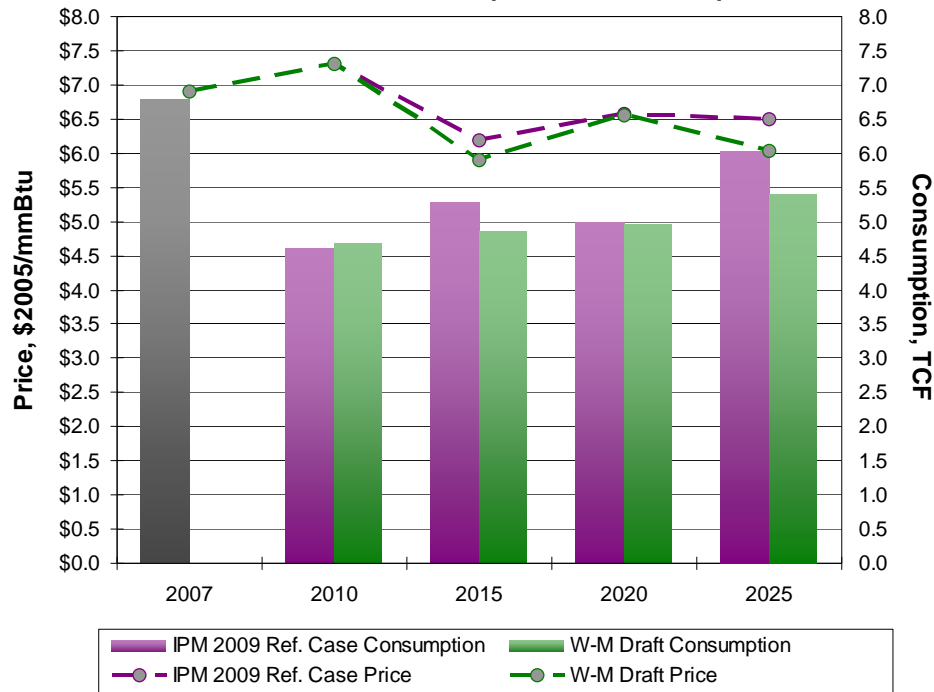




Power Sector Natural Gas Consumption and Prices (IPM)

Natural Gas Consumption and Average Delivered Prices (Electric Power)



		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 CO₂ 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 CO₂ 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-CO₂ 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-CO₂ 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-CO₂ 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 (CO₂ and non-CO₂) 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 (SO₂), nitrogen oxides (NO_x), carbon dioxide (CO₂), 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>



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This analysis is available online at:

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