial sectors.
- For mitigation of nitrous oxide, sources evaluated include adipic and nitric acid production.
- Only currently available or close-to-commercial technologies are evaluated.
- The estimated reductions and costs are assembled into marginal abatement curves (MACs).
- MACs are straightforward, informative tools in policy analyses for evaluating economic impacts of GHG mitigation. A MAC illustrates the amount of reductions possible at various values for a unit reduction of GHG emissions and is derived by rank ordering individual opportunities by cost per unit of emission reduction. Any point along a MAC represents the marginal cost of abating an additional amount of a GHG.
- The total cost of meeting an absolute emission reduction target can be estimated by taking the integral of a MAC curve from the origin to the target.
- Global mitigation estimates are available aggregated into nine major regions of the world including the U.S. and are reported for the years 2010, 20015 and 2020.
- The data used in the report are from *Global Mitigation of Non-CO_2 Greenhouse Gases* (EPA Report 430-R-06-005). www.epa.gov/nonco2/econ-inv/international.html

Forest and Agriculture Sector Optimization Model-GHG

- FASOM-GHG simulates land management and land allocation decisions over time to competing activities in both the forest and agricultural sectors. In doing this, it simulates the resultant consequences for the commodity markets supplied by these lands and, importantly for policy purposes, the net greenhouse gas (GHG) emissions.
- The model was developed to evaluate the welfare and market impacts of public policies and environmental changes affecting agriculture and forestry. To date, FASOMGHG and its predecessor models FASOM and ASM have been used to examine the effects of GHG mitigation policy, climate change impacts, public timber harvest policy, federal farm program policy, biofuel prospects, and pulpwood production by agriculture among other policies and environmental changes.
- FASOMGHG is a multiperiod, intertemporal, price-endogenous, mathematical programming model depicting land transfers and other resource allocations between and within the agricultural and forest sectors in the US. The model solution portrays simultaneous market equilibrium over an extended time, typically 70 to 100 years on a ten year time step basis.
- The results from FASOMGHG yield a dynamic simulation of prices, production, management, consumption, GHG effects, and other environmental and economic indicators within these two sectors, under the scenario depicted in the model data.
- The principal model developer is Dr. Bruce McCarl, Department of Agricultural Economics, Texas A&M University.
- The data used in the report are from *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture* (EPA Report 430-R-05-006). http://www.epa.gov/sequestration/greenhouse_gas.html.
- Model Homepage: http://agecon2.tamu.edu/people.faculty/mccarl-bruce/FASOM.html

Global Timber Model (GTM)

- GTM is an economic model capable of examining global forestry land-use, management, and trade responses to policies. In responding to a policy, the model captures afforestation, forest management, and avoided deforestation behavior.
- The model estimates harvests in industrial forests and inaccessible forests, timberland management intensity, and plantation establishment, all important components of both future timber supply and carbon flux. The model also captures global market interactions.
- The model is a partial equilibrium intertemporally optimizing model that maximizes welfare in timber markets over time across approximately 250 world timber supply regions by managing forest stand ages, compositions, and acreage given production and land rental costs. The model equates supply and demand in each period, and predicts supply responses to current and future prices. The 250 supply regions are delineated by ecosystem and timber management classes, as well as geo-political regional boundaries. The model runs on 10-year time steps.
- The model has been used to explore a variety of climate change mitigation policies, including carbon prices, stabilization, and optimal mitigation policies.
- The principal model developer is Brent Sohngen, Department of Agricultural, Environmental, and Development Economics, Ohio State University. Other key developers and collaborators over the life of the model include Robert Mendelsohn, Roger Sedjo, and Kenneth Lyon. For this analysis, the model was run by Dr. Sohngen for EPA.
- Website for GTM papers and input datasets: http://aede.osu.edu/people/sohngen.1/forests/ccforest.htm#gfmod

Mini-Climate Assessment Model (MiniCAM)

- The MiniCAM is a highly aggregated integrated assessment model that focuses on the world's energy and agriculture systems, atmospheric concentrations of greenhouse gases (CO_2 and non-CO_2) and sulfur dioxide, and consequences regarding climate change and sea level rise.
- It has been updated many times since the early eighties to include additional technology options. MiniCAM is capable of incorporating carbon taxes and carbon constraints in conjunction with the numerous technology options including carbon capture and sequestration.
- The model has been exercised extensively to explore how the technology gap can be filled between a business-as-usual emissions future and an atmospheric stabilization scenario.
- The MiniCAM model is designed to assess various climate change policies and technology strategies for the globe over long time scales. It is configured as a partial equilibrium model that balances supply and demand for commodities such as oil, gas, coal, biomass and agricultural products.
- The model runs in 15-year time steps from 1990 to 2095 and includes 14 geographic regions.
- The model is developed and run at the Joint Global Change Research Institute, University of Maryland. Model Homepage**:** http://www.globalchange.umd.edu

The Integrated Planning Model (IPM)

- EPA uses the Integrated Planning Model (IPM) to analyze the projected impact of environmental policies on the electric power sector in the 48 contiguous states and the District of Columbia.

- IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector.

- The model provides forecasts of least-cost capacity expansion, electricity dispatch, and emission control strategies for meeting energy demand and environmental, transmission, dispatch, and reliability constraints.

- IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), and mercury (Hg) from the electric power sector.

- The IPM was a key analytical tool in developing the Clean Air Interstate Regulation (CAIR) and the Clean Air Mercury Rule (CAMR).

- IPM provides both a broad and detailed analysis of control options for major emissions from the power sector, such as power generation adjustments, pollution control actions, air emissions changes (national, regional/state, and local), major fuel use changes, and economic impacts (costs, wholesale electricity prices, closures, allowance values, etc.).

- The model was developed by ICF Resources and is applied by EPA for its Base Case. IPM® is a registered trademark of ICF Resources, Inc.
- EPA's application of IPM Homepage: http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html

National Energy Modeling System (NEMS)

- When Senators Lieberman and McCain requested that EPA analyze S. 280, they sent a similar request to the Energy Information Administration (EIA).
- EIA is using NEMS for its analysis of S. 280.
- NEMS is also used to produce the Annual Energy Outlook (AEO).
- NEMS represents domestic energy markets by explicitly representing the economic decision making involved in the production, conversion, and consumption of energy products.
- Where possible, NEMS includes explicit representation of energy technologies and their characteristics.
- NEMS is organized and implemented as a modular system.
  - For each fuel and consuming sector, NEMS balances the energy supply and demand, accounting for the economic competition between the various energy fuels and sources.
  - The modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system.
  - NEMS also includes a macroeconomic and an international module.
  - For purposes of S.280 analysis, NEMS is augmented with a representation of greenhouse gas emissions outside of the energy sector and uses marginal abatement curves to represent opportunities to reduce them.
- NEMS includes regional detail (nine Census divisions).
- NEMS runs in annual time steps through 2030.

Differences between NEMS and IGEM / ADAGE

- Analysis Time Frame
  - ADAGE and IGEM report through 2050
  - NEMS reports through 2030
- Technology Detail
  - ADAGE and IGEM are top-down models with limited technology detail
  - NEMS is a bottom-up model with extensive technology detail
- Macroeconomic Effects
  - NEMS Macroeconomic Activity Module is based on the Global Insight Model of the U.S. Economy, which is a macroeconomic forecasting model.
    - Based on estimated relationships at an aggregate level, using adaptive rather than rational expectations.
    - Forecasts effects at the aggregate level, such as how GDP and unemployment, are affected by changes in inflation or fiscal and monetary policies.
    - These types of models can capture short- and medium-term disequilibrium adjustments in response to exogenous shocks. They can address short and medium-term transition costs of energy policies as the economy transitions to a long-run growth path. They have more detailed government sectors and a well-defined set of fiscal policies. In addition, they can incorporate accommodating monetary policies.
  - IGEM and ADAGE are Computable General Equilibrium models
    - Structural models based on microeconomic foundations.
    - They build up their representation of the whole economy through the interactions of multiple agents (e.g. households and firms), whose decisions are based upon optimization.
    - These models are best suited for capturing long-run equilibrium responses, and unique characteristics of specific sectors of the economy.

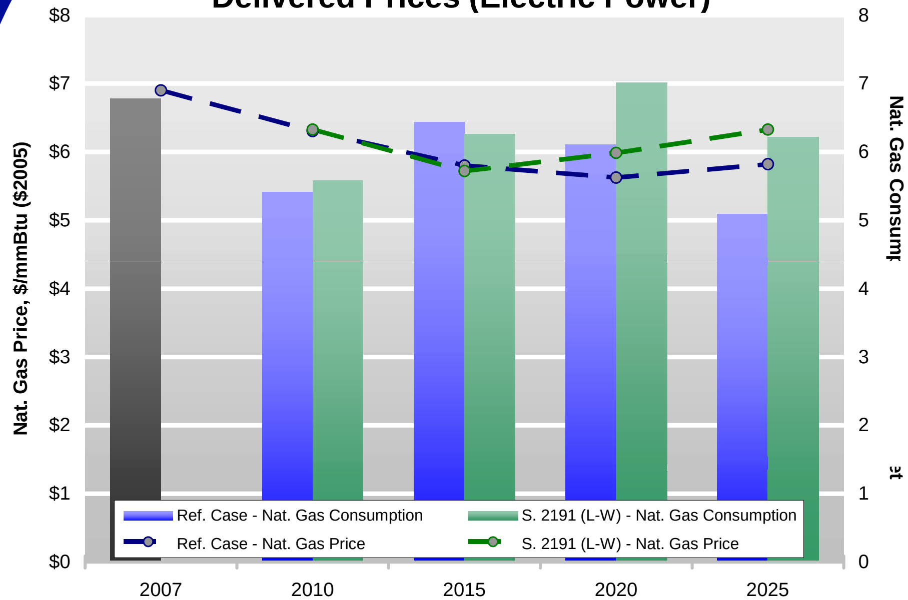
Appendix 8: Additional Slides Power Sector Natural Gas and Global CO_2 Concentrations

5/5/08

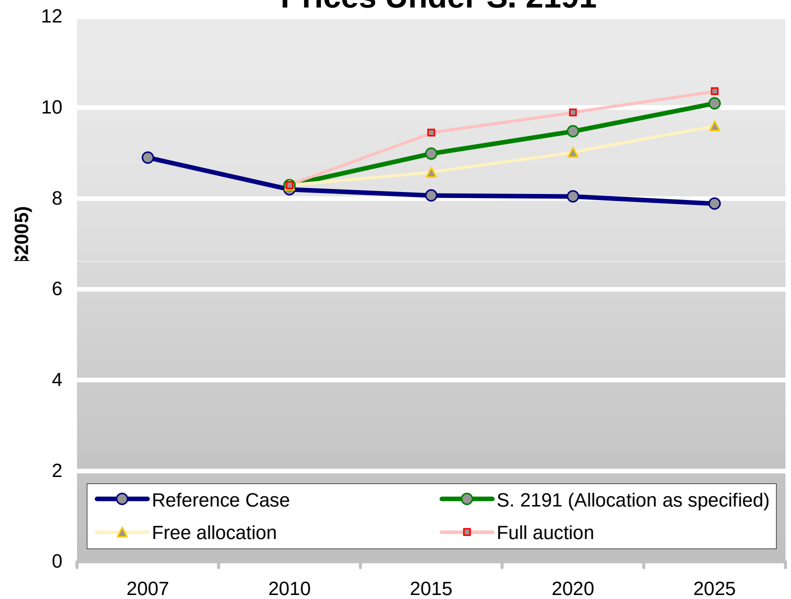
* This slide was added 5/5/08.

Power Sector Natural Gas Consumption, Prices, and Retail Electricity Prices (IPM)

Natural Gas Consumption and Average Delivered Prices (Electric Power)



Average Nationwide Retail Electricity Prices Under S. 2191



		Natural Gas Consumption and Prices						Retail Electricity Prices (¢/kWh)				
		2007	2010	2015	2020	2025		2007	2010	2015	2020	2025
Nat. Gas Consumption (TCF)	Ref. Case	*6.8*	5.4	6.4	6.1	5.1	Ref. Case	*8.9*	8.2	8.1	8.0	7.9
	S. 2191		5.6	6.3	7.0	6.2	S. 2191 (allocation as specified)		8.3	9.0	9.5	10.1
Nat. Gas Price ($/mmBtu)	Ref. Case	*6.90*	6.30	5.80	5.60	5.80	S. 2191 (free allocation)		8.3	8.6	9.0	9.6
	S. 2191		6.30	5.70	6.00	6.30	S. 2191 (full auction)		8.3	9.4	9.9	10.4

Source: 2007 data is from EIA, projections are from EPA's IPM Outlook 2006 and analysis of S. 2191 using IPM.

Note: Natural gas prices and consumption presented here are determined endogenously in IPM and do not reflect changes in supply/demand (and thus prices) outside the power sector as a result of S. 2191 (the ADAGE model is the economy-wide model that EPA uses to reflect this dynamic). To the extent that natural gas demand increases outside the power sector, the price impacts reflected here may be a bit lower than if the total demand for natural gas were reflected in IPM. However, demand for natural gas in ADAGE outside the power sector is not projected to increase significantly, so the price projections presented here would not be greatly impacted by demand from other sectors.

* This slide was added 5/5/08.

Global CO_2 Concentrations (MiniCAM) Scenarios

Reference Scenario

- Reference scenario emissions come from the Climate Change Science Program (CCSP) Synthesis and Assessment Product 2.1a MiniCAM reference case.
- The CCSP SAP 2.1a reference case assumes that in the post-2012 period existing measures to address climate change expire and are never renewed or replaced.

Scenario Without International Action

- S. 2191
  - USA adopts Lieberman-Warner (S. 2191).
  - All other countries adopt no additional policies or measures.
  - Emissions leakage as estimated by the ADAGE model is taken into account.
  - After 2050, the U.S. holds emissions caps constant at 2050 levels.

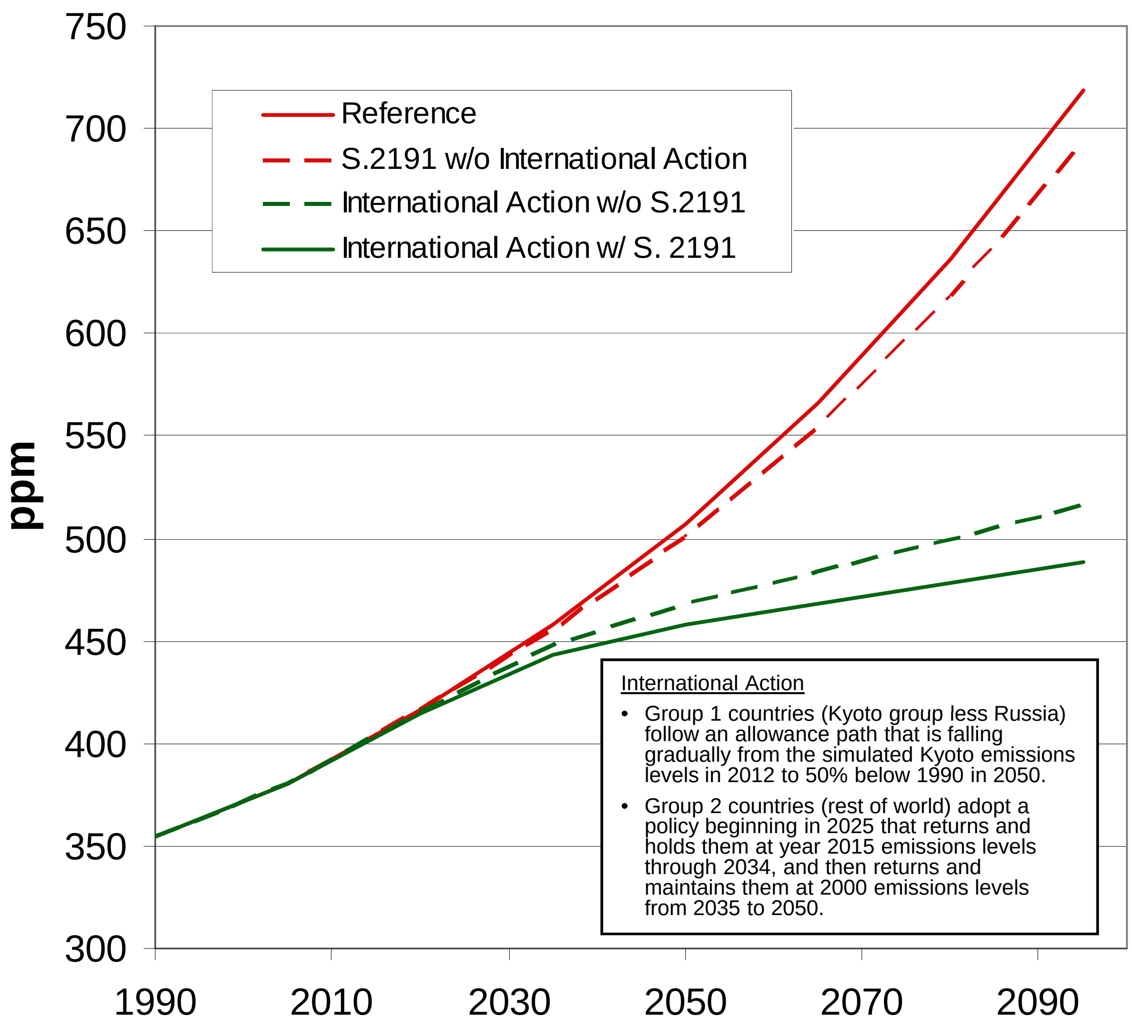
Scenarios with International Action

- International Action w/o S. 2191
  - USA adopts no additional polices or measures.
- International Action w/ S. 2191
  - USA adopts Lieberman-Warner (S. 2191).
  - After 2050, the U.S. holds emissions caps constant at 2050 levels.

- All scenarios with international action assume widespread international actions by developed and developing countries over the modeled time period. International policy assumptions are based on those used in the recent MIT report, “Assessment of U.S. Cap-and-Trade Proposals”
  - Group 1 countries (Kyoto group less Russia) follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050.
  - Group 2 countries (rest of world) adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050.
- After 2050, all countries hold emissions caps constant at 2050 levels.

* This slide was added 5/5/08.

Global CO_2 Concentrations (MiniCAM) Results



In the reference scenario,* Global CO_2 concentrations rise from historical levels of 354 parts per million (ppm) in 1990 to 718 ppm in 2095.

Effect of S. 2191

Assuming the international community adopts no additional policies or measures, the global CO_2 concentrations in 2095 are estimated to be 694 ppm, which is 25 ppm lower than the reference case. Note that this incremental effect accounts for emissions leakage.

Effect of International Action plus S. 2191

Assuming the international community takes the actions described in the diagram to the left and the U.S. takes no action, the global CO_2 concentrations in 2095 are estimated to be 516 ppm; and if the U.S. adopts S. 2191 global CO_2 concentrations in 2095 would be 488 ppm, which is an additional 28 ppm lower than the case without U.S. action.

While CO_2 concentrations are significantly reduced in the scenarios with international action, they are not on a stabilization trajectory.

* Reference scenario emissions come from the Climate Change Science Program (CCSP) Synthesis and Assessment Product 2.1a MiniCAM reference case.

* This slide was added 5/5/08.