U.S. Environmental Protection Agency
Office of Atmospheric Programs

EPA Analysis of the Low Carbon Economy Act of 2007

S. 1766 in 110th Congress

January 15, 2008*

* This version was updated on 1/25/08 to reflect a change to slide #52, which incorrectly included coal production levels from EPA's reference case scenario rather than the S. 1766 scenario.

Request for EPA Analysis

- On July 26, 2007 Senators Bingaman and Specter requested that EPA estimate the economic impacts of the Low Carbon Economy Act of 2007 (S. 1766).
- The request had two main parts:
  1) Analyze S. 1766 in line with assumptions used for EPA's analysis of S.280 and other additional sensitivities. The work presented here his the response to this first part of the request. The full analysis is available online at: www.epa.gov/climatechange/economicanalyses.htm.
  2) Evaluate CO_2 concentrations from:
     a) a historical perspective showing individual nation's and region's contributions to current concentrations; and
     b) a projections perspective showing the effects of the emissions targets of three bills:
        1. Lieberman-McCain, "Climate Stewardship and Innovation Act," (S. 280),
        2. Kerry-Snowe, "Global Warming Reduction Act," (S. 485),
        3. Bingaman-Specter, "Low Carbon Economy Act," (S. 1766).

     The response to this second part of the request was delivered to the Senators on October 2, 2007, and is available online at: www.epa.gov/climatechange/economicanalyses.html.
- The analysis was conducted by EPA's
  Office of Atmospheric Programs.
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Key Results & Insights

S. 1766 places a GHG emission cap on all GHGs in the Transportation, Electricity, Industrial, and Commercial sectors, establishes an auction and after-market for emission allowances, allows for unlimited domestic offsets, and does not allow the use of foreign credits or international offset projects.

Emissions Impacts

S. 1766 with the Technology Accelerator Payment (TAP)

- Under S. 1766 with the TAP, total U.S. GHG emissions are approximately 23% (~ 2,100 $MtCO_2e$) lower than reference case emissions in 2030 (approximately equal to 2000 levels), and ~40% (~ 4,300 $MtCO_2e$) lower in 2050 (or approximately 10% below 2000 levels).
- Covered U.S. GHG emissions make up 87% of total U.S. GHG emissions in 2030, and 86% in 2050.
- After 2030, banked allowances are exhausted and firms begin making TAP payments.
- Over the time period from 2012 – 2050, cumulative covered emissions (less offsets) exceed the emissions cap (with the optional 2050 target of 60% below 2006 levels) by approximately 65%, and exceed the looser emissions cap (with constant caps after 2030 equal to 1990 levels) by approximately 45%.

S. 1766 without the Technology Accelerator Payment (TAP)

- Under S. 1766 without the TAP, total U.S. GHG emissions are approximately 37% (~ 3,600 $MtCO_2e$) lower than reference case emissions in 2030 (or approximately 6% below 1990 levels), and ~52% (~ 5,600 $MtCO_2e$) lower in 2050 (or approximately 17% below 1990 levels).
- Covered U.S. GHG emissions make up 85% of total U.S. GHG emissions in 2030 and in 2050.

Greenhouse Gas Concentration Impacts

- In the reference case, global CO_2 concentration rises from 380 ppm in 2005 to 718 ppm in 2095.
- The incremental effect of S. 1766 on lowering global CO_2 concentrations in 2095, accounting for emissions leakage when the rest of the world adopts no additional policies or measures, is between10 and 12 ppm with the TAP; between 21 and 25 ppm without the TAP and with the optional 2050 target of 60% below 2006 levels; and between 11 and 13 ppm without the TAP and with constant caps after 2030 equal to 1990 levels.
- 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, is lowered to 504 ppm if the US adopts S. 1766 with the TAP; 491 ppm if the US adopts S. 1766 without the TAP and with the optional 2050 target of 60% below 2006 levels; and 503 ppm if the US adopts S. 1766 without the TAP and with constant caps after 2030 equal to 1990 levels.

Key Results & Insights (con't)

Economic Impacts

Reference

- By 2030 GDP is projected to increase between 78 - 81% from 2010 levels in the reference case, and by 2050 the projected increase in GDP is between 181 - 192%.

S. 1766 with the TAP

- The allowance price is bound by the TAP level throughout the entire time frame of the analysis ($25 / t$CO_2$e in 2030 and $65 in 2050).
- Under S. 1766 with the TAP, GDP is projected to be between 0.5% ($124 billion) and 1.4% ($370 billion) lower in 2030, and between 0.9% ($401 billion) and 2.9% ($1,199 billion) lower in 2050 than in the *Reference Scenario*.
- The average annual growth rate of consumption is ~ 0.03 percentage points lower. In 2030 per household average annual consumption is ~$500 lower and gasoline prices increase ~$0.22 per gallon. In 2050 per household average annual consumption is ~$1,600 lower and gasoline prices increase ~$0.57 per gallon
- Total annual abatement cost is $25-28 billion in 2030 and $133 – 146 billion in 2050.
- Electricity prices are projected to increase 20% in 2030 and 21% in 2050, assuming the full cost of allowances are 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 may not be passed on to consumers in regulated electricity markets, so electricity price increases would be lower in much of the country.

S. 1766 without the TAP

- Under S. 1766 without the TAP, modeled allowance prices range between $57 - 61/t$CO_2$e in 2030, and $149 - 162/t$CO_2$e in 2050, assuming the 2050 target of 60% below 2006 emissions levels is adopted.
- GDP is projected to be between 0.8% ($219 billion) and 2.9% ($757 billion) lower in 2030, and between 2.2% ($952 billion) and 5.5% ($2,268 billion) lower in 2050 than in the reference case.
- The average annual growth rate of consumption is ~ 0.07 percentage points lower. In 2030 per household average annual consumption is ~$1,200 lower and gasoline prices increase ~$0.35 per gallon. In 2050 per household average annual consumption is ~$3,600 lower and gasoline prices increase ~$0.91 per gallon.
- Total annual abatement cost is $108 - 137 billion in 2030 and $452 - 478 billion in 2050.
- Electricity prices are projected to increase 40% in 2030 and 25% in 2050, assuming the full cost of allowances are 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 may not be passed on to consumers in regulated electricity markets, so electricity price increases would be lower in much of the country.

General

- In our modeling market outcomes are invariant to the auctioning of allowances given the assumption of lump sum transfers of auction and TAP 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)

Sector Impacts

- The greatest emission abatement under S. 1766 with or without the TAP 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 the weak and indirect price signal an upstream cap and trade program sends to the transportation sector.
  - The price signal provided by S. 1766 (~$0.22 increase in the price of gasoline in 2030, ~$0.57 increase in 2050 with the TAP), does not overcome the market barriers in the transportation sector that prevent larger reductions in GHG emissions.
  - This analysis did not estimate the reductions that could be achieved under a direct fuel and vehicle regulatory framework.

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 by 2020
- Detailed power sector modeling suggests most existing coal plants continue to operate but are less profitable in the near-term while economy-wide models indicate the near-term impact on coal may be greater, these models show that coal usage rebounds after 2020 with the deployment of CCS technology.
- The rate of CCS penetration is subject to a great deal of uncertainty. Given our assumptions about availability, cost and performance of CCS technology, the economy-wide model shows a small amount of CCS built in 2020 with the rate increasing until all traditional fossil is displaced by 2050 (S. 1766 with TAP) or 2040 (S. 1766 without TAP). Detailed power sector modeling suggests that the initial penetration of CCS may be much faster.
- Without the CCS subsidy the economy-wide model shows the initial penetration of CCS to be delayed by 5 years. Detailed power sector modeling shows that without the CCS bonus allowances, CCS does not penetrate before 2025.
- In the economy-wide model, other non-fossil generation (e.g. biomass, wind and solar) plays a significant role under S. 1766; however, detailed electricity sector modeling shows that these options may play less of a role.
- In the core scenarios nuclear power grows by ~150% by 2050. A sensitivity run to demonstrate the importance of key enabling technologies, constrains the growth in nuclear power to ~ 75% and prevents deployment of CCS technology, results in US GHG emissions increasing by 26% in 2030 and 35% in 2050, with the TAP, compared to the core S. 1766 scenario.

Key Results & Insights (con't)

Emissions Leakage and International Climate Policy Sensitivity

- Under the core S. 1766 international assumptions, no international emissions leakage occurs. In fact, emissions in Group 2 developing countries fall by over 15,000 million metric tons CO_2 equivalent ($MtCO_2e$) as they adopt emission targets beginning in 2025.
- As Group 2 adopts targets, the U.S. imports fewer energy-intensive manufacturing goods from Group 2, and exports more.
- Under Alternative International Action assumptions, developing countries do not take any action. Emissions leakage occurs under these assumptions, with Group 2 emissions rising by 304 $MtCO_2e$ in 2030, and 298 $MtCO_2e$ in 2050, or an increase of 0.8% & 0.6% above reference emissions. (For comparison, U.S. emissions reductions are approximately 2,100 $MtCO_2e$ in 2030 and 4,300 $MtCO_2e$ in 2050). The amount of leakage is somewhat limited by Group 2 countries selling CDM style offsets to Group 1 countries.
- 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 310 $MtCO_2e$ in 2030, and 312 $MtCO_2e$ in 2050.
- Under Alternative International Action, the U.S. exports 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. Imports of energy-intensive manufacturing goods from Group 2 countries 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.

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 by 2050, coal use has rebounded due to CCS.
- In the majority of regions, GDP and consumption impacts are less than 1% 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 an cooling needs, and average distance traveled; and existing fossil fuel capacity in the electricity sector).

Key Results & Insights (con't)

Offsets Sensitivities

- If international credits and offset projects are allowed to make up 10% of allowance submissions, then under a TAP scenario the total amount of abatement increases; under a "no TAP" scenario, the cost of meeting the cap decreases.
  - With the TAP the purchase of international offsets results in cumulative GHG abatement form 2012 – 2050 equal to 5% of cumulative US emissions in the reference case over the same period, and the amount by which emissions exceed the cap is reduced by 35%.
  - Without the TAP, allowance prices decrease by 27%; and GDP impacts decrease by approximately 20%.
- If the use of international credits and offset projects is unlimited, then given the assumptions about international policy and offset availability, the TAP is not triggered.
  - Allowance prices are 12% lower than the TAP, and 65% lower than the allowance price without the TAP.
  - GDP impacts are 14% lower than the scenario with the TAP, and 60% lower than the scenario without the TAP.

Technology Accelerator Payment (TAP)

- The TAP acts as a safety valve and reduces uncertainty about the cost of S. 1766, but increases the uncertainty about the resulting level of emissions.
- Under S. 1766, TAP payments begin in 2030.
  - If international credits and offset projects are allowed to make up 10% of allowance submissions, TAP payments begin in 2036, and the cumulative number of tons of GHG emissions for which TAP payments are made is reduced by 35%.
  - If non-specified domestic offsets are allowed to be used on a ½ credit for each ton of GHG emissions reduced basis, then TAP payments do not begin until 2032, and the cumulative number of tons of GHG emissions for which TAP payments are made is reduced by 18%.
  - If international credits and non-specified offsets are both allowed as described above, TAP payments do not begin until 2040, and the cumulative number of tons of GHG emissions for which TAP payments are made is reduced by 58%.
  - If the growth of nuclear power is constrained to ~ 75% by 2050, and CCS is not available, TAP payments are made two years earlier, the cumulative number of tons of GHG emissions for which TAP payments are made increases by 47%.
- The TAP level is an important design decision.
  - A higher TAP price will lead to higher costs of abatement when the TAP is triggered.
  - A lower TAP price will reduce costs. If it is too low:
    - the TAP may be triggered in all expected scenarios, nullifying the expected GHG reductions from the emissions cap, and
    - there will be less of an incentive to develop new GHG reduction technologies.
  - The CCS bonus allowance provision is designed to ensure that CCS technology is deployed in the presence of the TAP.
  - It is difficult to determine the appropriate CCS bonus level that is high enough to for the technology to penetrate, without being so high that it creates excessive market distortions and generates 'windfall' profits.

Key Results & Insights (con't)

High Technology Sensitivities

- Under High Technology assumptions, in 2030 the reference case emissions are ~7% (~650 $MtCO_2e$) lower than under the core technology assumptions.
- Under S. 1766 High Technology with the TAP, total U.S. GHG emissions are approximately 22% (~1,900 $MtCO_2e$) lower than the High Tech reference case emissions in 2030, and 37% (~3,700 $MtCO_2e$) lower in 2050. While this is a slightly smaller reduction than the reduction under the core reference assumptions, the resulting level of total U.S. GHG emissions is approximately 6% (~425 $MtCO_2e$) lower than policy case reductions under the core reference case.
- Under S. 1766 High Technology without the TAP, total U.S. GHG emissions are approximately 32% (~2,800 $MtCO_2e$) lower than reference case emissions in 2030, and 47% (~4,700 $MtCO_2e$) lower in 2050. While this is a lower reduction than under the core technology assumptions, the resulting levels of emissions are similar since both scenarios meet the same emissions cap.
- In the High Technology no TAP scenario, modeled allowance prices range between 15-30% lower than under the scenario without the TAP using the core technology assumptions.
- Under S. 1766 High Technology no TAP scenario, GDP is projected to be between 0.5% and 2.4% lower in 2030, and between 1.5% and 4.7% lower in 2050 than in the High Technology reference case. The GDP impacts of S. 1766 in the High Technology Scenario without the TAP, are significantly lower than the GDP impacts under the core technology assumptions without the TAP. However, these GDP impacts only reflect the difference from the High Technology reference case, and do not include the full impact on the economy of achieving this high technology baseline.

Key Uncertainties

- There are many uncertainties that affect the economic impacts of S. 1766.
- This analysis contains a set of scenarios that cover some of the most important uncertainties:
  - The inclusion of the TAP.
  - 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
- GHG Emissions Results
- Detailed Near-Term Electricity Sector Modeling Results
- Energy Sector Modeling Results
- Economy-Wide and Sectoral Modeling Results
- Regional Modeling Results
- Global Results: Emissions Leakage and Alternative International Action Sensitivities
- Global Results: International Offsets Sensitivities
- Global Results: CO_2 Concentrations
- Additional Qualitative Considerations
- Appendix 1: Scenario Comparison Tables
- Appendix 2: High Technology Scenarios
- Appendix 3: Additional Information
- Appendix 4: Detailed Near-Term Electricity Modeling Results and Sensitivities
- Appendix 5: Comparison to EPA's Analysis of S. 280
- Appendix 6: Model Descriptions
- Appendix 7: Request Letter from Senators Bingaman and Specter

Legislative Assessment and Analytical Approach

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)

  2030: 4,819 $MtCO_2e$ (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

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) Core Reference Scenario

- Does not include any additional climate policies or measures to reduce international GHG emissions
- For domestic projections, benchmarked to AEO 2006
- For international projections, use CCSP Synthesis and Assessment Report 2.1 A MiniCAM Referece

2) S. 1766

- Cap on covered sectors and entities
- Technology Accelerator Payment
- Unlimited specified domestic offsets, and no unspecified domestic offsets allowed
- No foreign credits or international offset project credits allowed
- Bonus allowances for CCS
- Substantial growth in nuclear power (nuclear power generation increases by ≈150% from 782 bill. kWh in 2005 to 1,982 bill. kWh in 2050).
- 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
- The assumptions about nuclear power and international actions are consistent with the assumptions used in EPA's analysis of "The Climate Stewardship and Innovation Act of 2007" (S. 280)

Analytical Scenarios (con't)

In the following scenarios all assumptions are identical to scenario 2 unless specified.

3) **S. 1766 – No TAP**
   - No Technology Accelerator Payment provision
4) **S. 1766 – 10% International Offsets**
   - Up to 10% of allowance submission requirements may come from foreign credits or international offset project credits
5) **S. 1766 – Unlimited International Offsets**
   - No restrictions on the use of foreign credits or international offset project credits
6) **S. 1766 – No TAP, 10% International Offsets**
   - No Technology Accelerator Payment provision
   - Up to 10% of allowance submission requirements may come from foreign credits or international offset project credits
7) **S. 1766 – No TAP, Unlimited International Offsets**
   - No Technology Accelerator Payment provision
   - No restrictions on the use of foreign credits or international offset project credits
8) **S. 1766 – No CCS Subsidy**
   - No bonus allowances for carbon capture and storage
9) **S. 1766 – No TAP, No CCS Subsidy**
   - No Technology Accelerator Payment provision
   - No bonus allowances for carbon capture and storage
10) **S. 1766 – No CCS, Low Nuclear**
   - Assumes that carbon capture and storage technology is not available
   - Nuclear power generation increases by ~75% by 2050 (half of S. 1766 scenario)
11) **S. 1766 – Alternative International Action**
   - Group 1 countries (Kyoto group less Russia) follow Kyoto forever path
   - Group 2 countries (rest of world) adopt no additional policies or measures

Analytical Scenarios (con't)

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.

12) High Technology Reference Scenario

- 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

13) S. 1766 High Technology

- Based on the High Technology Reference Scenario
- Cap on covered sectors and entities
- Technology Accelerator Payment
- Unlimited specified domestic offsets, and no unspecified domestic offsets allowed
- No foreign credits or international offset project credits allowed
- Bonus allowances for CCS
- Substantial growth in nuclear power (nuclear power generation increases by ≈150% from 782 bill. kWh in 2005 to 1,982 bill. kWh in 2050)
- 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
- The assumptions about nuclear power and international actions are consistent with the assumptions used in EPA's analysis of "The Climate Stewardship and Innovation Act of 2007" (S. 280)

Analytical Scenarios (con't)

In the following scenarios all assumptions are identical to scenario 13 unless specified.

14) S. 1766 High Technology – No TAP
- No Technology Accelerator Payment provision

15) S. 1766 High Technology – 10% International Offsets
- Up to 10% of allowance submission requirements may come from foreign credits or international offset project credits

16) S. 1766 High Technology – Unlimited International Offsets
- No restrictions on the use of foreign credits or international offset project credits

17) S. 1766 High Technology – No TAP, 10% International Offsets
- No Technology Accelerator Payment provision
- Up to 10% of allowance submission requirements may come from foreign credits or international offset project credits

18) S. 1766 High Technology – No TAP, Unlimited International Offsets
- No Technology Accelerator Payment provision
- No restrictions on the use of foreign credits or international offset project credits

19) S. 1766 High Technology – No CCS Subsidy
- No bonus allowances for carbon capture and storage

20) S. 1766 High Technology – No TAP, No CCS Subsidy
- No Technology Accelerator Payment provision
- No bonus allowances for carbon capture and storage

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
	Transportation	All GHGs	All GHGs					
	Industry	All GHGs	All GHGs	CH_4, N_20, F-gases				
	Commercial	All GHGs	All GHGs					
	Agriculture (& Forestry)	All GHGs	All GHGs		CO_2, CH_4, N_20			
	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 (Sonhgen, 2006)
MiniCAM Mini-Climate Assessment Model (Edmonds, 2005)

EPA Models Used for Different Analytical Scenarios

Table: Models Used for Different Scenarios

Scenario					
1) Core Reference	ADAGE	IGEM	IPM	MiniCAM	
2) S. 1766	ADAGE	IGEM	IPM	MiniCAM	NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
3) S. 1766 - No TAP	ADAGE	IGEM		MiniCAM	NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
4) S. 1766 - 10% Int'l Offsets		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
5) S. 1766 - Unlimited Int'l Offsets		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
6) S. 1766 - No TAP, 10% Int'l Offsets		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
7) S. 1766 - No TAP, Unlimited Int'l Offsets		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
8) S. 1766 - No CCS Subsidy	ADAGE		IPM		
9) S. 1766 - No TAP, No CCS Subsidy	ADAGE				
10) S. 1766 - No CCS, Low Nuclear	ADAGE				
11) S. 1766 - Alternative Int'l Action	ADAGE				

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 (Sonhgen, 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.

EPA Models Used for Different Analytical Scenarios (con't)

Table: Models Used for Different Scenarios (continued)

12) High Technology Reference					
	ADAGE	IGEM	IPM		NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
13) S. 1766 High Technology					
	ADAGE	IGEM	IPM		NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
14) S. 1766 High Technology - No TAP					
	ADAGE	IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
15) S. 1766 High Technology - 10% Int'l Offsets					
		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
16) S. 1766 High Technology - Unlimited Int'l Offsets					
		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
17) S. 1766 High Technology - No TAP, 10% Int'l Offsets					
		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
18) S. 1766 High Technology - No TAP, Unlimited Int'l Offsets					
		IGEM			NCGM/FASOM/GTM/MiniCAM Offset Spreadsheet Tool
19) S. 1766 High Technology - No CCS Subsidy					
	ADAGE		IPM		
20) S. 1766 High Technology - No TAP, No CCS Subsidy					
	ADAGE				

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 (Sonhgen, 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. 1766.
- 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:

- 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.
  - The interaction between ADAGE and IPM is different in the S. 1766 analysis. Given the predictable allowance price path under the TAP feature of S. 1766, IPM used its internal electricity demand response rather than incorporating the demand response from ADAGE.
- Results reported
  - We are reporting regional impacts form the ADAGE model in the S. 1766 analysis.
  - We are also reporting international leakage from ADAGE in the S. 1766 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. 1766.
- 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. 1766 affects CO_2 concentrations throughout the 21^{st} 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. 1766 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. 1766 (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. 1766, 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. 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. 1766.
  - 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 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.

Domestic Offsets & International Credits Methodology Highlights

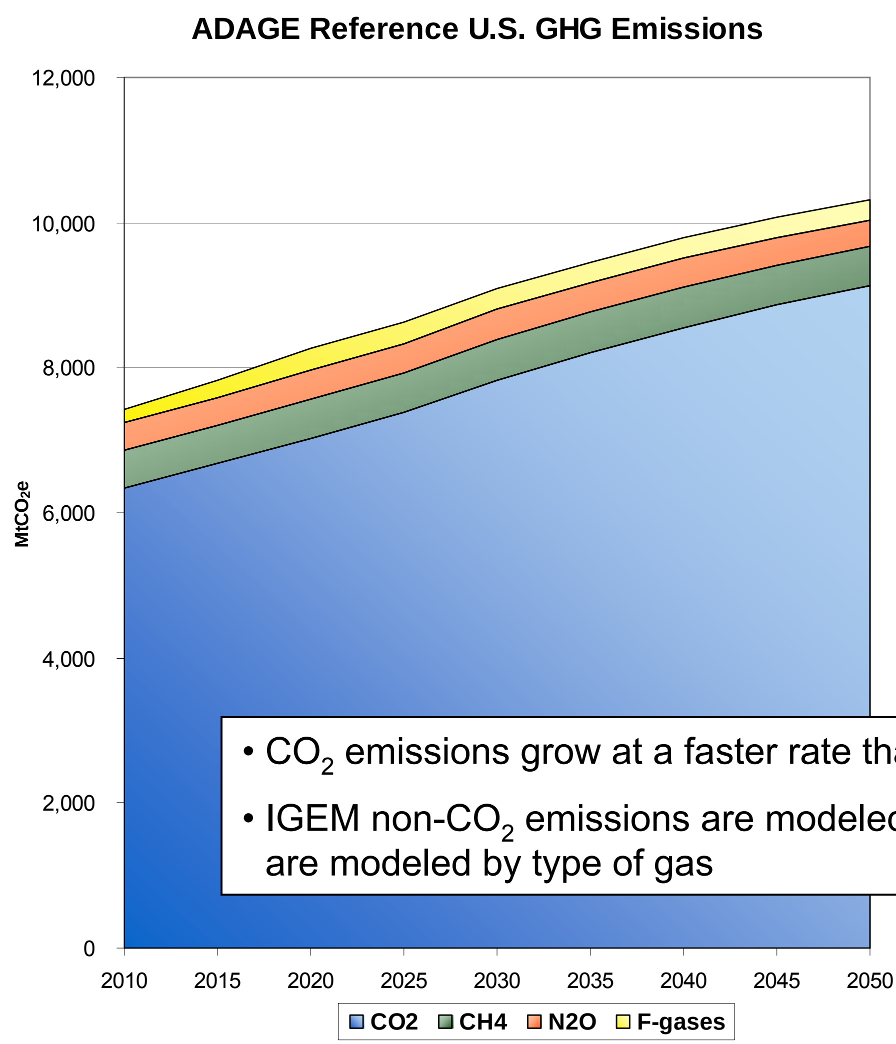
- EPA developed mitigation cost schedules for 24 offset mitigation categories, covering the following mitigation types:
  - Domestic non-CO_2 GHG emissions reductions
  - International non-CO_2 GHG emissions reductions
  - Domestic and international increases in terrestrial carbon sinks (soil and plant carbon stocks)
  - International energy-related CO_2 mitigation

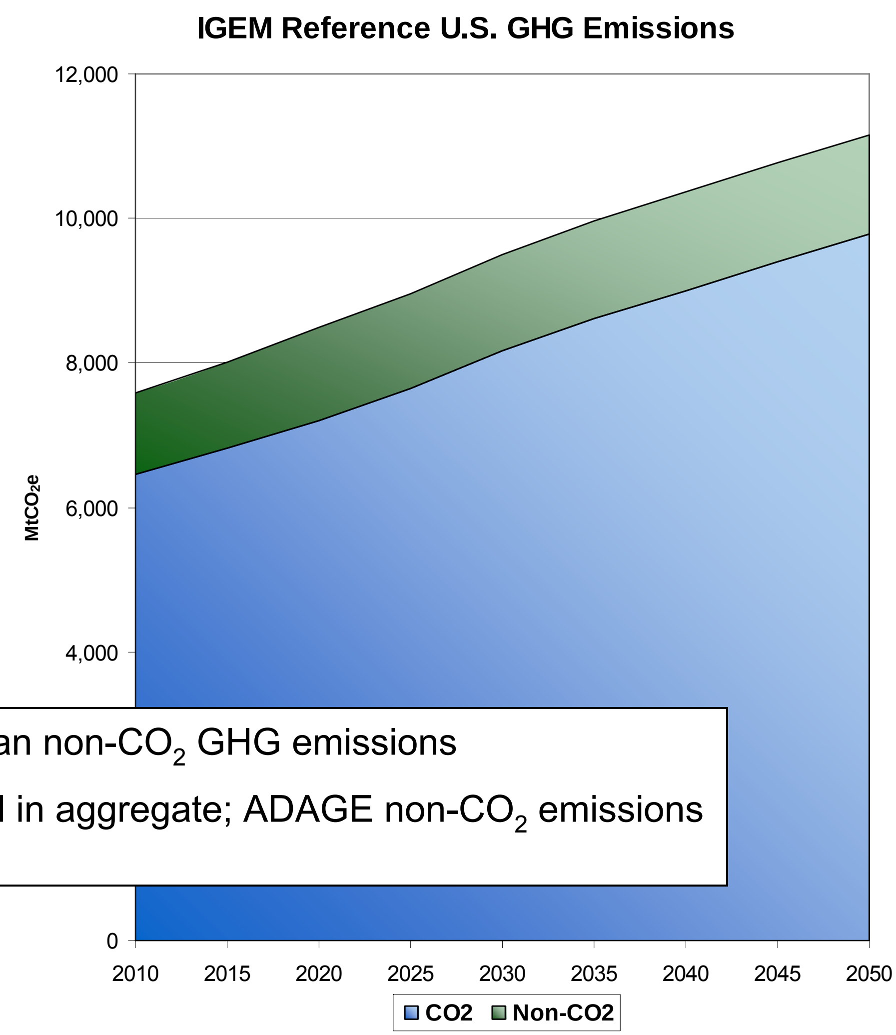
- EPA evaluated individual mitigation options to determine potential eligibility and feasibility over time for a future mitigation program
  - Based on EPA's emissions inventory & mitigation program expertise
    - Considered a broad set of factors, including existing and emerging programs/protocols/tools, 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.

GHG Emissions Results

Results: Scenario 1 – Reference

U.S. GHG Emissions

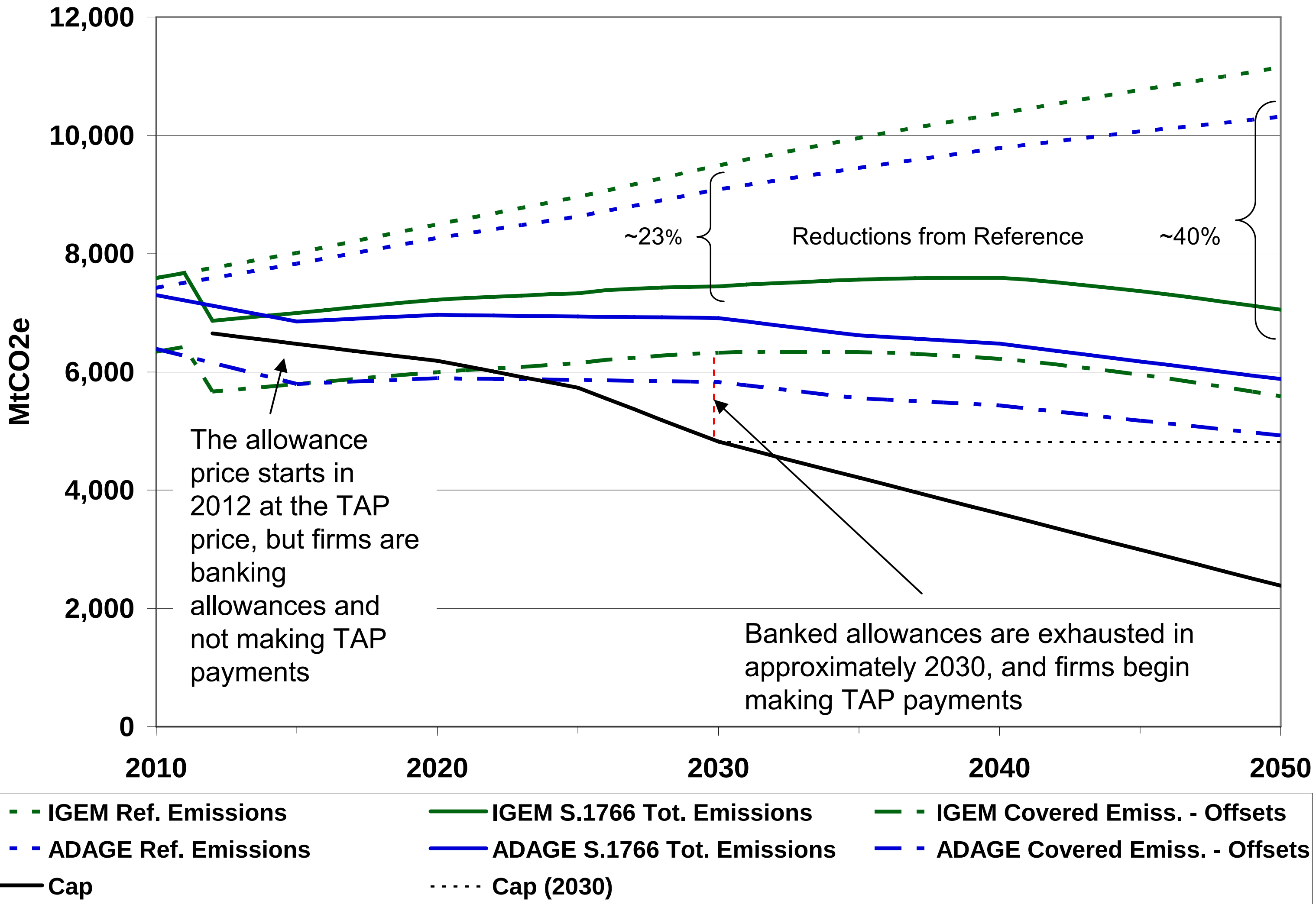




- CO_2 emissions grow at a faster rate than non-CO_2 GHG emissions
- IGEM non-CO_2 emissions are modeled in aggregate; ADAGE non-CO_2 emissions are modeled by type of gas

Results: Scenario 2 - S. 1766

U.S. GHG Emissions



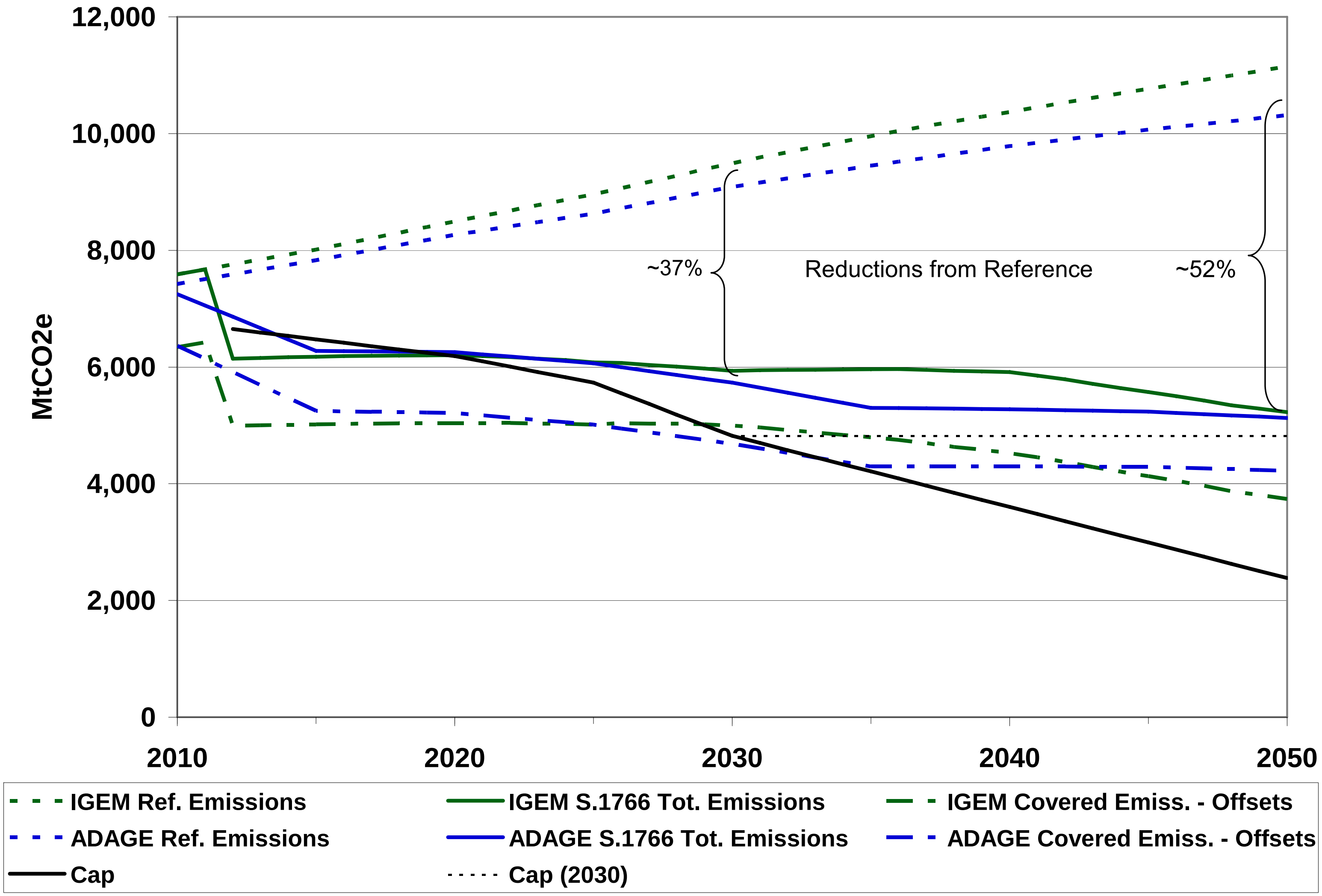
Results: Scenario 2 - S. 1766

U.S. GHG Emissions

- The previous chart shows the emissions results for S. 1766 with the TAP.
- 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 with additional reductions to at least 60% below 2006 levels by 2050.
  - The additional reductions are triggered if the President determines that the 5 largest trading partners of the U.S. are taking comparable actions with respect to greenhouse gas emissions (which is assumed in this scenario).
  - If the tighter caps are not triggered, the cap level remains constant after 2030, which is represented here by the dotted black line.
- The dashed blue and green lines show the emissions of covered sectors, taking into account purchases of offsets.
  - Note that if the cap were binding, these emissions would be equivalent to the total emissions allowed under the cap, but the time path would reflect the banking of allowances in the early years, as entities would "over comply" to avoid higher allowance prices in later years.
  - Initially, the dashed blue and green lines are below the cap, which represents the banking of allowances. Between 2020 and 2025, the dashed blue and green lines cross above the cap level, and firms begin drawing down the bank of allowances. By approximately 2030, the bank of allowances is exhausted, and firms begin making TAP payments.
  - Since the TAP is triggered in this scenario, the total emissions less offsets over the entire time period exceeds the emissions allowed under the cap.
  - The total emissions less offsets over the entire time period also exceeds the less stringent cap that remains constant after 2030.
- The solid blue and green lines show total U.S. emissions under S. 1766. These levels include emissions from non-covered sectors.
  - In 2030, total U.S. emissions under S. 1766 are reduced in IGEM by 2,045 $MtCO_2e$ from the Reference Scenario (22 percent reduction) and 2,178 $MtCO_2e$ in ADAGE (24 percent reduction).
  - In 2030, total U.S. emissions under S. 1766 are 4% above 2000 levels in IGEM, and 5% below 2000 levels in ADAGE.
  - In 2050, total U.S. emissions under S. 1766 are 1% below 2000 levels in IGEM, and 18% below 2000 levels in ADAGE.

Results: Scenario 3 - S. 1766, No TAP

U.S. GHG Emissions



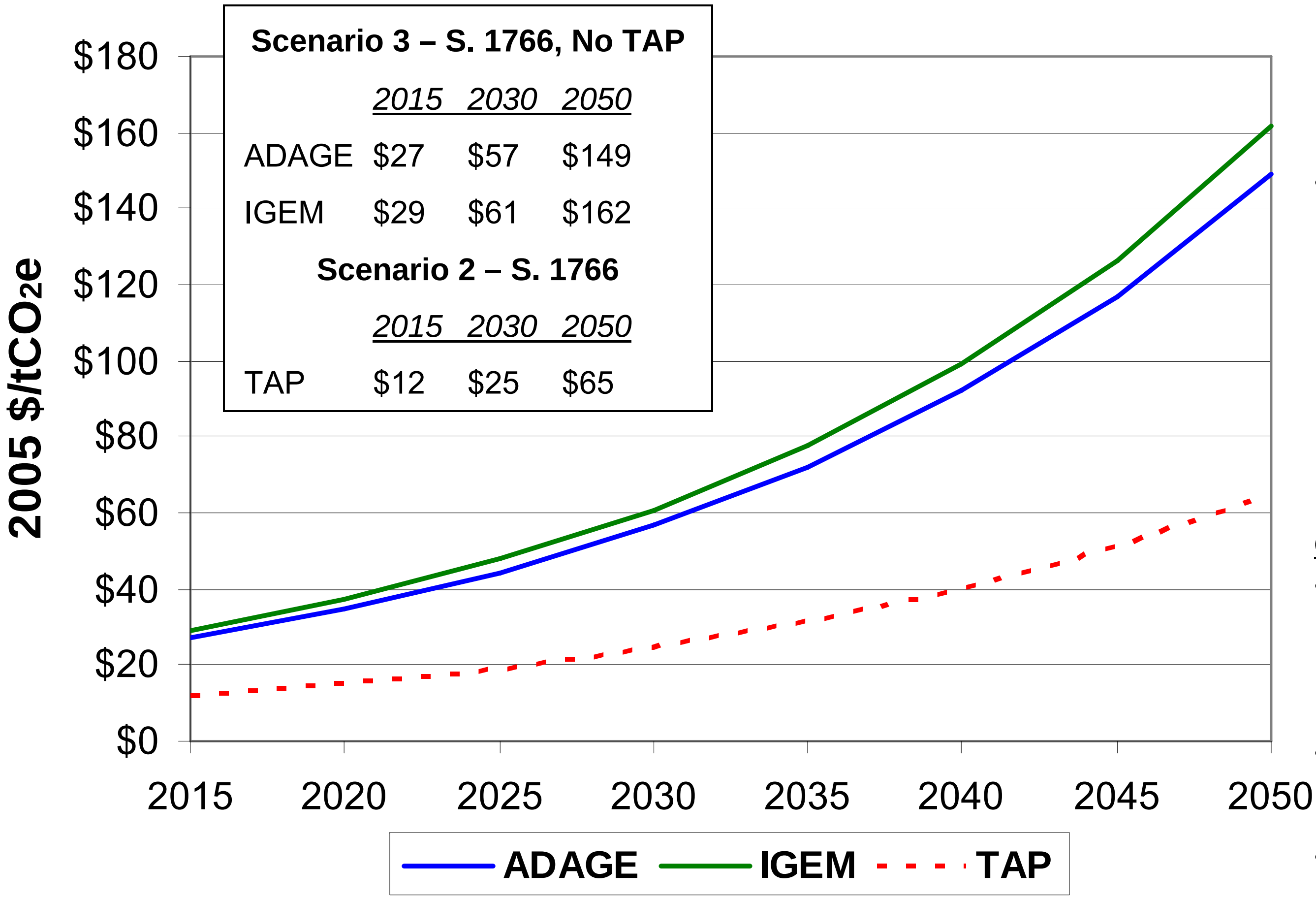
Results: Scenario 3 - S. 1766, No TAP

U.S. GHG Emissions

- The previous chart shows the emissions results for S. 1766 without the TAP.
- 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 with additional reductions to at least 60% below 2006 levels by 2050.
  - The additional reductions are triggered if the President determines that the 5 largest trading partners of the U.S. are taking comparable actions with respect to greenhouse gas emissions (which is assumed in this scenario).
  - If the tighter caps are not triggered, the cap level remains constant after 2030, which is represented here by the dotted black line.
- The dashed blue and green lines show the emissions of covered sectors, taking into account purchases of offsets (note that these emissions are equivalent to the total emissions allowed under the cap, but the time path reflects the banking of allowances in the early years, as entities "over comply" to avoid higher allowance prices in later years).
- The solid blue and green lines show total U.S. emissions under S. 1766. These levels include emissions from non-covered sectors.
  - In 2030, total U.S. emissions under S. 1766 are reduced in IGEM by 3,561 $MtCO_2e$ from the Reference Scenario (38 percent reduction) and 3,357 $MtCO_2e$ in ADAGE (37 percent reduction).
  - In 2030, total U.S. emissions under S. 1766 are 5% below 1990 levels in IGEM, and 8% below 1990 levels in ADAGE.
  - In 2050, total U.S. emissions under S. 1766 are 16% below 1990 levels in IGEM, and 18% below 1990 levels in ADAGE.

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

GHG Allowance Prices



- The $57 - $61 range of 2030 allowance prices only reflects differences in the models and does not reflect other scenarios or additional uncertainties discussed elsewhere.
- Even though TAP payments are not made before ~2030, the allowance price follows the TAP price over the entire time horizon. This happens because the 5% interest rate that determines the rate of growth of the allowance price with banking is the same as the 5% rate at which the TAP price increases. As a result, there is no kink in the allowance price path when the TAP is triggered.

<u>Comparison with Other Analyses</u>

- The recent MIT report, "Assessment of U.S. Cap-and-Trade Proposals" analyzed several scenarios, none of which directly corresponded to S. 1766.
- For comparison, we ran one of the MIT scenarios (203 bmt) with the ADAGE model.
- For the 203 bmt scenario, the MIT analysis gave an allowance price of $41 in 2015 rising at 4%, while the ADAGE model gave a price of $40 in 2015 rising at 5%.

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

GHG Allowance Prices

- The previous chart shows the allowance prices from ADAGE and IGEM under S. 1766 in scenario 2 with the TAP, and scenario 3 without the TAP.
- The allowance price is equal to the marginal cost of abatement in the U.S.
- S. 1766 allows the banking of allowances, as a result the allowance prices in both models grow at the exogenously set 5% interest rate in scenario 3 without the TAP (which is the same rate at which the TAP price is specified to increase).
  - If instead the allowance price were rising faster than the interest rate, firms would have an incentive to increase abatement in order to hold onto their allowances, which would be earning a return better than the market interest rate. This would have the effect of increasing allowance prices in the present, and decreasing allowance prices in the future. Conversely, if the allowance price were rising slower than the interest rate, firms would have an incentive to draw down their bank of allowances, and use the money that would have been spent on abatement for alternative investments that earn the market rate of return. This behavior would decrease prices in the present and increase prices in the future. Because of these arbitrage opportunities, the allowance price is expected to rise at the interest rate.
- The terminal year for banking is assumed to be 2050 in this analysis. If later terminal year for banking was used instead, or if the terminal year for banking was endogenously determined, the allowance prices and costs of the policy would be higher, as a non-zero bank of emissions in 2050 would imply greater total emissions reductions.
  - A terminal year for banking of 2050 ensures that the cumulative covered emissions less offsets over the time period from 2012 – 2050 are equal to the cumulative emissions allowed under the cap. An assumption about the terminal year for banking is required for the models used in this analysis, and the assumption of 2050 is consistent with the time horizon of the models. If the terminal year for banking were not fixed, we would expect an increase in the allowance price beginning in 2012 absent the TAP, so that in whichever year the bank of allowances is exhausted, the allowance price would not have to increase more than the usual 5% in order to meet the cap. The 2050 terminal year for banking used in this analysis is consistent with the treatment of banking through 2050 in the recent MIT report, "Assessment of U.S. Cap-and-Trade Proposals".
- IGEM runs in annual time steps, so the policy is implemented in 2012. ADAGE runs in 5 year time steps, so the policy is implemented in 2015.
- Note that the range of allowance price presented here simply represents the results of the two models and should not be interpreted as a confidence interval.

Scenario Comparison

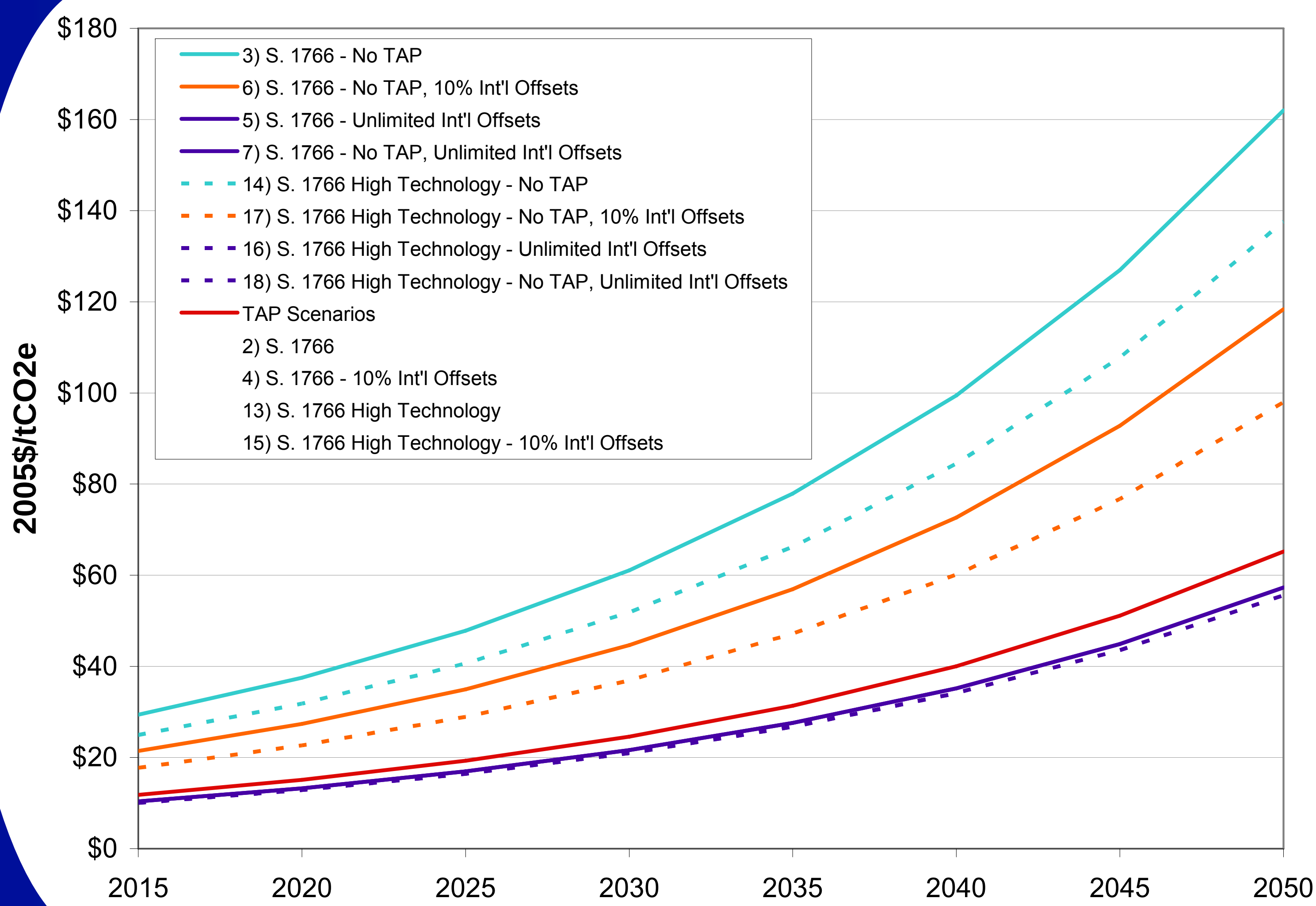
GHG Allowance Prices

Table: Allowance Price Comparisons (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
1) Core 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. 1766								
ADAGE	$12	$15	$19	$25	$31	$40	$51	$65
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
3) S. 1766 - No TAP								
ADAGE	$27	$35	$44	$57	$72	$92	$117	$149
IGEM	$29	$37	$48	$61	$78	$99	$127	$162
4) S. 1766 - 10% Int'l Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
5) S. 1766 - Unlimited Int'l Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$10	$13	$17	$22	$28	$35	$45	$57
6) S. 1766 - No TAP, 10% Int'l Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$21	$27	$35	$45	$57	$73	$93	$118
7) S. 1766 - No TAP, Unlimited Int'l Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$10	$13	$17	$22	$28	$35	$45	$57
8) S. 1766 - No CCS Subsidy								
ADAGE	$12	$15	$19	$25	$31	$40	$51	$65
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) S. 1766 - No TAP, No CCS Subsidy								
ADAGE	$28	$36	$46	$59	$75	$95	$121	$155
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10) S. 1766 - No CCS, Low Nuclear								
ADAGE	$12	$15	$19	$25	$32	$40	$51	$65
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
11) S. 1766 - Alternative Int'l Action								
ADAGE	$12	$15	$19	$25	$32	$40	$51	$65
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Scenario Comparison

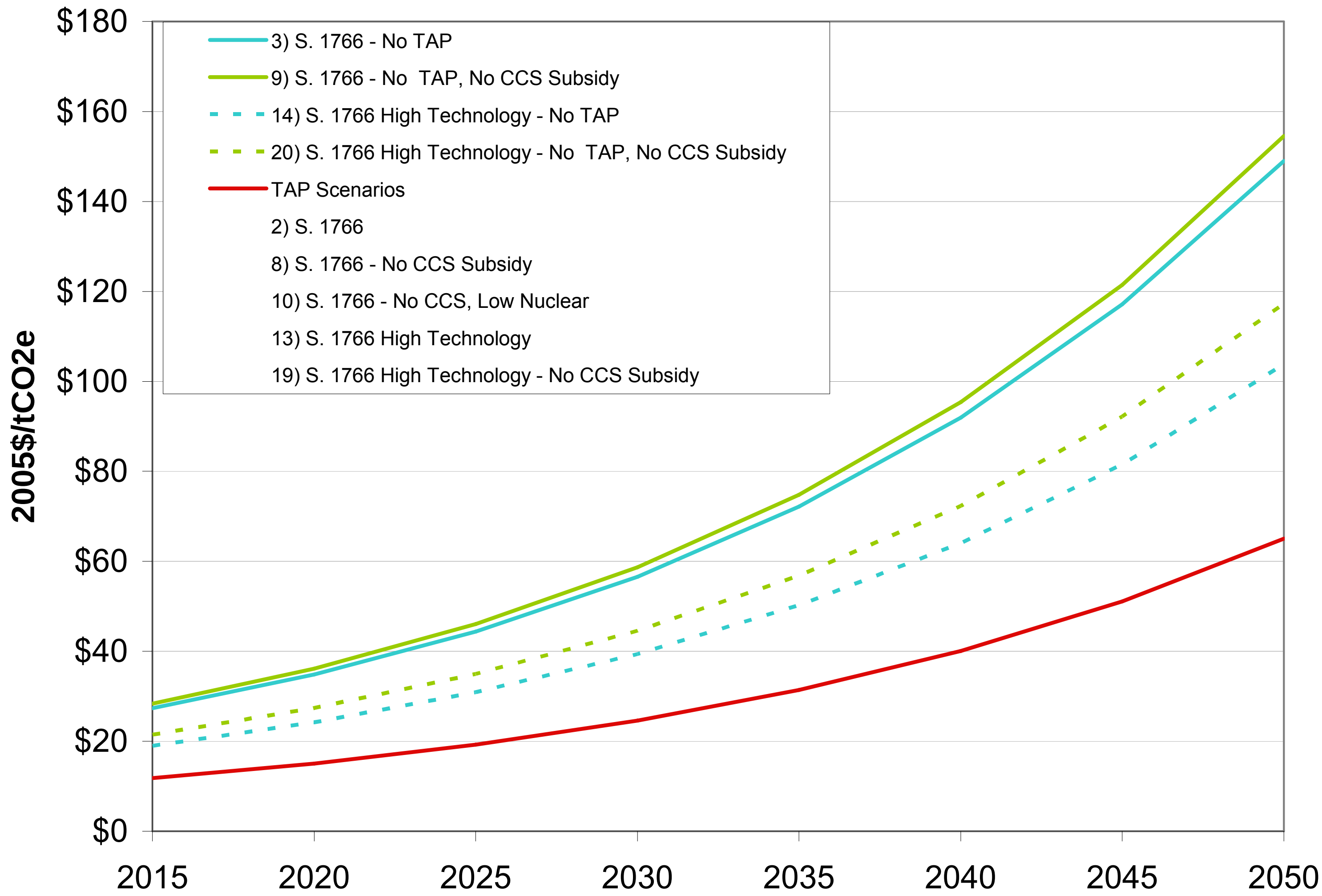
GHG Allowance Prices (IGEM)



- In the unlimited offset scenarios, the emissions target is met at an allowance price lower than the TAP, so in the scenarios where the TAP is available and international offsets are unlimited, the TAP is not triggered. Therefore, scenarios 5 & 7 are equivalent to each other, and scenarios 13 & 15 are equivalent to each other.

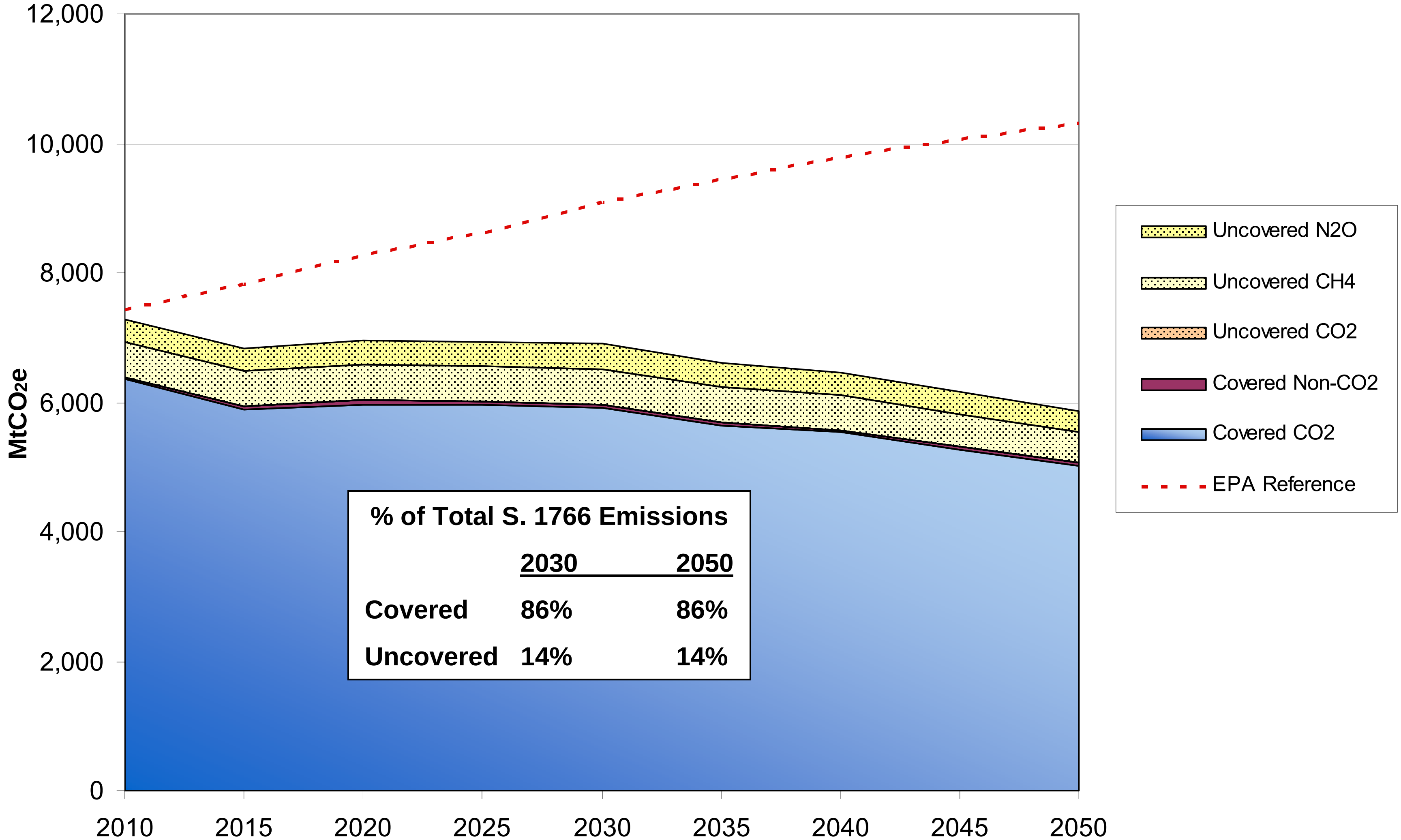
Scenario Comparison

GHG Allowance Prices (ADAGE)



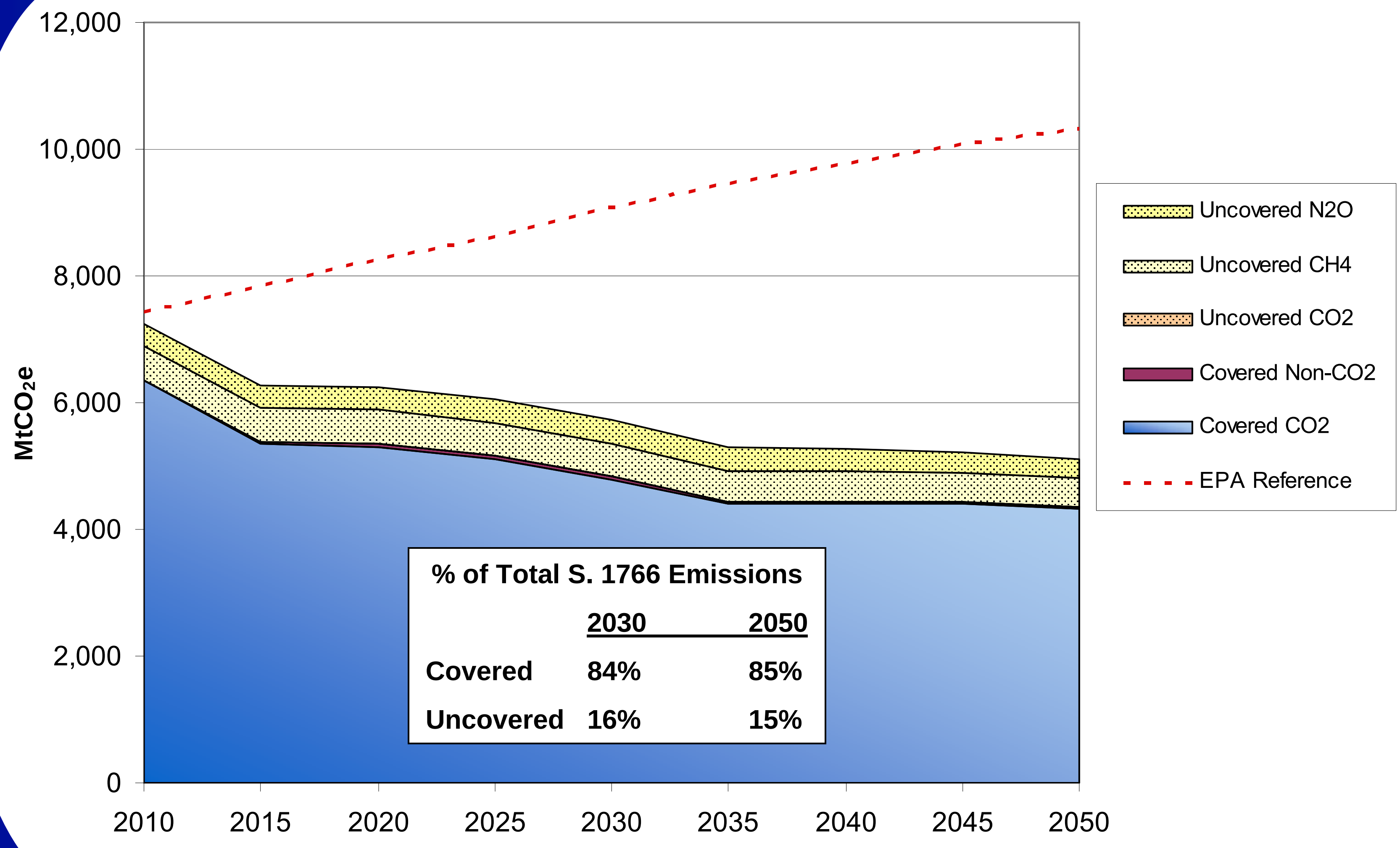
Results: Scenario 2 - S. 1766

Total U.S. GHG Emissions (ADAGE)



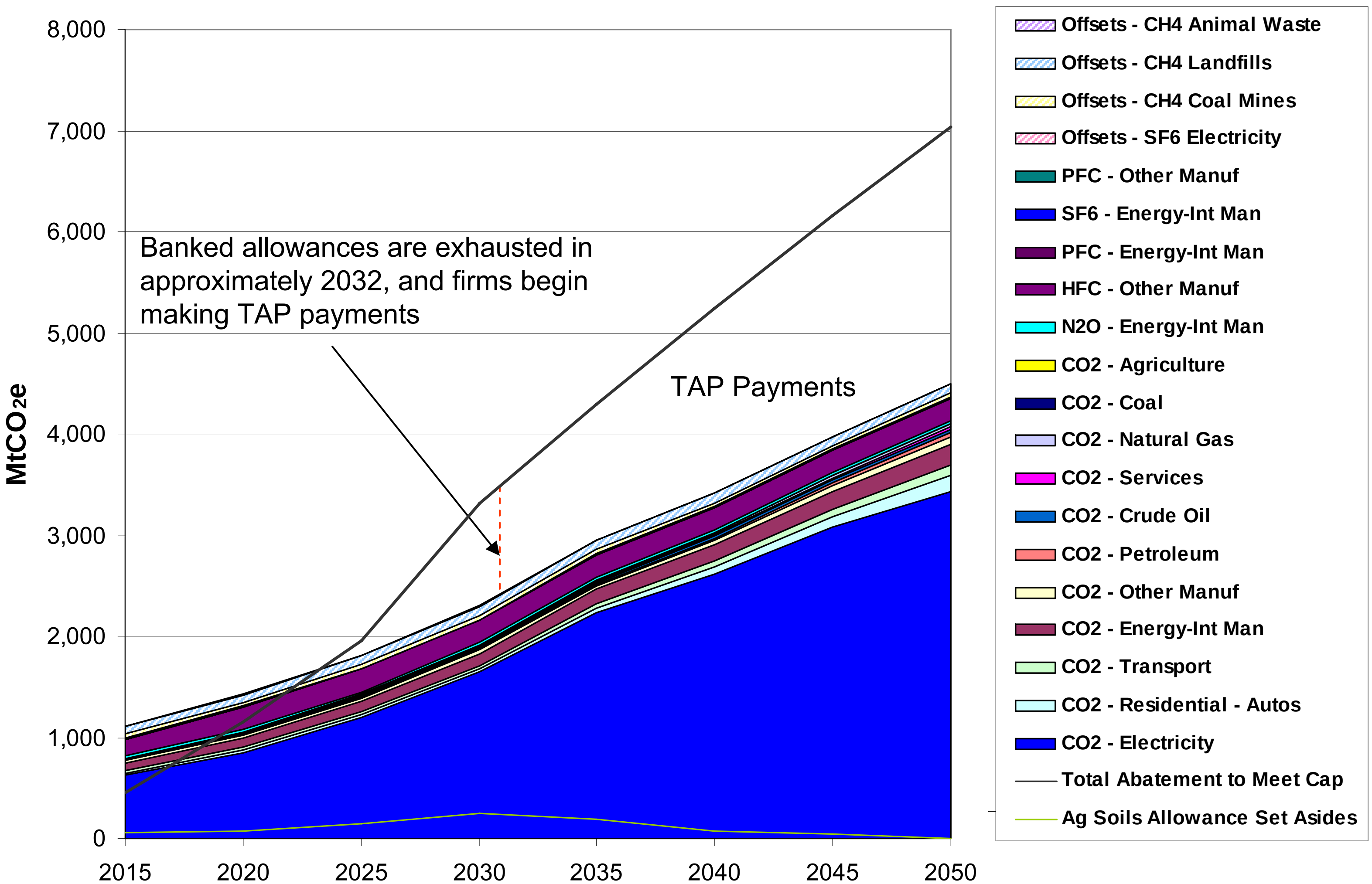
Results: Scenario 3 - S. 1766, No TAP

Total U.S. GHG Emissions (ADAGE)



Results: Scenario 2 - S. 1766

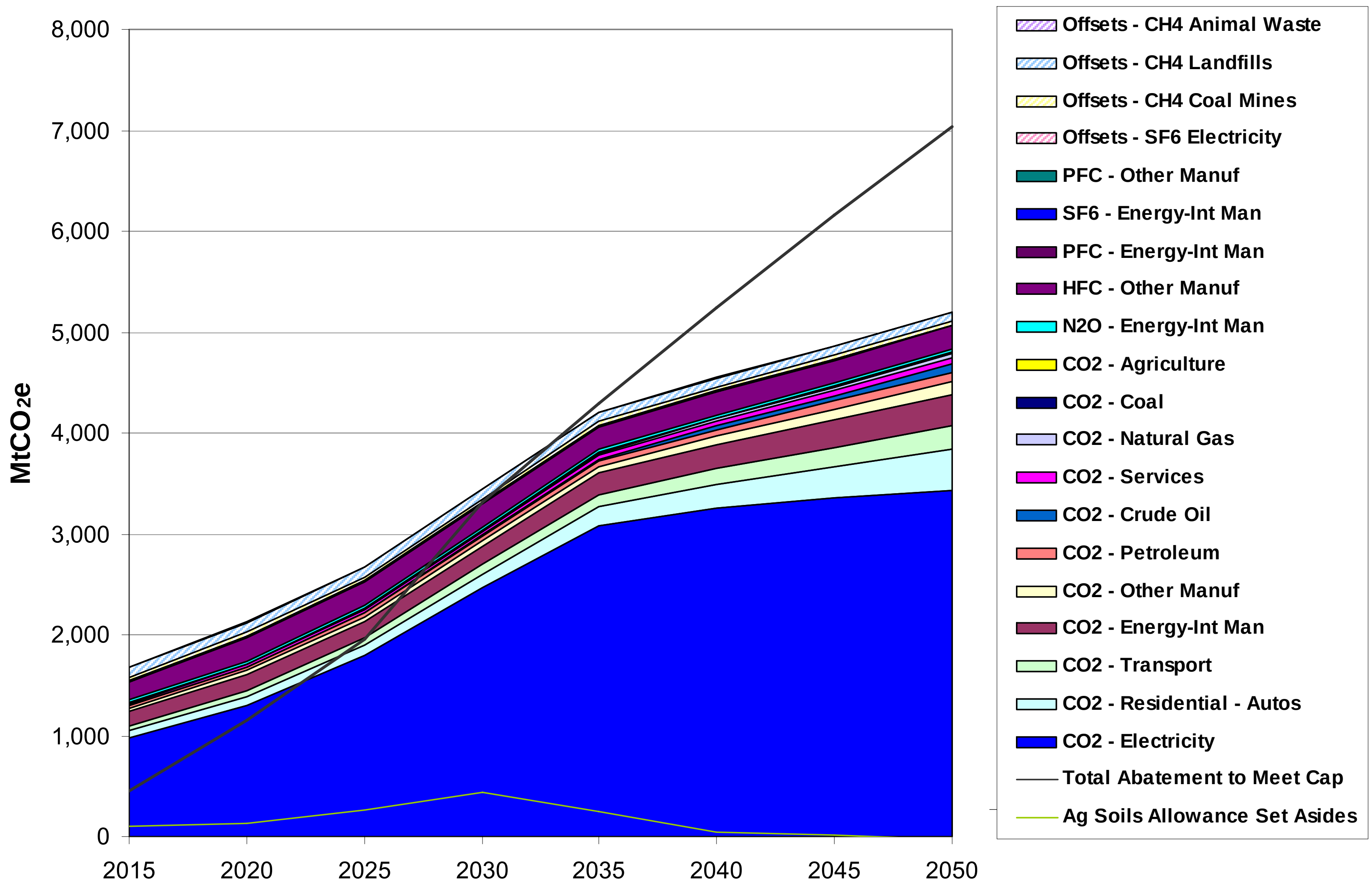
Sources of GHG Abatement (ADAGE)



- In this scenario, the TAP is triggered, and the total GHG emissions abatement is not sufficient to meet the cap.
- The solid black line at the top of the graphic represents the total abatement required to meet the cap (without banking).
- The stacked areas represent all the sources of GHG abatement.
- In the early years firms bank allowances, in approximately 2024 firms begin drawing down the bank, which is exhausted by ~2032, after which firms make TAP payments.
- The light blue line at the bottom represents additional abatement from ag-soils allowance set-asides that is in addition to abatement required to meet the cap.

Results: Scenario 3 - S. 1766, No TAP

Sources of GHG Abatement (ADAGE)



- The solid black line at the top of the graphic represents the total abatement required to meet the cap (without banking).
- In the early years, firms over comply and build up a bank of allowances that is used up in later years.
- The area under the black line is equal to the stacked areas, so over the entire time frame the GHG abatement is sufficient to meet the cap.
- The light blue line at the bottom represents additional abatement from ag-soils allowance set-asides that is in addition to abatement required to meet the cap.

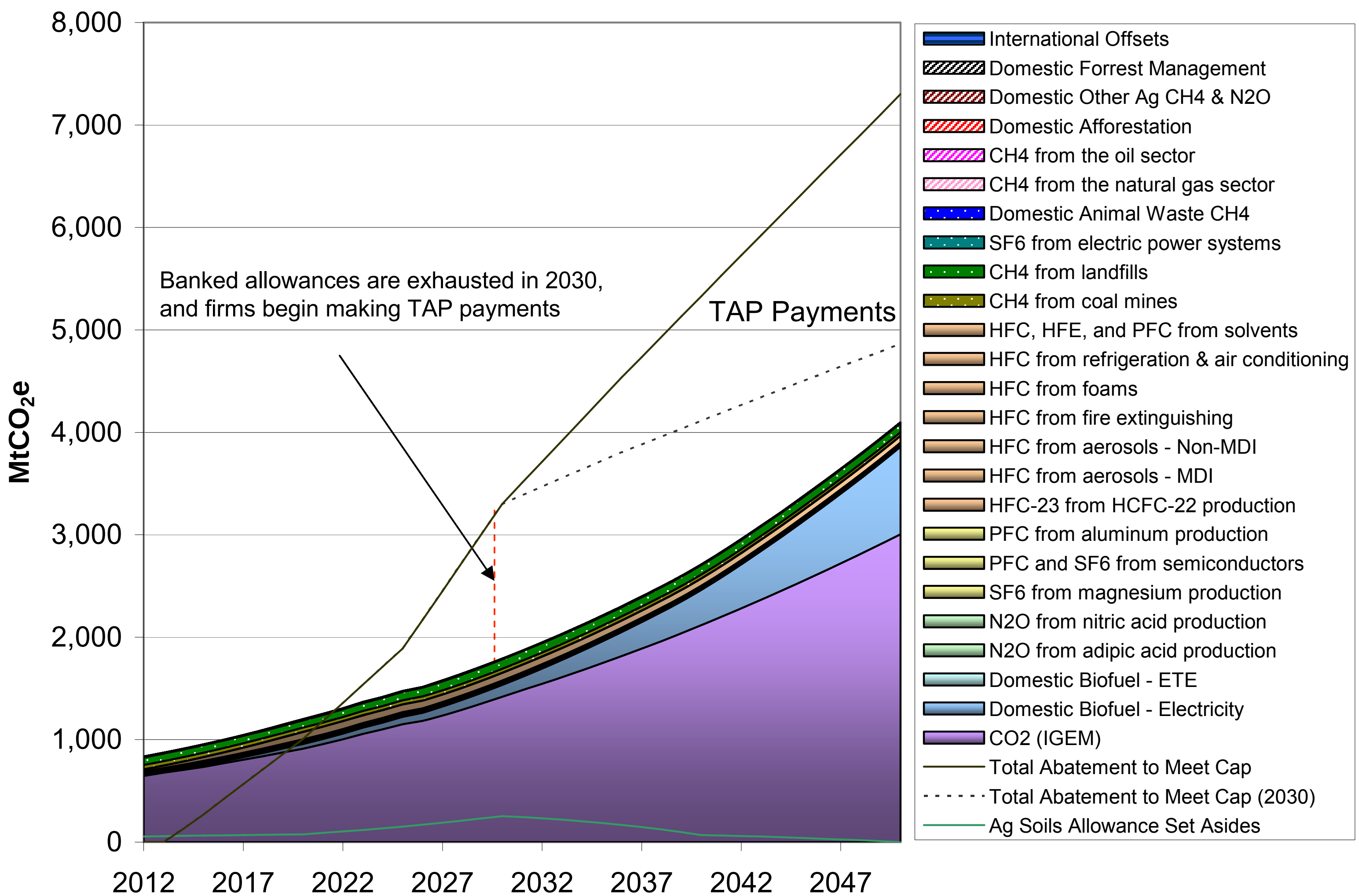
Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

Sources of GHG Abatement (ADAGE)

- The previous two charts show, for the ADAGE model, the sources by sector of GHG abatement under S. 1766 in scenario 2 with the TAP, and scenario 3 without the TAP.
- In scenario 2 with the TAP, the emissions cap is exceeded.
  - The solid black line at the top represents the total amount of abatement (with banking) required to meet the cap, so the white space between the black line and the top of the abatement area is the total amount by which the cap is exceeded.
- CO_2 emissions from the electricity sector (the blue area at the bottom) represent the largest source of domestic reductions in both scenarios.
- The area toward the top of the chart shaded with hashed lines show emissions reductions from domestic offset projects.
- Although S. 1766 places no restrictions on the amount of domestic offsets that may be used, only a limited set of offset project types are allowed.
  - As a result, offsets provide a relatively small portion of emissions reductions.
  - If agricultural and forestry sector offset projects were allowed, they would provide a significant amount of abatement at the allowance prices in both of these scenarios.
- The light blue line at the bottom represents GHG abatement from ag/soils 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.
- 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. 1766

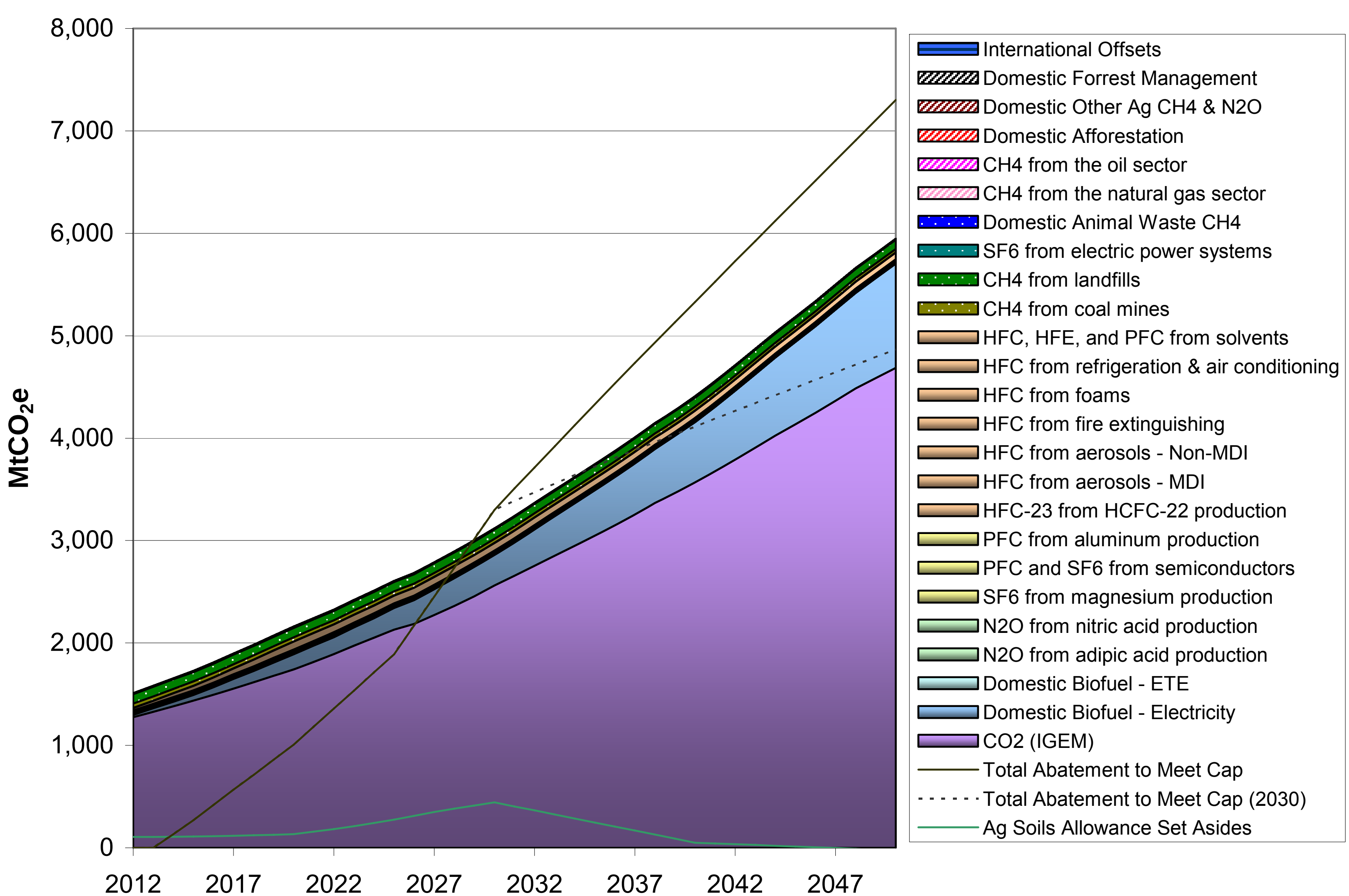
Sources of GHG Abatement (IGEM)



- The solid black line at the top represents the total amount of abatement required to meet the cap (without banking).
- In the early years firms bank allowances, after 2022 firms begin drawing down the bank, which is exhausted by 2030, after which firms make TAP payments.
- The dotted black line represents the total amount of abatement (without banking) required to meet the cap assuming that the cap remains constant after 2030.
- This scenario is identical to the tighter cap except the size of the TAP payments is smaller
- The light blue line at the bottom represents additional abatement from ag-soils allowance set-asides that is in addition to abatement required to meet the cap

Results: Scenario 3 - S. 1766, No TAP

Sources of GHG Abatement (IGEM)



- The solid black line at the top represents the total amount of abatement required to meet the cap (without banking).
- In the early years firms bank allowances, after 2028 firms begin drawing down the bank, which is exhausted in 2050.
- The cumulative amount of abatement over the 2012-2050 time period is enough to comply with the cap.
- The dotted black line represents the total amount of abatement (without banking) required to meet the cap assuming that the cap remains constant after 2030.
- The light blue line at the bottom represents additional abatement from ag-soils allowance set-asides that is in addition to abatement required to meet the cap

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

Sources of GHG Abatement (IGEM)

- The previous two charts show, for the IGEM model, the sources of CO_2 and non-CO_2 GHG abatement under S. 1766 in scenario 2 with the TAP, and scenario 3 without the TAP.
- 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 area toward the top of the chart shaded with dotted colors show emissions reductions from domestic offset projects.
- Although S. 1766 places no restrictions on the amount of domestic offsets that may be used, only a limited set of offset project types are allowed.
  - As a result, offsets provide a relatively small portion of emissions reductions.
  - If non-specified offset projects (sources shaded with hashed lines in the legend) were allowed, they would provide a significant amount of abatement at the allowance prices in both of these scenarios.

Detailed Near-Term Electricity Sector Modeling Results

Detailed Electricity Sector Modeling with IPM

Motivation for Using 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. 1766 on the electricity sector as a complement to the broader picture presented by the CGE models.

Power Sector Modeling (IPM v3.01):

- This version of IPM builds off recently released EPA Base Case v3.0 using IPM, with the following updates for purposes of modeling carbon policies:
  - Carbon capture and storage (for new plants)
  - Biomass co-firing retrofit option
  - Constraints on new nuclear, renewable, and advanced coal with CCS capacity
  - Percent change in electricity demand was calculated endogenously by the model in response to electricity prices

Modeling Approach:

For this analysis, EPA's Base Case v3.01 using IPM was used and incorporated CO_2 allowance price projections from the ADAGE model.

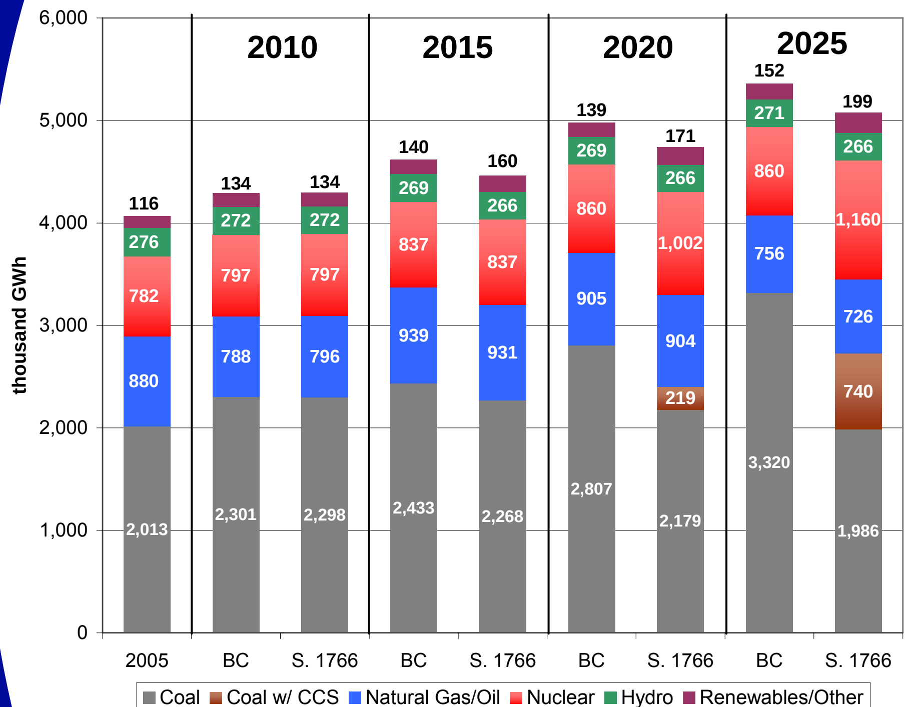
Key Insights from IPM Results for the Near-Term

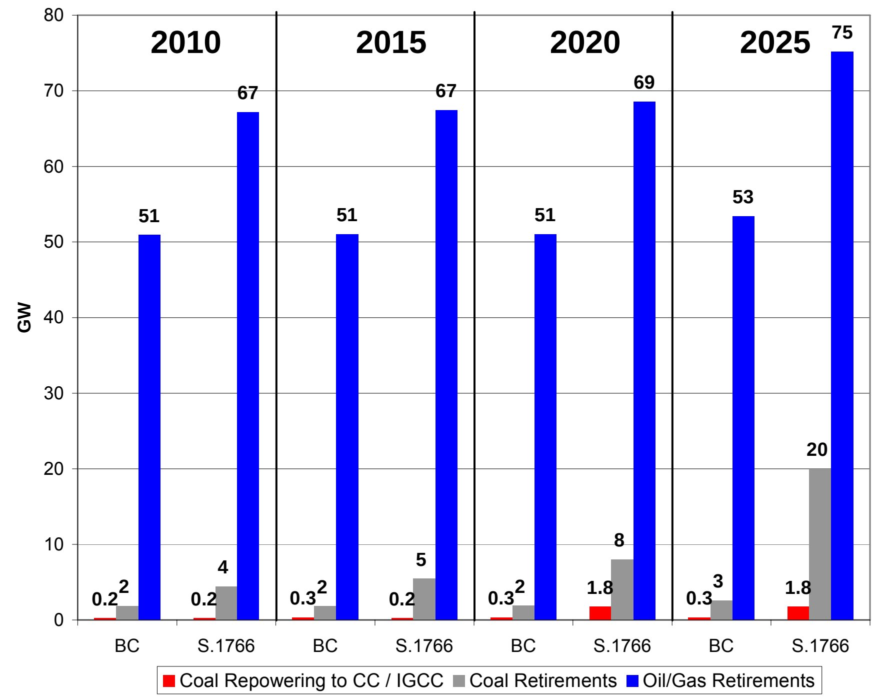
- The reduced electricity demand levels produce the largest share of reductions in the early years (prior to 2020).
- Due to the bonus allowance provision for CCS, GHG allowance prices will be high enough to justify significant penetration of CCS starting in 2020. Further, the carbon price incurred by various emitting technologies (e.g., coal) makes new nuclear plants more economic to build.
  - In IPM, advanced coal with CCS penetrated at the maximum permissible rate in the model in 2025. The rate of penetration was significantly higher in IPM than in ADAGE in the near term.
  - In IPM, CCS penetrates to the point that it causes additional retirements of both coal and oil/gas steam units.
  - Without the bonus subsidy, IPM does not project penetration of CCS by 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 RPS), it is very difficult to specify TAP levels and bonus allowance ratios to achieve desired deployment of CCS.

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 nuclear capacity, the model places an exogenous constraint on the total amount of new nuclear 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.

Electricity Generation Mix and Retirements/Repowerings

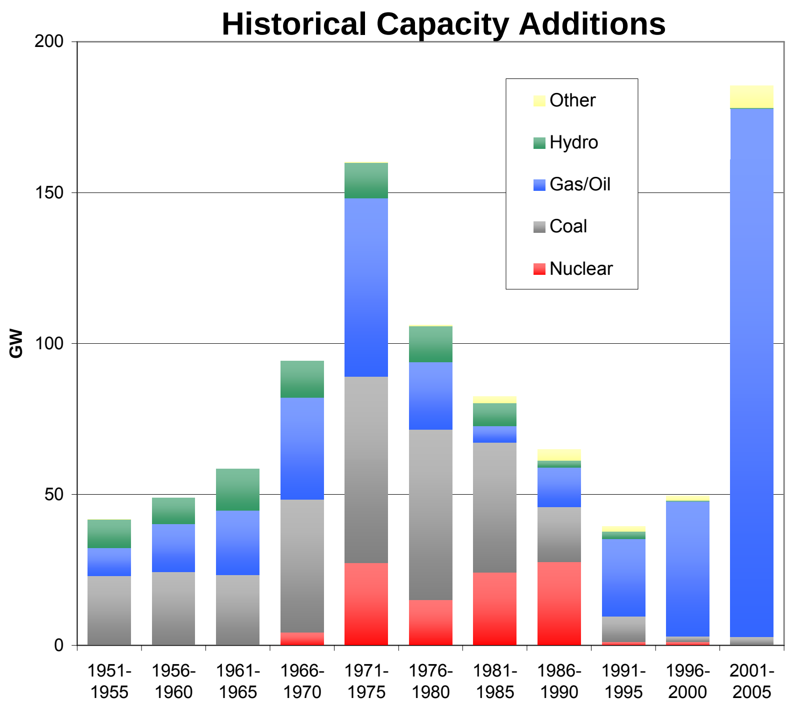




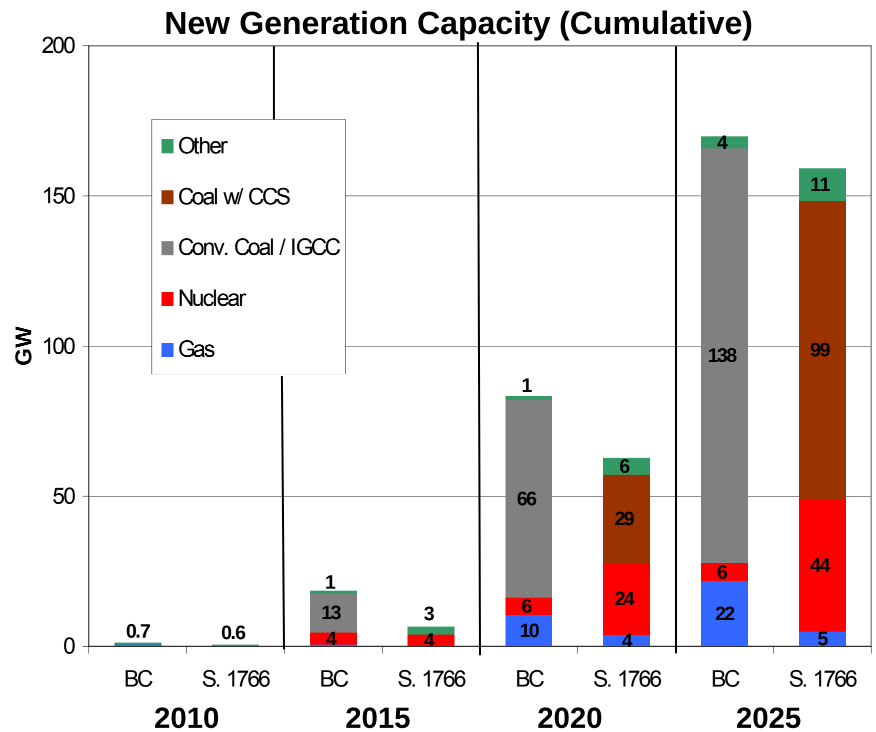
* Many of the retired coal units are older, less efficient units operating at lower capacity rates.

New Generation Capacity and Historical Capacity Additions

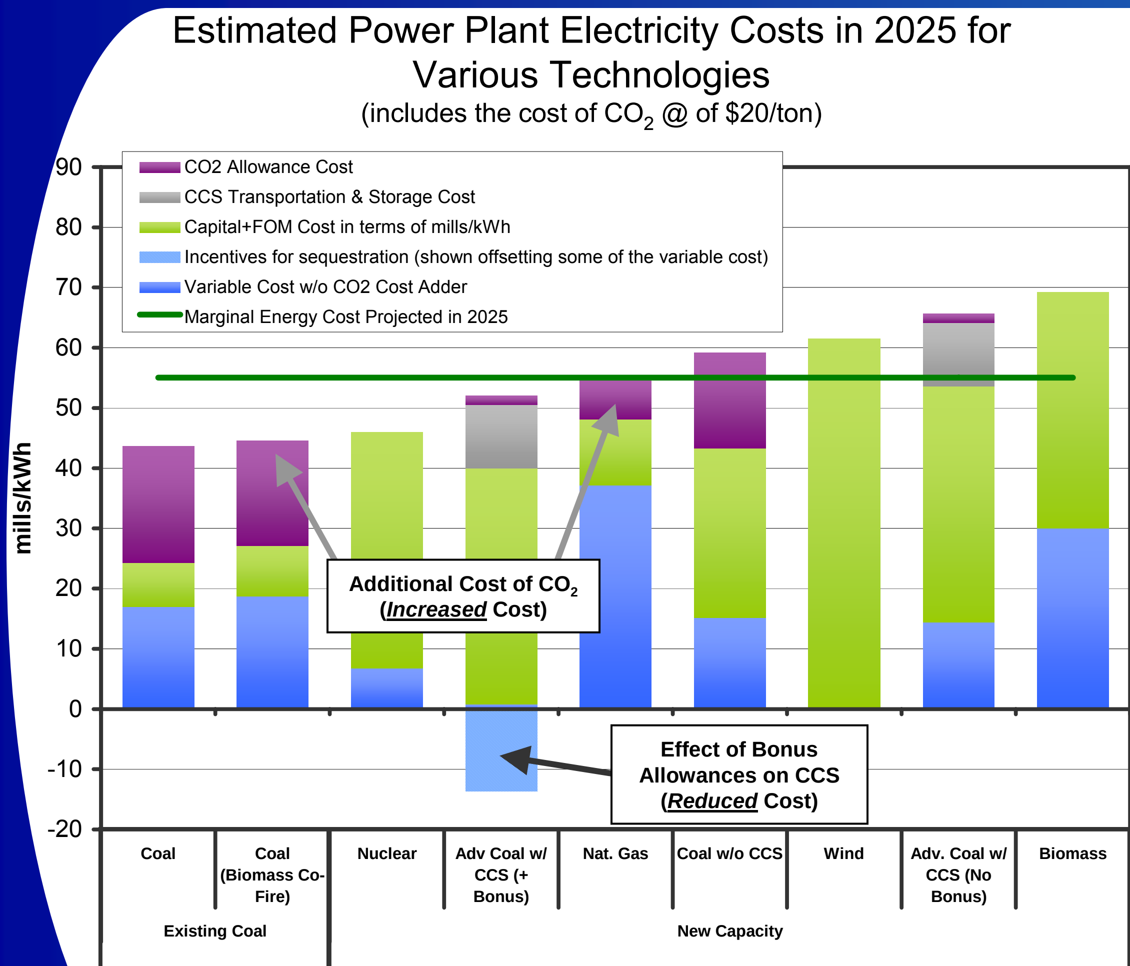
- IPM indicates that a large amount of coal with CCS will be built under S. 1766.
- Historical data from EIA and EPA show that large amounts of electricity generation capacity can be built over relatively short periods of time under the appropriate conditions. For example, between 1971-75, around 70 GW of coal and 25 GW of nuclear capacity was added in the U.S.
- Although much uncertainty about CCS remains, it is plausible that large amounts could be built quickly if given the right signals and incentives. EPA has constrained nuclear and CCS capacity, and those constraints are met in IPM in 2025.



Source: EPA, 2006 National Electric Energy Data System.



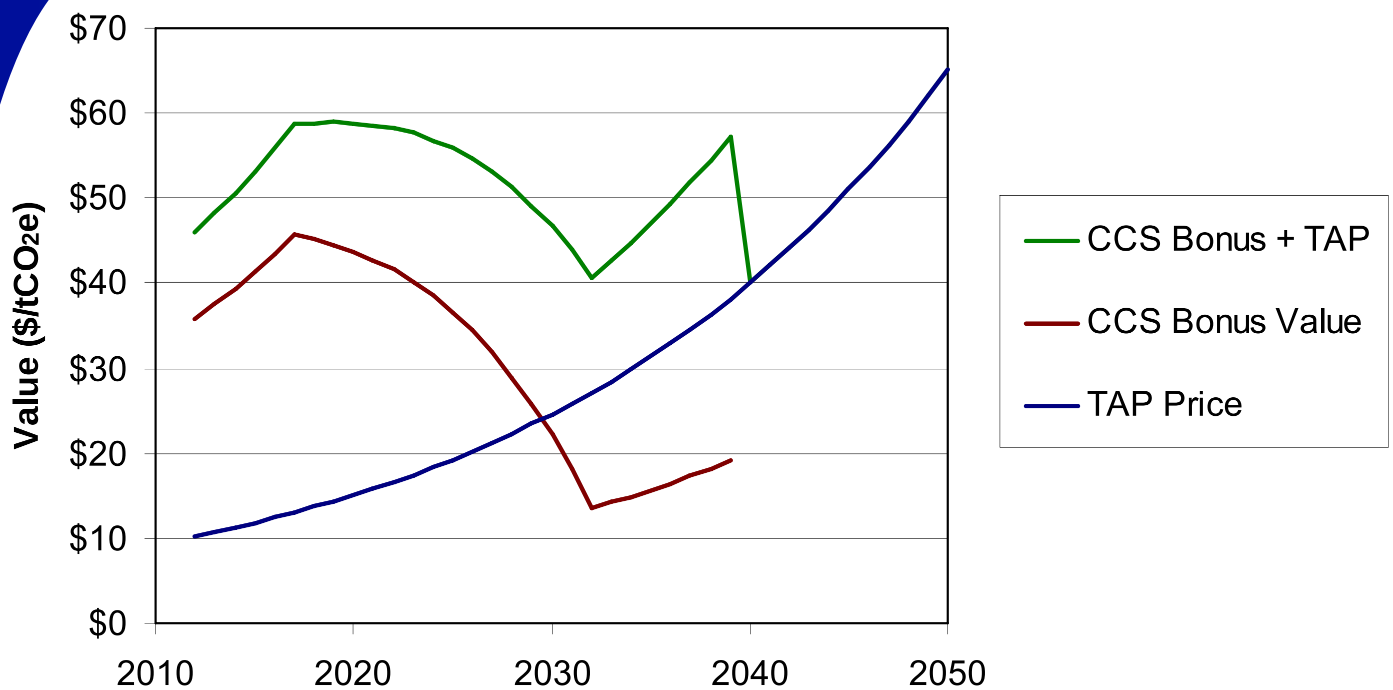
Near-Term Power Plant Economics with CO_2 Allowance Costs



- 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 $20/ton in 2025 increase variable costs of existing coal plants, but these costs are still generally below the marginal energy costs of producing electricity.
- However, S. 1766 provides significant incentives for CCS technology for coal plants in the form of bonus allowances, resulting in more coal retirements post-2020 as new capacity with CCS is built in this timeframe.
- With regards to new technology, advanced coal w/ CCS would not be competitive in this timeframe without the bonus allowances.

Notes: For the case with bonus allowances, the variable cost is actually an aggregate of the solid part and the dotted part but the net cost is only the solid part. For this illustrative calculation, EPA used a conservative efficiency metric (10,500 Btu/kWh), which most existing coal 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.

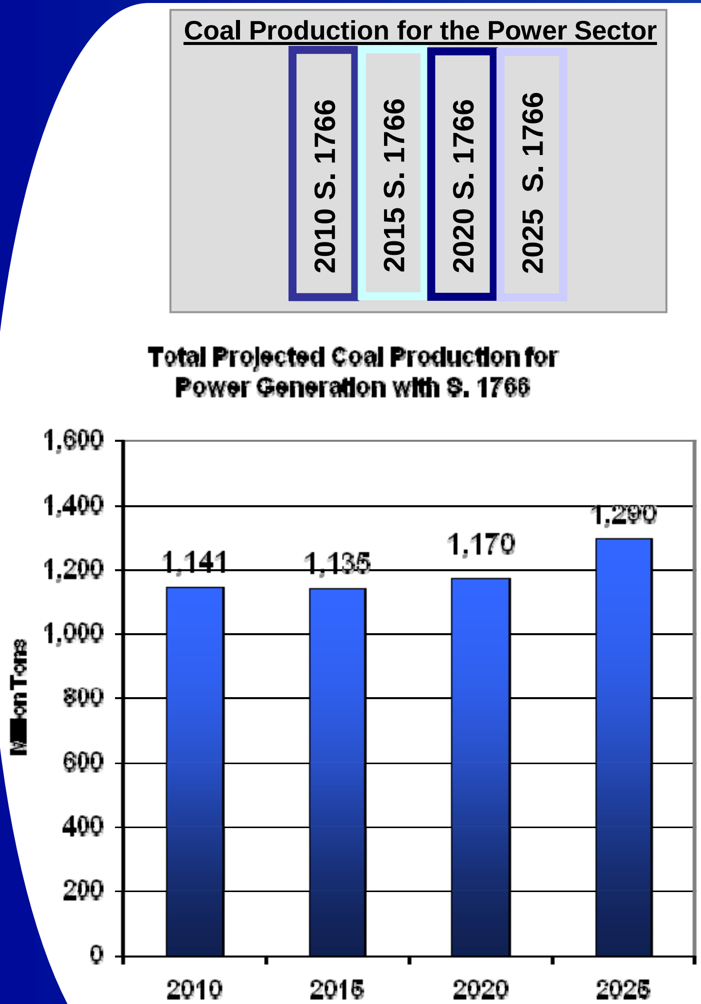
S. 1766 Bonus Allowances for CCS

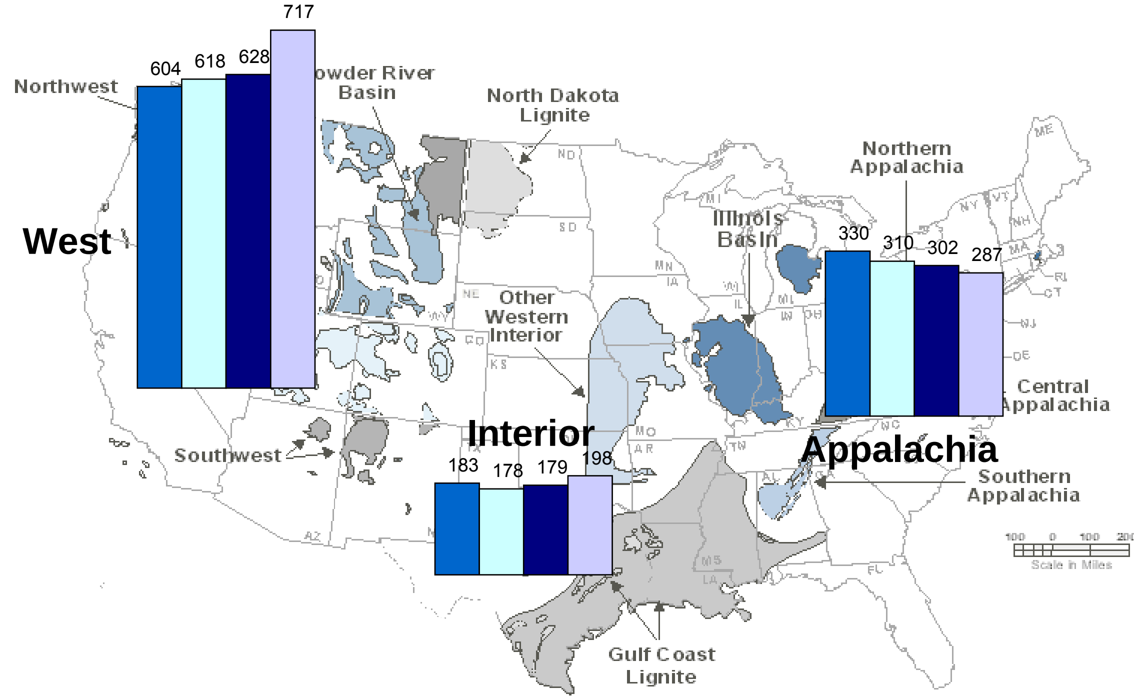


Year	Bonus Allowance Rate
2012-2017	3.5
2018	3.3
2019	3.1
2020	2.9
2021	2.7
2022	2.5
2023	2.3
2024	2.1
2025	1.9
2026	1.7
2027	1.5
2028	1.3
2029	1.1
2030	0.9
2031	0.7
2032-2039	0.5

- The value of the CCS bonus allowances changes as the allowance price changes and the bonus allowance rate changes. The kinks in the CCS bonus value curve are due to the way the bonus allowance rate changes over time.
- S. 1766 distributes bonus allowances to entities that implement geological sequestration projects.
- Qualifying projects receive CCS bonus allowances only for the first ten years of operation, and must begin operation between 2008 and 2030.
- The value of the CCS bonus plus the TAP value is the monetary benefit to a source that captures and sequesters one ton of CO_2.

Coal Production for Electricity Generation with S. 1766

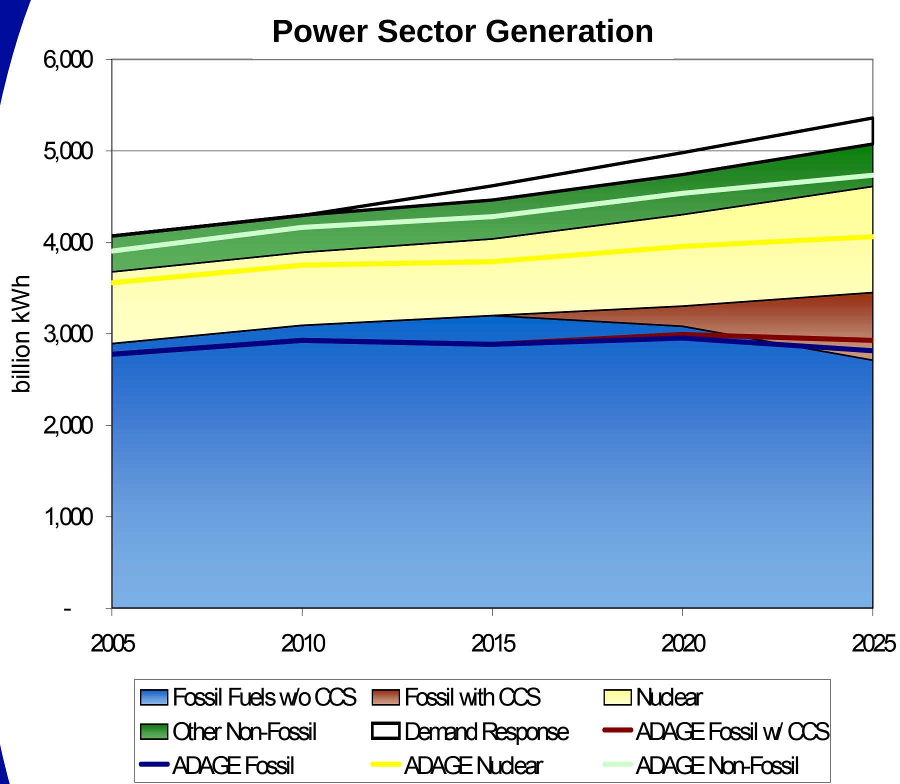


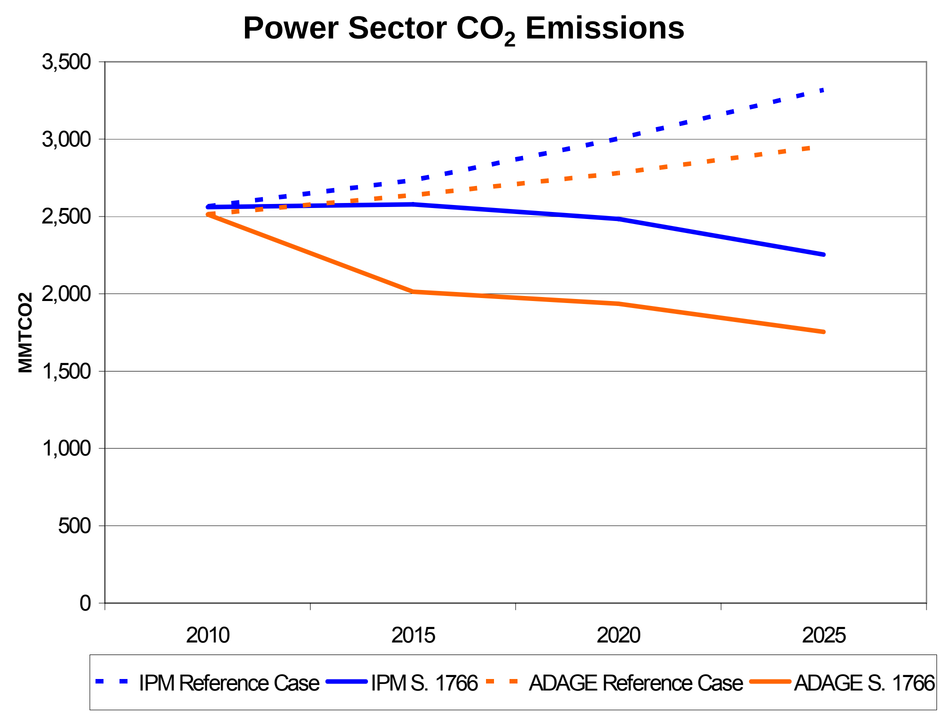


Note: Regional coal production data includes coal production for power generation only, while nationwide data includes coal production for power generation, waste coal, and coal imports. Coal production data for use by other sectors is not presented here.

*This slide was updated on 1/25/08. The original slide incorrectly included coal production levels from EPA's reference case scenario rather than the S. 1766 scenario.

Electricity Generation and CO_2 Emissions: Near-Term Results with IPM and ADAGE





Comparison of ADAGE and IPM Electricity Generation Results

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.

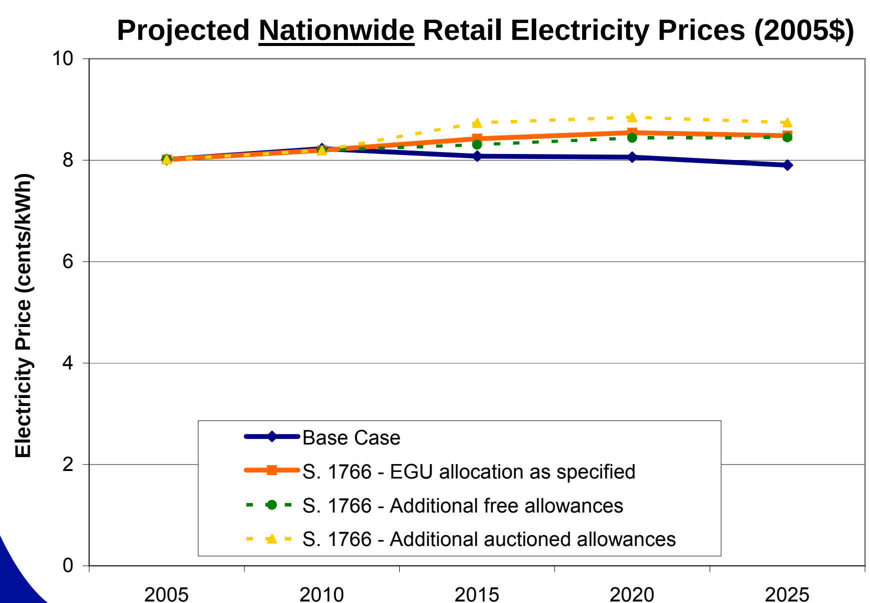
- In ADAGE, nuclear generation is an exogenous input to the model and the cost curves developed for biomass penetration do not account for the CCS subsidy. Although there are some constraints in IPM, all types of generation compete against each other based on their economics (including the impact of the CCS subsidy).
- IPM reaches the upper constraint set on new capacity for advanced coal with CCS in 2025 while ADAGE does not. ADAGE is meeting more demand through renewable energy, specifically biomass. Coal with CCS only becomes an option starting in 2020 after nuclear and renewables have been used to meet demand.
- More of the demand in IPM is met through nuclear energy, coal w/ CCS, and demand response, and less renewable capacity is added because it is not as competitive to build.
- While ADAGE does not have representation of coal unit vintaging, the implied capital turnover rate indicates faster turnover of the existing fleet to new coal units, when compared to IPM. In IPM, most coal units remain economic at the projected allowance prices.
- ADAGE shows greater reductions in power sector CO_2 emissions in the near term compared to IPM. This is largely due to efficiency gains and higher new renewable energy capacity in ADAGE.

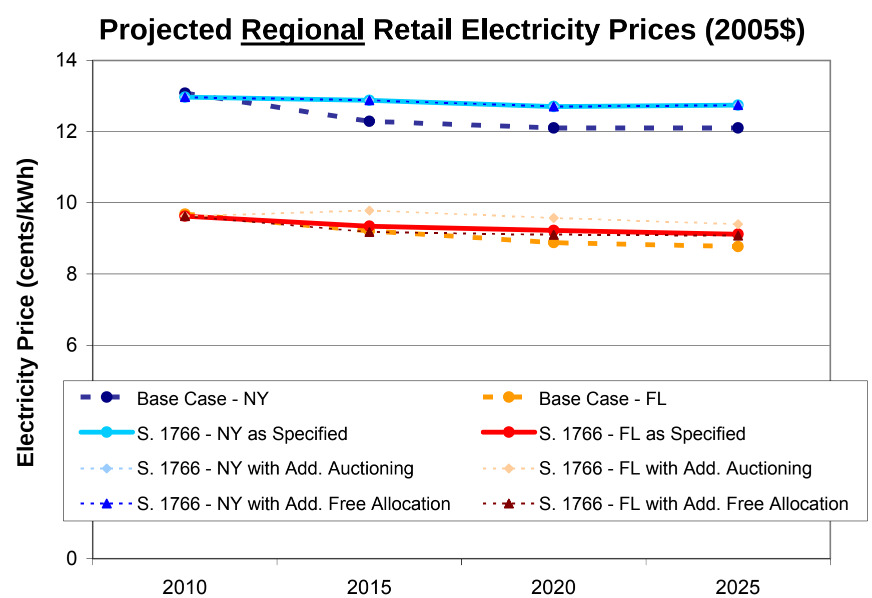
Detailed documentation of IPM v3.01, its assumptions, and constraints is available on the EPA website. Links to the ADAGE and IGEM documentation are provided in the Appendix of this presentation.

National and Regional Projected Electricity Prices

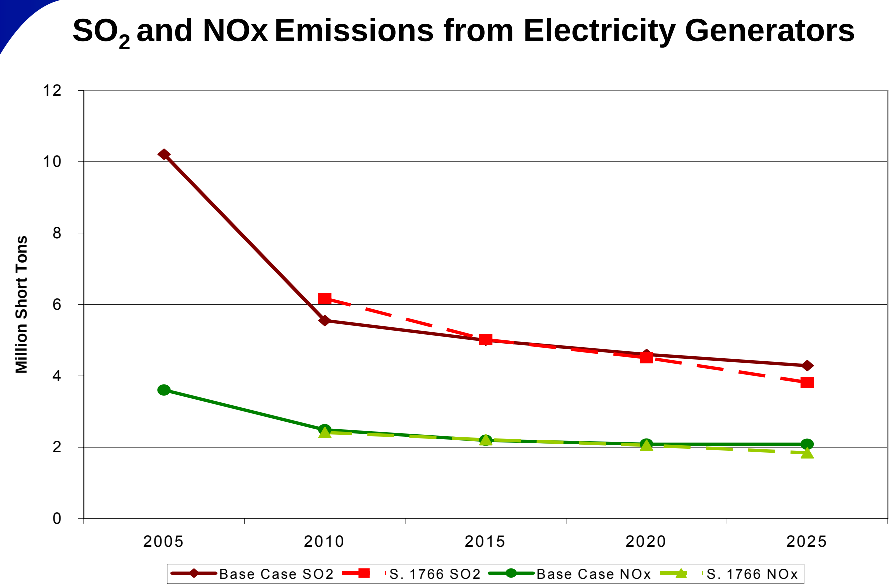
These graphs present the average national and regional impacts of S. 1766 on retail electricity prices:

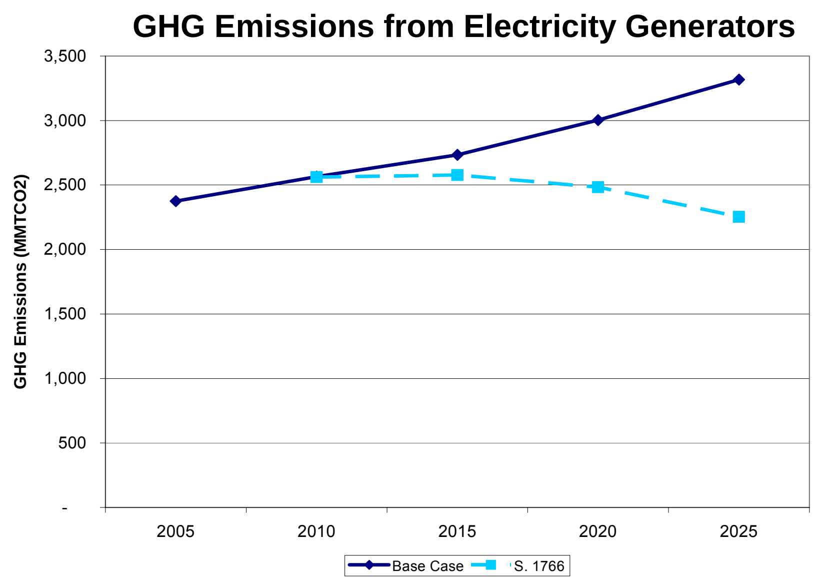
- Consumers in regions with deregulated electricity markets, like New York, will see similar price impacts regardless of allocation methodology.
- Consumers in regions with regulated electricity markets, like Florida, will see more variance in price effects depending on allocation methodology.
- Nationwide electricity prices increase by 7.4% in 2025 (Electricity prices increase 5.3% in New York and 4.0% in Florida in 2025).

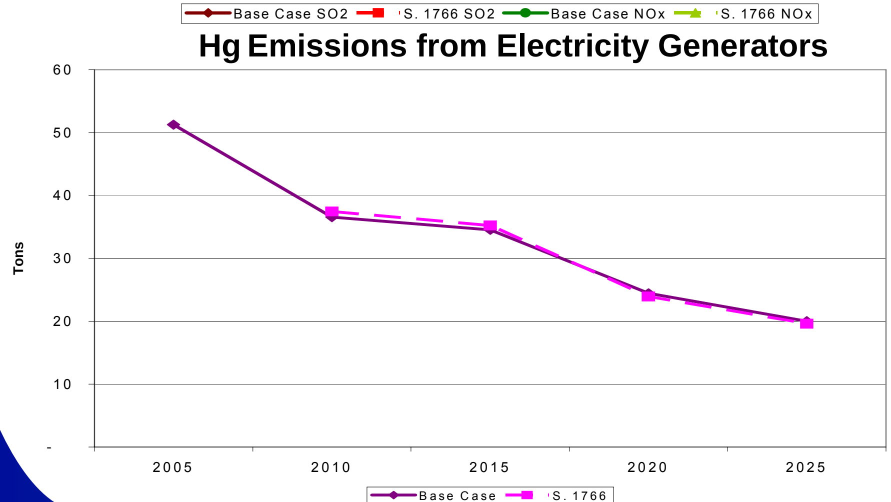




Power Sector Emissions

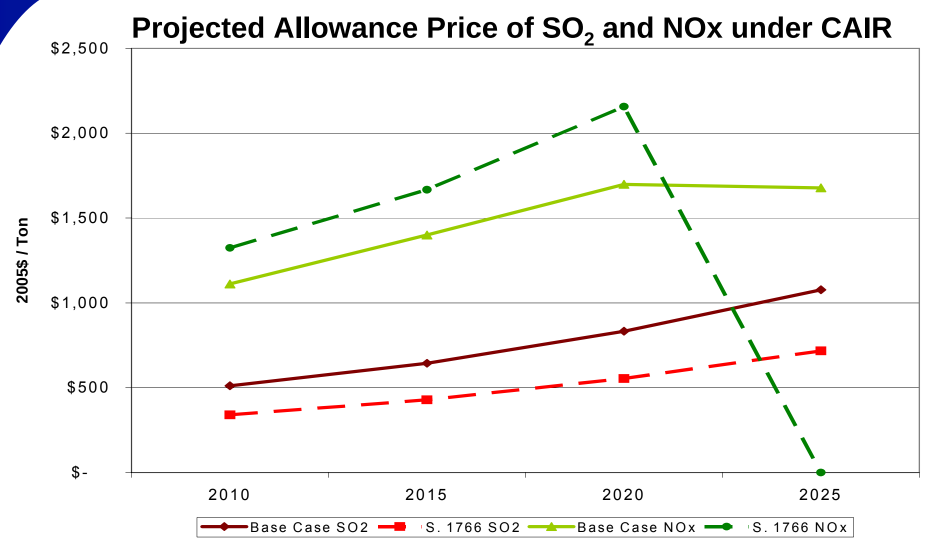


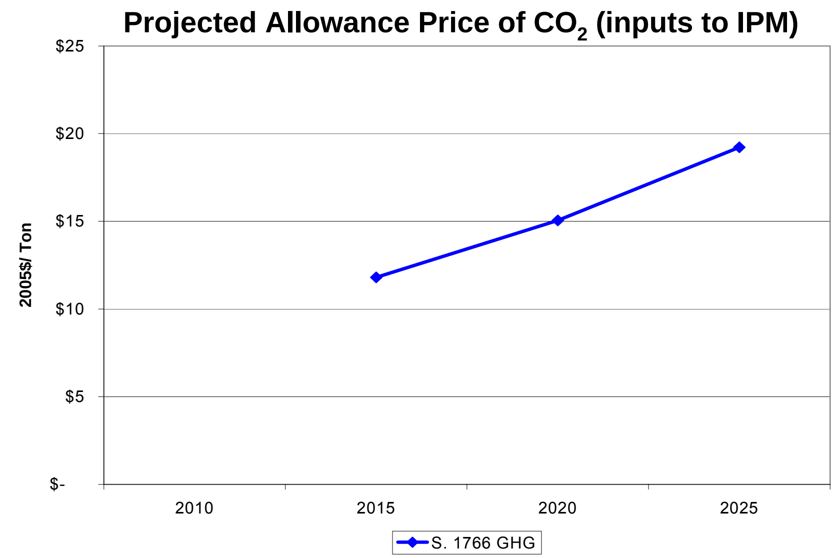


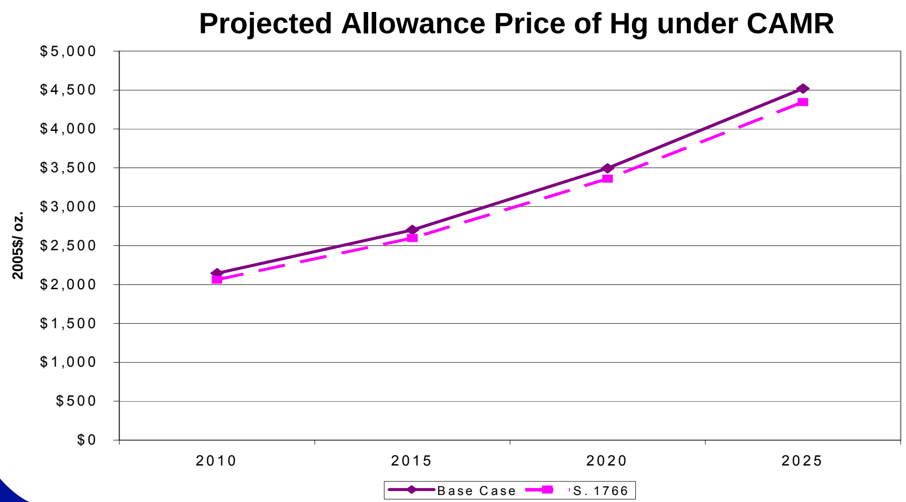


CO_2 allowance prices projected in S. 1766 influence the timing of SO_2 and Mercury emissions because of existing cap and trade programs and emission banking provisions of the CAIR and CAMR programs.

CAIR and CAMR Allowance Price Comparisons







Notes:

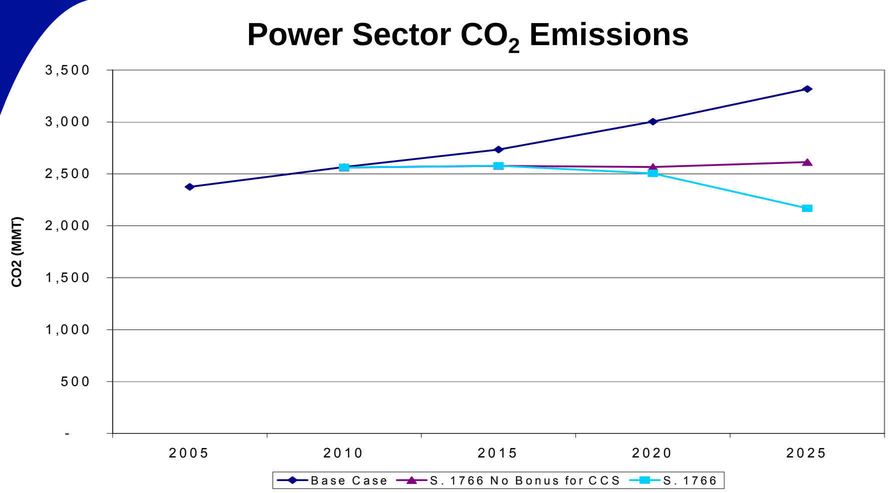
SO_2 allowance prices are for CAIR affected sources on a $/ton of emissions basis; Title IV allowance prices are not shown separately, but would be a fraction of this amount.

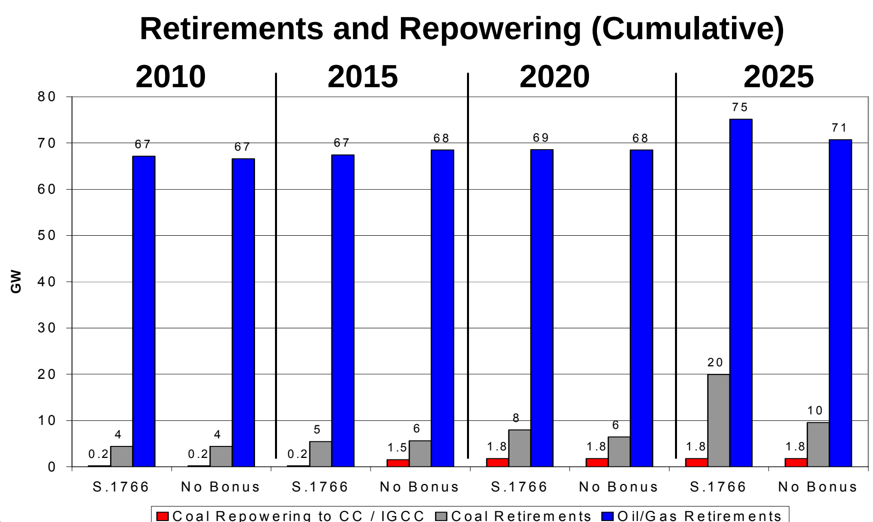
The CO_2 allowance price is an input to IPM. The CO_2 allowance price reaches the TAP level in all years. The price would be higher without the TAP constraint.

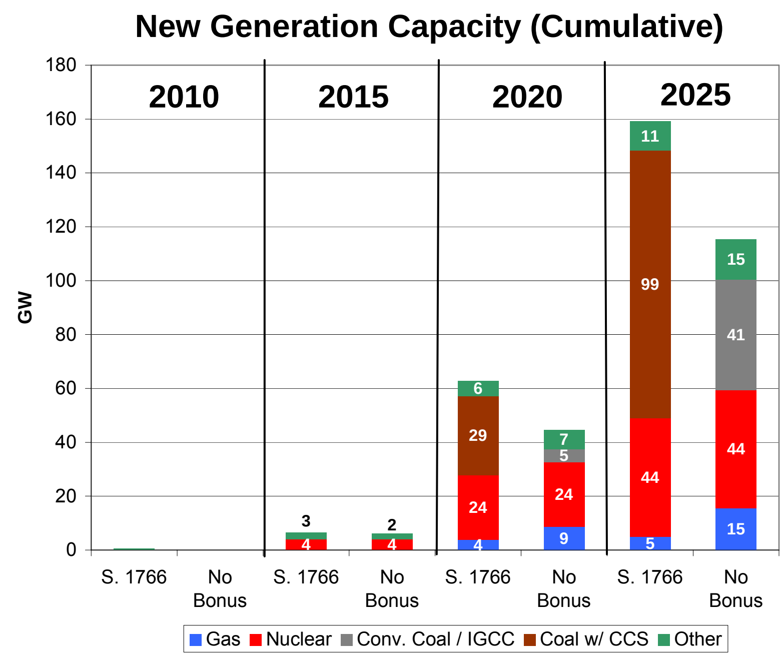
Analysis of Bonus Allowances for CCS

- 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: Nearly 100 GW of advanced coal with CCS built by 2025 (in 2025, the bonus allowances account for 18% of all allowances).
- Observations:
  - Investment in CCS is very sensitive in IPM to the allowance price and bonus allowance ratio.
  - 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.

S. 1766 With and Without CCS Bonus Allowances



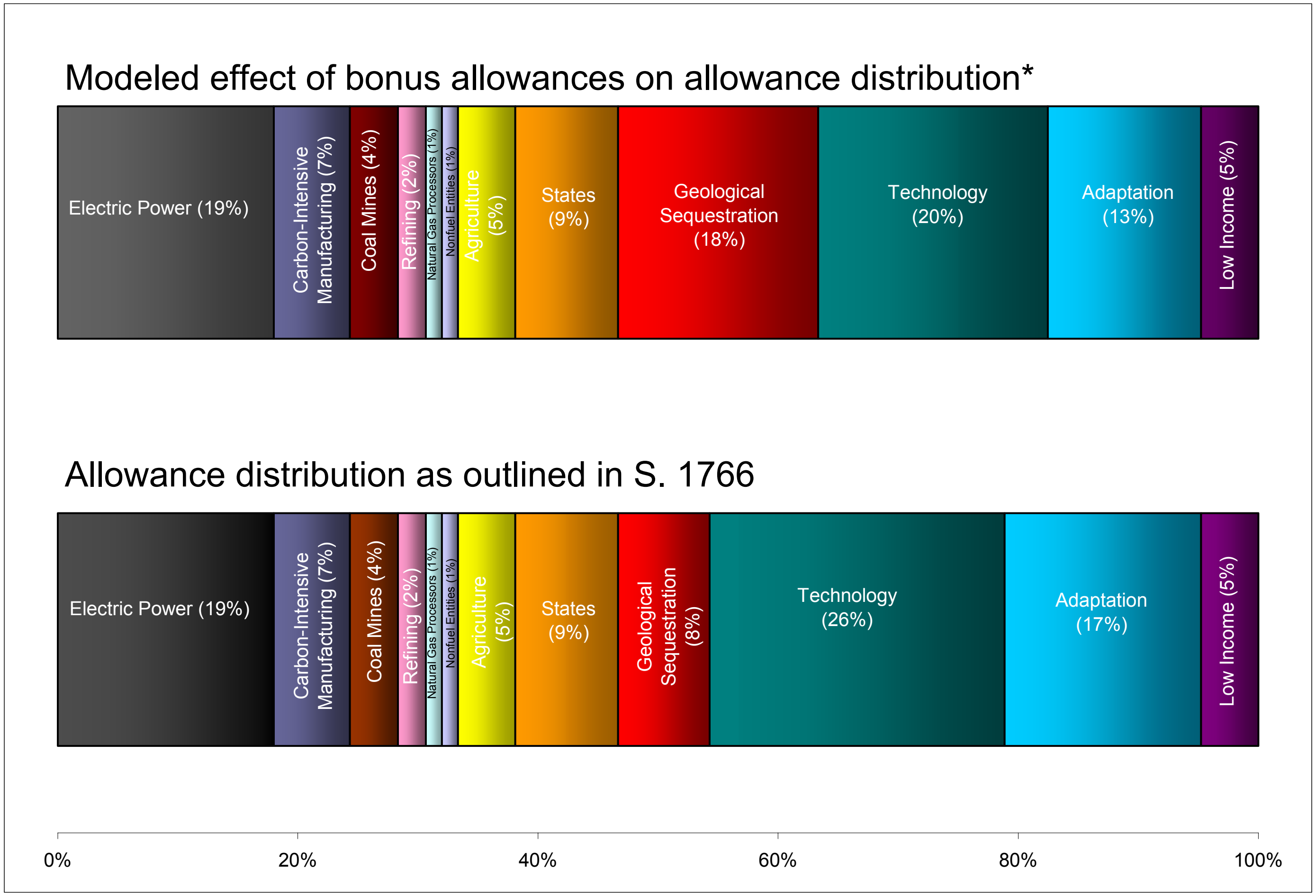




- No advanced coal with CCS is built when allowance prices are at the TAP level and there are no bonus allowances.
- GHG emissions from the power sector are higher when no bonus allowances are provided for CCS.
- Fewer oil, gas, and coal retirements without CCS bonus allowances, but still considerably more than in the base case.

Modeled Impact of Bonus Allowances on Allowance Distribution in 2025

In 2025, the bonus allowances for CCS will draw significantly from the auction, resulting in lower revenues for technology and adaptation. The impact is smaller in other years.



* Allocation changes in the agriculture set-aside were not fully modeled.

Additional Observations on CCS Development

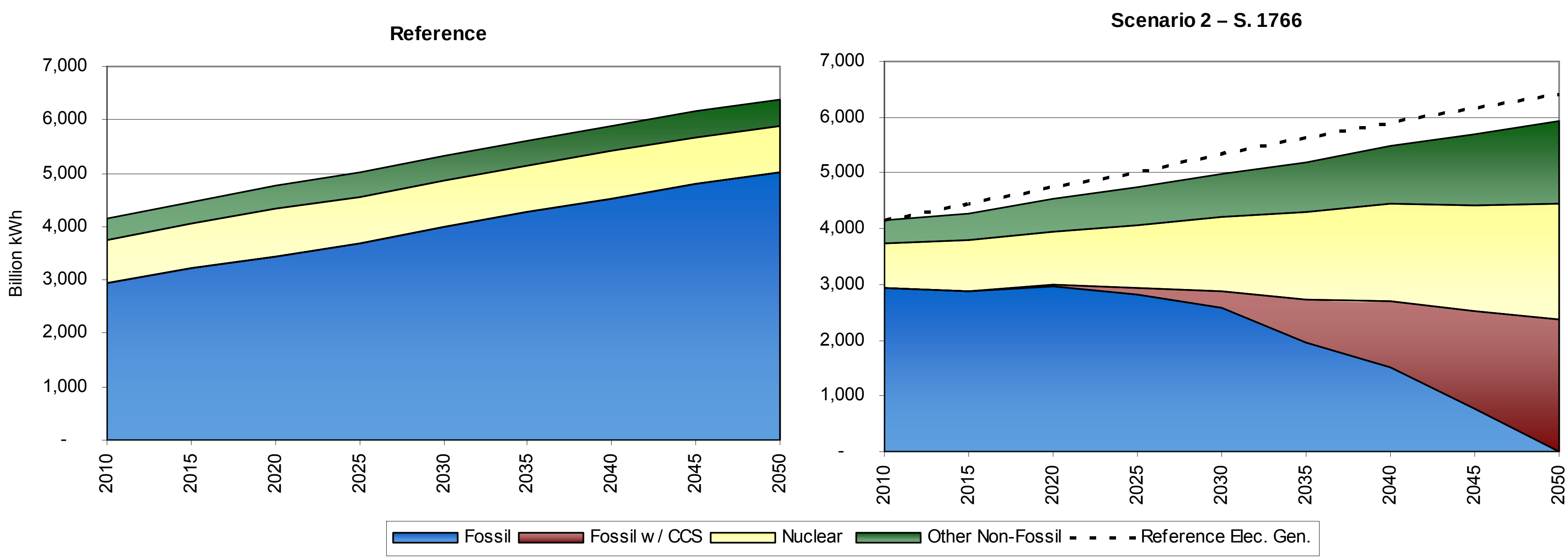
EPA also modeled additional policy options to analyze the impact on CCS deployment in the near-term.

- Low Carbon Portfolio Requirement (Performance Standard)
  - Assuming levels of CCS comparable to those in the policy case, this policy approach yields results very similar to using bonus allowances.
- Mandate for all new coal generation to capture CO_2
  - No new coal would be built after the mandate becomes effective.
  - May have the unintended effect of promoting more conventional coal capacity to be built earlier, before the requirement becomes effective.
  - Significantly more renewable and natural gas capacity is built to meet the cap coinciding with higher natural gas prices and greater demand response.
- There are several other types of policies (e.g., tax credits, subsidies, etc.) that could also be used to promote CCS deployment, but were not modeled as part of this analysis.

Energy Sector Modeling Results

Results: Scenario 1 – Reference; Scenario 2 – S. 1766

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



- Under S. 1766, both nuclear and renewable electricity generation expands above the reference levels.
- In addition, CCS deployment on fossil-fuel generation begins in 2020.
- By 2050, 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 all fossil fuel generation by 2050 may be overly optimistic).

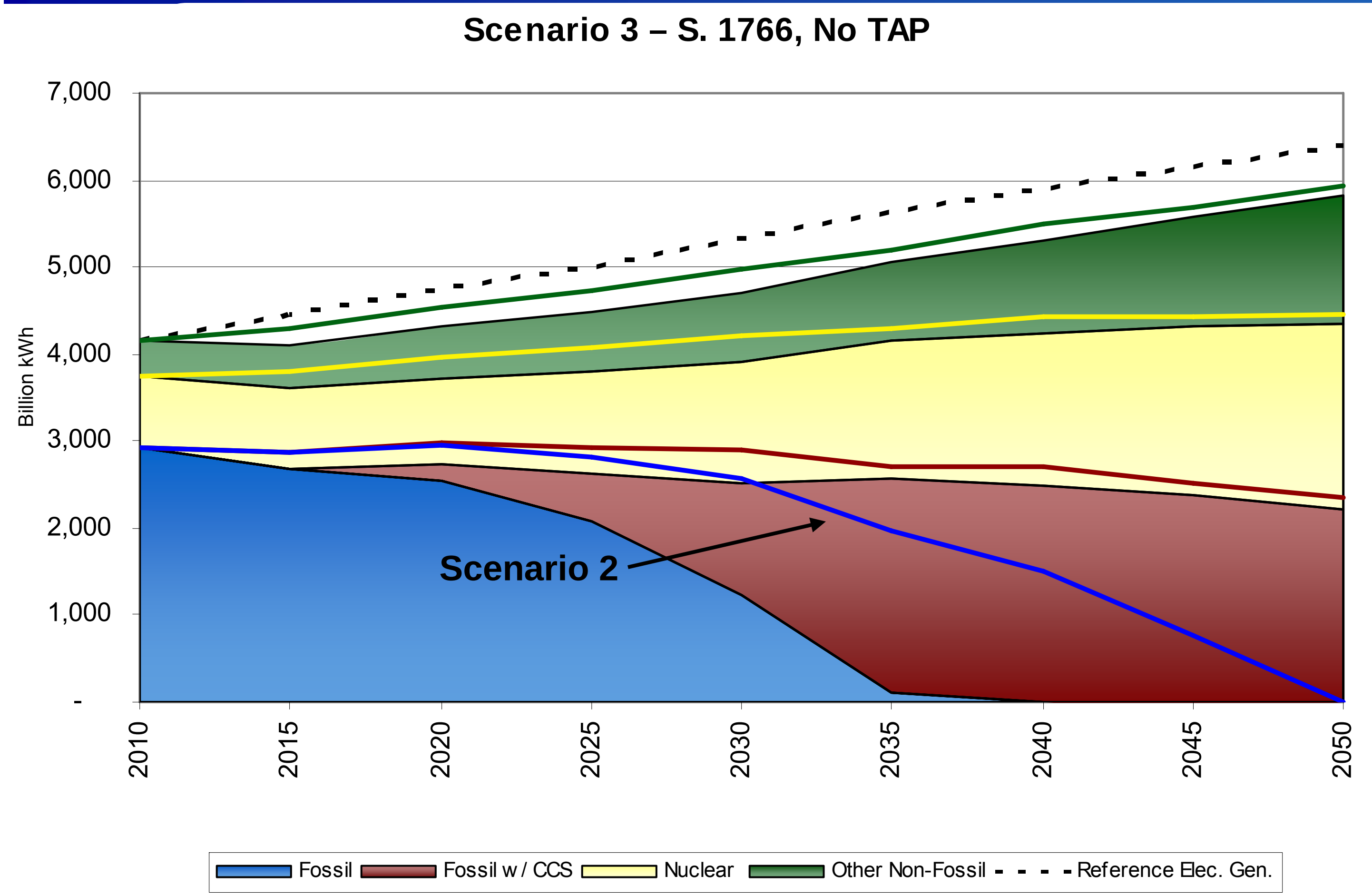
Note: Other non-fossil includes hydro, geothermal, wind, solar, biomass and municipal solid waste.

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 3 – S. 1766, No TAP

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



- In the absence of the TAP, CCS deploys beginning in 2020 but to a much greater degree than in Scenario 2.
- Full saturation of CCS on fossil generation is reached in 2040, a decade earlier than in Scenario 2.

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

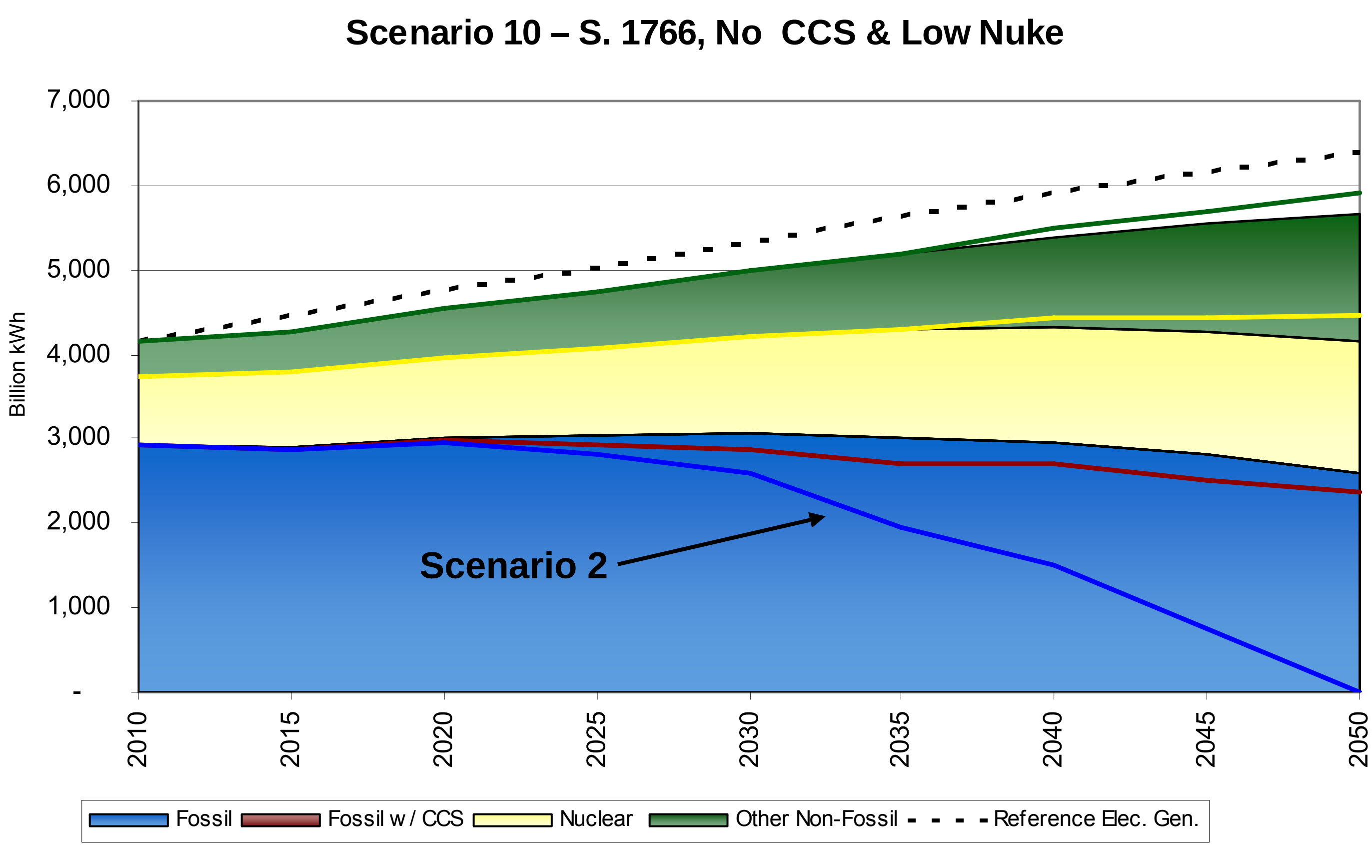
Results: Scenario 1 – Reference; Scenario 2 – S. 1766; and Scenario 3 – S. 1766, No TAP

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

- Electricity generation grows at a slower rate under S. 1766 due to efficiency gains and reduced consumption.
- Generation technology mix shifts towards non-GHG-emitting technologies such as nuclear and CCS.
- In Scenario 2 with the TAP advanced coal with CCS begins to deploy by 2020, and by 2050 CO_2 emissions from all fossil-fuel generated electricity are being captured and stored. This result is similar to the recent MIT report, "Assessment of U.S. Cap-and-Trade Proposals."
- In Scenario 3 without the TAP advanced coal with CCS begins to deploy by 2015, and by 2040 CO_2 emissions from all fossil-fuel generated electricity are being captured and stored.
- Cost assumptions for transportation and storage of CO_2 are based on the Battelle 2006 report "Carbon Dioxide Capture and Geologic Storage." Capture costs are based on AEO 2006 assumptions.
- Nuclear generation increases by ~150% by 2050 based on exogenous assumptions from the U.S. CCSP Synthesis and Assessment Report 2.1a (MiniCAM Level 1 Scenario), which are consistent with the IPM nuclear assumptions.

Results: Scenario 10 – S. 1766, No CCS & Low Nuke

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

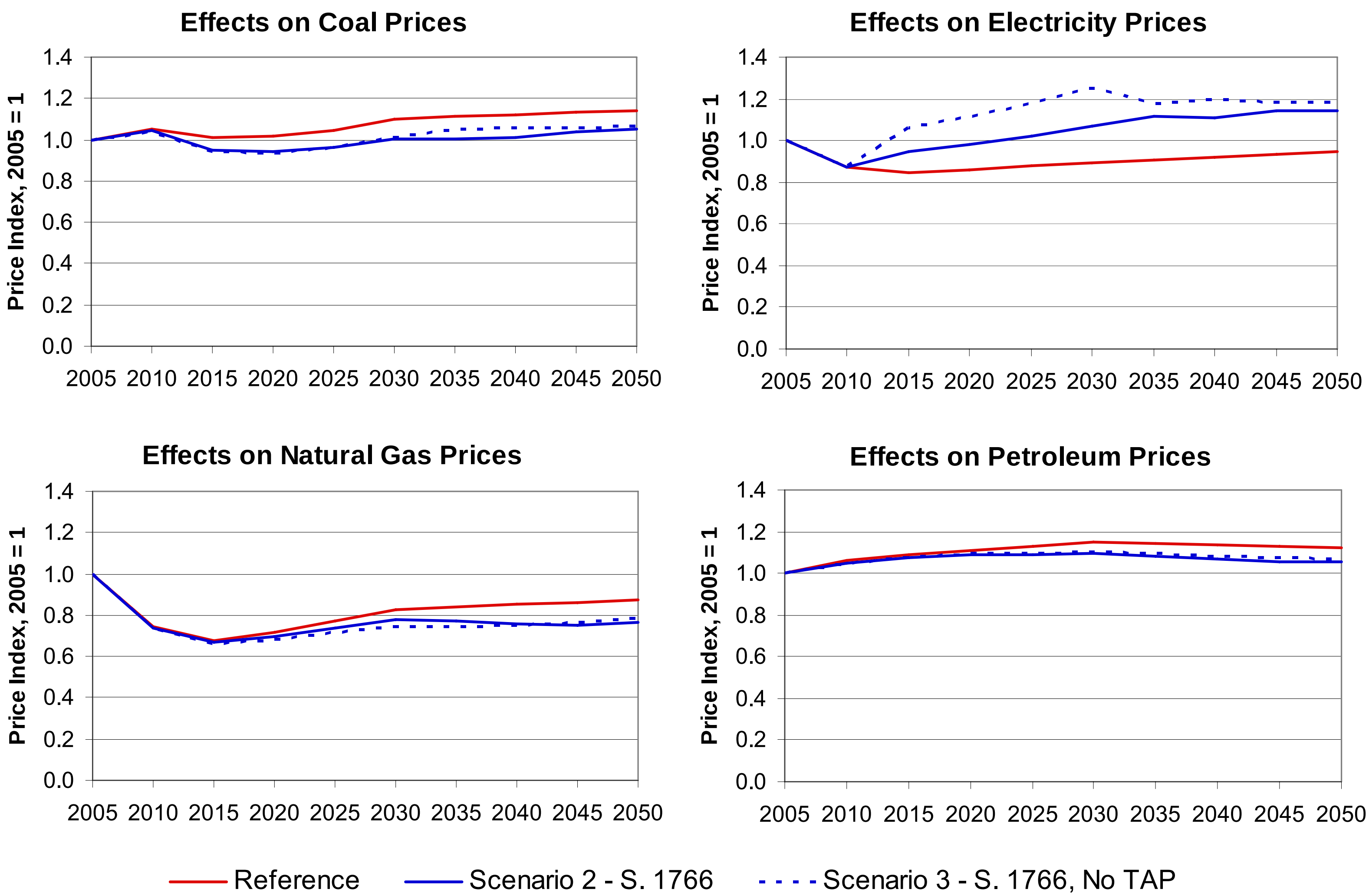


- Without the option of CCS, and the amount of nuclear growth limited, the amount of total electricity generation declines in the later years.
- However, the extent of this effect is limited by the TAP, allowing for a significant amount of fossil fuel generation without capture.
- While the allowance price is unchanged due to the TAP, the GDP impacts increase by 18% in 2030 and 36% in 2050 compared to *Scenario 2 – S. 1766*. (These impacts would be dramatically greater without the TAP).
- Compared to *Scenario 2 – S. 1766*, total U.S. GHG emissions increase by 4% in 2030 and 18% in 2050.

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

Results: Scenario 1 – Reference; Scenario 2 – S. 1766; and Scenario 3 – S. 1766, No TAP

Fuel Prices (ADAGE)



Results: Scenario 1 – Reference; Scenario 2 – S. 1766; and Scenario 3 – S. 1766, No TAP

Fuel Prices (ADAGE)

- The S. 1766 electricity price reflects the full allowance price the consumer would face.
- S. 1766 electricity prices are 19% higher than in the Reference Scenario in 2030 and 21% 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.
- For coal, natural gas, and petroleum, the price effect of S. 1766 before adding in the allowance price is shown. This is the price producers of these fuels would face.
- Lower demand for fossil fuel drives coal, petroleum and natural gas prices lower than in the Reference Scenario.
  - The impact of S. 1766 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 10 – S. 1766, No CCS, Low Nuclear' natural gas prices fall much less, since CCS is not allowed to penetrate, and the electricity sector engages in more fuel switching from coal to natural gas in order to reduce emissions.

Results: Scenario 2 - S. 1766

Fuel Price Adders for 2030 (ADAGE)

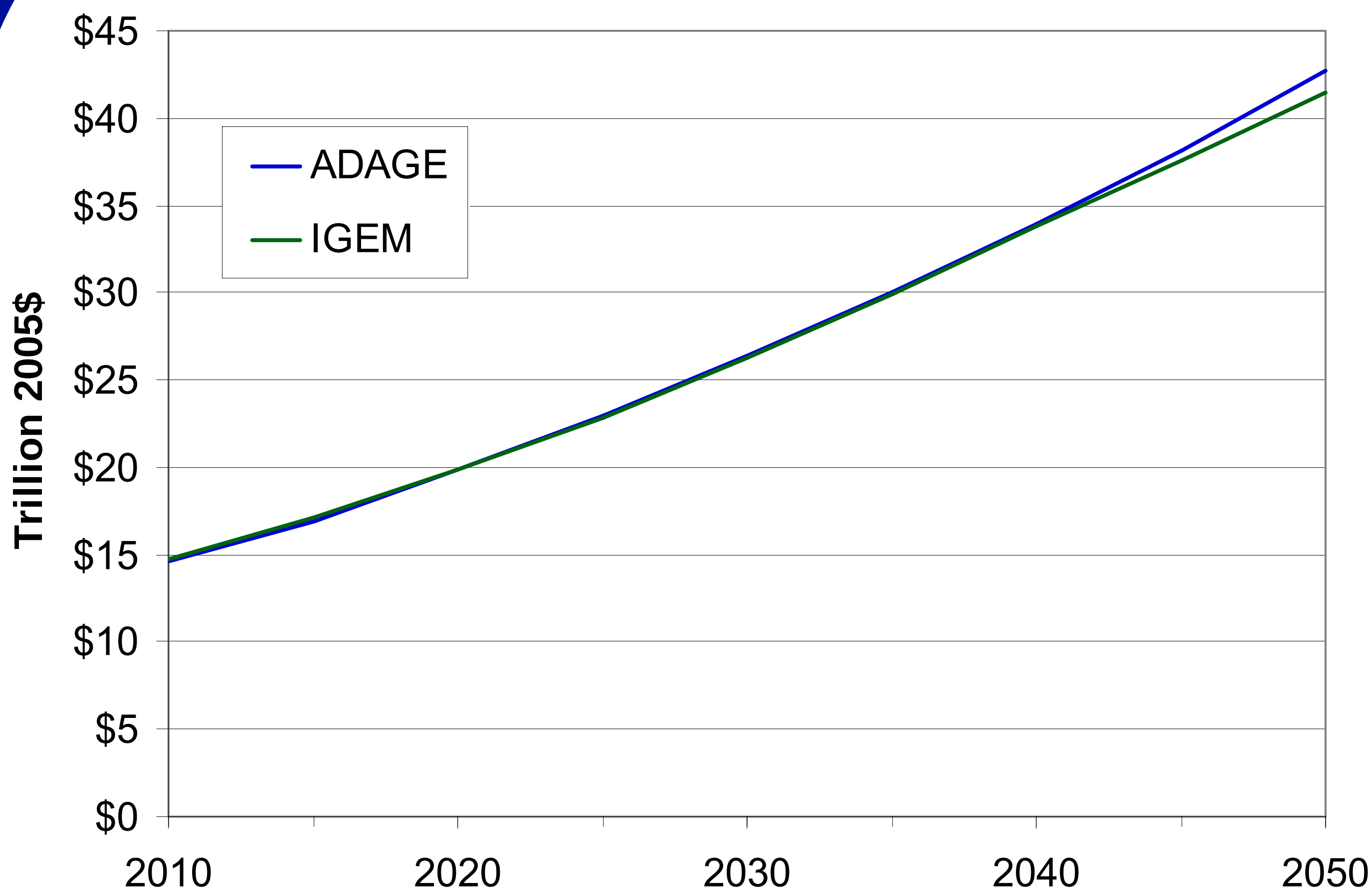
		2030		
	2005 Price	**Producer Price**	**Cost of Carbon Content**	**End - User Price**
Metric Ton of CO_2	n/a		$24.57	
Metric Ton of Carbon	n/a		$90.09	
Barrel of Oil	$50.28	$55.22	$10.52	$65.74
Gallon of Gasoline	$2.34	$2.57	$0.22	$2.79
Short Ton of Coal	$36.79	$37.00	$54.31	$91.31
Short Ton of Coal w/ CCS	$36.79	$37.00	$5.43	$42.43
tCf of Natural Gas	$7.51	$5.86	$1.34	$7.19

- 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, which in this scenario is determined by the TAP.
- 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 lower the consumer price accordingly.
- The cost of the carbon content increases the price of gasoline by 8%, increases the price of oil by 19%, increases the price of natural gas by 23%, increases the price of coal by 147%, and increases the price of coal used with CCS by 15%.
- Bonus allowances for CCS are not considered here.

Economy-Wide and Sectoral Modeling Results

Results: Scenario 1 - Reference

GDP

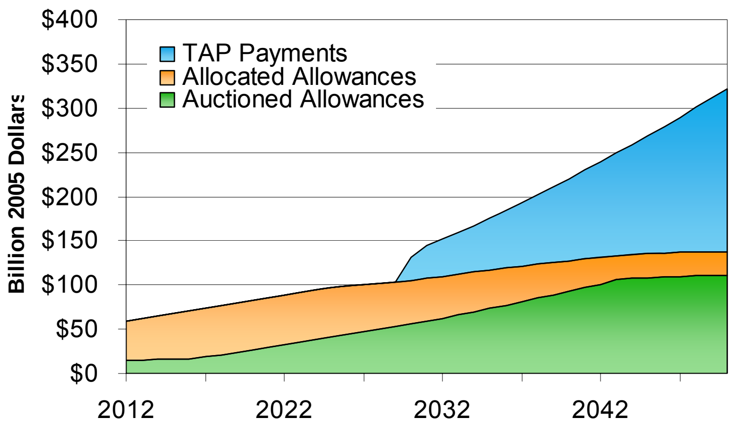


- GDP growth to 2030 is benchmarked to AEO2006
- Average annual GDP growth from 2010 to 2030 is ~3%.
- Differences in GDP growth in the later years are due to differences in underlying model assumptions

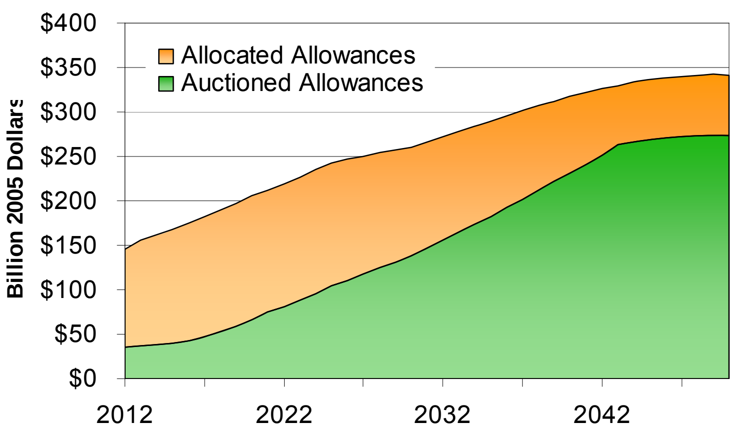
Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

Value of Allocated & Auctioned Allowances, and TAP Payments (IGEM)

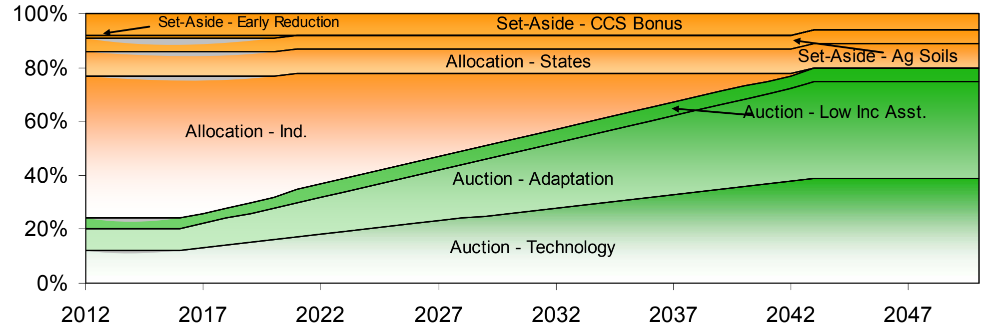
Scenario 2 - S. 1766



Scenario 3 - S. 1766, No TAP



- The share of allowances that are auctioned, allocated, or designated for set-aside programs is specified in S. 1766 Title II Sec. 201.



- Actual shares may vary as the bill allows for adjustment of these shares based on the need of different programs.
- 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.

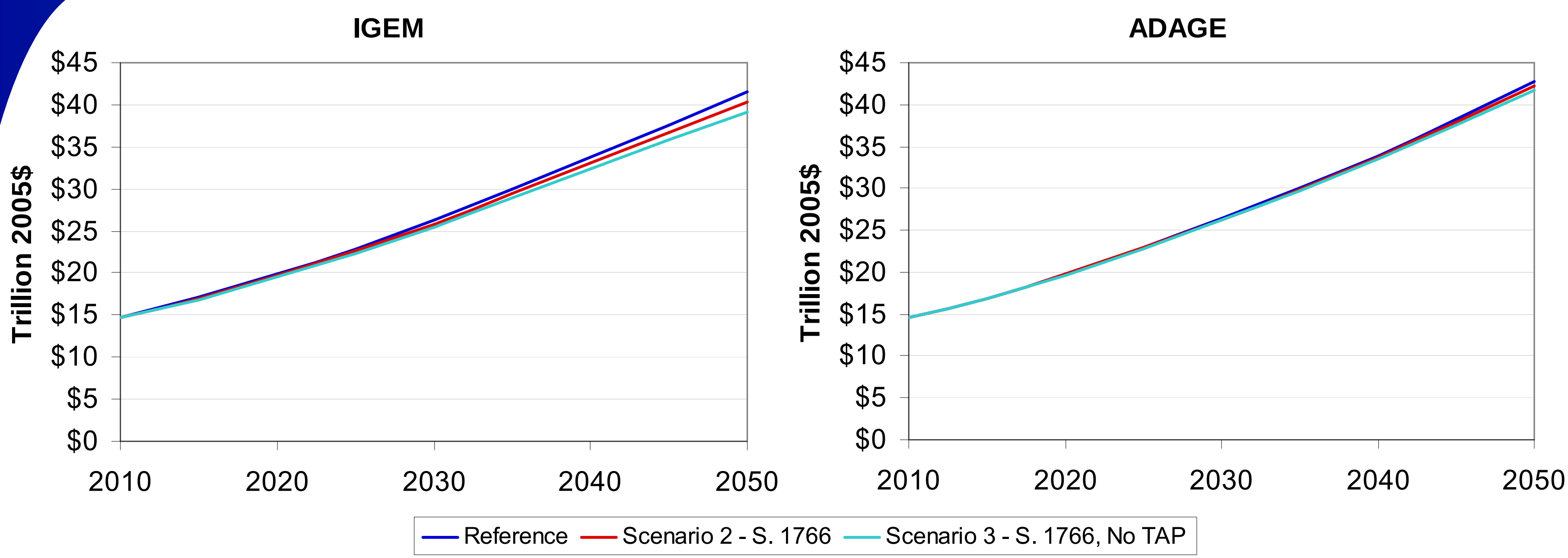
Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

GDP (Billion 2005$)

	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 1 - Reference						
ADAGE	$14,620	$19,820	$26,438	$33,958	$42,696	2.72%
IGEM	$14,767	$19,898	$26,234	$33,795	$41,468	2.61%
Scenario 2 - S. 1766						
ADAGE	$14,604	$19,742	$26,315	$33,758	$42,295	2.69%
IGEM	$14,716	$19,715	$25,864	$33,103	$40,269	2.55%
Absolute Change						
ADAGE	-$17	-$78	-$124	-$200	-$401	*-0.02 Percentage Points*
IGEM	-$51	-$182	-$370	-$692	-$1,199	*-0.07 Percentage Points*
% Change						
ADAGE	-0.12%	-0.39%	-0.47%	-0.59%	-0.94%	
IGEM	-0.35%	-0.92%	-1.41%	-2.05%	-2.89%	
Scenario 3 - S. 1766, No TAP						
ADAGE	$14,587	$19,710	$26,219	$33,489	$41,744	2.66%
IGEM	$14,657	$19,512	$25,477	$32,426	$39,200	2.49%
Absolute Change						
ADAGE	-$33	-$110	-$219	-$470	-$952	*-0.05 Percentage Points*
IGEM	-$110	-$386	-$757	-$1,369	-$2,268	*-0.13 Percentage Points*
% Change						
ADAGE	-0.23%	-0.56%	-0.83%	-1.38%	-2.23%	
IGEM	-0.74%	-1.94%	-2.89%	-4.05%	-5.47%	

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

GDP



IGEM

	2010	2020	2030	2040	2050
Scenario 2 - S. 1766					
Absolute Change	-$51	-$182	-$370	-$692	-$1,199
% Change	-0.35%	-0.92%	-1.41%	-2.05%	-2.89%
Scenario 3 - S. 1766, No TAP					
Absolute Change	-$110	-$386	-$757	-$1,369	-$2,268
% Change	-0.74%	-1.94%	-2.89%	-4.05%	-5.47%

ADAGE

	2010	2020	2030	2040	2050
Scenario 2 - S. 1766					
Absolute Change	-$17	-$78	-$124	-$200	-$401
% Change	-0.12%	-0.39%	-0.47%	-0.59%	-0.94%
Scenario 3 - S. 1766, No TAP					
Absolute Change	-$33	-$110	-$219	-$470	-$952
% Change	-0.23%	-0.56%	-0.83%	-1.38%	-2.23%

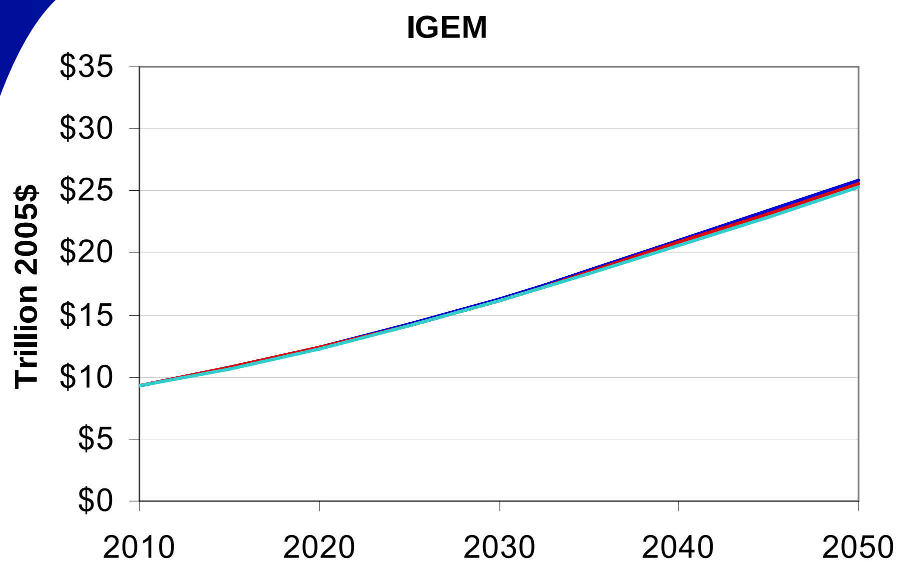
Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

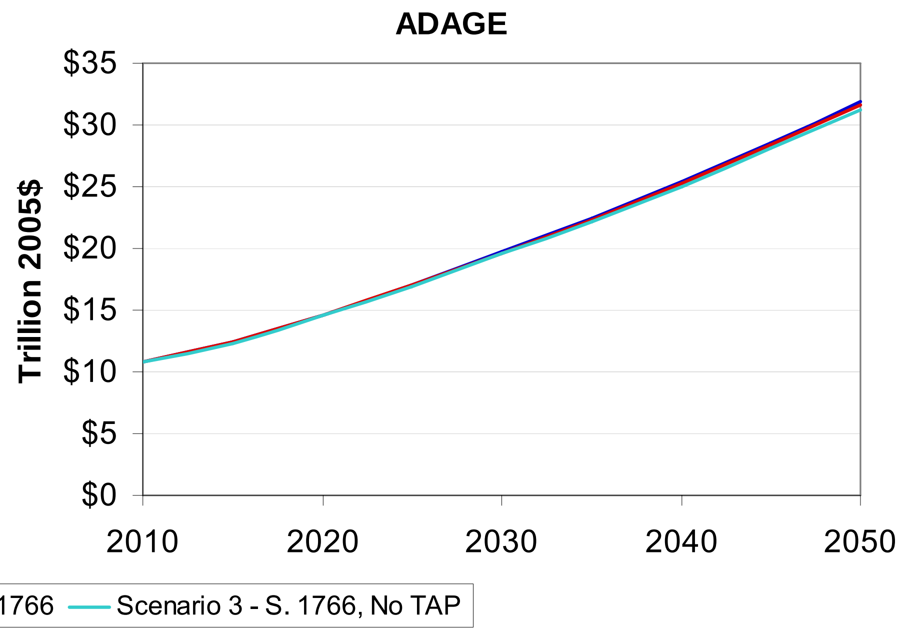
Consumption (Trillion 2005$)

	2010	2020	2030	2040	2050	Average Annual Growth 2010-2050
Scenario 1 - Reference						
ADAGE	$10,783	$14,638	$19,721	$25,350	$31,887	2.75%
IGEM	$9,244	$12,375	$16,269	$20,970	$25,898	2.61%
Scenario 2 - S. 1766						
ADAGE	$10,811	$14,591	$19,651	$25,223	$31,619	2.72%
IGEM	$9,257	$12,351	$16,193	$20,809	$25,605	2.58%
Absolute Change						
ADAGE	$28	-$47	-$70	-$127	-$267	*-0.03 Percentage Points*
IGEM	$13	-$24	-$76	-$161	-$293	*-0.03 Percentage Points*
% Change						
ADAGE	0.26%	-0.32%	-0.36%	-0.50%	-0.84%	
IGEM	0.14%	-0.19%	-0.47%	-0.77%	-1.13%	
Annual Change per Household (2005$)						
ADAGE	$214	-$333	-$459	-$785	-$1,590	
IGEM	$111	-$176	-$512	-$992	-$1,660	
Scenario 3 - S. 1766, No TAP						
ADAGE	$10,847	$14,562	$19,537	$25,015	$31,281	2.68%
IGEM	$9,273	$12,315	$16,095	$20,609	$25,255	2.54%
Absolute Change						
ADAGE	$64	-$75	-$184	-$335	-$606	*-0.06 Percentage Points*
IGEM	$29	-$60	-$173	-$361	-$643	*-0.07 Percentage Points*
% Change						
ADAGE	0.60%	-0.52%	-0.93%	-1.32%	-1.90%	
IGEM	0.31%	-0.48%	-1.07%	-1.72%	-2.48%	
Annual Change per Household (2005$)						
ADAGE	$495	-$533	-$1,199	-$2,074	-$3,604	
IGEM	$238	-$443	-$1,171	-$2,222	-$3,640	

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

Consumption





IGEM

	2010	2020	2030	2040	2050
Scenario 2 - S. 1766					
Absolute Change	$13	-$24	-$76	-$161	-$293
% Change	0.14%	-0.19%	-0.47%	-0.77%	-1.13%
Scenario 3 - S. 1766, No TAP					
Absolute Change	$29	-$60	-$173	-$361	-$643
% Change	0.31%	-0.48%	-1.07%	-1.72%	-2.48%

ADAGE

	2010	2020	2030	2040	2050
Scenario 2 - S. 1766					
Absolute Change	$28	-$47	-$70	-$127	-$267
% Change	0.26%	-0.32%	-0.36%	-0.50%	-0.84%
Scenario 3 - S. 1766, No TAP					
Absolute Change	$64	-$75	-$184	-$335	-$606
% Change	0.60%	-0.52%	-0.93%	-1.32%	-1.90%

Results: Scenario 2 - S. 1766

2030 Selected Sectoral Results (IGEM)

Sector	2007	2030				
		Reference		S. 1766 Scenario 2		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Personal and business services	4304	8108	88%	8091.9	88%	0%
Finance, insurance and real estate	2642	6075	130%	6041.3	129%	-1%
Transportation and warehousing	681	1284	89%	1260.8	85%	-2%
Food and kindred products	565	1155	104%	1182.2	109%	2%
Motor vehicles	513	1095	114%	1065.6	108%	-3%
Electric utilities (services)	384	548	43%	508.2	32%	-7%
Petroleum refining	296	389	31%	350.9	18%	-10%
Gas utilities (services)	51	60	20%	54.0	7%	-11%
Coal mining	29	40	39%	27.5	-5%	-32%

- 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 3.

Results: Scenario 3 - S. 1766, No TAP

2030 Selected Sectoral Results (IGEM)

Sector	2007	2030				
		Reference		S. 1766 Scenario 3		
	Output ($Billions)	Output ($Billions)	Percent Change from 2007	Output ($Billions)	Percent Change from 2007	Percent Change from Reference
Personal and business services	4304	8108	88%	8075.7	88%	0%
Finance, insurance and real estate	2642	6075	130%	6012.2	128%	-1%
Transportation and warehousing	681	1284	89%	1235.3	81%	-4%
Food and kindred products	565	1155	104%	1217.1	115%	5%
Motor vehicles	513	1095	114%	1037.5	102%	-5%
Electric utilities (services)	384	548	43%	466.2	21%	-15%
Petroleum refining	296	389	31%	308.7	4%	-21%
Gas utilities (services)	51	60	20%	46.2	-9%	-24%
Coal mining	29	40	39%	19.7	-32%	-51%

- 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 3.

Results: Scenario 2 – S. 1766 and Scenario 3 – S. 1766, No TAP

2030 Selected Sectoral Results (IGEM)

- The previous slides shows the impacts of S. 1766 and the “No TAP” 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. 1766, 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]

[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. 1766 and Scenario 3 – S. 1766, No TAP

Total Abatement Cost

Scenario 2 - S. 1766

	2015	2020	2025	2030	2035	2040	2045	2050
Total Covered and Offset Abatement (MMTCO2e)								
ADAGE	1,194	1,448	1,820	2,304	2,952	3,415	3,979	4,497
IGEM	1,016	1,274	1,627	2,045	2,396	2,777	3,400	4,097
Allowance Price ($/tCO2e)								
ADAGE	$12	$15	$19	$25	$31	$40	$51	$65
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
Total Abatement Cost (Billion 2005 Dollars)								
ADAGE	$7	$11	$18	$28	$46	$68	$102	$146
IGEM	$6	$10	$16	$25	$38	$56	$87	$133

Scenario 3 - S. 1766, No TAP

	2015	2020	2025	2030	2035	2040	2045	2050
Total Abatememt (Covered, Offsets, and Allowance Set Asides) (MMTCO2e)								
ADAGE	2,690	3,181	3,877	4,847	5,405	5,540	5,790	6,063
IGEM	1,835	2,292	2,881	3,561	3,991	4,455	5,195	5,919
Allowance Price ($/tCO2e)								
ADAGE	$27	$35	$44	$57	$72	$92	$117	$149
IGEM	$29	$37	$48	$61	$78	$99	$127	$162
Total Abatement Cost (Billion 2005 Dollars)								
ADAGE	$37	$55	$86	$137	$195	$255	$339	$452
IGEM	$27	$43	$69	$108	$155	$221	$329	$478

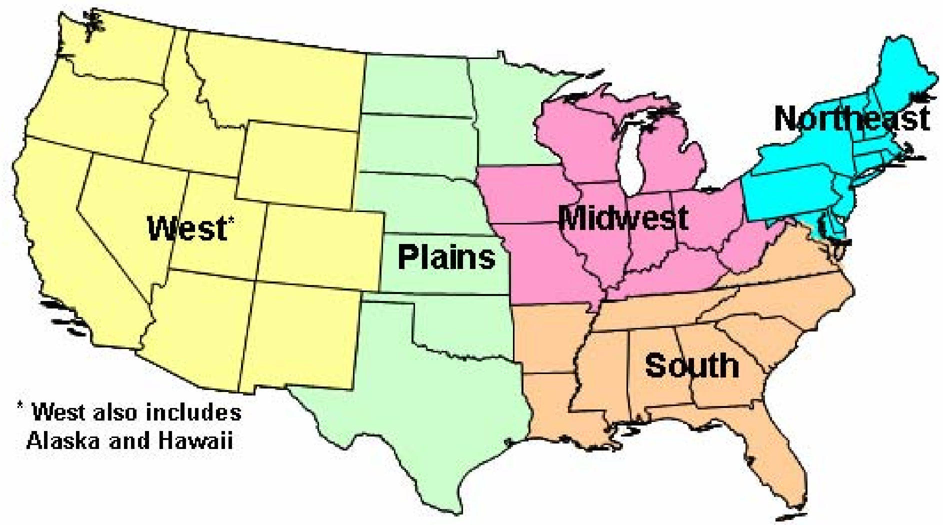
- The allowance price is equal to the marginal cost of abatement.
- Total abatement cost is approximated for each model as the product of total GHG emissions abatement and the allowance price divided by two.
  - Division by 2 is assumed to represent the fact that most reduction measures are not implemented at the S. 1766 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.

Regional
Modeling Results

Introduction to Regional Results

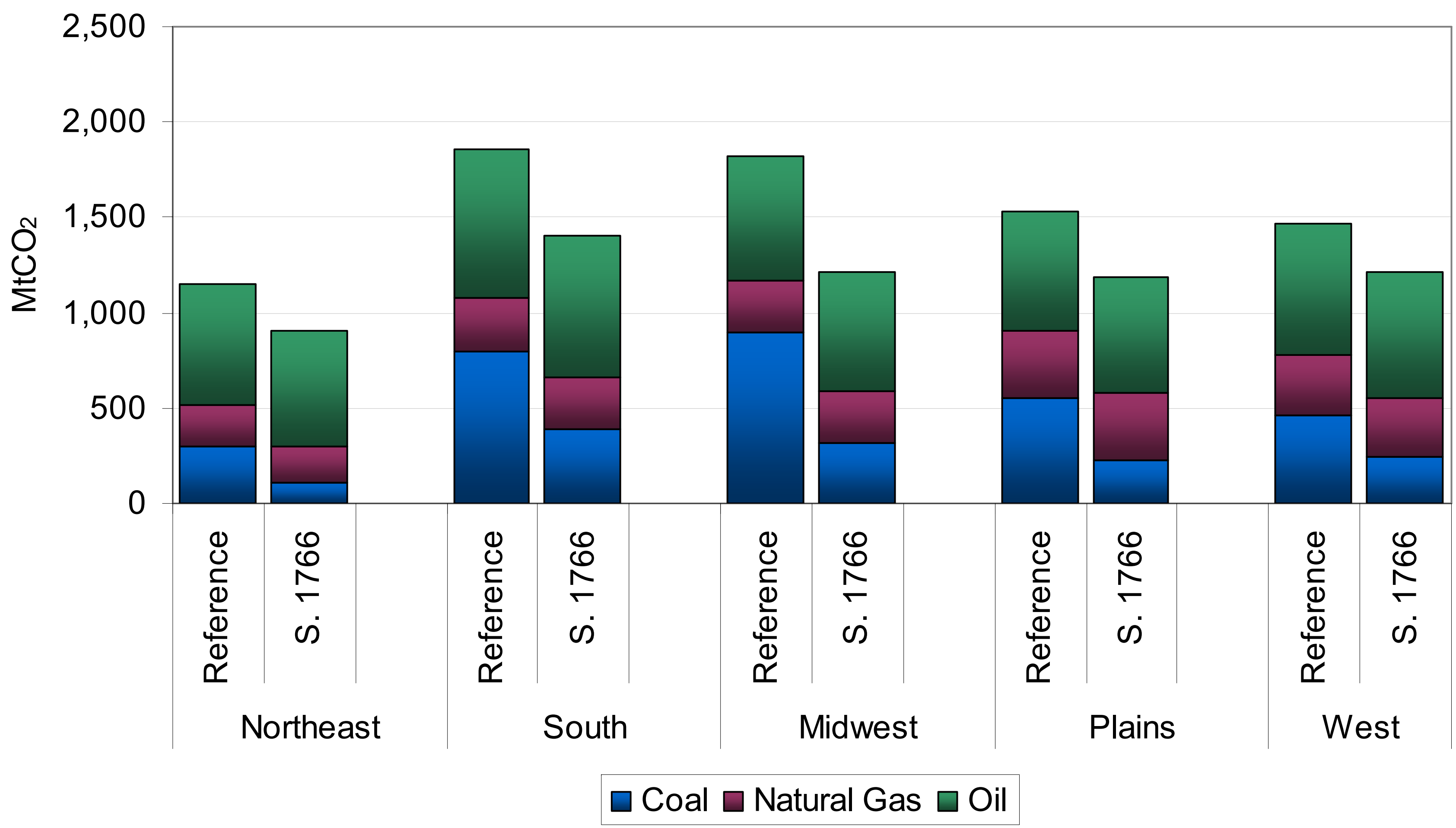
(ADAGE)

- 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



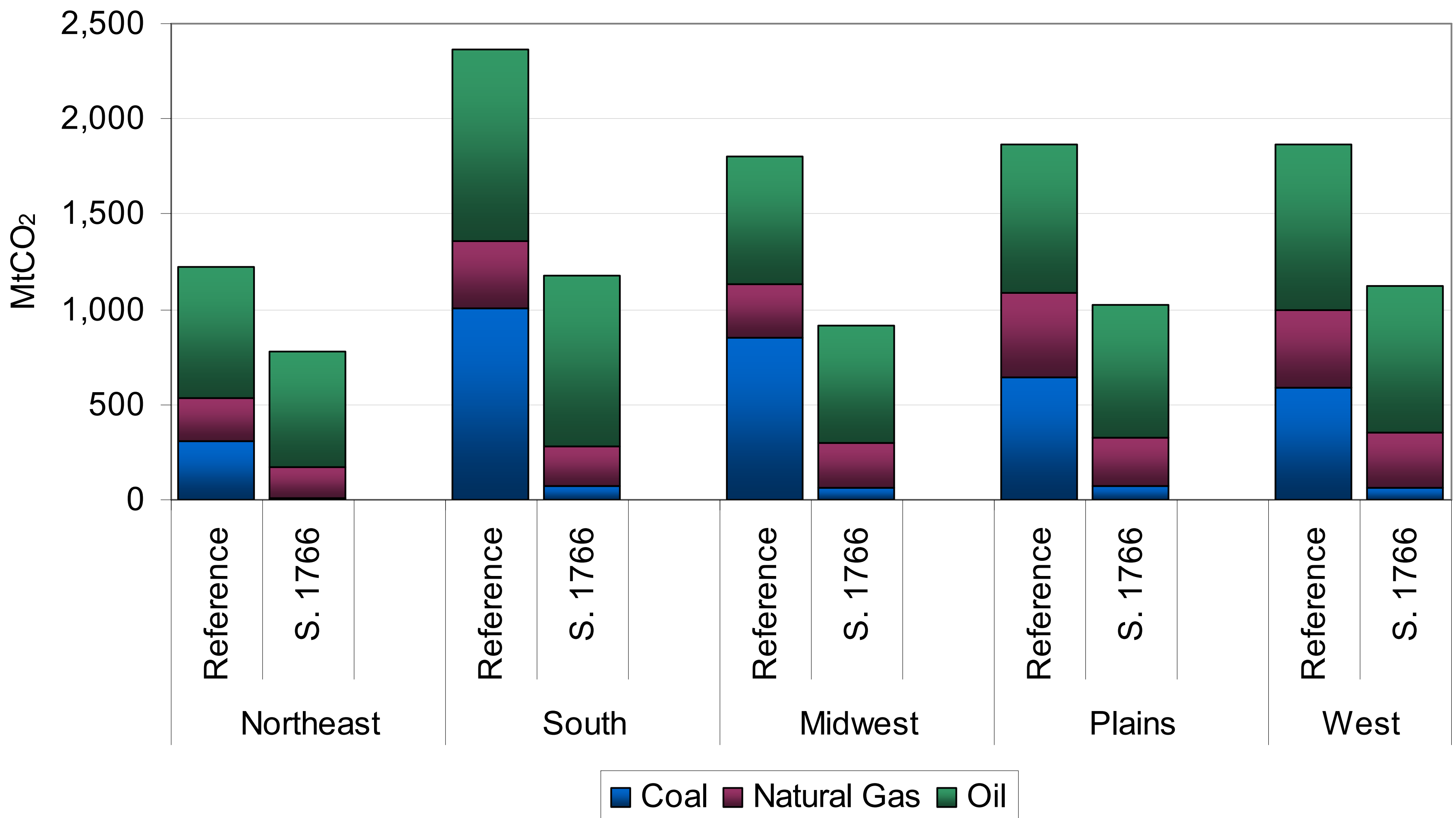
Results: Scenario 2 - S. 1766

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



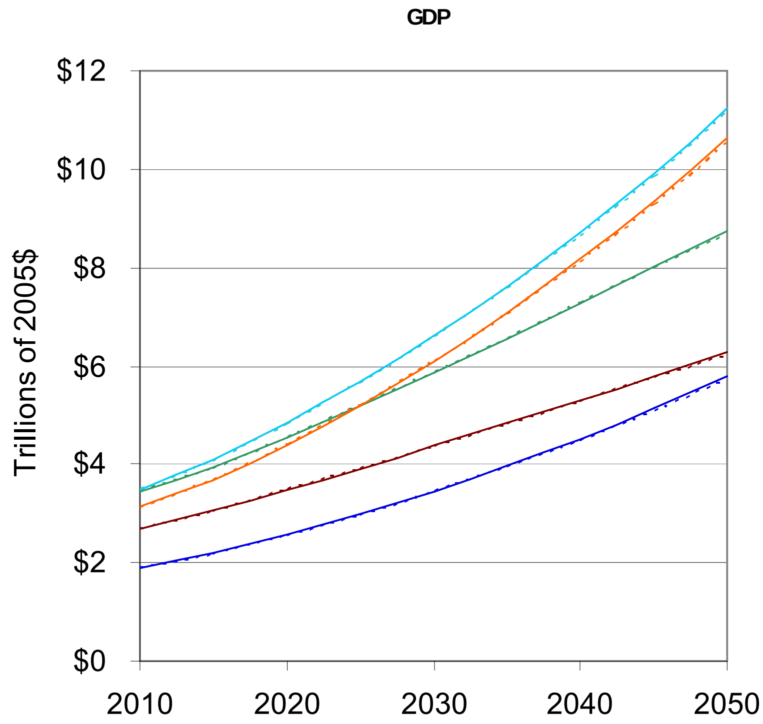
Results: Scenario 2 - S. 1766

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



Results: Scenario 2 - S. 1766

Regional GDP and Consumption (ADAGE)



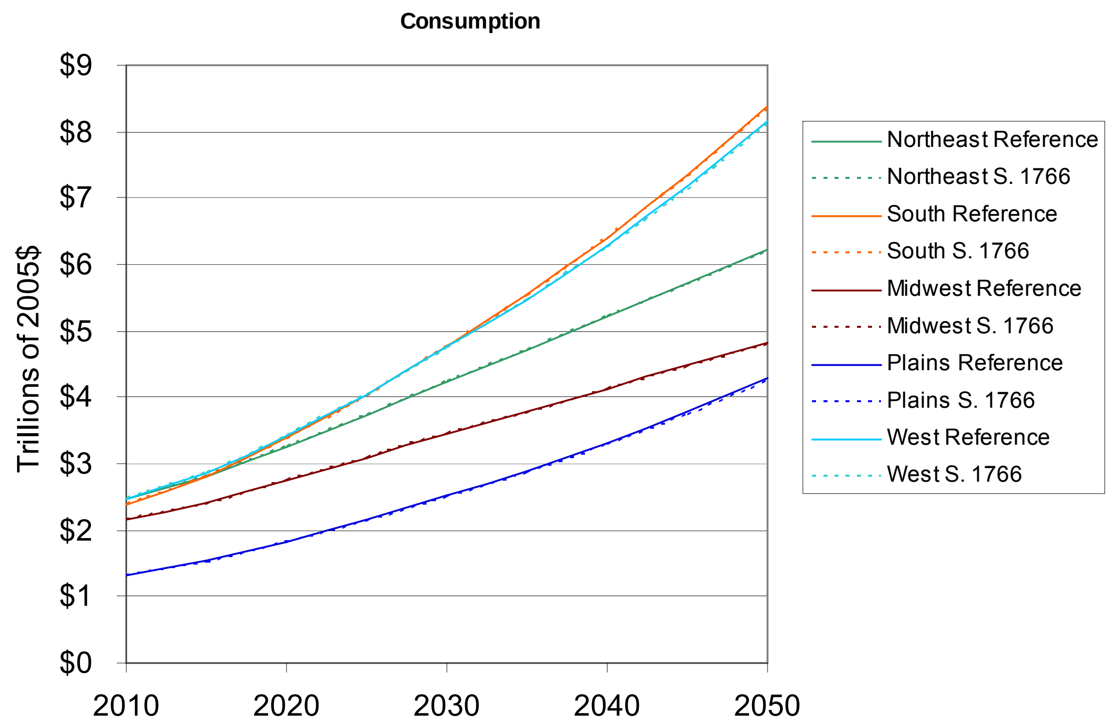


Table: % Change in Regional GDP Scenario 2 - S. 1766

	2010	2020	2030	2040	2050
Northeast	-0.1%	-0.3%	-0.3%	-0.3%	-0.6%
South	-0.1%	-0.4%	-0.5%	-0.6%	-0.9%
Midwest	-0.1%	-0.4%	-0.3%	-0.5%	-0.9%
Plains	-0.1%	-0.7%	-0.9%	-1.2%	-1.6%
West	-0.1%	-0.4%	-0.5%	-0.6%	-0.9%

Table: % Change in Regional Consumption Scenario 2 - S. 1766

	2010	2020	2030	2040	2050
Northeast	0.3%	-0.2%	-0.2%	-0.4%	-0.7%
South	0.3%	-0.2%	-0.2%	-0.4%	-0.7%
Midwest	0.3%	-0.3%	-0.4%	-0.5%	-0.9%
Plains	-0.1%	-0.9%	-1.0%	-1.1%	-1.5%
West	0.2%	-0.3%	-0.3%	-0.4%	-0.7%

Results: Scenario 2 - S. 1766

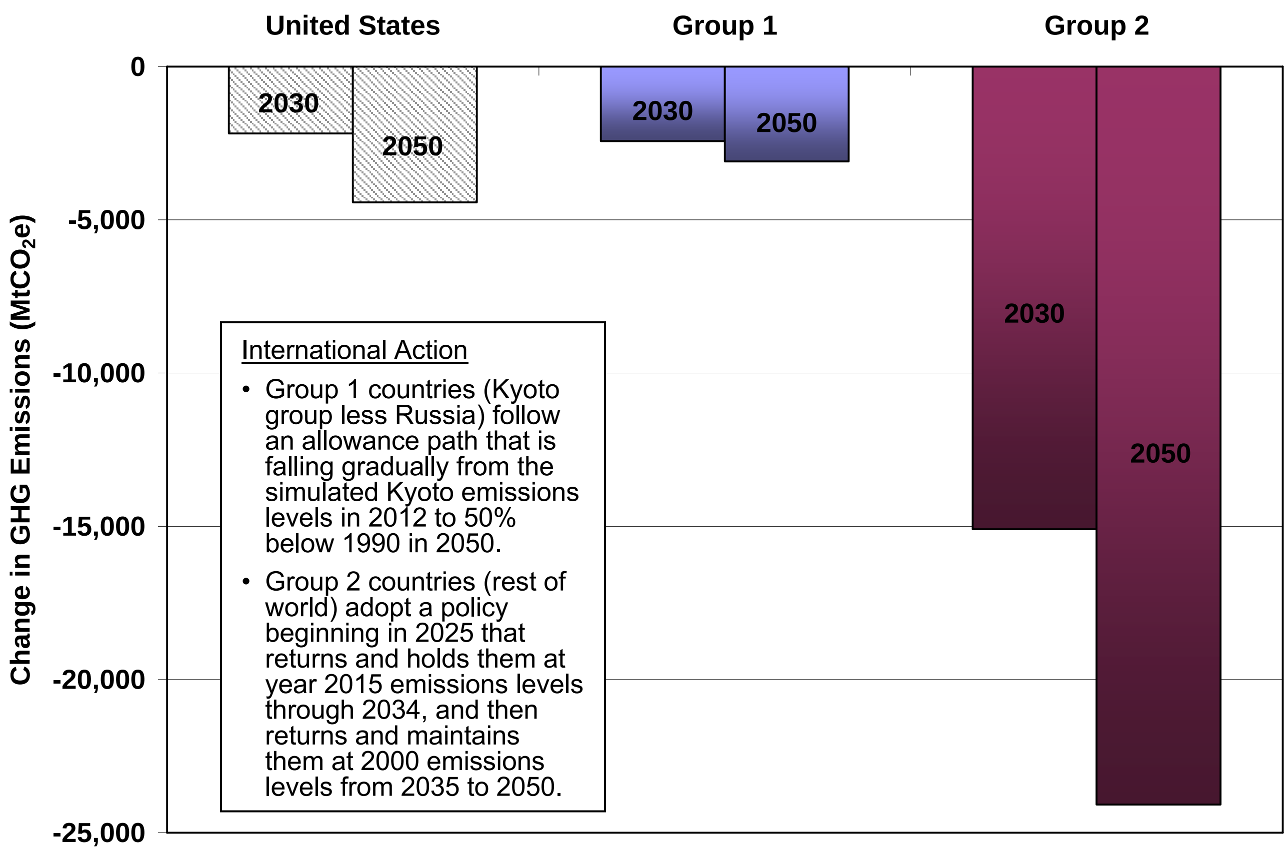
Regional Results Discussion (ADAGE)

- 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 regions.
- 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 1% 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. 1766

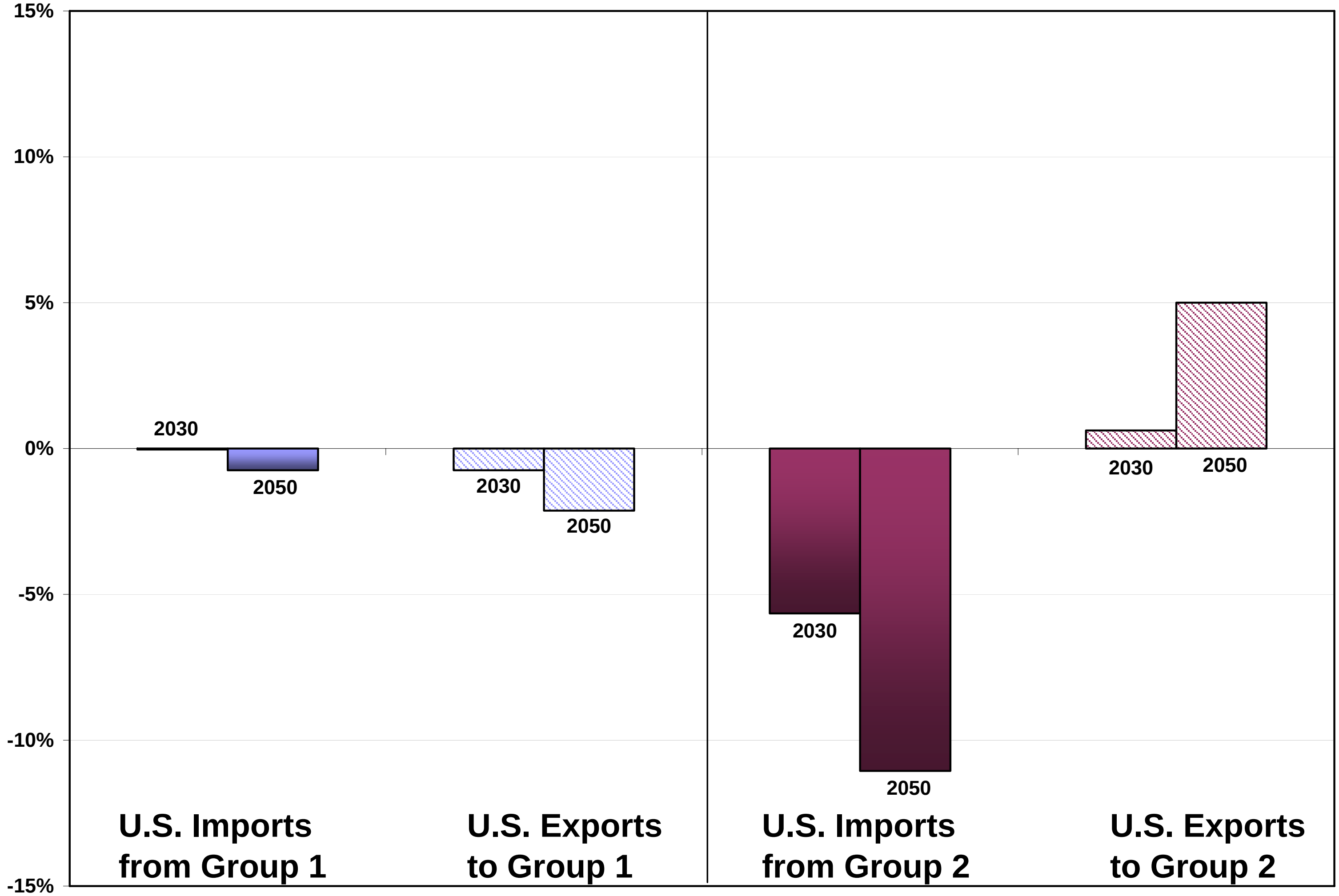
International GHG Emissions Leakage (ADAGE)



- 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. 1766 international assumptions, no international emissions leakage occurs.
- Emissions in Group 2 fall by over 15,000 $MtCO_2e$ 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.

Results: Scenario 2 – S. 1766

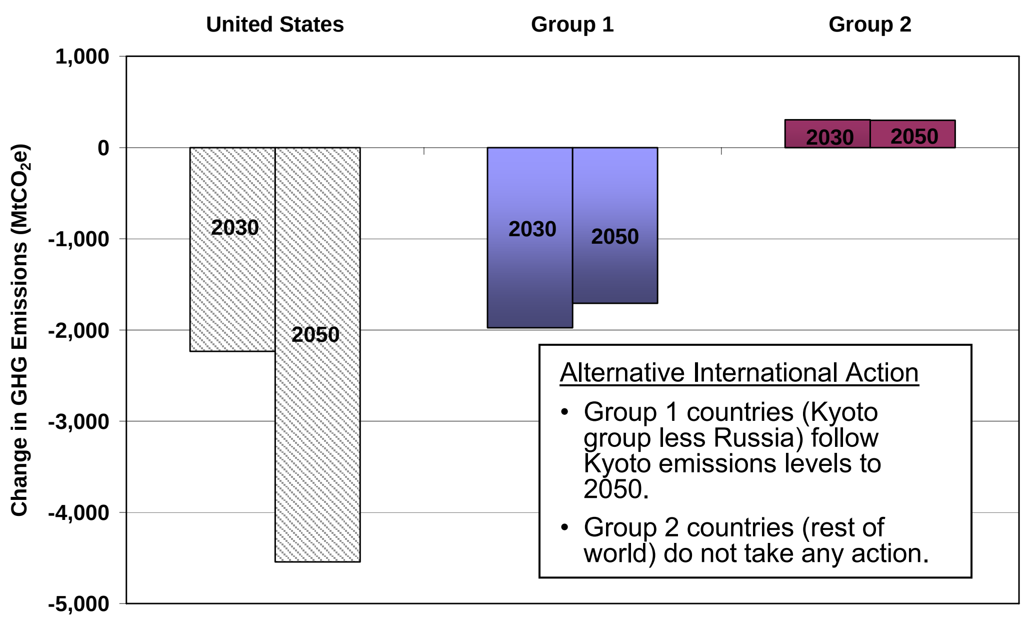
International Trade Leakage for Energy-Intensive Manufacturing (ADAGE)



- Under Scenario 2 – S. 1766, 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 11 - S. 1766, Alternative International Action

International GHG Emissions Leakage (ADAGE)



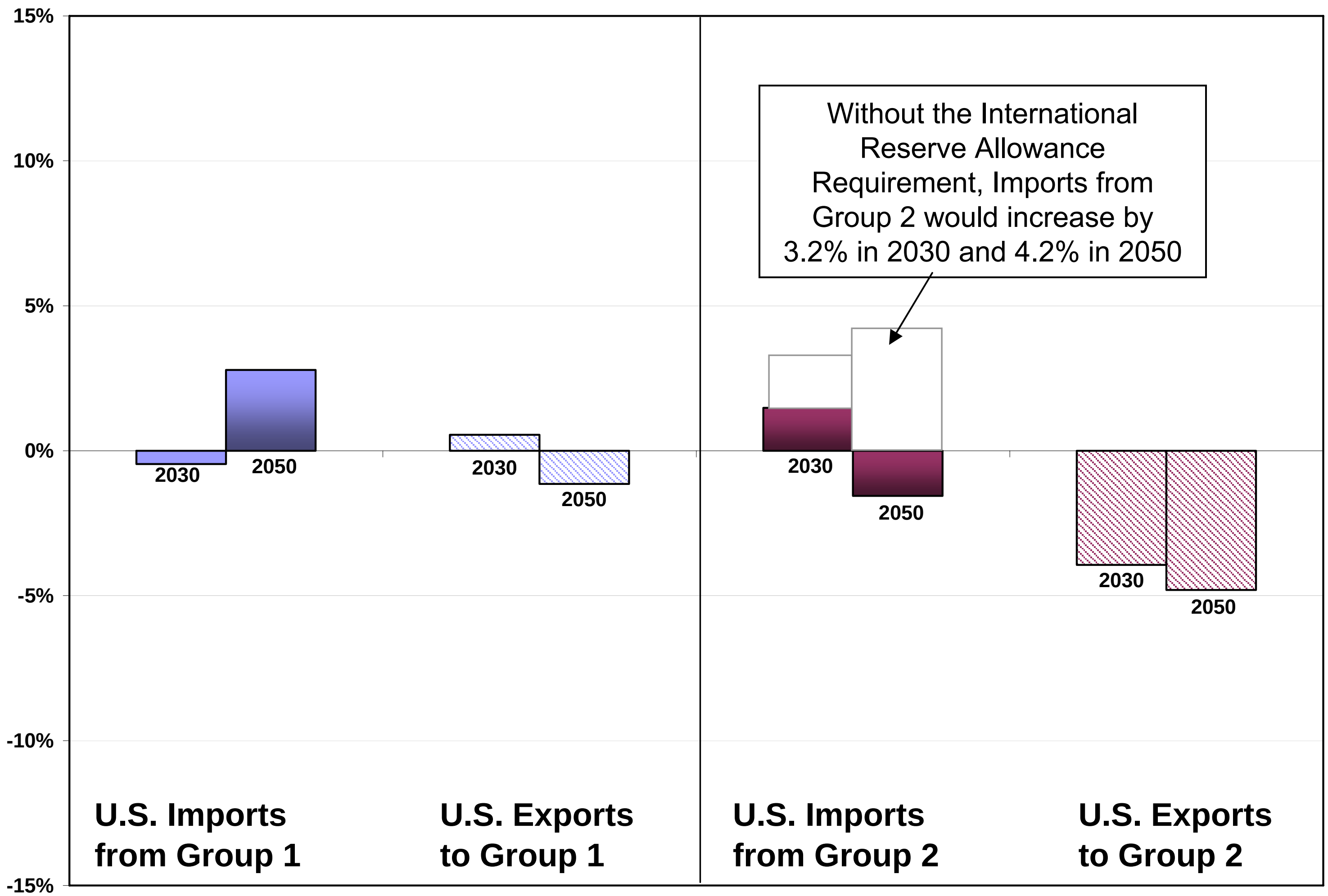
- Emissions leakage occurs when a domestic GHG policy causes a relative price differential between domestically produced and imported goods. This causes domestic production, which embodies the GHG allowance price to shift abroad, and thus an increase in GHG emissions in other countries.
- As a result of S. 1766, 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 11 – S. 1766, 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 304 $MtCO_2e$ in 2030, and 298 $MtCO_2e$ 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 14% in 2030 and 7% in 2050.
- While Group 2 is not taking any action in this scenario, their emissions are somewhat limited by demand from 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 310 $MtCO_2e$ in 2030, and an increase of 312 $MtCO_2e$ 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. 1766 requires greater emissions reductions than those modeled in Paltsev (2001). This means that economic activity is reduced more under S. 1766, 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 11 - S. 1766, Alternative International Action

International Trade Leakage for Energy-Intensive Manufacturing (ADAGE)

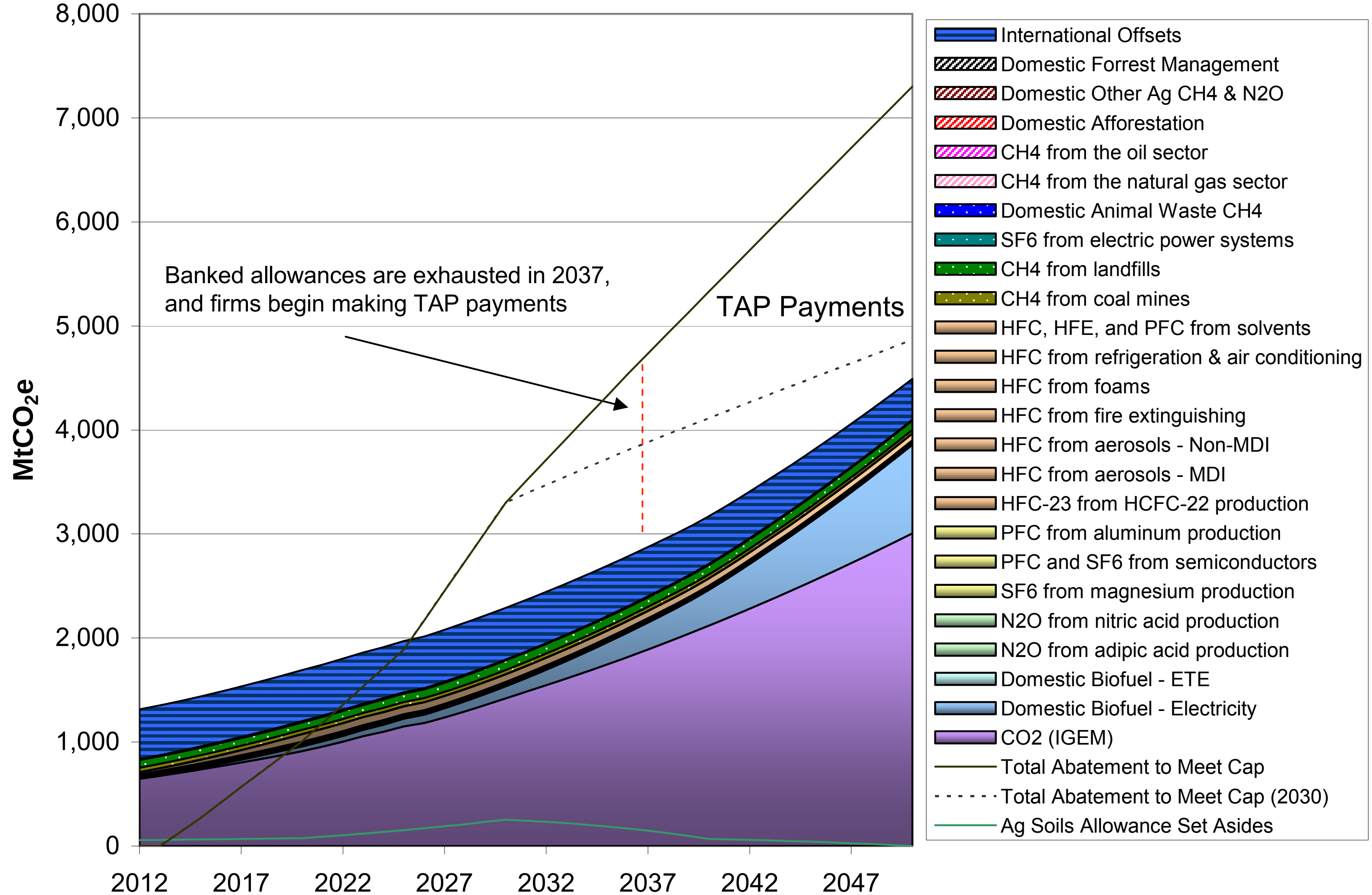


- Under Scenario 11 – S. 1766, Alternative International Action, imports of energy-intensive manufacturing goods from Group 2 countries to the U.S. rise in 2030 since Group 2 countries are not taking any emissions action.
- The International Reserve Allowance Requirement limits the imports from Group 2.
  - The International Reserve Allowance Requirement has no effect on GDP in 2030, and increases GDP impacts by $15 billion (or 0.04 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.

Global Results:
International Offsets Sensitivities

Results: Scenario 4 - S. 1766, 10% Int'l Offsets

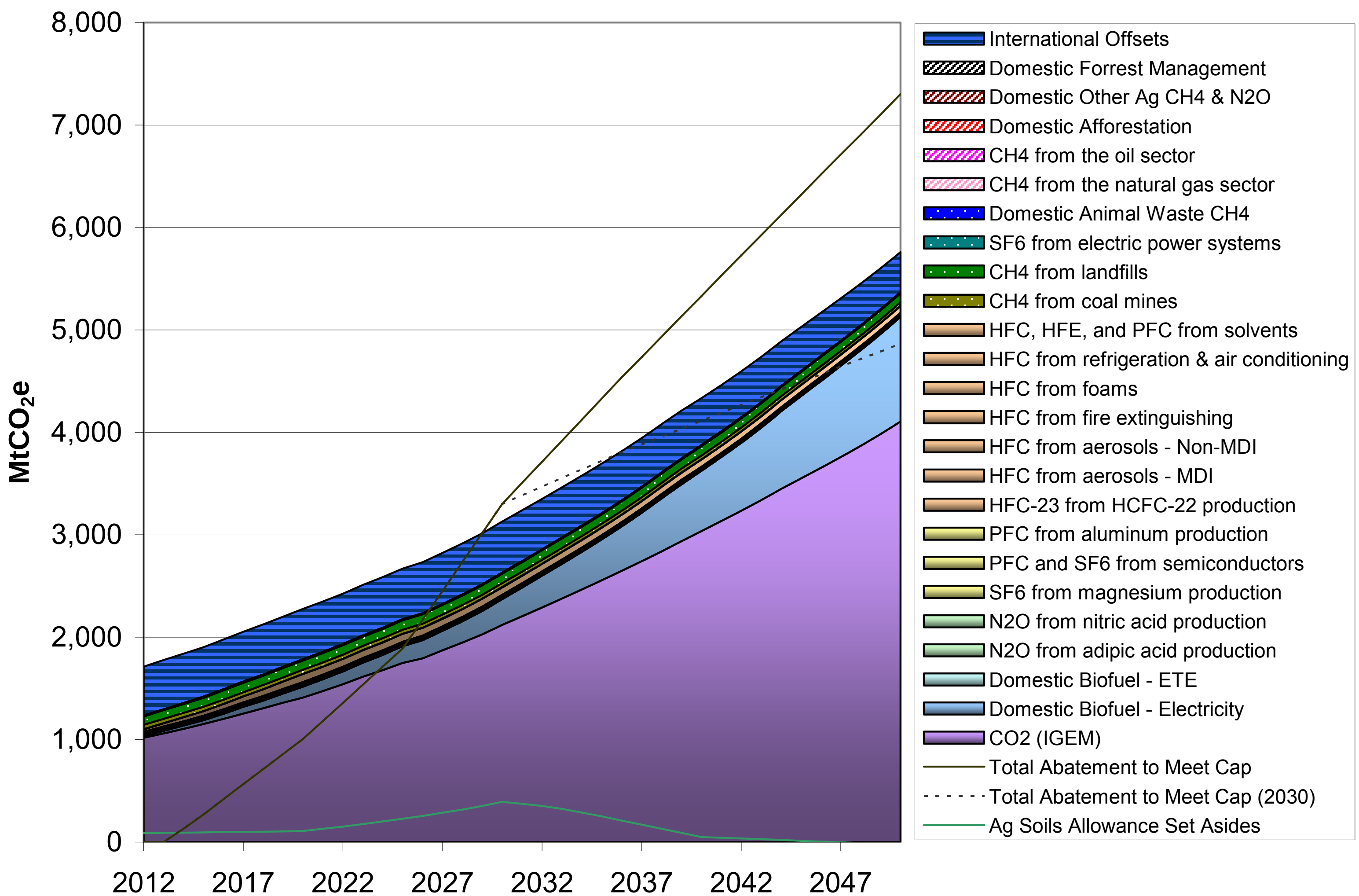
Sources of GHG Abatement (IGEM)



- Allowing a limited amount of international offsets in in a scenario where the TAP is triggered does not change domestic abatement behavior, so long as the TAP is still triggered.
- The purchase of international offsets does not displace domestic abatement.
- Since international offsets can be purchased at a lower price than the TAP, international offsets displace TAP allowance purchases

Results: Scenario 6 - S. 1766, No TAP, 10% Int'l Offsets

Sources of GHG Abatement (IGEM)



- Allowing a limited amount of international offsets in in a scenario without the TAP lowers the allowance price, and lowers the overall costs of the policy.
- The use of international offsets will also have the result of increasing domestic emissions, since some of the abatement required to meet the cap is now occurring abroad.

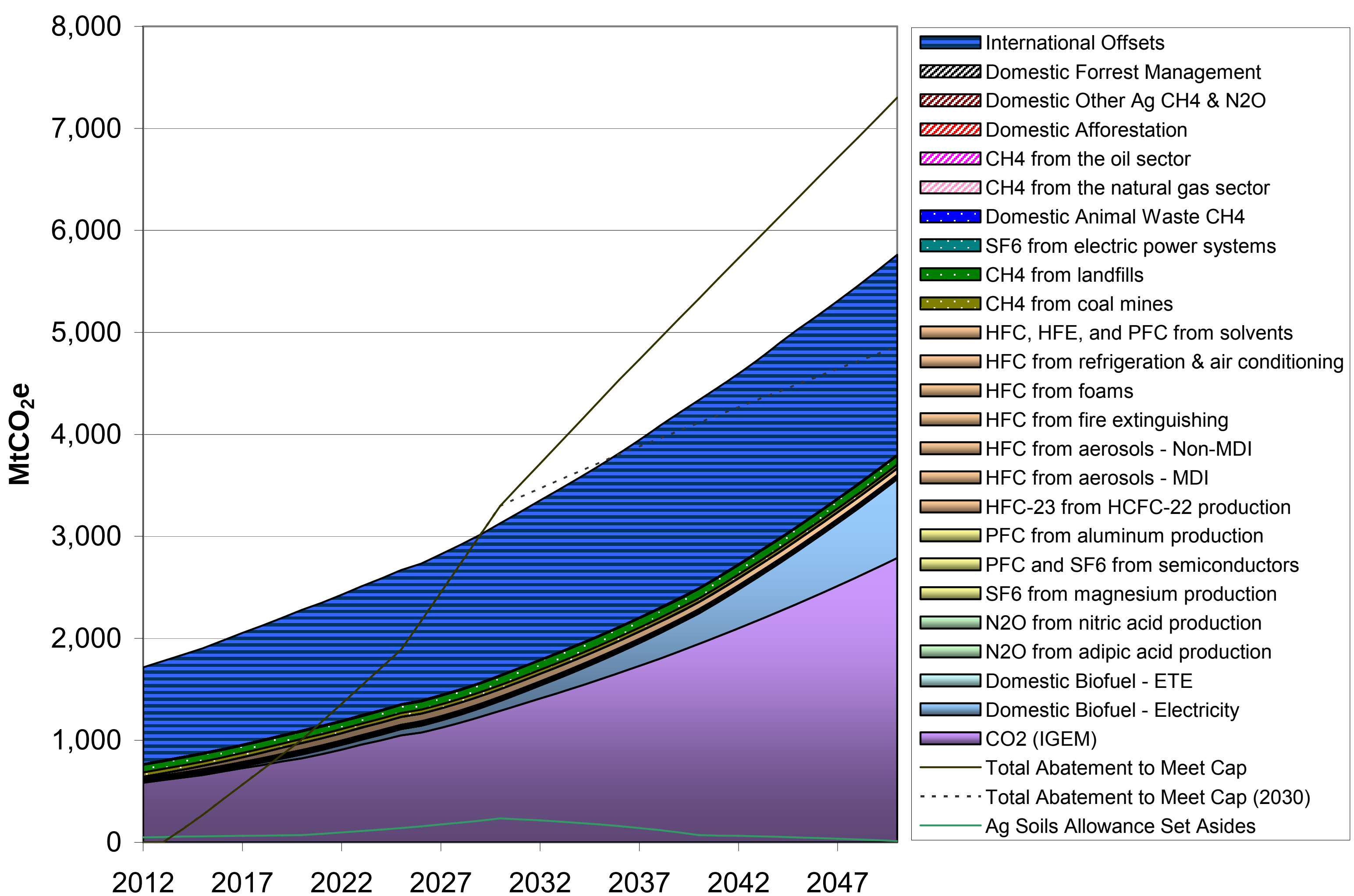
Results: Scenario 4 – S. 1766, 10% Int'l Offsets and Scenario 6 – S. 1766, No TAP, 10% Int'l Offsets

Sources of GHG Abatement (IGEM)

- The previous two charts show, for the IGEM model, the sources of CO_2 and non-CO_2 GHG abatement under S. 1766 in scenario 4 with the TAP and a 10% limit on international offsets, and scenario 6 without the TAP and a 10% limit on international offsets.
- In scenario 4 with the TAP, the emissions cap is exceeded, so the TAP is triggered even with the extra abatement from international offsets.
  - The solid black line at the top represents the total amount of abatement required to meet the cap (without banking).
  - In the early years firms bank allowances, after 2026 firms begin drawing down the bank, which is exhausted by 2037, after which firms make TAP payments.
  - Compared to *Scenario 2 – S. 1766*, cumulative tons for which TAP payments are made in *Scenario 4 – S. 1766, 10% Int'l Offsets* are reduced by the amount of abatement from international credits.
    - Early purchases of international credits increase the amount of banking, and delays the year that the bank begins to be drawn down from 2022 to 2026.
    - After 2026 purchases of international credits allow the bank to last longer, so that it is depleted in 2036 instead of 2030.
    - After 2037, purchases of international credits directly displace TAP payments.
  - The dotted black line represents the total amount of abatement (without banking) required to meet the cap assuming that the cap remains constant after 2030. With the constant cap after 2030, TAP payments begin in 2038 instead of 2036.
- 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 EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH4, N2O, and F-gases (NCGM), and the Forest and Agriculture Sector Optimization Model, GHG version (FASOMGHG).
  - International offsets are derived from the Mini Climate Assessment Model (MiniCAM) and the Global Timber Model (GTM).
- The area toward the top of the chart shaded with dotted colors show emissions reductions from domestic offset projects.
- The blue striped area represents international offsets.
- Although S. 1766 places no restrictions on the amount of domestic offsets that may be used, only a limited set of offset project types are allowed.
  - As a result, offsets provide a relatively small portion of emissions reductions.
  - If non-specified offset projects (sources shaded with hashed lines in the legend) were allowed, they would provide a significant amount of abatement at the allowance prices in both of these scenarios.
- The light blue line at the bottom represents GHG abatement from ag/soils 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. 1766, Unlimited Int'l Offsets, or Scenario 7 - S. 1766, No TAP, Unlimited Int'l Offsets

Sources of GHG Abatement (IGEM)



- With unlimited international offsets, the TAP is not triggered, and thus the emissions cap is binding even when the TAP is an option.
- The use of international offsets will also have the result of increasing domestic emissions, since some of the abatement required to meet the cap is now occurring abroad.

Results: Scenario 5 – S. 1766, Unlimited Int'l Offsets and Scenario 7 – S. 1766, No TAP, Unlimited Int'l 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. 1766 in scenario 5 with the TAP and unlimited international offsets, or scenario 7 without the TAP and with unlimited international offsets.
- In scenario 5 with the TAP, the emissions cap is met and the TAP is not triggered.
- 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 EPA's non-CO_2 GHG spreadsheet tools for estimating projections and mitigation of CH4, N2O, and F-gases (NCGM), and the Forest and Agriculture Sector Optimization Model, GHG version (FASOMGHG).
  - International offsets are derived from the Mini Climate Assessment Model (MiniCAM) and the Global Timber Model (GTM).
- The area toward the top of the chart shaded with dotted colors show emissions reductions from domestic offset projects.
- The blue striped area represents international offsets.
- Although S. 1766 places no restrictions on the amount of domestic offsets that may be used, only a limited set of offset project types are allowed.
  - As a result, offsets provide a relatively small portion of emissions reductions.
  - If non-specified offset projects (sources shaded with hashed lines in the legend) were allowed, they would provide a significant amount of abatement at the allowance prices in both of these scenarios.
- The light blue line at the bottom represents GHG abatement from ag/soils 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, 6, and 7)

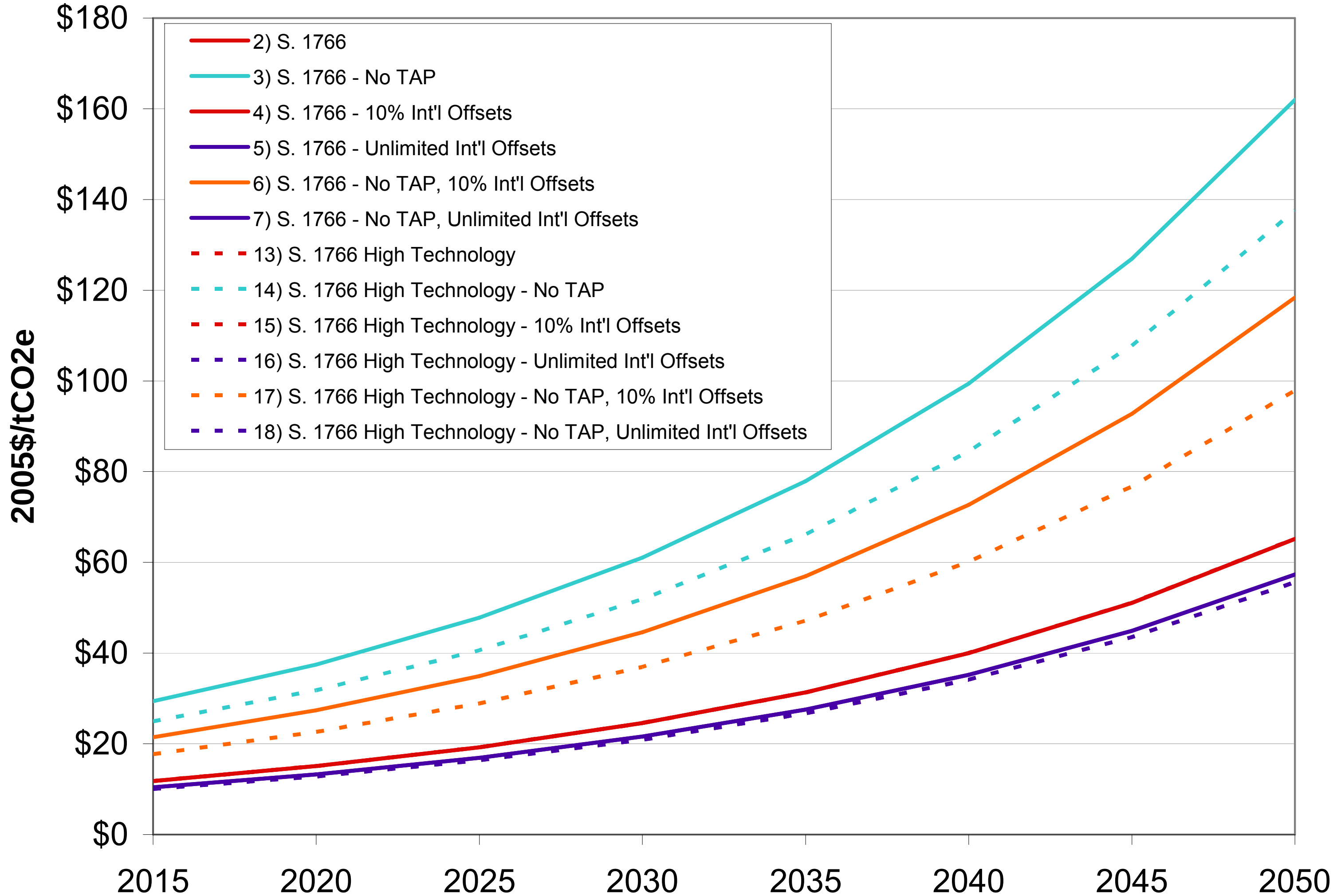
Allowance Price (IGEM)

Table: Allowance Price Comparisons (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
2) S. 1766								
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
3) S. 1766 - No TAP								
IGEM	$29	$37	$48	$61	$78	$99	$127	$162
4) S. 1766 - 10% Int'l Offsets								
IGEM	$12	$15	$19	$25	$31	$40	$51	$65
5) S. 1766 - Unlimited Int'l Offsets								
IGEM	$10	$13	$17	$22	$28	$35	$45	$57
6) S. 1766 - No TAP, 10% Int'l Offsets								
IGEM	$21	$27	$35	$45	$57	$73	$93	$118
7) S. 1766 - No TAP, Unlimited Int'l Offsets								
IGEM	$10	$13	$17	$22	$28	$35	$45	$57

Scenario Comparison

GHG Allowance Prices (IGEM)



Results: International Offsets Sensitivity Scenarios (4, 5, 6, and 7)

International Offset Price (IGEM)

Table: International Offset Price Comparisons (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
4) S. 1766 - 10% Int'l Offsets								
	$9	$12	$15	$19	$25	$32	$40	$52
6) S. 1766 - No TAP, 10% Int'l Offsets								
	$9	$12	$15	$19	$25	$32	$40	$52
7) S. 1766 - No TAP, Unlimited Int'l Offsets								
	$10	$13	$17	$22	$28	$35	$45	$57
15) S. 1766 High Technology - 10% Int'l Offsets								
	$9	$12	$15	$19	$25	$32	$40	$52
17) S. 1766 High Technology - No TAP, 10% Int'l Offsets								
	$9	$12	$15	$19	$25	$32	$40	$52
18) S. 1766 High Technology - No TAP, Unlimited Int'l Offsets								
	$10	$13	$16	$21	$27	$34	$44	$56

Results: International Offsets Sensitivity Scenarios (4, 5, 6, and 7)

GDP and Consumption (IGEM)

Table: GDP Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
2) S. 1766								
IGEM	-0.7%	-0.9%	-1.2%	-1.4%	-1.7%	-2.0%	-2.4%	-2.9%
3) S. 1766 - No TAP								
IGEM	-1.5%	-1.9%	-2.4%	-2.9%	-3.5%	-4.1%	-4.7%	-5.5%
4) S. 1766 - 10% Int'l Offsets								
IGEM	-0.7%	-0.9%	-1.2%	-1.4%	-1.7%	-2.1%	-2.5%	-2.9%
5) S. 1766 - Unlimited Int'l Offsets								
IGEM	-0.6%	-0.8%	-1.0%	-1.2%	-1.5%	-1.8%	-2.1%	-2.5%
6) S. 1766 - No TAP, 10% Int'l Offsets								
IGEM	-1.1%	-1.5%	-1.9%	-2.3%	-2.7%	-3.2%	-3.8%	-4.4%
7) S. 1766 - No TAP, Unlimited Int'l Offsets								
IGEM	-0.6%	-0.8%	-1.0%	-1.2%	-1.5%	-1.8%	-2.1%	-2.5%

Table: Consumption Comparisons (% Change from Reference)

	2015	2020	2025	2030	2035	2040	2045	2050
2) S. 1766								
IGEM	0.0%	-0.2%	-0.3%	-0.5%	-0.6%	-0.8%	-0.9%	-1.1%
3) S. 1766 - No TAP								
IGEM	-0.1%	-0.5%	-0.8%	-1.1%	-1.4%	-1.7%	-2.1%	-2.5%
4) S. 1766 - 10% Int'l Offsets								
IGEM	0.0%	-0.2%	-0.3%	-0.5%	-0.6%	-0.8%	-1.0%	-1.2%
5) S. 1766 - Unlimited Int'l Offsets								
IGEM	0.0%	-0.2%	-0.3%	-0.4%	-0.6%	-0.7%	-0.9%	-1.0%
6) S. 1766 - No TAP, 10% Int'l Offsets								
IGEM	-0.1%	-0.4%	-0.6%	-0.8%	-1.1%	-1.3%	-1.6%	-1.9%
7) S. 1766 - No TAP, Unlimited Int'l Offsets								
IGEM	0.0%	-0.2%	-0.3%	-0.4%	-0.6%	-0.7%	-0.9%	-1.0%

Global Results:
CO_2 Concentrations

Scenarios (MiniCAM)

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.

Scenarios Without International Action

- S. 1766 TAP w/o International Action
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is triggered.
- S. 1766 Cap w/o International Action
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is not available.
  - 2050 targets of 60% below 2006 emissions levels are adopted.
- S. 1766 Cap (2030) w/o International Action
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is not available.
  - Emissions caps are held constant at 1990 levels after 2030.

- In all scenarios without international action, all other countries adopt no additional policies or measures.
- In all scenarios without international action, emissions leakage as estimated by the ADAGE model is taken into account.
- After 2050, the U.S. holds emissions caps constant at 2050 levels.

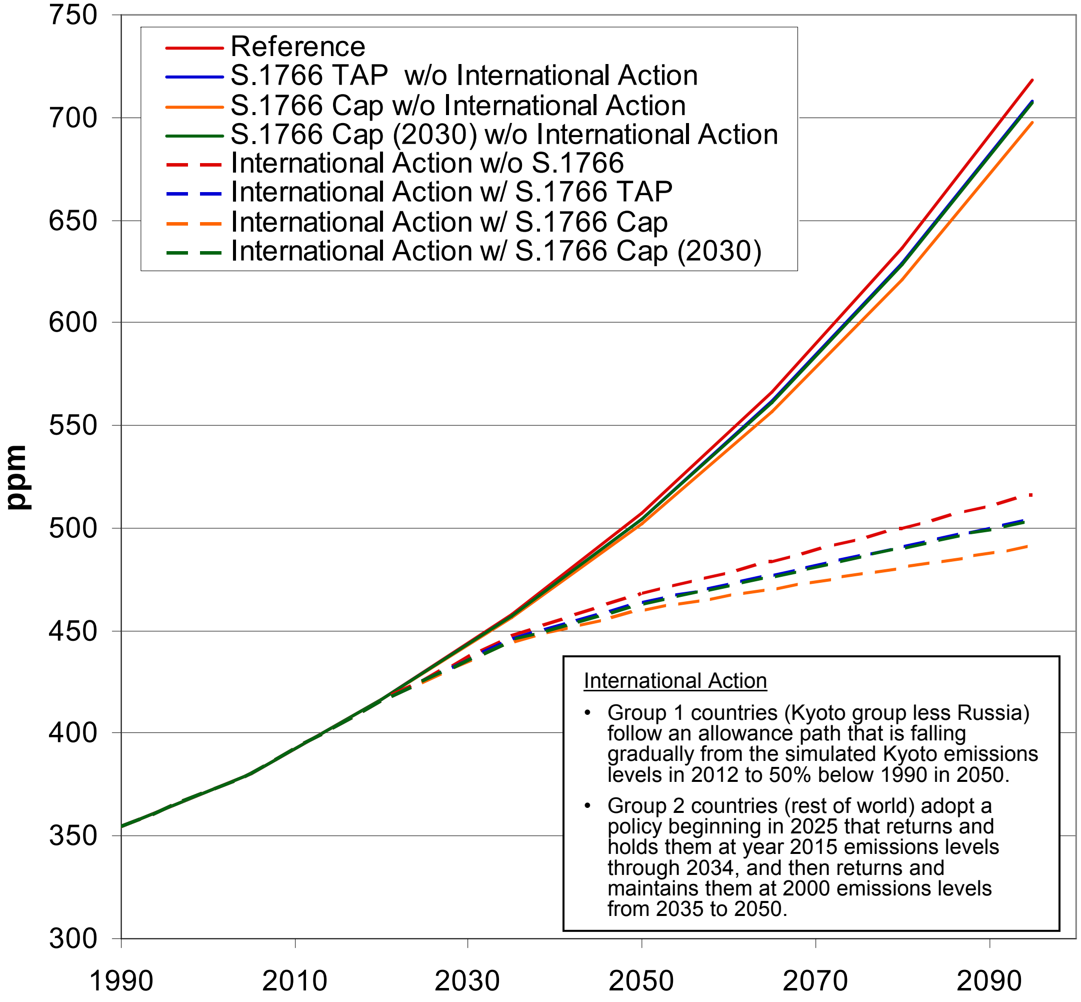
Scenarios (MiniCAM) (con't)

Scenarios with International Action

- International Action w/o S. 1766
  - USA adopts no additional polices or measures.
- International Action w/ S. 1766 TAP
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is triggered.
- International Action w/ S. 1766 Cap
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is not available.
  - 2050 targets of 60% below 2006 emissions levels are adopted.
- International Action w/ S. 1766 Cap (2030)
  - USA adopts Bingaman-Specter (S. 1766).
  - The Technology Accelerator Payment (TAP) is not available.
  - Emissions caps are held constant at 1990 levels after 2030.

- 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.

Global CO_2 Concentrations (MiniCAM)



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

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. 1766

Assuming the international community adopts no additional policies or measures, the global CO_2 concentrations in 2095 are estimated to be between 10 and 21 ppm lower than the reference case depending on which of the following forms of S. 1766 is adopted:

- S. 1766 with the TAP (10 ppm)
- S. 1766 without the TAP and with 2050 targets equal to 60% below 2006 levels (21 ppm)
- S. 1766 without the TAP and with emissions caps constant at 1990 levels after 2030 (11 ppm)

Effect of International Action plus S. 1766

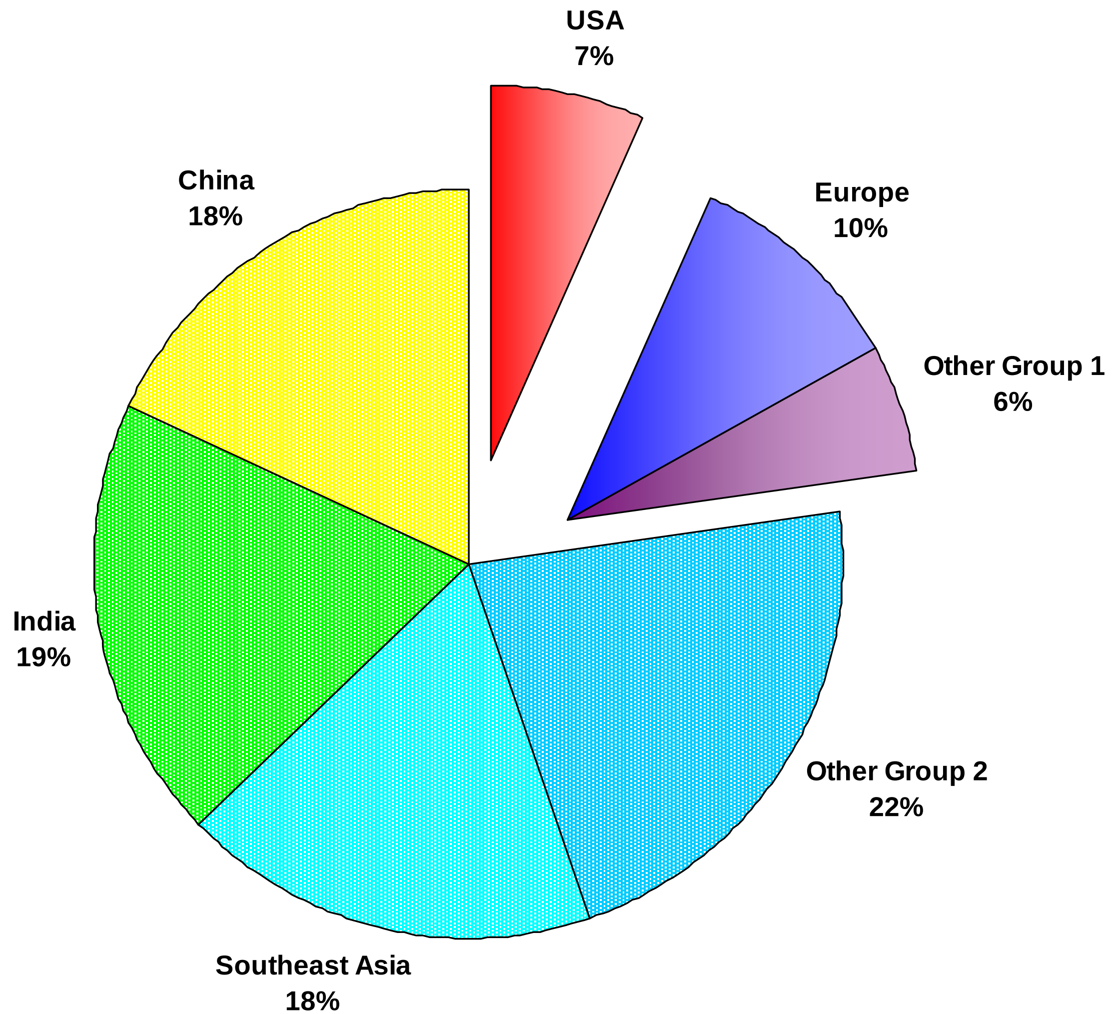
Assuming the international community takes the actions described in the diagram to the left and the U.S. takes no action, the global CO_2 concentrations in 2095 are estimated to be 516 ppm; and if the U.S. adopts S. 1766 global CO_2 concentrations in 2095 depend on which of the following forms of S. 1766 is adopted:

- S. 1766 with the TAP (504 ppm)
- S. 1766 without the TAP and with 2050 targets equal to 60% below 2006 levels (491 ppm)
- S. 1766 without the TAP and with emissions caps constant at 1990 levels after 2030 (503 ppm)

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

Results: Scenario 2 - S. 1766

Share of Cumulative GHG Abatement in the 21st Century (MiniCAM)

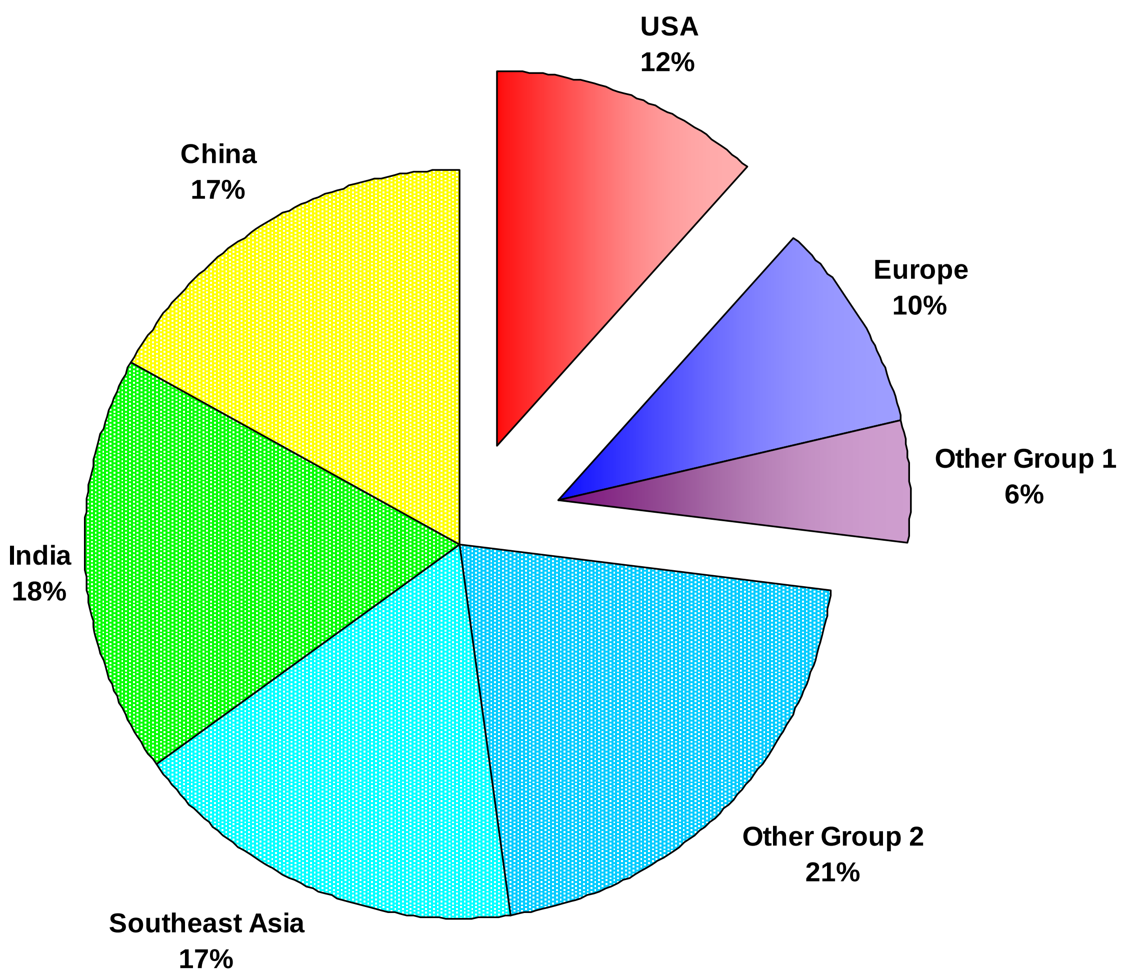


- For Group 1 and Group 2 countries, abatement is determined by the cap levels set in each country, so abatement associated with the purchase of international credits is attributed to the country that purchases the credits to meet its cap, not the country that sells the credits.
- U.S. abatement from the implementation of S. 1766 (with the TAP) through the end of the century makes up 7% of global GHG emissions abatement.
- All Group 1 countries combined account for 16% of cumulative abatement over the century.
- Group 2 countries make up 77% of cumulative abatement.

Share of 21st Century Reference GHG Emissions	
USA	13%
Group 1	16%
Group 2	71%

Results: Scenario 3 - S. 1766, No TAP

Share of Cumulative GHG Abatement in the 21st Century (MiniCAM)



- For Group 1 and Group 2 countries, abatement is determined by the cap levels set in each country, so abatement associated with the purchase of international credits is attributed to the country that purchases the credits to meet its cap, not the country that sells the credits.
- U.S. abatement from the implementation of S. 1766 (with the TAP) through the end of the century makes up 12% of global GHG emissions abatement.
- All Group 1 countries combined account for 16% of cumulative abatement over the century.
- Group 2 countries make up 73% of cumulative abatement.

Share of 21st Century Reference GHG Emissions	
USA	13%
Group 1	16%
Group 2	71%

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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