U.S. Environmental Protection Agency
Office of Atmospheric Programs

EPA Preliminary Analysis of the Waxman-Markey Discussion Draft

The American Clean Energy and Security Act of 2009 in the *111th Congress*

Appendix

4/20/09

Appendix 1: Bill Summary, Modeling Approach and Limitations

Waxman Markey Discussion-Draft – Bill Summary

Title I and Title II

- Titles I and II of the American Clean Energy and Security Act of 2009 (WM-Draft) deal with clean energy and energy efficiency. These titles are not explicitly modeled in this analysis.

- *Title I – Clean Energy*
  - *Subtitle A* - Renewable Electricity Standard
  - *Subtitle B* - Carbon Capture and Sequestration
  - *Subtitle C* - Low Carbon Fuel Standard
  - *Subtitle D* - State Energy Efficiency Development Funds
  - *Subtitle E* - Smart Grid Advancement
  - *Subtitle F* - Transmission Planning
  - *Subtitle G* - Federal Purchases Electricity Generated by Renewable Energy
  - *Subtitle H* - Technical Corrections to Energy Laws

- *Title II – Energy Efficiency*
  - *Subtitle A* - Building Energy Efficiency Programs
  - *Subtitle B* - Lighting and Appliance Energy Efficiency Programs
  - *Subtitle C* - Transportation Efficiency
  - *Subtitle D* - Utilities Energy Efficiency
  - *Subtitle E* - Industrial Energy Efficiency Programs
  - *Subtitle F* - Improvements in Energy Savings Performance Contracting
  - *Subtitle G* - Public Institutions

Waxman Markey Discussion-Draft – Bill Summary
Title III

- *Title III – Reducing Global Warming*
- Amends the Clean Air Act by adding "*Title VII – Global Warming Pollution Reduction Program*" which establishes a cap and trade system for greenhouse gases.
  - These provisions are included in this analysis unless otherwise noted
  - Economy-wide coverage phased in over time:
    - All electricity sources
    - Refiners/importers of petroleum with sales/distribution greater than 25kT CO_2e
    - Producers and importers of CO_2, N_2O, PFCs, SF_6, or other designated gases in amounts greater than 25kT CO_2e
    - Industrial sources larger than 25kT CO2e
    - LDCs for gas which deliver more than 460mcf of gas (~25kT CO2e)
    - Propane (Industrial sector phases in: 2014, Residential, industrial and commercial natural gas users served by LDCs phase in: 2016)
    - Based on EPA's 2005 *Inventory of US Greenhouse Gas Emissions and Sinks* covered emissions represent approximately the following percentages of total US GHG emissions
      - 68% in Phase 1 (2012 – 2013)
      - 76% in Phase 2 (2014 – 2015)
      - 85% in Phase 3 (2016 – 2050)
  - GHG emission targets for covered sectors (targets decline in each calendar year):
    - 2012: 4,770 $MtCO_2e$ (3% below 2005 emissions levels for covered sectors)
    - 2020: 4,873 $MtCO_2e$ (20% below 2005 emissions levels for covered sectors)
    - 2030: 3,533 $MtCO_2e$ (42% below 2005 emissions levels for covered sectors)
    - 2050: 1,035 $MtCO_2e$ (83% below 2005 emissions levels for covered sectors)

Waxman Markey Discussion-Draft – Bill Summary
Title III (continued)

- *Title III – Reducing Global Warming (Continued)*
  - Banking of allowances is unlimited, a two year compliance period allows borrowing from one year ahead without penalty, limited borrowing from two to five years ahead.
  - Offsets are limited to 2,000 $MtCO_2e$ per year split evenly between domestic and international.*
  - Offsets discounting requires entities using offsets to submit 1.25 tons of offsets credits for each ton of emissions being offset.
  - Supplemental emissions reductions from reduced deforestation
  - Strategic Reserve Allowances (Not modeled in this analysis)
    - Reserves allowances from the cap for the purpose of reducing price volatility
      - 2012 - 2019: 1% of allowances reserved
      - 2020 - 2029: 2% of allowances reserved
      - 2030 - 2050: 3% of allowances reserved
    - Reserve allowances auctioned off with a minimum strategic reserve allowance price that starts at twice the EPA modeled allowance price in 2012 growing at a real rate of 5 percent through 2014. In subsequent years, the minimum price is 100 percent above the rolling 36 month average price of that year's allowance vintage.
    - The models used in this analysis do not include price volatility, so the modeled price will never rise above the minimum strategic reserve allowance price. For this reason, the strategic reserve allowance has not been included in this analysis (i.e., the allowances are available for use, not reserved from the total cap).

- Amends the Clean Air Act by adding "*Title VIII – Additional Greenhouse Gas Standards*"
  - These provisions are not modeled in this analysis
    - Stationary source standards
    - Separate cap and trade system for HFCs
    - Black carbon provisions

* p. 372 of WM-Draft seems to indicate that the limit on offsets usage declines over time, however, committee staff have indicated to EPA that their intent is for the limit to be constant over time.

Waxman Markey Discussion-Draft – Bill Summary
Title IV

- Title IV addresses competitiveness issues and the transition to a clean energy economy. The only part of Title IV modeled here is *Subtitle A – Part 1*.

- *Title IV – Transition to a Clean Energy Economy*
  - *Subtitle A* - Ensuring Domestic Competitiveness
    - Part 1 - Preserving Domestic Competitiveness
      - Based on H.R. 7146 (Inslee / Doyle)
      - Applies to energy- or greenhouse gas-intensive industries that are also trade-intensive
      - Rebates on average 85 percent of the direct and indirect cost of allowances
      - Gradually phases out between 2021 and 2030.
    - Part 2 - International Reserve Allowance Program
      - Only applies if the President finds that direct and indirect compliance costs after being mitigated by the rebates provided in part 1 adversely impact production, jobs, or greenhouse gas emissions leakage
  - *Subtitle B* - Green Jobs and Worker Transition
  - *Subtitle C* - Consumer Assistance
  - *Subtitle D* - Exporting Clean Technology
  - *Subtitle E* - Adapting to Climate Change

Waxman Markey Discussion-Draft – Bill Summary

Additional Assumptions from Committee Staff

- The bill is silent on how allowances will be allocated or auctioned.
- In order to model the bill, we need to make assumptions about how allowances will be allocated and how auction revenue will be used.
- House Energy and Commerce Committee Staff directed EPA to use the following assumptions:
  - CCS Bonus Allowances: 2% 2012-2016; 5% 2017-2050
    - Included in all scenarios.
  - International Forest Carbon: 5% through 2025, 3% through 2030, 2% through 2050.
    - Included in all scenarios.
  - Energy Efficiency: 12.5%
    - Included in all scenario 3.
  - Output-Based Rebate: 15% through 2020, should decline at 10% per year after that.
    - Included in all scenario 4.
  - Necessary allowances for deficit neutrality
    - Included in all scenarios.
  - Remaining allowance value is recycled to households lump sum.
    - Included in all scenarios
- The following assumptions about the CCS bonus allowance provisions were also given:
  - CCS bonus allowance provisions should be modeled as specified in the Dingell-Boucher discussion draft.
  - No set bonus allowance rate. The number of bonus allowances given for each ton sequestered is determined so that the value of the bonus allowances is equal to $90 for the first 3 GW of CCS, $70 for the second 3 GW of CCS, and $50 for the rest (values are in 2005 dollars).
  - If the program is oversubscribed, then you can borrow from future period allocations until the total pool of bonus allowances is used.

Analytical Scenarios

EPA analyzed 5 different scenarios in this preliminary report. A full report will include a larger list of scenarios to evaluate a range of assumptions and key parameters. These scenarios do not account for the American Recovery and Reinvestment Act, which could further advance the deployment of clean energy technologies. The assumptions about other domestic and international policies that affect the results of this analysis do not necessarily reflect EPA's views on what is most likely to occur.

1) EPA 2009 Reference Scenario

- This reference scenario is benchmarked to the revised AEO 2009 forcast and includes EISA.
  - Does not include any additional climate policies or measures to reduce international GHG emissions.
  - For domestic projections, benchmarked to AEO 2009.
  - For international projections, use CCSP Synthesis and Assessment Report 2.1 A MiniCAM Reference.
    - Note that this referenece scneario is a 'no policy scenario' and thus assumes no policies or measures internationally in the baseline. As countries begin adopting GHG policies and the likelyhood of future policies causes firms to make descions in anticipation of those policies, the 'reference' or 'business as usual' scenario looks less like a 'no policy scenario'.

2) WM-Draft Scenario

- This core policy scenario models the cap-and-trade program established in Title III of the Waxman-Markey Discussion Draft.
  - The strategic allowance reserve is not modeled (i.e., these allowances are assumed to be available for use and not held in reserve).
- This scenario does not include provisions from Titles I, II, or IV.
- Additional assumptions provided by committee staff on the use of allowances in this scenario are as follows:
  - CCS Bonus Allowances: 2% 2012-2016; 5% 2017-2050
  - International Forest Carbon: 5% through 2025, 3% through 2030, 2% through 2050.
  - The necessary allowances for the policy to be deficit neutral.
  - All remaining allowances are returned to households in a lump sum fashion.
- Widespread international actions by developed and developing countries over the modeled time period. International policy assumptions are based on those used in the 2007 MIT report, "Assessment of U.S. Cap-and-Trade Proposals."
  - Group 1 countries (Kyoto group less Russia) follow an allowance path that is falling gradually from the simulated Kyoto emissions levels in 2012 to 50% below 1990 in 2050.
  - Group 2 countries (rest of world) adopt a policy beginning in 2025 that returns and holds them at year 2015 emissions levels through 2034, and then returns and maintains them at 2000 emissions levels from 2035 to 2050.

Analytical Scenarios (continued)

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

3) WM-Draft Scenario with Energy Efficiency Provisions

- Potential effect of using auction revenues to reduce direct use of electricity is modeled
- See Appendix 3 for a discussion of the limitations and caveats associated with the methodology used in this scenario.

4) WM-Draft Scenario with Output-Based Allocations

- Explicitly models the output-based allocations specified in *Title IV – Subtitle A – Part 1 Preserving Domestic Competitiveness,* which is similar to H.R. 7146 (Inslee / Doyle).
  - Applies to energy- or greenhouse-gas intensive industries that are also trade-intensive.
  - Rebates on average 85 percent of the direct and indirect cost of allowances, based on an individual firm's output and the average GHG and energy intensity for the industry.
  - Gradually phases out between 2021 and 2030, or when other countries take comparable action on climate change.

5) WM-Draft Scenario with No International Offsets

- Does not allow the use of international offsets

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 climate change policies.
- 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
Reference Calibration and Composition of GDP (IGEM)

- In IGEM's AEO 2009 Reference Case, the composition of GDP arises as follows. First, there is an important accounting distinction. The Jorgenson-IGEM accounts treat consumer durables like housing differently than they are treated in the U.S. National Income Accounts (NIA). Specifically, expenditures on these appear as part of investment, not consumption as in the NIA, while their capital services flows are added both to consumption and GDP. This accounting treatment lowers consumption's share of GDP and raises investment's share of GDP in comparison to pure NIA-based ratios.

- Second, government purchases are endogenous and result from combining an exogenous deficit with endogenous tax receipts, tax rates being exogenous. Model closure requires that government debt eventually stabilizes which implies the government deficit is zero in steady state. Reference case assumptions regarding annual deficits and tax rates are based on Congressional Budget Office (CBO) projections that are several years old, vintage 2003-04, with the government deficit projected to vanish by 2037 at a rate slower than the CBO forecast.

- Third, exports are driven by exogenous export demands combined with endogenous relative prices, U.S. versus rest-of-world. Imports are driven purely by relative price effects, import prices being exogenous. Model closure requires that rest-of-world debt also eventually stabilizes which implies the exogenous current account deficit is zero in steady state. Aside from oil and gas import prices which are scaled to reflect the Energy Information Administration's (EIA's) AEO 2009 Reference Case pricing, the trends in export demands and import prices also are of the 2003-04 vintage and reflect the CBO forecasts and their underlying data; here, the current account deficit vanishes also more slowly but by 2025. In simulation, the exchange rate adjusts so that relative prices, U.S. versus rest-of-world, yield export and import patterns aligned to the current account deficit.

- In developing IGEM's AEO 2009 Reference Case, the model is calibrated using industry and aggregate productivity adjustments to match closely the levels and growth in real GDP and coal, petroleum, gas and electricity consumption of EIA's AEO 2009 Reference Case. In examining IGEM's simulated share composition of GDP, it is important to note that all shares are consistent with their respective long-run historical averages and, thus, offers a reasonable basis against which to frame the WM-Draft policy outcomes. Nevertheless, it is worthwhile to consider what likely would occur were the government and trade assumptions brought more up-to-date. For government, the deficits would be larger and the tax rates lower, combining to yield a lower government share than forecasted by the model. For trade, rest-of-world demands would grow more rapidly, import prices, except for oil and gas, would be slightly lower and current account deficits would be larger. With an endogenous exchange rate, these would combine primarily to yield a larger import share and slightly larger consumption and investment shares as net foreign saving (i.e., investment in U.S. assets) is presumed to be larger.

- In that the overall scale of the economy and energy consumption and greenhouse gas emissions patterns are very close across the ADAGE, IGEM and NEMS reference cases, does it matter that their compositions of GDP slightly differ? The following point cannot be emphasized too strongly. *While it is tempting to focus on levels, it is the absolute and relative changes and their underlying causes that matter most once a common scale among variables of interest and across methodologies has been achieved.* Indeed, a common scale only becomes necessary to the extent that overall model outcomes arise from dominant non-constant elasticities and response surfaces somewhere in their functional representations. Also, model outcomes to policy changes are more than likely to be qualitatively very robust and relatively insensitive across small compositional differences within a methodology and a common scale; in short, model differences matter much more than do starting points.

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 the WM-Draft.
- 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 a 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 CGE models do not explicitly represent end-use efficiency technologies.
- 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 previous analyses, EPA has used the Mini-Climate Assessment Model (MiniCAM) to supplement to provide information on how S. 2191, S. 1766, and S. 280 affect CO_2 concentrations throughout the 21st century. These analyses are available at http://www.epa.gov/climatechange/economics/economicanalyses.html.
- None of the models used in this analysis currently represent the benefits of GHG abatement.
- Using sectoral models to construct offset curves limits ability to estimate all leakage effects.

Modeling Limitations (continued)

- The models used in this analysis do not incorporate the effects of changes in conventional pollutants (SO_2, NOx, and Hg) on labor productivity and public health.
  - While this is an important limitation of the models, the impact on modeled costs of the policy is small because the WM-Draft does not necessarily reduce overall emissions of conventional pollutants covered by existing cap and trade programs. Instead, allowance prices for conventional pollutants would fall.
- The federal government costs of administering the WM-Draft (e.g. monitoring and enforcement) are not captured in this analysis.
- Household effects are not disaggregated by demographic characteristics (e.g. income class).
- 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 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 (continued)

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

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

Modeling Limitations

Specified Uses of Auctioned / Allocated Allowances

- 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).
    - Note that 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). However, the value of the subsidy needed to fully correct the market failure is not known.
- In IGEM we assume that the policy is deficit and revenue neutral, which implies that the market outcomes are invariant to the auction/allocation split.
  - Allowance auction revenues flow to the U.S. government, and are redistributed to households lump sum to the extent that deficit and spending levels are maintained. If auction revenues were directed to special funds instead of returned directly to households as modeled, the reduction in household annual consumption and GDP would likely be greater. If the auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower.
  - Private sector revenues from allocated allowances accrue to employee-shareholder households, and the government adjusts taxes lump sum to maintain deficit and spending levels.

Peer Review

- Over the past two years, EPA has analyzed the economic impacts of three GHG cap & trade bills at the request of Members of Congress: S. 280 (McCain-Lieberman), S. 1766 (Bingaman-Specter), and S. 2191 (Lieberman-Warner).
- EPA's approach to these analyses has been to use multiple models, each with different strengths. These models include economy-wide computable general equilibrium (CGE) models (IGEM, ADAGE), and detailed sector-specific models (IPM, FASOMGHG).
- Each of EPA's analyses (including this analysis) has undergone extensive internal EPA peer review and external inter-agency review by economists and other experts within the federal government.

- IGEM
  - IGEM stands for Inter-temporal General Equilibrium Model. IGEM is formerly known as the Jorgenson-Wilcoxen model and the Jorgenson-Wilcoxen-Ho model, after the researchers who developed it.
  - The model is described and results presented in a number of publications, including:
    - Jorgenson, Dale and Goettle, Richard, et al., *U.S. Market Consequences of Climate Change.* Prepared for the Pew Center on Global Climate Change. April 2004.
    - Jorgenson, Dale and Goettle, Richard, et al., *The Role of Substitution in Understanding the Costs of Climate Change Policy.* Prepared for the Pew Center on Global Climate Change. September 2000.
    - Jorgenson, Dale and Goettle, Richard, et al., *Carbon Mitigation, Permit Trading and Revenue Recycling.* Prepared for U.S. Environmental Protection Agency. 1998.
    - Jorgenson, Dale, *Econometric General Equilibrium Modeling (Growth, Volume 1)*, Cambridge, The MIT Press, 1998.
    - Jorgenson, Dale, *Energy, the Environment, and Economic Growth (Growth, Volume 2)*, Cambridge, The MIT Press, 1998.
    - *The Benefits and Costs of the Clean Air Act, 1970 to 1990.* Washington, DC: Prepared for the U.S. Congress by the U.S. Environmental Protection Agency, October 1997.
    - *The Clean Air Act and the U.S. Economy.* Cambridge, MA: Prepared for the U.S. Environmental Protection Agency by Dale W. Jorgenson Associates, August 1993.
  - IGEM underwent a peer review through the EPA Scientific Advisory Board as part of the Clean Air Act Amendments of 1990 Section 812 process that produced *The Benefits and Costs of the Clean Air Act, 1970 to 1990.* The peer review of the 812 approach was completed October 1996.
  - EPA has initiated an updated outside experts-based peer review of IGEM that will proceed through the rest of 2009.

Peer Review (continued)

- ADAGE
  - ADAGE stands for Applied Dynamic Analysis of the Global Economy. It is a dynamic computable general equilibrium (CGE) model capable of investigating economic policies at the international, national, U.S. regional, and U.S. state levels.
  - Peer-reviewed articles based on ADAGE modeling include an article in *B.E. Journal of Economic Analysis* and an article in a forthcoming special issue of *Energy Economics*.
  - The core model of ADAGE is based on the MIT Emissions Predictions and Policy Analysis (EPPA) model, also a multi-sector, multi-region CGE model of the world economy. EPPA analyses have been published in multiple peer-reviewed academic energy, economic, and environmental journals.
  - EPA has initiated an updated outside experts-based peer review of ADAGE that will proceed through the rest of 2009.

- IPM
  - Periodic formal peer review of IPM includes separate expert panels on the model itself, and EPA's key modeling input assumptions. For example, within the past six years separate panels of independent experts have been convened to review IPM's coal supply and transportation assumptions, natural gas assumptions, and model formulation.
  - Rulemaking process provides opportunity for expert review and comment by
    - Operators of the electricity sector that is represented in IPM
    - Stakeholders affected by the policies being modeled
    - Developers of other models of the U.S. electricity sector
    - This feedback provides a highly detailed reality check of
      - Input assumptions
      - Model representation
      - Model results
    - EPA is required to respond to every significant comment submitted
    - Comments on IPM have been solicited in most of the major air regulations that EPA has promulgated in the last 15 years
  - IPM has been used by states (e.g., for RGGI, WRAP, OTAG), other Federal agencies (e.g., FERC, GAO), environmental groups (including the Clean Air Task Force), and industry (e.g., TVA, SoCAL), all of whom subject the model to their own review procedures
  - Extensive review by energy and environmental modeling experts from states, industry and other groups during the 2 years of the OTAG process in 1997-1998,
  - Science Advisory Board review of IPM as part of the CAAA Section 812 prospective study 1997-1999

Peer Review (continued)

- FASOMGHG
  - The FASOMGHG model has been vetted through an extensive refereeing process in numerous academic publications including: *Science, Nature, American Journal of Agricultural Economics, Environmental and Resource Economics, Climatic Change, Ecological Economics, Land Economics, Forest Ecology and Management, Journal of Soil and Water Conservation*, and more.
  - FASOMGHG and its predecessors have been used for assessments on ozone impacts (Adams et al., 1984), acid rain (Adams et al., 1993), soil conservation policy (Chang et al., 1994), global climate change impacts (Reilly et al., 2000), and GHG mitigation (USEPA, 2005, USEPA, 2007), among many others.

    - Adams, R.M., S.A. Hamilton, and B.A. McCarl. September 1984. "The Economic Effects of Ozone on Agriculture." *Research Monograph*. EPA/600-3-84-90. Corvallis, OR: USEPA, Office of Research and Development.
    - Adams, R.M., D.M. Adams, J.M. Callaway, C.C. Chang, and B.A. McCarl. 1993. "Sequestering Carbon on Agricultural Land: Social Cost and Impacts on Timber Markets." *Contemporary Policy Issues* 11:76-87
    - Chang, C.C., J.D. Atwood, K. Alt, and B.A. McCarl. 1994. "Economic Impacts of Erosion Management Measures in Coastal Drainage Basins." *Journal of Soil and Water Conservation* 49(6):606-611
    - Reilly**,** J., F. Tubiello, B. McCarl, and J. Melillo. 2000. "Climate Change and Agriculture in the United States." In *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, pp. 379-403. Report for the U.S. Global Change Research Program. New York: Cambridge University Press.
    - USEPA, 2005. Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture, U.S. Environmental Protection Agency, EPA 430-R-05-006, Washington D.C., November 2005.
    - USEPA, 2007. "EPA S.280 mitigation cost schedules for capped sectors and domestic and international offsets." *EPA memo to the Energy Information Administration (EIA), March 2007.* Available at: www.epa.gov/climatechange/economics/economicanalyses.html.

Appendix 2: Analysis and Model Updates

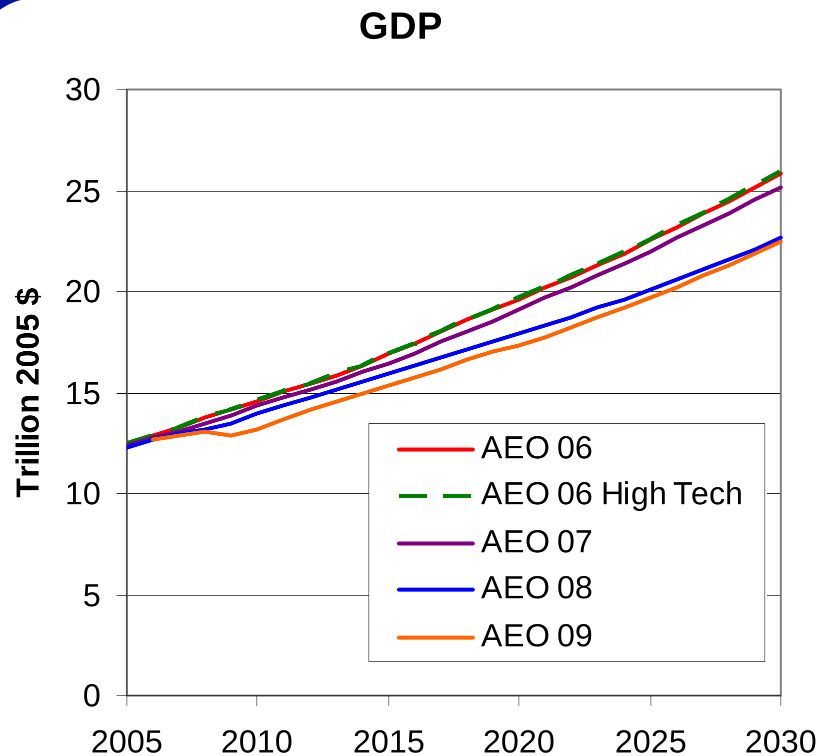
Major Changes for this Analysis

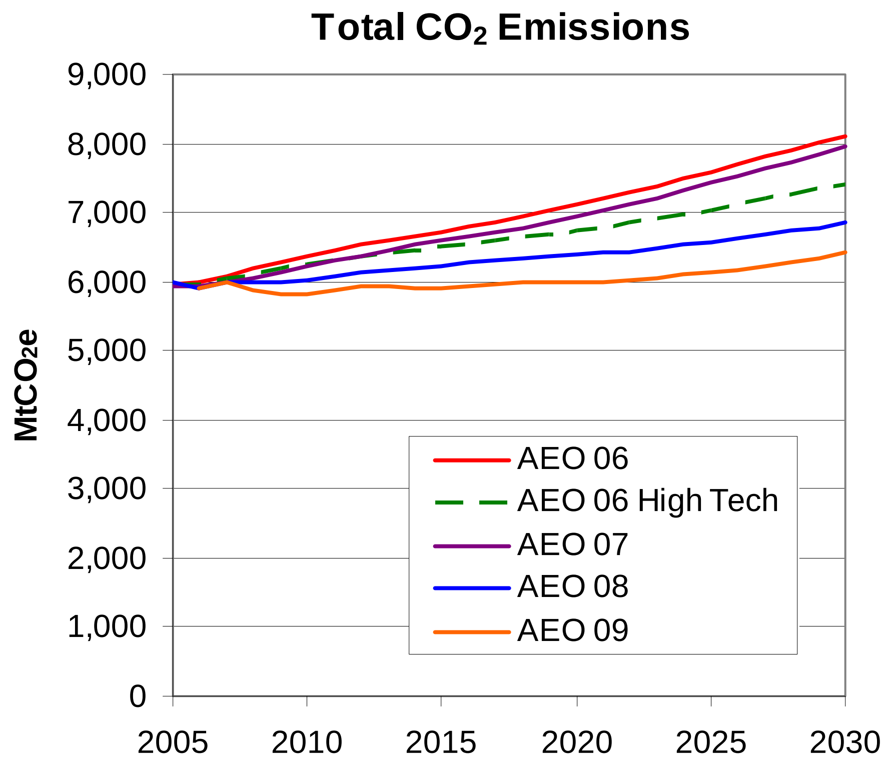
- Several changes have been made in this analysis compared to EPA's previous analyses of Senate cap and trade bills (S. 2191, S. 1766, and S. 280).

- Updated reference case (Annual Energy Outlook (AEO) 2009 which includes EISA provisions)
  - This has the largest impact on results. The inclusion of EISA as well as actions of the states, such as renewable electricity standards in AEO 2009, as well as a lower GDP growth rate in AEO 2009 compared to the old AEO 2006 reference case used in the previous analysis leads to considerably lower emissions in baseline. Lower reference case emissions lead to lower allowance prices as less abatement is required.
- ADAGE model updates
  - Model updates include a new less flexible putty-clay approach to capital movements, and higher capital costs for new electricity generation capacity based on AEO 2009. Both of these changes tend to increase allowance costs.
- IGEM model updates
  - IGEM now includes a representation of CCS abatement potential, which will tend to lower allowance prices. The baseline calibration procedure for IGEM now also results in GHG emissions that are closer to ADAGE. Since IGEM GHG emissions were higher than ADAGE GHG emissions in the old reference case, the updated reference case has a bigger impact on allowance prices in IGEM than in ADAGE.
- IPM model updates
  - Model updates include an enhanced approach for modeling natural gas supply; updated capital costs; representation of state RPS and climate programs; CCS retrofits; and updated constraints on new renewable, nuclear, and coal with CCS capacity.
- New FASOM marginal abatement cost curves (MACs)
  - The updated FASOM MACs tend to show mixed potential for agriculture and forestry offsets compared to the old FASOM MACs depending on the year and practice.

Updated Reference Scenario

Comparison of AEO 2006, 2007, 2008, and 2009

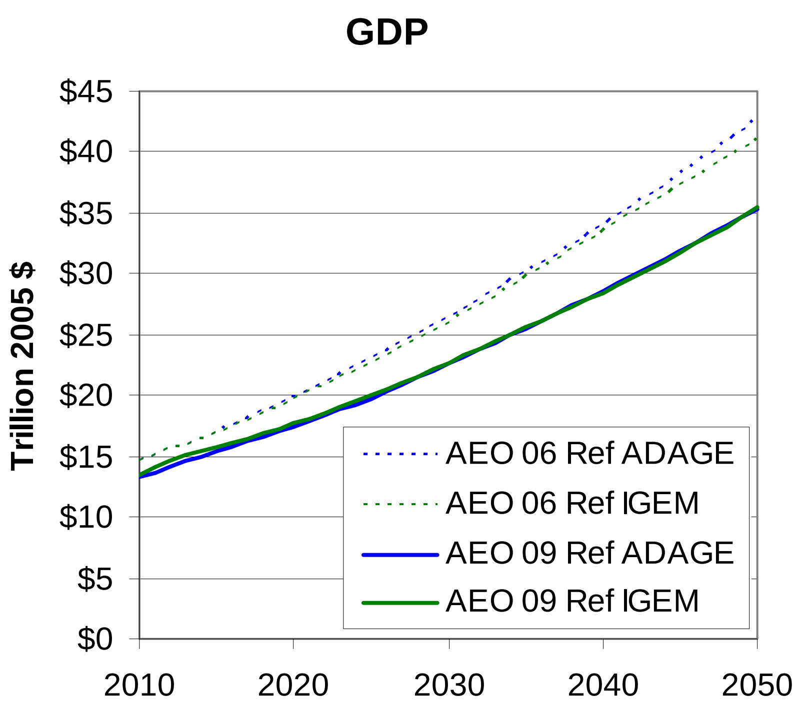


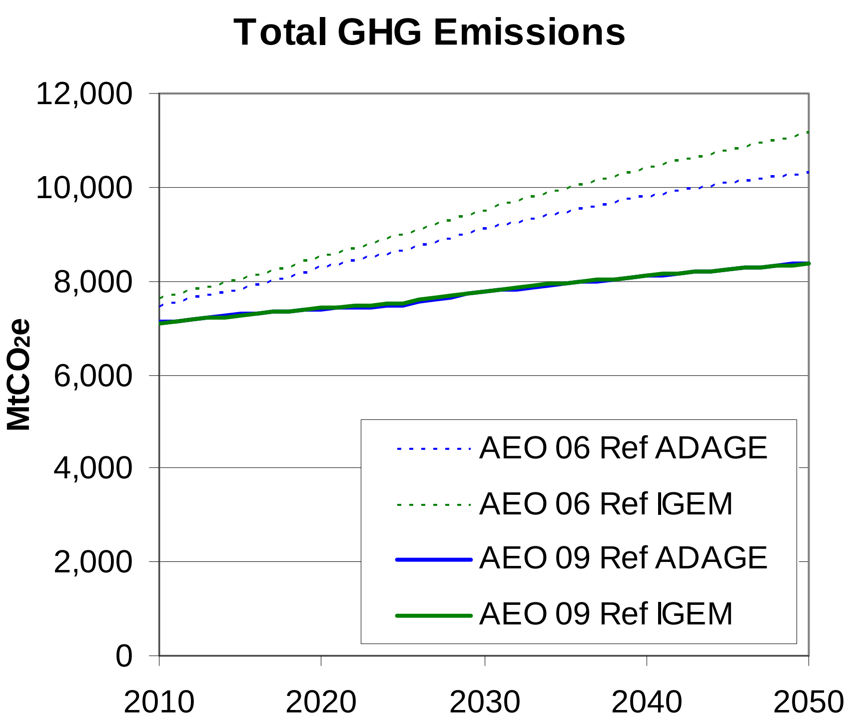


- AEO 2009 indicates lower near term GDP, but a faster GDP growth rate; and lower total GHG emissions than AEO 2008.
- The average annual GDP growth rate varies by 60 basis points across these scenarios (a high of 3.0% in AEO 2006 and a low of 2.4% in AEO 2008).
- In 2010, the difference between the AEO 2006 and AEO 2009 GDP forecasts compared above is $1.4 trillion, in 2020 the difference is $2.3 trillion, and in 2030 the difference is $3.4 trillion.
- The difference in CO_2 emissions across forecasts is even larger, showing that significant down payments on our energy and climate objectives have been made through EISA as well as actions of the states, such as renewable electricity standards.

Updated Reference Scenario

Comparison of ADAGE & IGEM





- The updated reference case for this analysis is based on the AEO 2009 early release, and the old reference case from EPA's S. 2191 analysis was based on AEO 2006.
- Cumulative 2012-2050 GHG emissions are 18% (67 billion metric tons (bmt)) lower in the AEO 09 baseline compared to the AEO 06 baseline in IGEM; and 14% (51 bmt) lower in the AEO 09 baseline compared to the AEO 06 baseline in ADAGE. Cumulative emissions in the two models are closer in the updated AEO 09 baseline.
- The projected GDP growth rate is lower in the AEO 09 baseline (2.5%) than in the AEO 06 baseline (3.0%).

ADAGE / IGEM Model Updates

- ADAGE
  - Adjusted capital structure in model
    - New capital movement approach that essentially represents a slower turnover from existing capital into new investments. ADAGE now uses a putty-clay approach that controls movements in existing capital stocks compared to old quadratic adjustment-cost approach. This structure is important for capturing longer useful lifetimes for capital in the electricity sector as initiation date of possible climate legislation moves closer. In the putty-clay approach new capital is malleable, however once the capital is installed it cannot be moved to another sector.
  - Added CO_2 emissions from non-energy sources (e.g., cement)
  - Initial year of model and data moved from 2005 to 2010
  - Baseline calibrated to AEO 2009 with EISA, World Energy Outlook 2007, and EPA GHG Inventory 2006
  - AEO 2009 higher capital costs for all new electricity generation capacity
  - Improved ability of model to represent responses of renewable (wind/solar) electricity generation to climate policies
  - Updated biomass supplies for electricity from FASOM (taking EISA into consideration)
  - Updated FASOM-related offset curves

- IGEM
  - Now includes Carbon Capture and Sequestration (CCS) in the form of marginal abatement cost curves generated by ADAGE
  - Baseline calibrated to AEO 2009, with post 2030 calibration now more closely aligned with ADAGE calibration

More Details on Key Updates Included in EPA's Base Case 2009 using IPM

- **Electricity Demand Growth:**
  - EPA uses AEO 2009 as the basis for future electricity demand projections for the reference case.
  - Growth rate of just under 1% is now used in the reference case, compared to a growth rate of 1.5% in past IPM modeling applications.
- **Cost of New Power Technologies:**
  - The capital costs of new power plants have increased by 50% compared to past IPM applications, and are based on AEO 2009. Because of higher capital costs, a higher CO_2 price signal is needed for CCS to be cost competitive.
  - A capital charge rate penalty of 3% has been added to reflect the implicit cost being added to GHG-intensive projects to account for additional risk associated with future climate regulation. This assumption was also made in the AEO 2009.
- **Natural Gas:**
  - An enhanced approach reflecting recent trends in infrastructure investment and gas supply has been used, and prices are generally 5-15% higher than past IPM applications.
  - EPA has relied upon a more recent gas supply projection from ICF.
- **State RPS and Climate Programs:**
  - EPA has calibrated state RPS Requirements to AEO 2009 in IPM, resulting in more renewable energy investment in the reference case.
  - EPA has modeled finalized climate programs, such as RGGI, in IPM.
- **CCS Retrofit Option for Existing Coal Fleet:**
  - This is a new option for coal-fired units provided they have (or add) highly efficient scrubber for SO_2 removal.
- **Limits for New Power:**
  - Limits on new renewables, nuclear, and coal with CCS have been updated to ensure realistic build patterns in response to CO_2 regulatory policies.

Note: For more detail on the assumptions used in EPA's application of IPM, please see more detailed documentation for IPM at http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html.

Key FASOM Updates

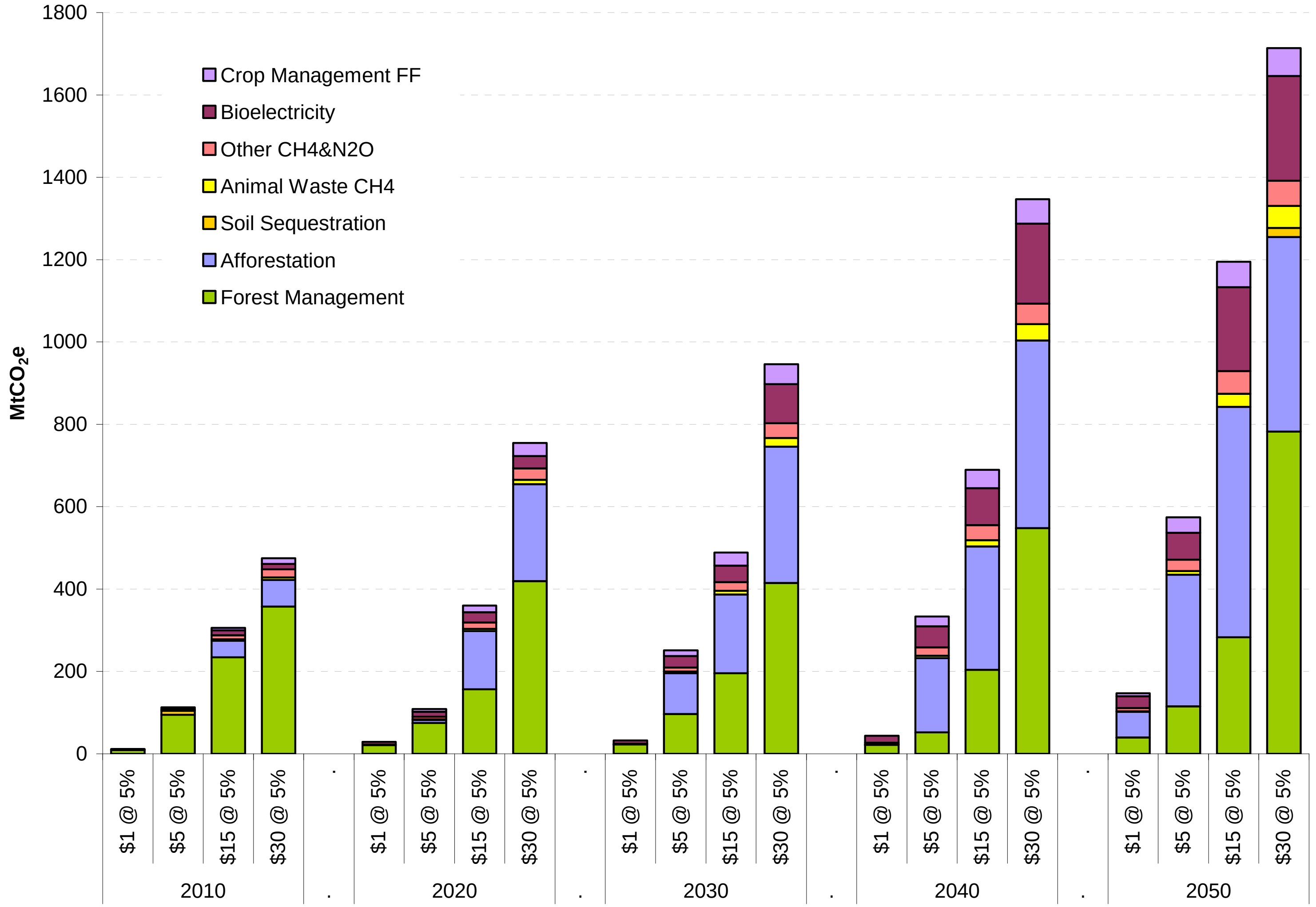
- FASOM has been updated to reflect several changes in policies, as well as structural improvements:
  - New policies that impact land use, such as Energy Independence and Security Act of 2007 (EISA) / Renewable Fuels Standard (RFS2) and new Conservation Reserve Program (CRP) provisions in the 2008 Farm Bill.
    - Renewable fuels volumes follow prescribed pathway in EISA up to 30 billion gallons per year from 2022 through 2050.
    - Maximum CRP enrollment reduced to 32 million acres.
  - Increased spatial (63 ag regions) and temporal (5 year time steps) resolution.
  - Energy prices and assumptions follow AEO2008.
  - Agriculture sector has updated commodity prices, quantities and acres.
  - Forest sector updated using projections from 2007 update of Resources Planning Act (RPA) and most recent Forest Inventory and Analysis (FIA) inventories.
  - Bioenergy sector now includes starch- and sugar-based ethanol, cellulosic ethanol, biodiesel, and bioelectricity.
  - Stocks and flows of GHGs for more than 50 sources and sinks.
  - Projections for land use change for development follow USDA Forest Service 2010 RPA land base assessment.

Estimating WM-Draft Offsets

- Marginal abatement cost (MAC) curves for forest and agriculture sector constructed using rising price runs.
  - With a limit of 1 billion tons per year, offsets from this sector will likely be non-binding.
  - Offsets not discounted in FASOM estimates, but rather at the time they are traded in for allowances.
  - The feedstocks that are used as substitutes for fossil fuels in the capped sector always face an allowance price that is rising at 5%
- Liquid biofuels not a mitigation option because model was constrained to prescribed RFS2 volumes for all scenarios.
  - Still, important to model all feedstocks and mitigation options that could impact competition for land use.

Offset Categories
Afforestation C Sequestration
Forest Management C Sequest.
Soil Carbon Sequestration
Animal Waste CH_4
Other Agriculture CH_4 & N_2O
Capped-Sector Categories
Bioelectricity
Crop Fossil Fuel Mgmt

FASOM GHG Mitigation Potential



GHG Mitigation Potential in Forestry and Agriculture

- Estimates indicate a reduction in overall potential of forest and agriculture sector compared to previous results (EPA, 2005).
  - Attributed to changes in demand for agricultural commodities, RFS2 requirements, income and population growth, etc.
  - Total mitigation potential assumes that all offsets are available from start of policy and that no offset categories are discounted.
  - Model tracks biomass feedstock and crop management fossil fuel GHGs, but these are not included as offsets in WM Draft analysis.
    - Biomass feedstocks tracked because potential substitute for fossil fuels in capped sectors.
  - Results could be considered an upper bound of mitigation potential because key assumption is total welfare maximization with perfect foresight.
    - Model accounts for costs of land conversion, but no other ‘transaction’ costs as a result of a carbon policy.
- Mitigation potential still quite large for sector and increasing with price.
  - Highest mitigation potential generally from forestry practices.
  - Abatement from feedstocks for bioelectricity increases over time.
  - Relatively small potential from other agriculture categories a result of:
    - Landowners converting cropland to forests
    - Use of conventional cropping methods to produce additional biofuel feedstocks are netting out mitigation by farmers that are implementing agriculture best management practices.

Appendix 3: Modeling of Energy Efficiency Provisions

Scenario 3 – WM-Draft Energy Efficiency

Explicitly modeled at direction of House Energy and Commerce Staff

- *12.5% of allowance value each year through 2050 (~$565 billion, estimated) applied to Energy Efficiency program administration*
- *Similar to S.3036, Title VI, Subtitle A, Section 601, providing allowance value to* local distribution companies (electric and gas) for energy efficiency and other purposes
- Assumed similar division to electric and gas LDCs as in S.3036

Not explicitly modeled

- *Title II – Energy Efficiency*
  - *Subtitle A* - Building Energy Efficiency Programs
  - *Subtitle B* - Lighting and Appliance Energy Efficiency Programs
  - *Subtitle D* - Utilities Energy Efficiency
  - *Subtitle E* - Industrial Energy Efficiency Programs

Basis for Scenario 3 – WM-Draft EE

House Energy and Commerce Staff Assumption

<u>Basis for Energy Efficiency Scenario (#3)</u>

- 12.5% of allowance value directed towards end-use energy efficiency programs. Revenues estimated based upon forecast allowance prices through 2050 applied to portion of allowances addressed under this section.
- Forecast electricity and natural gas demand adjusted assuming cost of saved energy (COSE) at rate of $35/MWh (electric) and $3/mmBTU (gas) and average measure lives of 10 and 15 years, respectively, for electric and gas programs.
- Sources (available at www.epa.gov/eeactionplan):
  - National Action Plan for Energy Efficiency (July 2006)
  - National Action Plan for Energy Efficiency Vision for 2025: Developing a Framework for Change (November 2007)
- COSE is escalated at rate of 1%/year through 2050.

Scenario 3 – WM-Draft EE Caveats

- A significant electricity demand price response is forecast by ADAGE. This response is driven by a number of factors including substitution away from energy consumption to other products/services, conservation behavior (e.g., turning off lights), as well as increased investments in energy efficiency.
- A portion of estimated electricity demand reduction from the energy efficiency subsidy (Title VI Subtitle A Section 601) may be a-priori incorporated into the baseline responsiveness of demand to a price increase in ADAGE. Further analyses are needed to quantify the extent to which demand reduction may be double counted in this scenario.
- The ADAGE model does not represent the capital cost associated with the electricity demand reduction from the energy efficiency subsidy (Title VI Subtitle A Section 601), and the cost of saved energy for energy efficiency programs is not endogenous to the model.

Energy Efficiency Modeling in Context

- The modeling of non-price policies in tandem with the analysis of GHG mitigation policy is the subject of much current research, including an on-going effort by the Energy Modeling Forum (EMF 25).
- There has been, historically, a disagreement between “top down” modeling, including the use of computable general equilibrium (CGE) models and “bottom up” or engineering economic models.
  - CGE models account for capital and labor flows between different sectors, representing the full effects of changes in prices, but they assume that markets are efficient. Because of this assumption, top down modeling implies that actors would adopt cost effective technology at an optimum rate, and that policies to increase investment in energy efficiency could come at the expense of other investments in the economy.
  - Bottom up models examine specific energy uses and show that there are large cost effective opportunities for energy efficient technologies. These studies often don’t include the opportunity costs of increased investment in any particular sector.
- Economists recognize that there are market failures which may lead to sub-optimal adoption of energy saving technology.
  - Undersupply of research and development, externalities related to energy security and pollution, and principal-agent (landlord/tenant) problems are widely accepted as potential market failures.
  - Some researchers argue that asymmetric information and transaction costs also inhibit the adoption of more energy efficient investments and thus merit government intervention.
  - Economists also point to already existing market distortions, such as average cost pricing in electricity markets and energy subsidies, that may reduce investments in energy efficiency.
  - Uncertainty due to fluctuations in energy prices, irreversibility of investments and imperfect information characterize many markets and are not usually considered to be market failures.

Energy Efficiency Modeling in Context

- There are disagreements in the literature regarding the extent of these market failures (Jaffe, Newell, and Stavins 2001), though study of market failures and the cost-effectiveness of policies to reduce them has been on-going (Brown, M. 2001, IEA 2007, Brown, R., Borgeson, Koomey and Biermayer 2008).
- Policies at the state and federal level have been implemented and studied for many years.
  - Technology standards/codes (reviewed under E.O. 12866)
  - Informational programs (Energy Star)
  - Utility “demand-side management” (DSM)
- Three decades of empirical, retrospective assessment of costs and energy savings provides a knowledge base for estimating prospective costs and benefits of expanded programs in the context of national GHG emissions policy
  - California developed and implemented mandatory *ex post* measurement and correction for selection bias in utility programs
  - Costs and outcomes have also been analyzed econometrically (Horowitz 2004, 2007)
  - Aggregate ex ante efficiency potential studies are a complementary source of information (NAPEE 2007)

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Appendix 4: 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 split.
  – 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 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 cannot 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.
  - Bovenberg and Goulder 2001 examines the degree to which freely allocated allowances maintain or increase profits.
- 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.

Allowance Allocation Issues (continued)

- 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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Appendix 5: Additional Information on Economy Wide Modeling (ADAGE & IGEM)

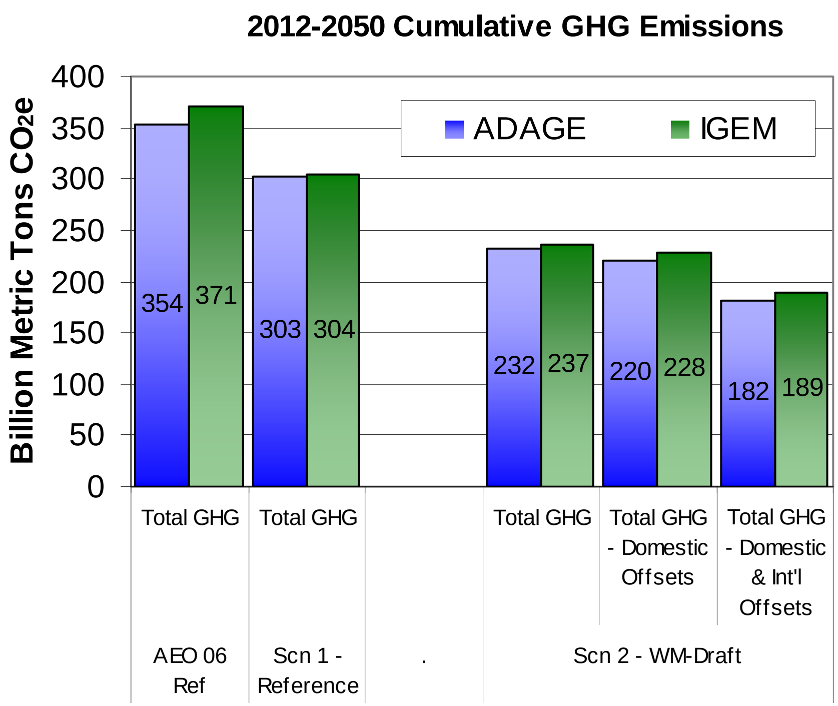
Appendix 5 Contents

- Additional Economy-Wide Impacts:
  GHG Emissions & Economic Costs
- Domestic & International Offsets and Set-Asides
- Global Results: Trade Impacts, Emissions Leakage, and Output-Based Allocation Scenario
- U.S. Regional Modeling Results

Additional Economy-Wide Impacts: GHG Emissions & Economic Costs

2012 – 2050 Cumulative GHG Emissions

Scenario 1 - Reference & Scenario 2 – WM-Draft



- Discounted offsets would provide an additional 12 to 13 bmt CO_2e of cumulative abatement in IGEM and ADAGE respectively.
- International forestry set-asides would provide an additional 6 to 8 bmt CO_2e of cumulative abatement in IGEM and ADAGE respectively.
- New source performance standards (NSPS) for CH_4 are estimated to provide an additional 5 bmt CO_2e of cumulative abatement.*
- The separate cap for HFC's is estimated to provided an additional 19 bmt CO_2e of cumulative abatement.*
- Cumulative emissions net of offsets, and all abatement described above is 141 and 145 bmt CO_2e in ADAGE and IGEM respectively. This is a 52 to 53 percent reduction from reference levels.
- For comparison, a target that reduces total U.S. GHG emissions gradually to 1990 levels by 2020 and to 80% below 1990 levels by 2050 results in 2012 – 2050 cumulative emissions of 168 bmt CO_2e.

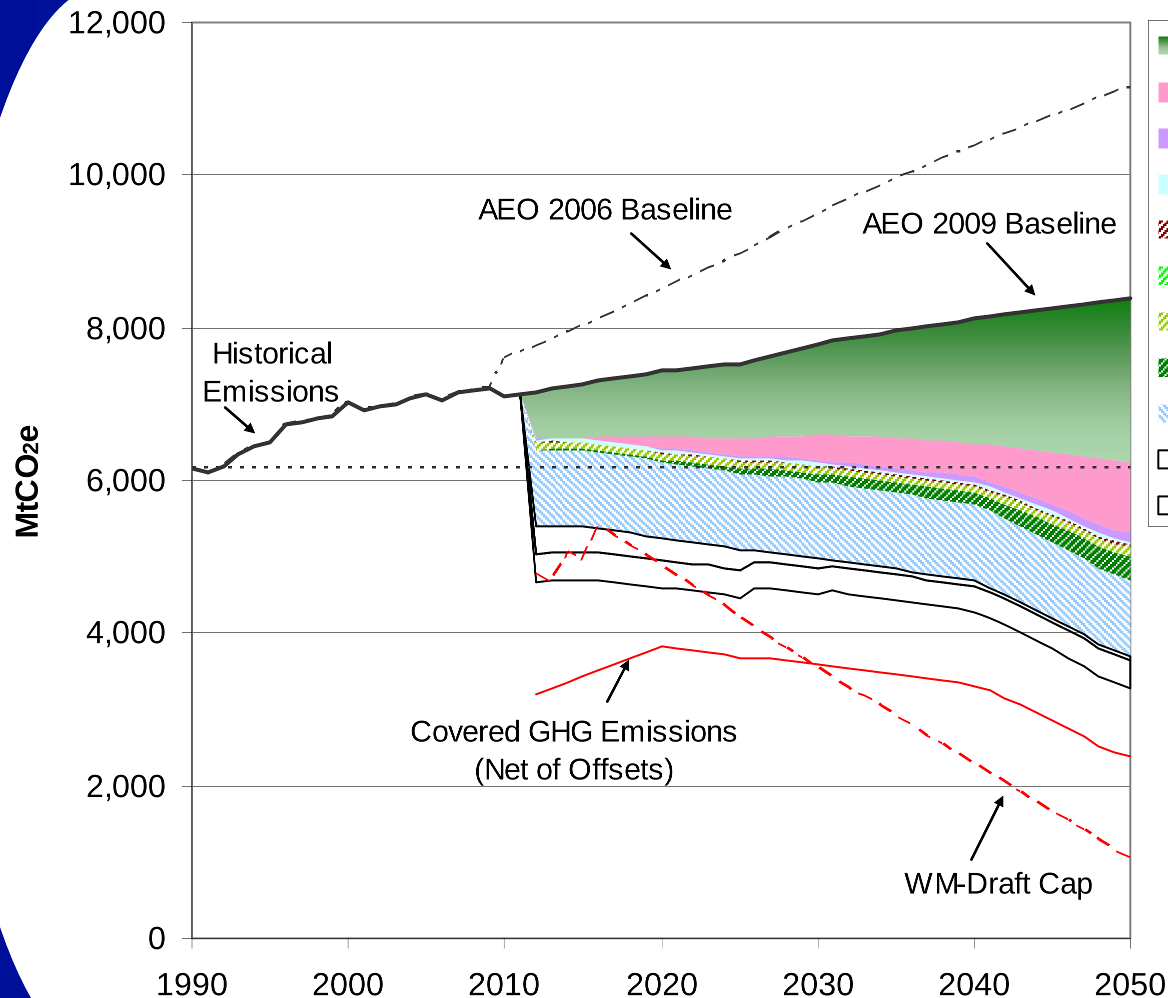
* The costs of these additional provisions are not modeled in this analysis.

% Reduction from Scenario 1 - Reference

	ADAGE	IGEM
Total GHG Emissions	-24%	-22%
Total GHG Emissions - Domestic Offsets (sinks)	-27%	-25%
Total GHG Emissions - Domestic Offsets - International Offsets	-40%	-38%

Total US GHG Emissions & Sources of Abatement

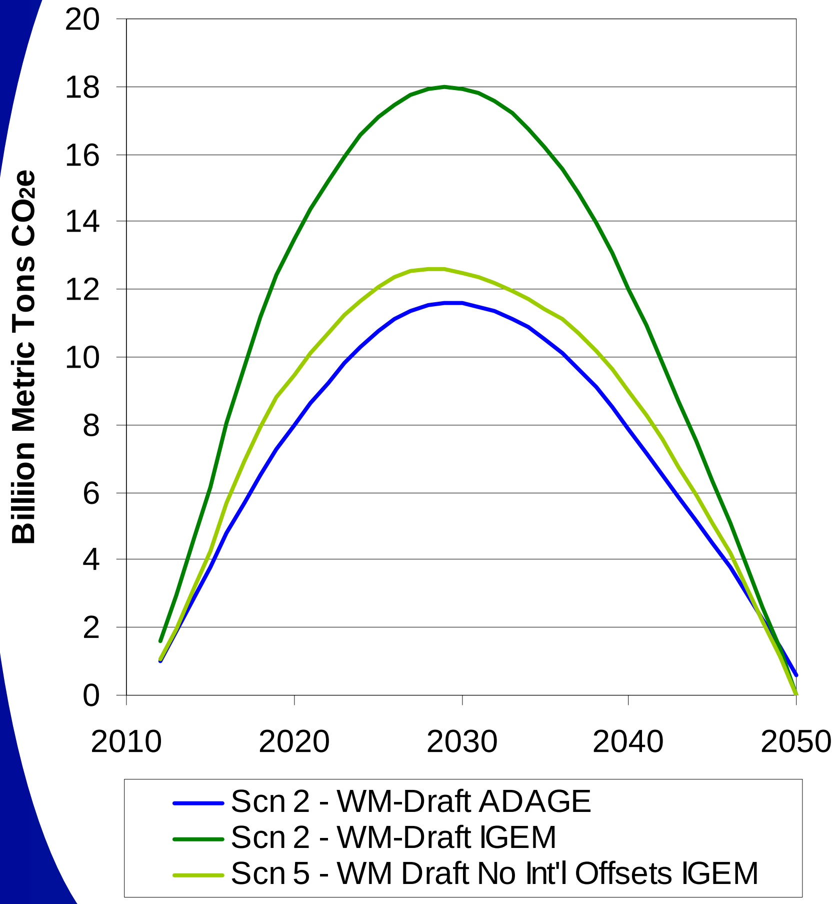
Scenario 1 - Reference & Scenario 2 – WM-Draft (IGEM)



- The updated reference case for this analysis is based on AEO 2009, and the old reference case from EPA's S. 2191 analysis was based on AEO 2006.
- Cumulative 2012-2050 GHG emissions are 18% (67 bmt) lower in the AEO 09 baseline compared to the AEO 06 baseline in IGEM.
- The main reason for the lower emissions is lower initial (2010) GDP ($13.2 trillion in AEO 09 vs $14.6 trillion in AEO 06), and a lower projected GDP growth rate (2.5% in AEO 09 vs 3.0% in AEO 06).
- WM-Draft allows a quantity of 2 billion tons CO_2e of offsets each year split evenly between domestic and international. The domestic limit is non-binding in this analysis.

Cumulative GHG Allowance Bank

Scenario Comparison

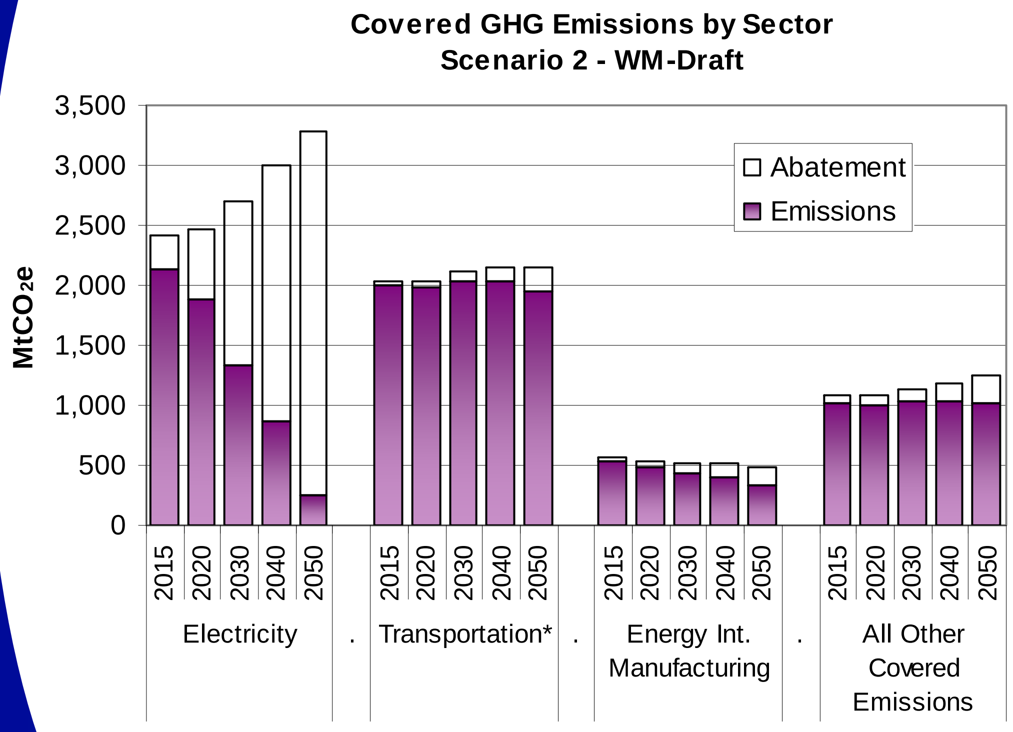


- The Waxman-Markey Discussion Draft allows for unlimited banking of allowances, as a result the allowance prices in both models grow at the exogenously set 5% interest rate.
  - If instead the allowance price were rising faster than the interest rate, firms would have an incentive to increase abatement 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.
- In all modeled scenarios, a bank of allowances is built up in early years, and drawn down in later years so that the cumulative covered emissions (net of offsets) over the 2012 – 2050 period is equal to cumulative emissions allowed under the cap.
- The IGEM model builds up a larger bank of allowances than the ADAGE model. The reason for this is mobility of capital in the two models. ADAGE has a putty-clay capital structure with quadratic capital adjustment costs, while IGEM has perfectly mobile capital. The capital adjustment costs in ADAGE slow down the movement of capital, and make it harder to build up a large bank of allowances in early years.
- As modeled, the allowance bank goes to zero in 2050, however unlike previous bills analyzed by EPA, the WM-Draft specifies a cap past 2050. The banking behavior predicted by the models is dependent on the complete credibility of the caps. Firms bank allowances beginning in 2012 in anticipation of rising allowance prices that are driven in part by the out year caps. If firms believe that Congress may revise the caps, then the incentive for banking is diminished, as an upwardly revised cap would reduce the value of banked allowances. If the caps past 2050 are credible, then a positive bank would still be held in 2050 at the end of the model run, and allowance prices would accordingly increase.

Total US GHG Emissions & Sources of Abatement

Scenario 1 - Reference & Scenario 2 – WM-Draft (ADAGE)

- CO_2 emissions from the electricity sector represent the largest source of domestic reductions.
- Only about 5% of covered sector GHG reductions come from transportation, although transportation is currently responsible for 28% of GHG emissions in the U.S.
- These emission estimates do not take into account full lifecycle GHG emissions, including international land use impacts.



* Transportation emissions consist of the ADAGE transportation category and residential category (which is primarily made up of personal automobile use).

- The increase in gasoline prices that results from the carbon price ($0.19 in 2015, $0.33 in 2030, and $0.91 in 2050 under Scenario 2 – WM-Draft) is not sufficient to substantially change consumer behavior in their vehicle miles traveled or vehicle purchases at the prices at which low GHG emitting automotive technologies can be produced.
- The relatively modest indirect price signal on vehicle manufacturers from this particular cap-and-trade policy creates little incentive for the introduction of low-GHG automotive technology.
- 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.
- This analysis did not estimate the emissions reductions that could be achieved from the transportation specific provisions of *WM-Draft - Title I – Subtitle C: Low Carbon Fuel Standard, and Title II – Subtitle C: Transportation Efficiency*.
- Depending on how the cap-and-trade program is designed, not all upstream emissions associated with the production of fuels would necessarily be covered under a cap. In addition, all biofuels are treated equally under a cap, therefore there are limited incentives for fuel producers to incorporate lower GHG biofuels. This issue could potentially be addressed by adjustments to the cap-and-trade program's design, or in a Low Carbon Fuel Standard (LCFS), created under WM-Draft *Title I subtitle C*, which was not considered as part of this analysis.

Consumption

Scenario 1 – Reference & Scenario 2 – WM-Draft

ADAGE	2015	2020	2030	2040	2050
Ref. Consumption per Household	$92,202	$99,888	$117,973	$140,233	$164,348
% Change (Scn. 2)	-0.11%	-0.19%	-0.37%	-0.67%	-0.78%
Consumption Loss per Household	-$100	-$192	-$441	-$936	-$1,288
NPV Cost per HH ($)	-$75	-$112	-$158	-$206	-$174

Average Annual NPV cost per Household	**-$140**
Total NPV Cost per Household (2010-2050)	**-$5,729**

IGEM	2015	2020	2030	2040	2050
Ref. Consumption per Household	$77,310	$83,367	$96,443	$113,760	$132,956
% Change (Scn. 2)	-0.02%	-0.17%	-0.39%	-0.62%	-0.85%
Consumption Loss per Household	-$19	-$137	-$358	-$647	-$1,018
NPV Cost per HH	-$14	-$80	-$128	-$143	-$138

Average Annual NPV cost per Household	**-$98**
Total NPV Cost per Household (2010-2050)	**-$4,015**

- The costs described here include the effects of higher energy prices, price changes for other goods and services, impacts on wages and returns to capital, and the value of auction revenues returned lump sum to households. The cost does not include the impacts on leisure.
- In the model the loss in consumption is calculated in each year and divided by the household size (~2.5) to find the cost per household.
- The economic discount rate (5%) is applied to find the net present value (NPV) of the cost in each year in the future.
- Average annual NPV cost per household is found by summing over all years and dividing by the number of years, which results in the $98 - $140 figure.

- For context, John Reilly of MIT's Joint Program on the Science and Policy of Global Change calculated that the average annual NPV cost per family of four (discounted at 4%) was $800 in a policy analyzed in MIT Report No., 146, Assessment of U.S. Cap-and-Trade Proposals, however this number is drawn from an older analysis that is not well calibrated to either current legislative proposals or US economic conditions. Converting this to a cost per household of average size (~2.5 persons / household), the average annual NPV cost per household would be $500 in MIT's analysis.

Consumption

Scenario 1 – Reference & Scenario 2 – WM-Draft

Table: Impacts on Average HH Consumption

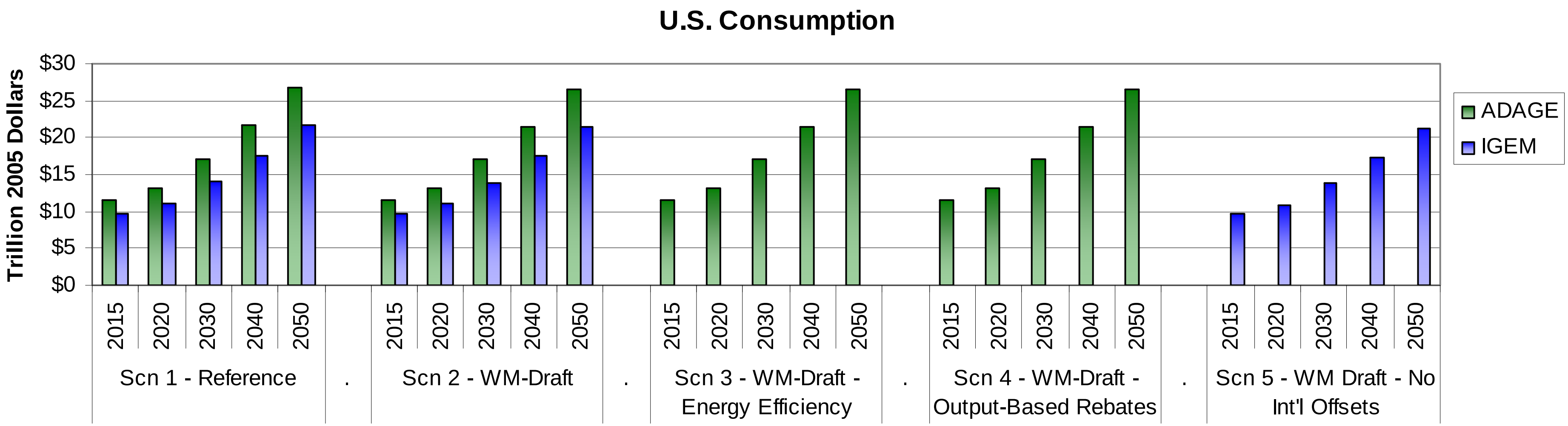
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Current Average HH Consumption (2010)									
ADAGE	$83,909								
IGEM	$70,671								
Average HH Consumption in *Scenario 1 - Reference*									
ADAGE		$92,202	$99,888	$107,898	$117,973	$128,895	$140,233	$151,989	$164,348
IGEM		$77,310	$83,367	$89,593	$96,443	$104,845	$113,760	$123,170	$132,956
Average HH Consumption in *Scenario 2 - WM-Draft*									
ADAGE		$92,102	$99,696	$107,628	$117,532	$128,228	$139,297	$150,840	$163,060
IGEM		$77,291	$83,225	$89,333	$96,067	$104,306	$113,061	$122,272	$131,821
Increase in Average HH Consumption in *Scenario 1 - Reference* Compared to 2010									
ADAGE		9.9%	19.0%	28.6%	40.6%	53.6%	67.1%	81.1%	95.9%
IGEM		9.4%	18.0%	26.8%	36.5%	48.4%	61.0%	74.3%	88.1%
Increase in Average HH Consumption in *Scenario 2 - WM-Draft* Compared to 2010									
ADAGE		9.8%	18.8%	28.3%	40.1%	52.8%	66.0%	79.8%	94.3%
IGEM		9.4%	17.8%	26.4%	35.9%	47.6%	60.0%	73.0%	86.5%
Benefits from Reduced Climate Change									
		Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated

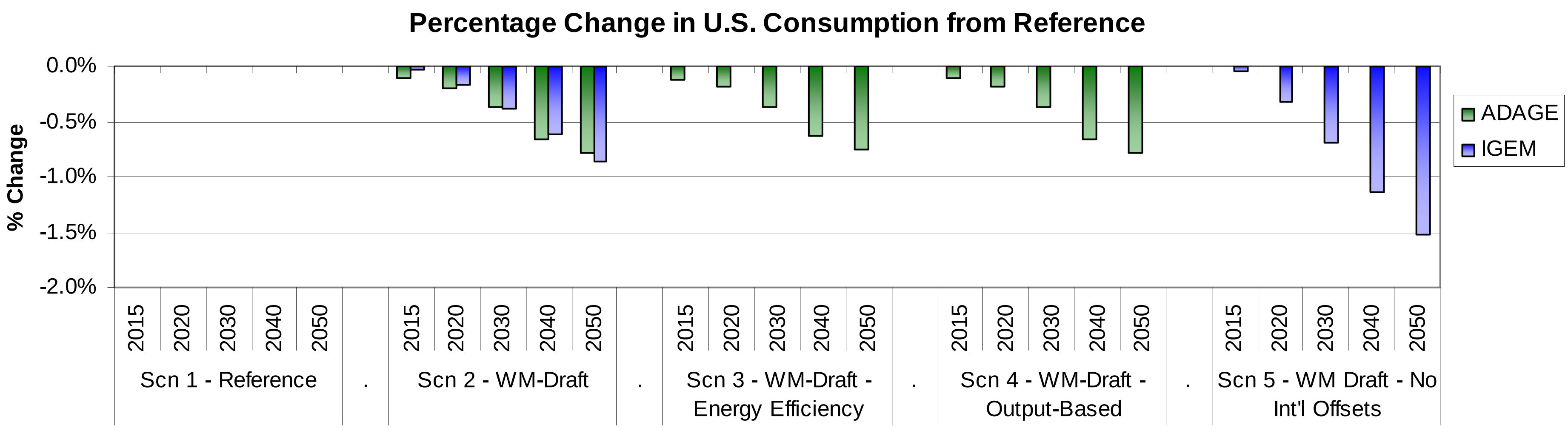
- This analysis is a cost-effectiveness analysis, not a cost-benefit analysis. As such, the benefits of reducing GHG emissions were not determined in this analysis.
- The consumption loss is the cost of achieving the climate benefits that would result from this bill.

- The difference in reference consumption between the two models arises from an important accounting distinction. The Jorgenson-IGEM accounts treat consumer durables like housing differently than they are treated in the U.S. National Income Accounts (NIA). Specifically, expenditures on these appear as part of investment, not consumption as in the NIA, while their capital services flows are added both to consumption and GDP. This accounting treatment lowers consumption’s share of GDP and raises investment’s share of GDP in comparison to pure NIA-based ratios.
- While it is tempting to focus on levels, it is the absolute and relative changes and their underlying causes that matter most once a common scale among variables of interest and across methodologies has been achieved.
- Model outcomes to policy changes are more than likely to be qualitatively very robust and relatively insensitive across small compositional differences within a methodology and a common scale.
- See Appendix 1 for a detailed discussion of the IGEM composition of GDP.

Consumption

Scenario Comparison





GDP

Discussion

- The structure of the IGEM model tends to lead to larger GDP impacts for a given allowance price than the ADAGE model.
- The compensated elasticity of labor supply is the driving force behind the relatively large economic impacts for a given allowance price in IGEM. The second stage of the household decision process is the allocation of full consumption between leisure and goods and services. The parameter that governs this decision plays a dominant role in model outcomes. Unfortunately there is not a consensus in the literature about what value this parameter should take. In ADAGE, this consumption-leisure parameter is adopted from values of related parameters in the empirical literature. Much of the empirical literature examines the effect of a real wage increase on the willingness to supply additional labor hours without simultaneously considering the impact on labor force participation. Attempts to combine both impacts in a single parameter have yielded estimates ranging from 0.1 to 0.6 for the compensated elasticity of labor supply. IGEM estimates the time-varying compensated elasticity of labor supply as part of a comprehensive model of household behavior and finds values ranging from 0.8 to 1.0. (Jorgenson et. al 2008).
  - In a sensitivity case run for a previous EPA analysis, the consumption-leisure tradeoff in IGEM was constrained so that the average compensated labor supply elasticity was reduced from its estimated value of 1.03 to a constrained value of 0.48. In this sensitivity the decline in GDP was reduced by approximately 20%, and the decline in consumption was reduced by 50%.
  - Jorgenson et. al (2008) shows an experiment reducing the compensated labor supply elasticity that reduces GDP impacts by 25 to 20 percent.
  - Goettle and Fawcett (2009) ran an experiment as part of the EMF-22 exercise reducing the compensated labor supply elasticity in half, and found the resulting welfare impact was also halved.
  - Jorgenson et al. (2009a) describes an experiment reducing the responsiveness of labor supply from 0.8 to 0.3 in IGEM reduces the impact on GDP by a third, and reduces the impact on household consumption by 70 to 80%. This bounded range of outcomes is useful in the absence of a definitive consensus on the value of the compensated elasticity of labor supply that should be used in these models.
- Changes in consumption may be a better measure of the costs of WM-Draft than changes in GDP since utility (and thus welfare) is a direct function of consumption.

References

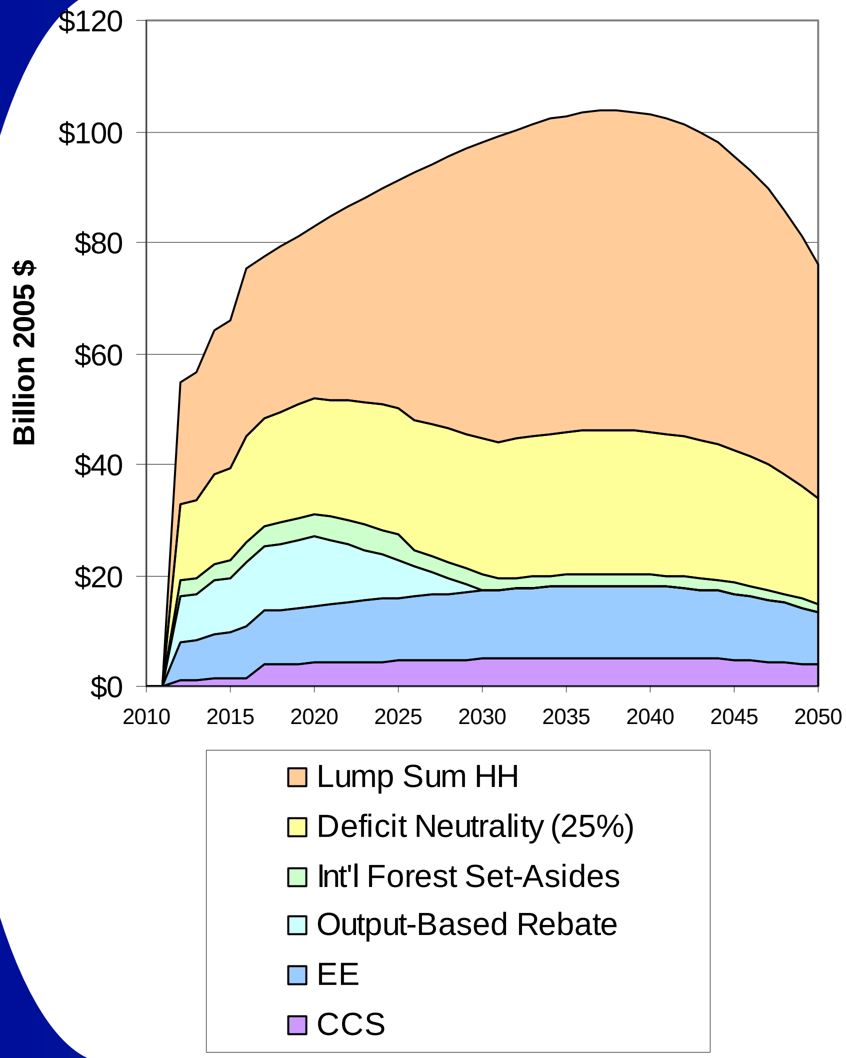
Goettle, R.J., and Fawcett, A.A. (2009), The structural effects of cap and trade climate policy. Energy Economics. Forthcoming.

Jorgenson, D.W., Goettle, R.J., Wilcoxen, P.J. and Ho, M.S. (2009), Cap and Trade Climate Policy and the Mechanisms of Economic Adjustment. Journal of Policy Modeling. Forthcoming.

Jorgenson, D.W., Goettle, R.J., Wilcoxen, P.J. and Ho, M.S. (2008). The Economic Costs of a Market-based Climate Policy. Arlington, VA: Pew Center on Global Climate Change. June.

Jorgenson, D.W., Goettle, R.J., Wilcoxen, P.J. and Ho, M.S. (2000). The Role of Substitution in Understanding the Costs of Climate Change Policy. Arlington, VA: Pew Center on Global Climate Change. September.

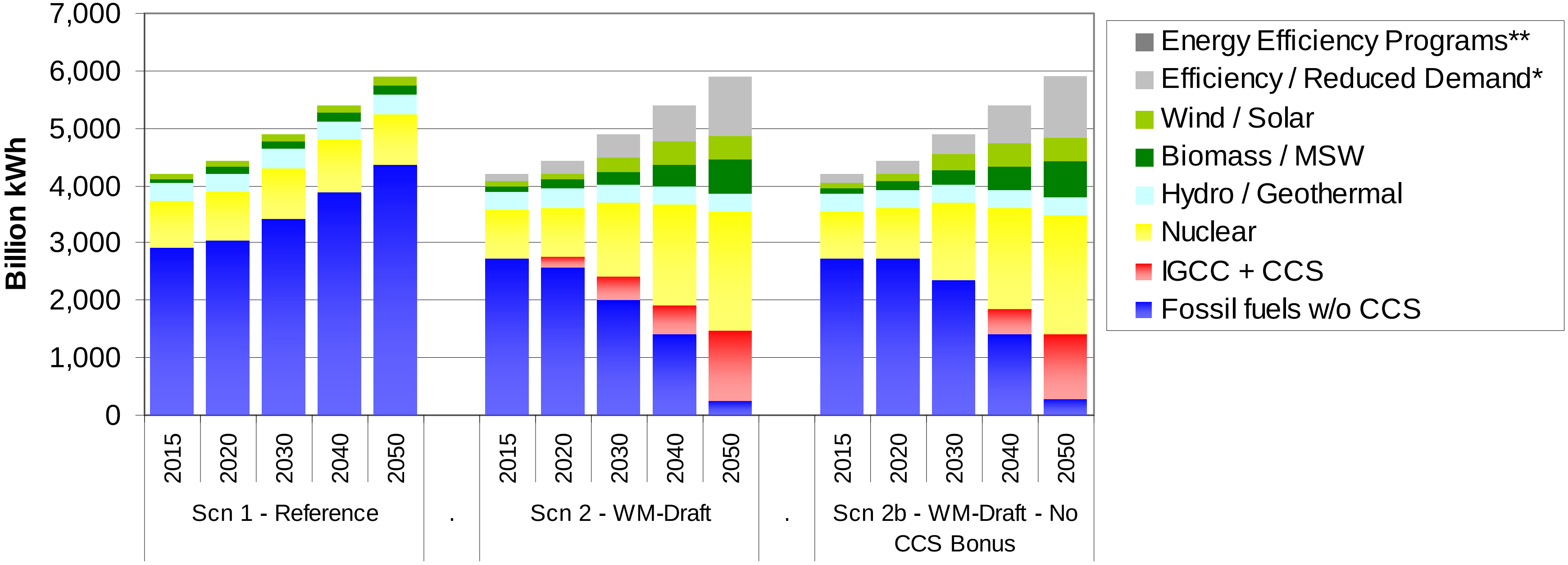
Value of Allocated & Auctioned Allowances



- The allowance allocations shown in this figure are not specified in the WM-Draft, but instead are taken from assumptions House Energy and Commerce Committee staff provided to EPA.
- The allowance price used in this figure is from the IGEM "*scenario 2 WM-Draft*"
- Not all uses of allowances specified here are modeled in each scenario. The figure thus does not represent a specific scenario, but instead allocations that would result if all allocation assumptions provided by the committee staff were included in a single scenario (with the deficit neutrality allowances at the CBO estimated 25%)
  - In the "*scenario 2 WM-Draft*" only the lump sum payment to households, the deficit neutrality, international forest set-asides, and CCS bonus allowances were modeled.
  - Allowance allocation for energy efficiency (EE) programs were modeled in scenario 3, and output-based rebates were modeled in scenario 4.
- In IGEM and ADAGE we assume that the policy is deficit and revenue neutral, which implies that the market outcomes are invariant to the auction/allocation split.
  - 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.
- For the first ten years of the policy (2012 – 2021), IGEM estimates that ~34% of allowances are needed for deficit neutrality, and ADAGE estimates that ~26% are needed for deficit neutrality.
- In IPM the auction/allocation split affects market outcomes because regulated electric utilities, which are included in IPM but not in the CGE models, are allowed to pass on the cost of auctioned allowances to consumers, but are not allowed to pass on the cost of using freely allocated allowances.

U.S. Electricity Generation

WM-Draft Scenario Comparison (ADAGE)



- Scenario 2b removes the allocation for CCS bonus allowances (and adds those allowances to the pool funding lump sum transfers back to households).
- Without the bonus allowances for CCS, the technology does not penetrate the market until 2040.
- This leads to a 13% increase in allowance prices.
- Allowance prices are lower in runs that include bonus allowances because the bonus allowances encourage the use of CCS that would otherwise be uneconomic. The carbon reductions provided by these technologies allow the economy to reach a given emission cap at lower prices for carbon allowances.
- See Appendix 6, slide 82 for additional discussion of CCS bonus allowances.

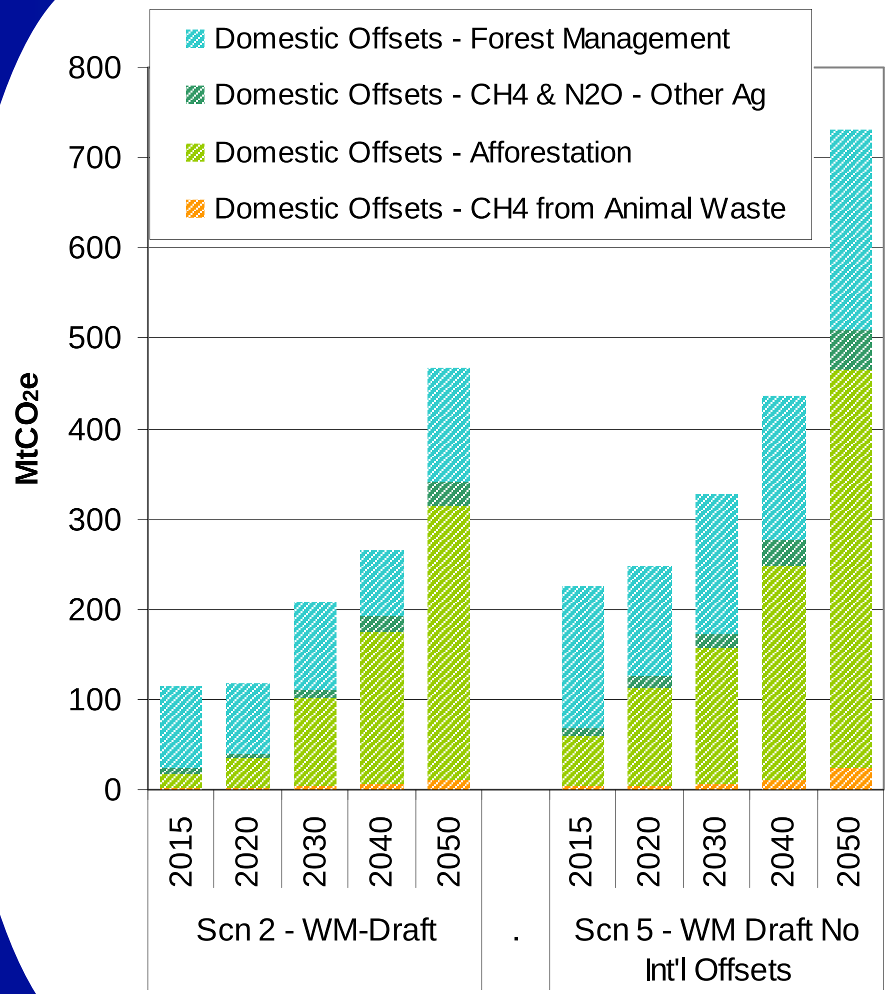
Domestic & International Offsets and Set-Asides

Domestic Offsets & International Credits Methodology Highlights

- EPA developed mitigation cost schedules for 24 offset mitigation categories, covering the following mitigation types:
  - Domestic non-CO_2 GHG emissions reductions
  - International non-CO_2 GHG emissions reductions
  - Domestic and international increases in terrestrial carbon sinks (soil and plant carbon stocks)
  - International energy-related CO_2 mitigation
- EPA evaluated individual mitigation options to determine potential eligibility and feasibility over time for a future mitigation program:
  - Based on EPA's emissions inventory & mitigation program expertise.
    - Considered a broad set of factors, including existing and emerging programs/protocols/tools, monitoring, measurement & verification (MMV), magnitude of potential, additionality, permanence, leakage, and co-effects.
  - Options evaluated both domestically, internationally (by region group), and over time.
  - Captured responses to rising carbon prices.
    - Modeled rising carbon price pathways (vs. constant) to capture investment behavior.
    - Applied in three mitigation categories: Domestic agriculture & forestry, international forestry, and international energy-related CO_2.
  - Capped sector non-CO_2 and bio-energy emissions reductions are also modeled.
  - For the individual mitigation options that were determined to be eligible, no further discounting was assumed.
  - EPA did not estimate transaction costs associated with the use of offsets in this analysis.

Offsets by Source

WM-Draft Scenario Comparison (IGEM)

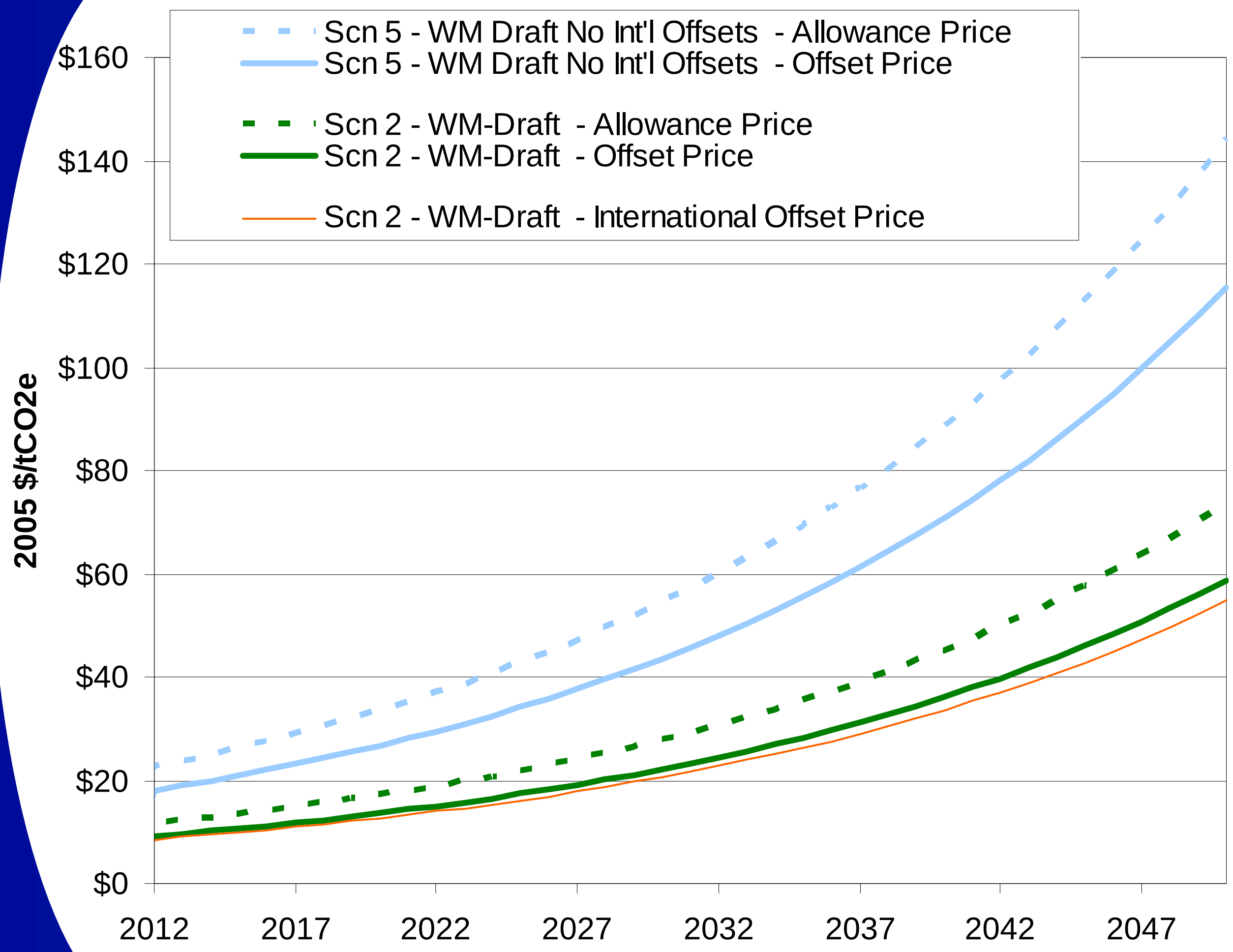


- The 1 billion ton CO_2e annual limit on the usage of domestic offsets is non-binding.
- Offsets discounting provisions in WM-Draft require that 5 tons of offsets be turned in for every 4 offsets used.
  - Eliminating this requirement would decrease allowance prices by 7%, increase the price received by offsets suppliers by 16%.*
  - Domestic offsets supply would increase by 11% and domestic offsets usage would increase by 39%.*
- In our analysis, we assume that landfill and coal mine CH_4 are covered under new source performance standards (NSPS) and are thus not available for offsets.
  - Allowing landfill and coal mine CH_4 as offset projects instead of covering them under NSPS would increase cumulative domestic offsets usage by 45%, and decrease allowance prices by 9%.*
- Restricting the use of international offsets, as in "*scenario 5 – WM Draft No Int'l Offsets*" has a large impact on allowance prices (91% increase).
  - Without the use of international offsets, covered sectors are forced to find an additional 39 billion metric tons of abatement.

* Allowance price and offsets usage impacts for these cases were determined in sensitivities run using a reduced form version of IGEM.

Offset and Allowance Prices

WM-Draft Scenario Comparison (IGEM)



- WM-Draft limits the use of domestic and international offsets each to 1 billion ton CO_2e per year.
- The limit on the use of domestic offsets is non-binding in all years.
- All offsets are discounted so that 5 tons of offsets must be turned in for every 4 offsets credits received.
- Since the limit on offsets is non-binding, demanders are willing to pay a price equal to the allowance price for each ton of offsets *after* discounting.
- Suppliers of offsets thus receive a price equal to 80% of the allowance price for each ton of offsets supplied *before* discounting
- The international offset price is driven by the international demand and supply of GHG abatement, the price shown here is the price *before* discounting.

Stationary Source Standards

- WM Draft requires standards of performance be established for uncapped stationary sources.
  - Any individual sources with uncapped emissions > 10,000 tons CO_2e
  - Any source category responsible for at least 20% of uncapped stationary GHG emissions.
  - Source categories to be identified by EPA shall include each source category that is responsible for at least 10% of uncapped **methane** emissions.
    - Sources potentially covered by this provision include at a minimum:
      - Landfills
      - Coal Mines
      - Natural Gas Systems
- EPA may also regulate uncapped emissions from capped sources (e.g., certain fugitive emissions) and uncapped emissions from other sources
- Emissions reductions from performance standards for the three methane source categories listed above in 2020 could be approximately 130 million tons CO_2e.
- Cumulative emissions reductions from performance standards for these sources by 2050 could be approximately 5 billion metric tons CO_2e.

Global Results:
Trade Impacts, Emissions Leakage, and Output-Based Allocation Scenario

International GHG Emissions & Leakage

Introduction

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

- Waxman-Markey Discussion Draft *Title IV Subtitle A* provides compensation to entities in eligible domestic industrial sectors for carbon emission costs incurred in order to prevent emissions leakage.
- Compensation is provided as rebates to eligible sectors based on direct and indirect compliance costs (i.e. costs of purchasing allowances and increased electricity costs). Covered entities receive rebates according to their annual level of output, direct emissions, indirect emissions from electricity, the sector average emissions intensity, and an 85% discount factor. Non-covered entities receive rebates according to indirect compliance costs using a similar formula.
- The rebates are phased out after 2020 provided that the risk of emissions leakage has been mitigated as other countries take comparable action. If the rebates are not effective in reducing production, jobs, and emissions leakage, an international reserve allowance requirement will be phased in after 2020 and the rebates will not be phased out.

* International policy assumptions are based on those used in the 2007 MIT report, “Assessment of U.S. Cap-and-Trade Proposals”

Energy Intensive Manufacturing – Emissions & Output

Discussion

WM Draft

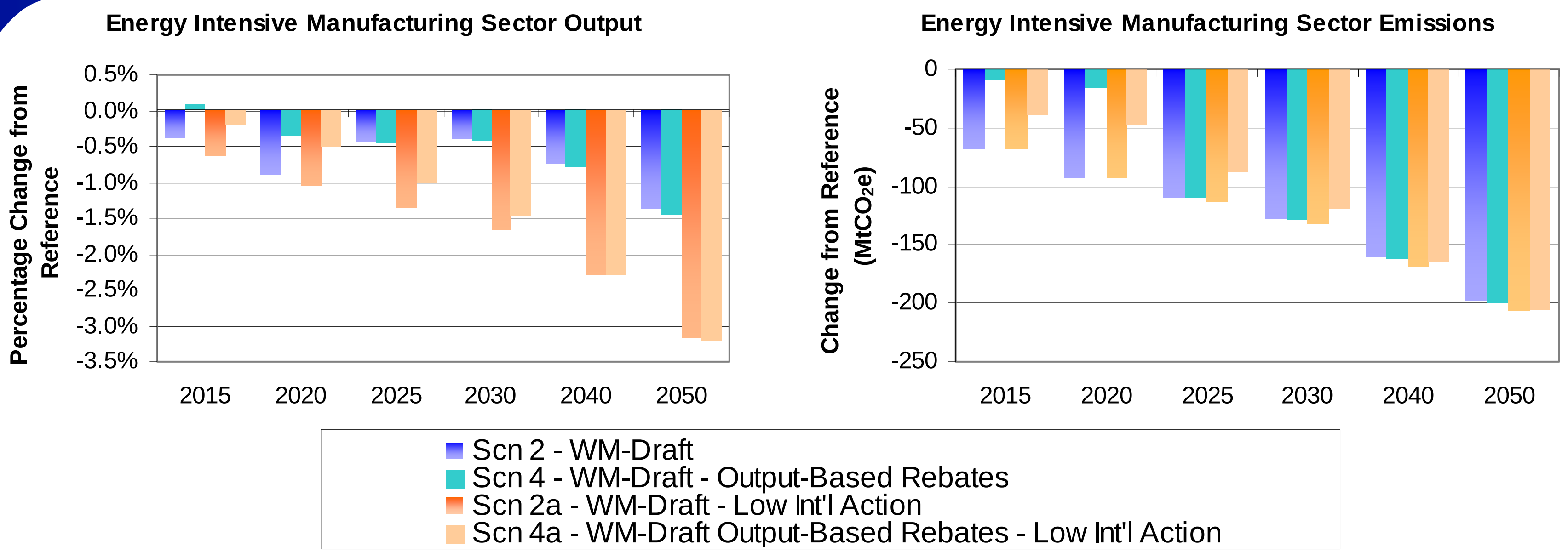
- Under EPA's analysis of the WM Draft, if comparable polices are not adopted globally, the prices of U.S. exports rise relative to prices in the rest of the world, and export volumes fall. Since exports are price-elastic, the volumes fall proportionally more than the price rises and thus the value of exports declines. Imports are reduced in part by the overall reduction in spending associated with the lower levels of consumption. Additionally, consumption of commodities directly affected by the emissions cap (e.g. oil) are reduced proportionally more than other imports due to the allowance prices embodied in their cost. Import substitution counterbalances the 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.

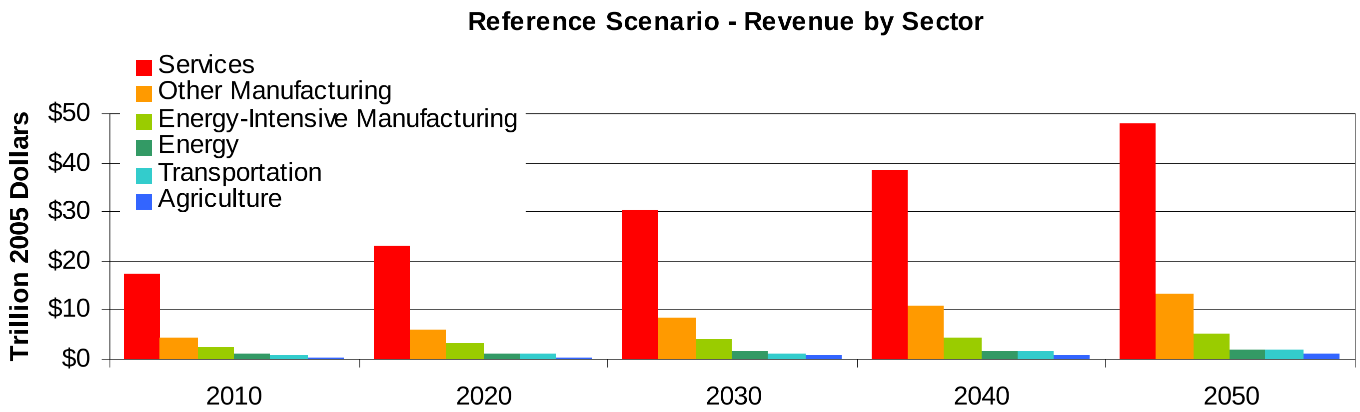
Scenarios

- ***Scenario 2- WM-Draft***
  - All sectors, including the energy intensive sector, are subject to the same allocation assumptions.
    - 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.
- ***Scenario 4- WM-Draft with Output-Based Rebates***
  - The energy intensive sector is provided rebates for costs of GHG emissions according to the provisions of the bill. Rebates are phased out after 2020 as allowance allocations for rebates phase out and other countries take comparable action.
- ***Scenario 2a- WM-Draft with Low International Action***
  - Same allocation assumptions as *Scenario 2*.
    - Group 1 countries (Kyoto group less Russia) maintain Kyoto emissions levels to 2050.
    - Group 2 countries (rest of world) do not take any action.
- ***Scenario 4a- WM-Draft with Output-Based Rebates and Low International Action***
  - Same allocation assumptions as *Scenario 4* and international action assumptions as *Scenario 2a*.

Energy Intensive Manufacturing – Emissions & Output

Output-Based Rebate, and Low International Action Scenarios (ADAGE)





Energy Intensive Manufacturing – Emission, Output, and Imports

Discussion

Results- Scenarios 2 and 4

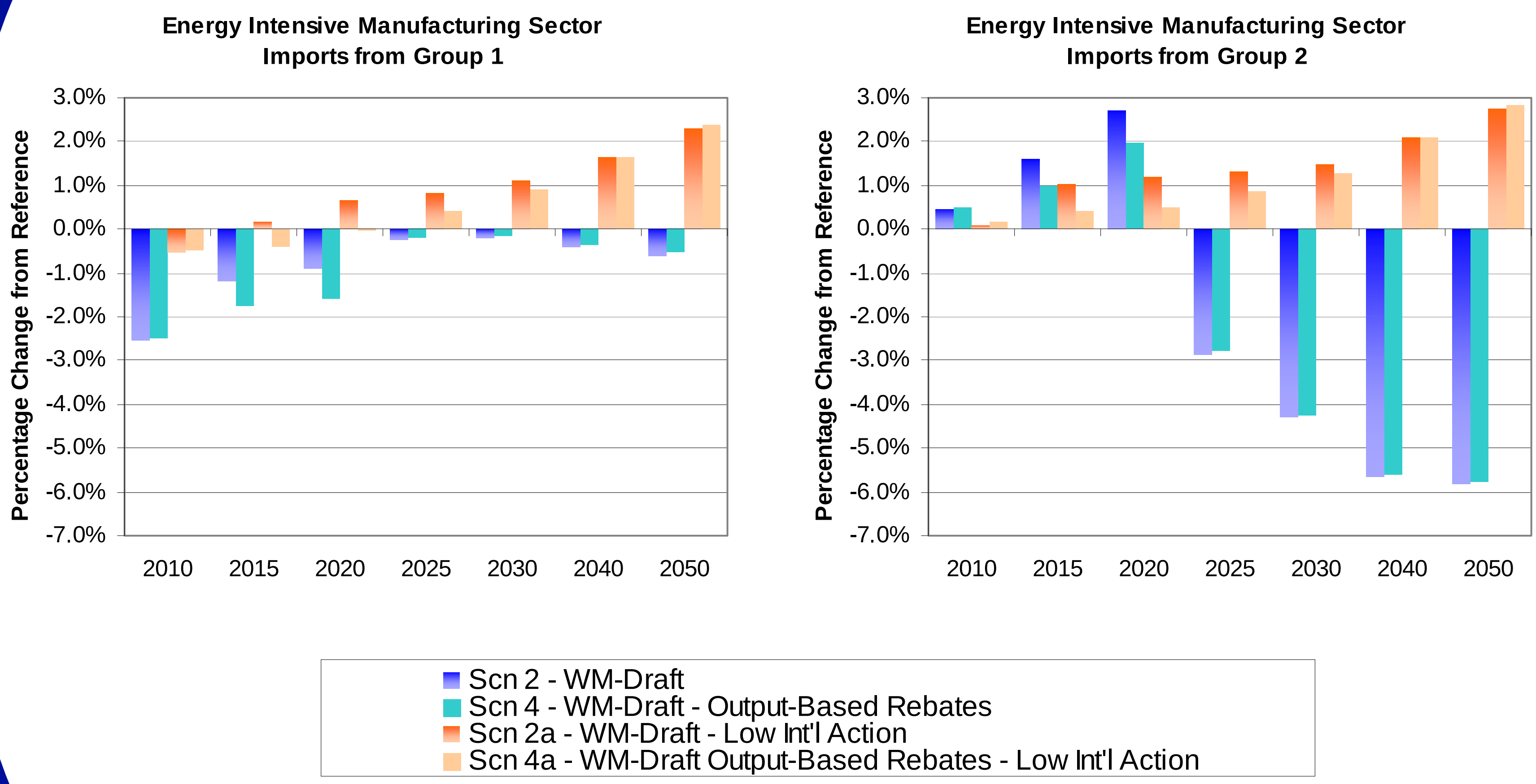
- Under the "*scenario 2 – WM Draft*" assumptions, the energy-intensive manufacturing sector (EIS) reduces emissions by 67 $MtCO_2e$ in 2015 and 92 $MtCO_2e$ in 2020, about 0.43% of the total cumulative cap of the policy. In 2020, reductions from EIS are 12% of total emissions reductions in that year.
- In *scenario 2*, EIS output declines by 0.4% in 2015 and 0.9% in 2020 from the reference case.
- Under the "*scenario 4 - WM Draft with output based rebates*" assumptions, EIS emissions are reduced by considerably less than in *scenario 2* (9 $MtCO_2e$ in 2015 and a6 $MtCO_2e$ in 2020), as eligible entities receive rebates tied to the level of output. Output rises by 0.1% in 2015 and declines by 0.3% in 2020 from reference case. Emissions and output are higher, and imports from Groups 1 and 2 are lower, with rebates than in scenario 2.
- In *scenario 4*, allowances prices are 2 percent higher, as emissions reductions that would have occurred in EIS under the "*scenario 2- WM Draft*" assumptions occur in other sectors at higher overall cost. In 2015 and 2020, GDP impacts are lower than in scenario 2 due to increased output in EIS, but in the long-run GDP impacts are greater under scenario 4 than under scenario 2 as costs have been shifted to other sectors of the economy.

Results- Scenarios 2a and 4a

- Under the two low international action scenarios (2a and 4a), imports from Group 2 are displaced by imports from Group 1 compared to scenarios 2 and 4, since both Groups take less action. Imports from both Groups increase through 2050.
- An addition of an international reserve allowance requirement after 2020 was not modeled.
- The level of international action has a larger effect on EIS emissions, output, and imports than does the use of output-based rebating.

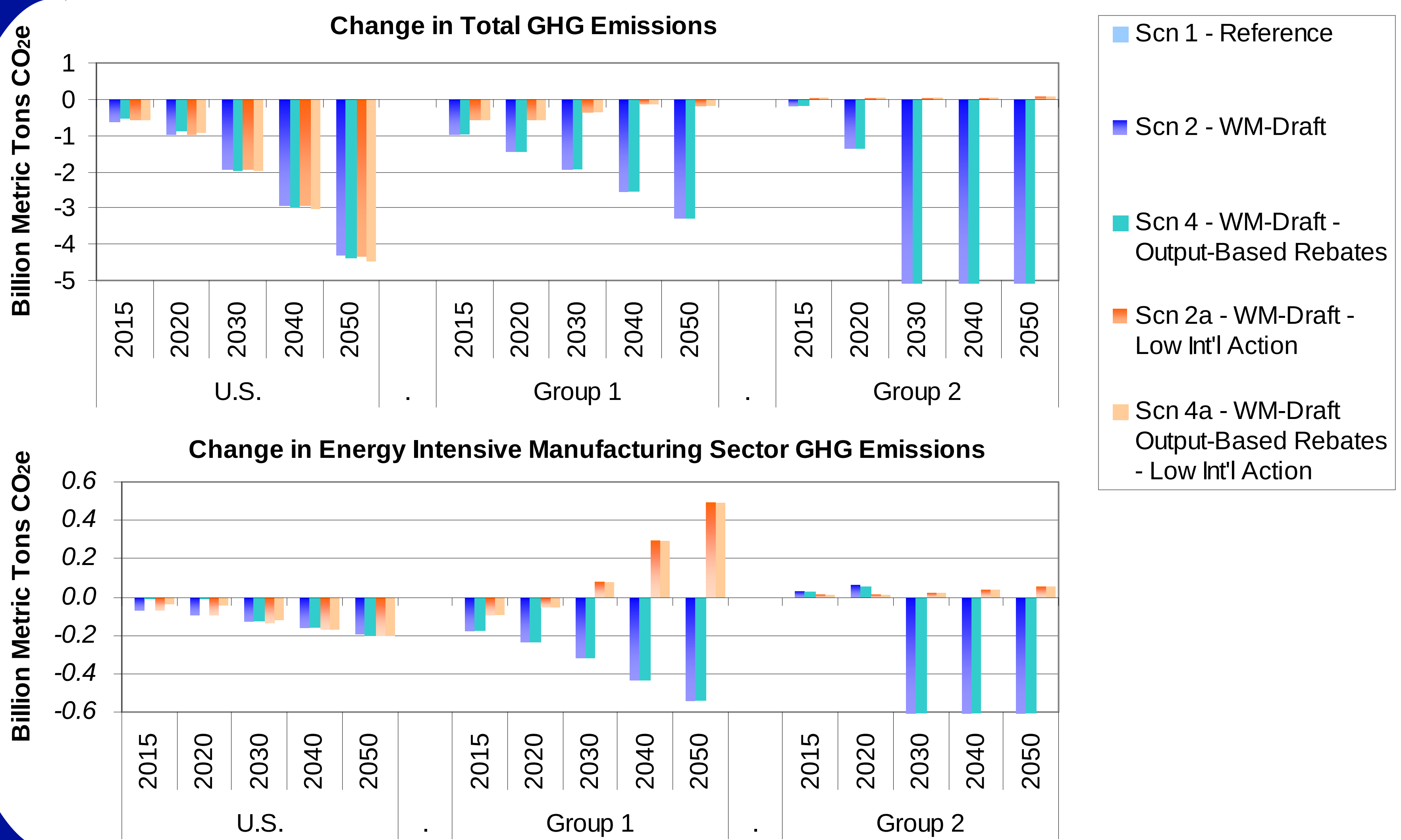
Energy Intensive Manufacturing – Imports

Output-Based Rebate, and Low International Action Scenarios (ADAGE)



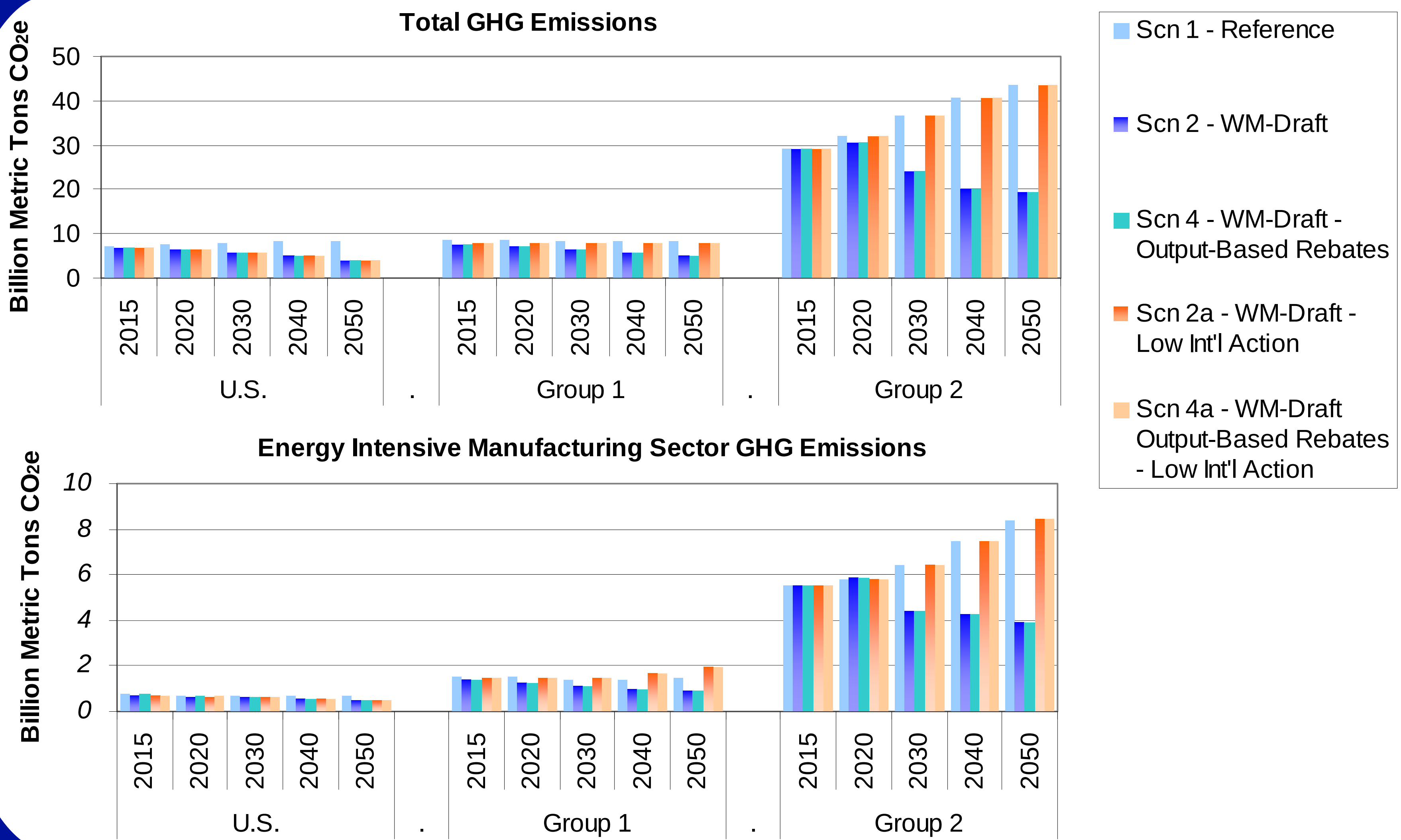
Change in World Emissions

Output-Based Rebate, and Low International Action Scenarios (ADAGE)



World Emissions

Output-Based Rebate, and Low International Action Scenarios (ADAGE)



International GHG Emissions Leakage

Scenarios 2 & 4

- Under the *scenario 2 WM-Draft* international assumptions, no international emissions leakage occurs as all regions take comparable action.
- Emissions in Group 2 fall by over 12,700 $MtCO_2e$ in 2030, after they adopt emission targets beginning in 2025.
- In scenario 2, EIS Emissions in Group 2 increase slightly before 2025 (28 $MtCO_2e$ in 2015), and fall after policy is adopted. In scenario 4, the increase in EIS emissions from Group 2 in 2020 is lessened by 3%.
- Under *Scenario 4- WM Draft with output-based rebates*, output based rebates for EIS are assumed to be phased out in 2025 as Group 2 adopts emission targets.
- In scenario 4, the increase in EIS emissions from Group 2 in 20115 is lessened by 7%.

Scenario 2a & 4a

- Under the scenario 2a international assumptions, Group 2 emissions rise by 27, 32 and 89 MtCO2e in 2015, 2030, and 2050 respectively, since Group 2 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 4% in 2015 and 2% in 2030 and 2050. Group 1 adopts less aggressive policy, and their emissions decline less than in *scenario 2-WM Draft.*
- While Group 2 is not taking any action in this scenario, their emissions are somewhat limited by demand from the U.S. and Group 1 for offset credits from Group 2. This results in smaller amounts of leakage than may otherwise be expected.*
- Group 2 EIS emissions under scenario 2a rise by 13, 23, and 57 MtCO2e in 2015, 2030, and 2050 respectively, corresponding to a U.S. emissions leakage rate of 19%, 17%, and 28% in 2015, 2030, and 2050. Because many key trading partners for EIS are located in Group 1, Group 1 EIS emissions under low international action (2a) rise by 81 MtCO2e in 2030, and 496 MtCO2e in 2050.
- The scenario with output-based rebating (4a) results in a very slight effect on emissions leakage within the EIS sector, with an increase in Group 2 EIS emissions of 23 MtCO2e in 2030 and an increase of 58 MtCO2e in 2050, It should be noted that the output-based rebates are applied to a single aggregated energy intensive manufacturing sector in ADAGE. A more disaggregated model may show different emissions leakage results as specific industrial sectors within energy intensive manufacturing would likely be more strongly impacted than indicated by ADAGE's aggregate representation.

*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 WM-Draft requires greater emissions reductions than those modeled in Paltsev (2001). This means that economic activity is reduced more under WM-Draft, 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.

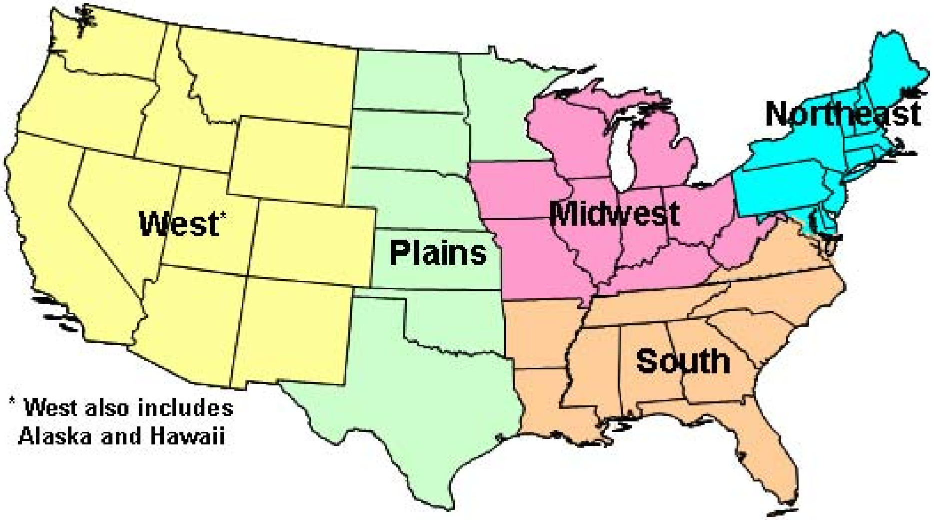
Paltsev, Sergey V. "The Kyoto Protocol: Regional and Sectoral Contributions to the Carbon Leakage." *The Energy Journal*, 2001, volume 22, number 4, pages 53-79.

U.S. Regional Modeling Results

Introduction to Regional Results

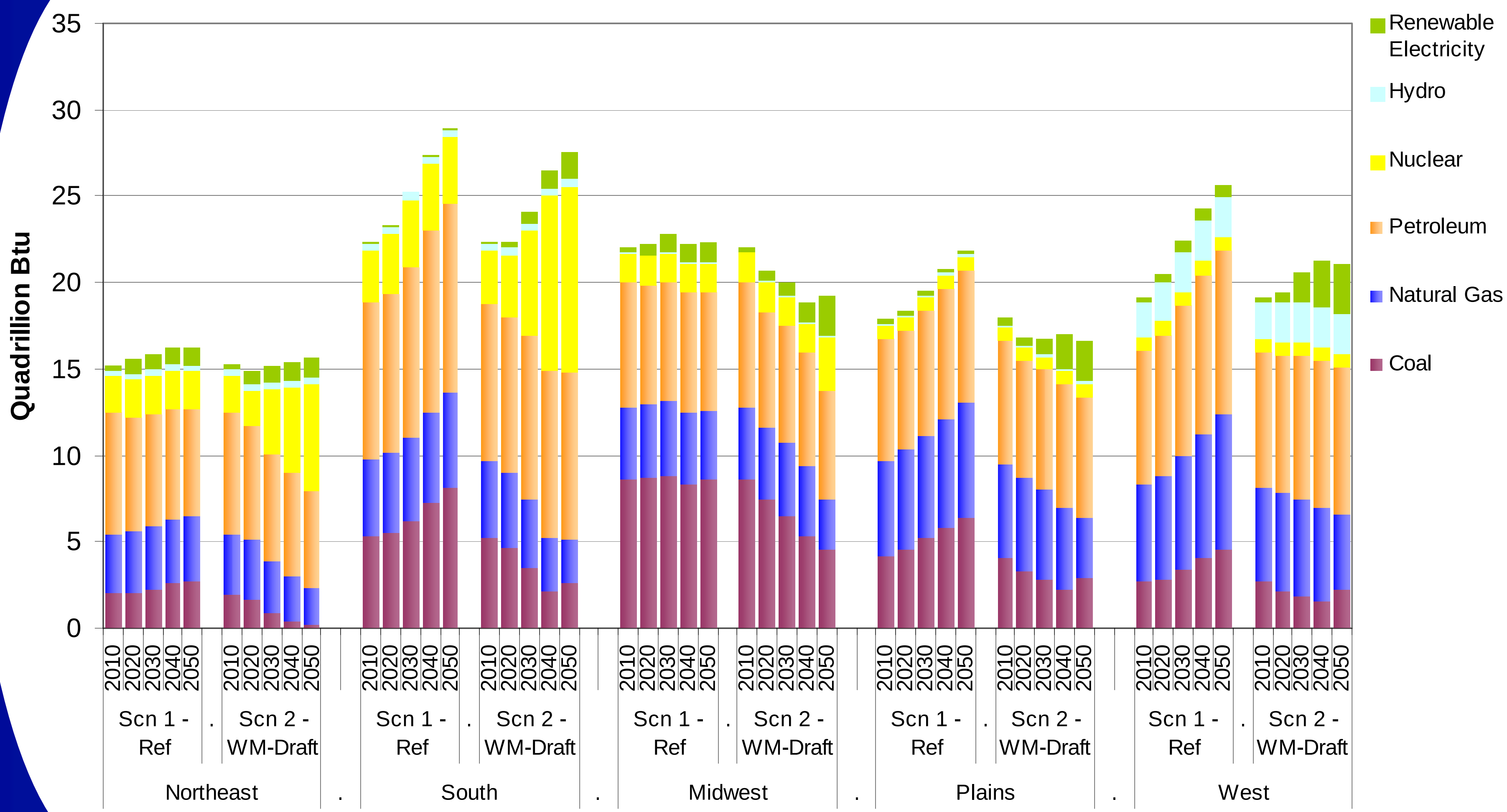
(ADAGE)

- 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



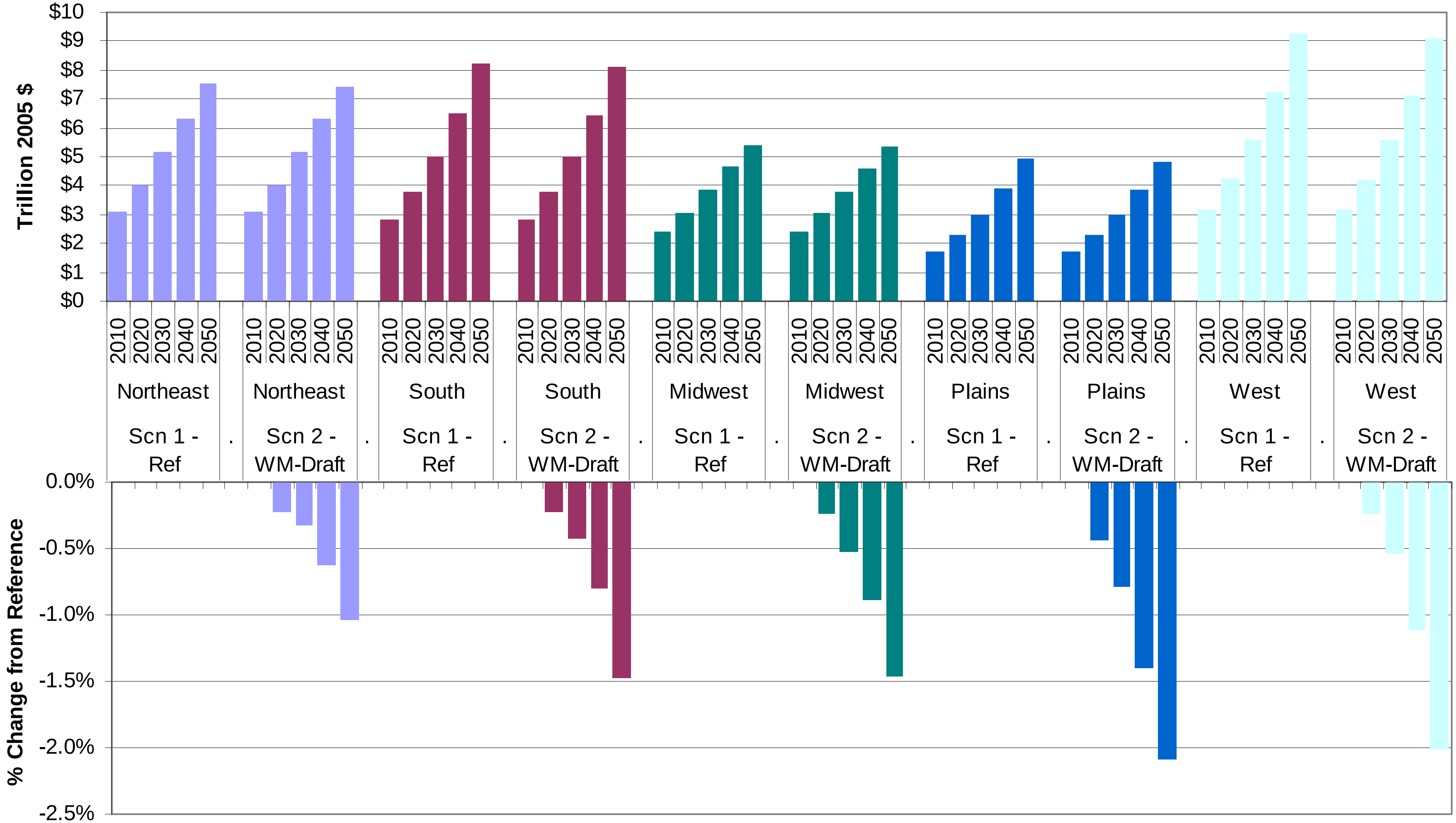
Regional Primary Energy Use

Scenario 1 - Reference and Scenario 2 – WM-Draft (ADAGE)



Regional GDP

Scenario 1 - Reference and Scenario 2 – WM-Draft (ADAGE)



Regional Results Discussion

- Impacts in several regions are close to U.S. averages.
- Plains region (which includes energy-producing states such as Texas) appear to experience declines in GDP that are above average.
  - In addition to its reliance on energy production, the Plains region has a higher overall energy intensity to its economy (Btus of energy per dollar of GDP) than the national average, and also depends more on fossil-fuel electricity generation than other regions.

Appendix 6: Additional Information on Near Term Electricity Sector Modeling (IPM)

More Details on Key Updates Included in EPA's Base Case 2009 using IPM

- **Electricity Demand Growth:**
  - EPA uses AEO 2009 as the basis for future electricity demand projections for the reference case.
  - Growth rate of just under 1% is now used in the reference case, compared to a growth rate of 1.5% in past IPM modeling applications.
- **Cost of New Power Technologies:**
  - The capital costs of new power plants have increased by 50% compared to past IPM applications, and are based on AEO 2009. Because of higher capital costs, a higher CO_2 price signal is needed for CCS to be cost competitive.
  - A capital charge rate penalty of 3% has been added to reflect the implicit cost being added to GHG-intensive projects to account for additional risk associated with future climate regulation. This assumption was also made in the AEO 2009.
- **Natural Gas:**
  - An enhanced approach reflecting recent trends in infrastructure investment and gas supply has been used, and prices are generally 5-15% higher than past IPM applications.
  - EPA has relied upon a more recent gas supply projection from ICF.
- **State RPS and Climate Programs:**
  - EPA has calibrated state RPS Requirements to AEO 2009 in IPM, resulting in more renewable energy investment in the reference case.
  - EPA has modeled finalized climate programs, such as RGGI, in IPM.
- **CCS Retrofit Option for Existing Coal Fleet:**
  - This is a new option for coal-fired units provided they have (or add) highly efficient scrubber for SO_2 removal.
- **Limits for New Power:**
  - Limits on new renewables, nuclear, and coal with CCS have been updated to ensure realistic build patterns in response to CO_2 regulatory policies.

Note: For more detail on the assumptions used in EPA's application of IPM, please see more detailed documentation for IPM at http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html.

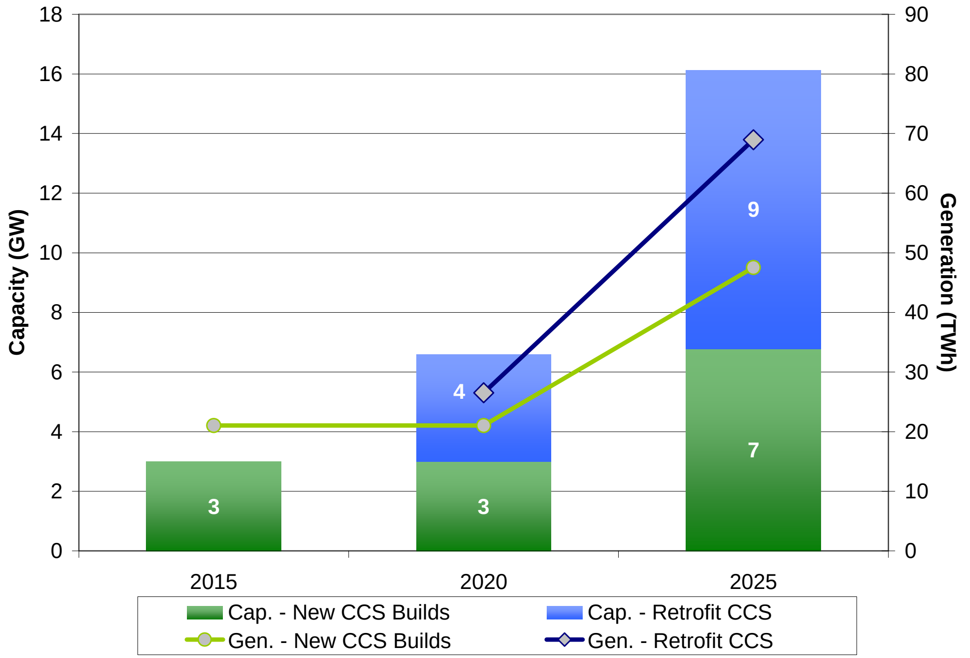
Key Insights from IPM Results for the Near-Term

- The price of carbon emissions under the Waxman-Markey Discussion Draft leads to reduced electricity demand and a shift towards lower emitting technologies.
  - The electricity demand reduction does not reflect all of the energy efficiency measures contained in the proposal.
- However, the shifts in electricity production away from GHG intensive facilities are more modest than in past EPA analyses due primarily to lower emissions in the baseline, increased capital costs for new power generating technologies, and lower allowance prices.
- These effects make the existing power generating fleet (particularly coal) more cost competitive relative to new power plants.
- Hence, emission reductions from the power sector in the shorter-term are less aggressive than past projections.
- The carbon price incurred by various emitting technologies (e.g., coal) results in a modest amount of new renewables and nuclear plants.
- Even with the bonus allowance provision for CCS, GHG allowance prices will not be high enough to justify significant penetration of *new* coal capacity with CCS technology.
  - New coal with CCS is projected to penetrate in 2015 in response to the Bill's early deployment program. Some additional new coal with CCS is built in 2025, driven by the bonus.
  - Some *existing* coal plants find it economic to retrofit with CCS starting in 2020, assisted by the CCS bonus. CCS retrofits meet the limit imposed in the model.
- Some oil/gas steam units are projected to retire, compared with the reference case, and some additional coal units also retire. Some of these units may be "mothballed," retired, or kept running to ensure generation reliability. The model is unable to distinguish among these potential outcomes. Most uneconomic units are part of larger plants that are expected to continue generating.
- Because of considerable uncertainties regarding technology cost, performance, and penetration, as well as uncertainty regarding implementation of other measures (such as a national RES), it is very difficult to specify bonus allowance ratios or provisions to achieve a desired deployment of CCS. Bonus ratios are likely to provide too little or too much incentive for investment.

Analysis of CCS Technology

- EPA has modeled the CCS early deployment program and has assumed that 3 GW of *new* coal with CCS is built by 2015.
- New CCS technology is not economic prior to 2025 even with incentives. An additional 4 GW of new coal with CCS is built in 2025 for a total of 7 GW.
- CCS retrofits are economic for a small portion of the existing fleet, up to the CCS retrofit limits applied in IPM.
- Due to the shorter-term nature of the IPM time horizon (2025), deployment patterns of CCS (both new and retrofit) would likely be different if the model had a longer horizon reflecting the increasing CO_2 price post-2025.

Adv. Coal with CCS Generation and Capacity under Waxman-Markey Draft



Note: CCS retrofit capacity projections reflect a post-retrofit capacity penalty of roughly 30%.

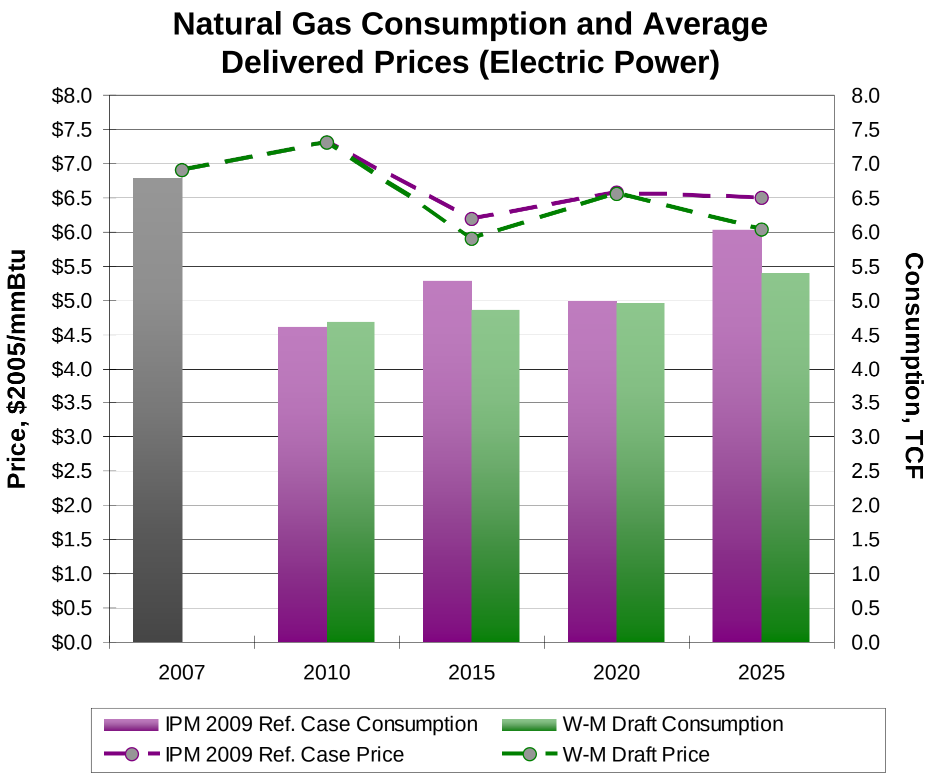
Analysis of CCS Technology

Observations:

- The CCS bonus provision is modeled as a fixed incentive, based on Committee direction. Allowance prices are lower in this analysis relative to past EPA analyses, resulting in more allowances that must be distributed as part of the fixed incentive (the allowance price affects the purely economic CCS beyond the bonus, but not the effective bonus incentive). However, the cost of new technologies has increased and energy demand in the reference case has decreased, creating less demand for new generating capacity.
- CCS is economic in the IPM timeframe only with the bonus. The bonus is exhausted first by CCS *retrofits* on existing units, up to the limit applied in the model, and then by *new* CCS starting in 2025.
- Cost assumptions are basically uniform nationwide in IPM, but 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.*
- Other policies contained in the proposal, such as the national Renewable Energy Standard and Energy Efficiency Standard, have not been modeled as part of this analysis. These provisions could dampen allowance prices, which would lessen the economic incentive for CCS in the longer term.
- It is very difficult to specify bonus value or provisions to achieve desired deployment of CCS. Because of considerable uncertainty regarding technology cost and performance, bonus incentives are likely to provide too little or too much incentive for investment.

* The next version of the EPA reference case using IPM will reflect more regional variability for CCS costs, particularly transportation and storage costs, and updated capital costs. For more detail on the assumptions used in EPA's application of IPM, please see more detailed documentation for IPM at http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html.

Power Sector Natural Gas Consumption and Prices (IPM)



		N. Gas Consumption and Prices				
		2007	2010	2015	2020	2025
Nat. Gas Consumption (TCF)	Ref. Case	*6.8*	4.6	5.3	5.0	6.0
	W-M Draft		4.7	4.9	4.9	5.4
Nat. Gas Price, Delivered ($2005/mmBtu)	Ref. Case	$6.90	$7.30	$6.20	$6.60	$6.50
	W-M Draft		$7.30	$5.90	$6.60	$6.00

Source: 2007 data is from EIA, projections are from EPA's IPM Base Case 2009 reference case and analysis of Waxman-Markey using IPM.

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

Effects of the Bonus Allowances

- **The bonus allowances for CCS has notable effects on markets**
  - Allowance prices are lower in scenarios that include bonus allowances because the bonus allowances encourage the use of CCS that would otherwise be uneconomic. The carbon reductions provided by these technologies allow the economy to reach a given emission cap at lower prices for carbon allowances.
  - The lower allowance prices, in turn, lead to lower electricity prices largely by limiting the effect of allowance costs on generation costs at fossil-fueled power plants.*
- **Despite the lower prices for allowances and electricity, the bonus programs are not cost-free**
  - By giving the energy sector incentives to reduce carbon using uneconomic technologies, bonus allowances substitute high-cost for low-cost emission reductions. The net effect is to increase the costs of meeting a given cap.
  - By keeping electricity prices lower than they otherwise would have been, bonus allowances indirectly reduce consumers' incentives for saving energy. Without those energy-saving actions, the total cost of meeting a given emission cap is higher.
  - These inefficiencies lead to "deadweight losses" and are not factored in the power sector modeling.
- **The tendency of bonus allowances to drive up the total costs of meeting the cap could be mitigated or even reversed if the impact on the deployment of CCS led to lower costs for those technologies. That possibility, however, has not been modeled.**

* In competitive markets, lower allowance prices cut electricity prices by reducing marginal generation costs. In cost-of-service areas, lower costs for purchasing allowances keep average generation costs down, and those lower costs are passed on to consumers.

Technology Limits in IPM

- Feasibility constraints have been updated for in IPM in order to limit the market penetration of the various electricity generating sources to ensure realistic build patterns in response to CO_2 regulatory policies.
- These limits are imposed on new renewable, nuclear, and coal with CCS technology.
- The limits were determined based upon various factors, including:
    1. Historical deployment patterns
    2. Potential to expand domestic engineering, construction, and manufacturing base
    3. Ability to educate and train workforce (this is particularly true for new coal with CCS and nuclear plants due to the highly technical nature of building these facilities)
- Because new nuclear and new coal with CCS are both complicated technologies that require sophisticated planning, engineering, and construction support, the same engineering/construction firms would be building both of these facilities and there would be a dynamic between the greater resources needed to build one technology relative to the other, in addition to the inherent limitations of increasing the skilled workforce.
    - To reflect this dynamic, EPA has incorporated a technology curve in the model, whereby the amount of new nuclear and coal with CCS is limited but also incorporates a trade-off between each technology (i.e., if you build more of one, you must build less of the other).
    - The amount of each technology that is built in IPM is determined in an economic manner, up to the limits.
- CCS retrofits to the existing coal fleet are also limited in IPM, and are constrained separately on the assumption that these projects can be handled by smaller and more specialized firms.

Note: In addition to the renewable capacity limitations, a 20% cap is set on the amount of electricity generation in a model region that can come from variable power sources (e.g., wind).

Incremental / Cumulative New Capacity Limitations in IPM for Renewables

GW	2010	2015	2020	2025
Wind	N/A	30 / 30	45 / 75	65 / 140
Other Renewables	N/A	10 / 10	15 / 25	20 / 45
All Renewables	N/A	40 / 40	60 / 100	85 / 185

Cumulative New Capacity Limitations in IPM for Nuclear and Coal with CCS*

GW	Nuclear	CCS	OR	Nuclear	CCS	CCS Retrofit
2010	N/A	N/A		N/A	N/A	N/A
2015	N/A	Hardwire (4 GW, or 8 projects)		N/A	Hardwire (4 GW, or 8 projects)	N/A
2020	12	0		0	27	5
2025	24	0		0	48	13

* Post 2015 new CCS constraints exclude the 4 GW of hardwired capacity. CCS retrofit capacity reflects pre-retrofit capacity.

Renewable and Transmission Challenges and IPM Modeling Limitations

Challenges to Developing and Integrating Renewables:

- Location: Wind and geothermal generation must be sited where the resources are available, leading to increased need for new transmission capacity. Biomass resource locations and transmission requirements will differ from existing fossil sources.
- Dispatch: Generation from some renewable resources cannot be adjusted ("dispatched") by system operators to meet changes in electrical load, so other sources of electricity are still critical for the power system to meet demand fluctuations.
- Intermittency: Wind and solar resources produce power only when there is sufficient wind or sunlight, so these resources need additional backup sources to meet reliability requirements for adequate capacity. Larger regions can support greater percentages of intermittent resources, but capacity from non-intermittent sources will still be needed.
- Communication and Control: Coupling renewable generation with flexible demand response can help address challenges to dispatch and intermittency. However, further development of a "smart grid" is needed, so that loads can be integrated and coordinated with the generation patterns of renewable resources.

IPM Base Case 2009 Transmission Modeling Limitations:

- Transmission constraints within IPM regions are not modeled.
- Transmission constraints between regions are modeled in IPM, but IPM does not currently attempt to model the construction of new transmission capacity.

General IPM Modeling Limitations

- The EPA version of the 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 will affect projections for new capacity additions and retrofit decisions in later years.
- EPA's application of IPM does not incorporate several technological innovations that can become available over time (e.g., ultra-supercritical coal, advanced renewables).
- Geographic deployment, cost, and performance of CCS is highly uncertain and still being developed in EPA's modeling applications.
- Allowance allocation and auctioning are not accounted for in the modeling.
- While IPM endogenously builds new capacity, the model places an exogenous constraint on the total amount of most new capacity builds.
- There are non-economic considerations for significant expansion of new coal with CCS, nuclear power, and renewables which are not reflected in IPM, such as the need for new transmission, siting concerns, and permitting.
- IPM assumes a 60 year life for nuclear power plants.
  - This has no practical effect on the IPM modeling since all existing nuclear plants would continue to operate in the IPM modeling time horizon.
- Life extension costs for existing power plants are not fully accounted for in IPM.

Appendix 7: Model Descriptions

Intertemporal General Equilibrium Model (IGEM)

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

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

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

Applied Dynamic Analysis of the Global Economy (ADAGE)

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

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

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

Non-CO_2 GHG Models

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

Forest and Agriculture Sector Optimization Model-GHG

- FASOM-GHG simulates land management and land allocation decisions over time to competing activities in both the forest and agricultural sectors. In doing this, it simulates the resultant consequences for the commodity markets supplied by these lands and, importantly for policy purposes, the net greenhouse gas (GHG) emissions.
- The model was developed to evaluate the welfare and market impacts of public policies and environmental changes affecting agriculture and forestry. To date, FASOMGHG and its predecessor models FASOM and ASM have been used to examine the effects of GHG mitigation policy, climate change impacts, public timber harvest policy, federal farm program policy, biofuel prospects, and pulpwood production by agriculture among other policies and environmental changes.
- FASOMGHG is a multiperiod, intertemporal, price-endogenous, mathematical programming model depicting land transfers and other resource allocations between and within the agricultural and forest sectors in the US. The model solution portrays simultaneous market equilibrium over an extended time, typically 70 to 100 years on a five year time step basis.
- The results from FASOMGHG yield a dynamic simulation of prices, production, management, consumption, GHG effects, and other environmental and economic indicators within these two sectors, under the scenario depicted in the model data.
- The principal model developer is Dr. Bruce McCarl, Department of Agricultural Economics, Texas A&M University.
- The data used in the report are documented in: U.S. EPA, 2009. *Updated Forestry and Agriculture Marginal Abatement Cost Curves*. Memorandum to John Conti, EIA, March 31, 2009.
- Model Homepage: http://agecon2.tamu.edu/people.faculty/mccarl-bruce/FASOM.html

Global Timber Model (GTM)

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

Mini-Climate Assessment Model (MiniCAM)

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

The Integrated Planning Model (IPM)

- EPA uses the Integrated Planning Model (IPM) to analyze the projected impact of environmental policies on the electric power sector in the 48 contiguous states and the District of Columbia.
- IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector.
- The model provides forecasts of least-cost capacity expansion, electricity dispatch, and emission control strategies for meeting energy demand and environmental, transmission, dispatch, and reliability constraints.
- IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), and mercury (Hg) from the electric power sector.
- The IPM was a key analytical tool in developing the Clean Air Interstate Regulation (CAIR) and the Clean Air Mercury Rule (CAMR).
- IPM provides both a broad and detailed analysis of control options for major emissions from the power sector, such as power generation adjustments, pollution control actions, air emissions changes (national, regional/state, and local), major fuel use changes, and economic impacts (costs, wholesale electricity prices, closures, allowance values, etc.).
- The model was developed by ICF Resources and is applied by EPA for its Base Case. IPM® is a registered trademark of ICF Resources, Inc.
- EPA's application of IPM Homepage: http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html

Contact Information

The analysis was conducted by EPA's Office of Atmospheric Programs.

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This analysis is available online at:
www.epa.gov/climatechange/economics/economicanalyses.html