EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the *111th Congress*

6/23/09

Request for Analysis

HENRY A. WAXMAN, CALIFORNIA
CHAIRMAN

JOE BARTON, TEXAS
RANKING MEMBER

ONE HUNDRED ELEVENTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE
2125 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6115

Majority (202) 225–2927
Minority (202) 225–3641

May 14, 2009

The Honorable Lisa Jackson
Administrator
Environmental Protection Agency
1200 Pennsylvania Avenue NW
Washington DC, 20460

Dear Administrator Jackson:

Passage of comprehensive clean energy legislation is one of the top priorities of the Committee on Energy and Commerce. We plan to report a bill from committee prior to the Memorial Day recess. This legislation will reflect the Committee's work product and may differ significantly from the discussion draft circulated in March. To facilitate Congressional consideration of the legislation, we are requesting additional technical assistance and modeling results from the Environmental Protection Agency (EPA). EPA's analysis of the committee passed legislation will prove useful to us and other members of the House as we move forward.

We ask that EPA begin this process by meeting with our committee staff in advance of committee passage. Please call Alexandra Teitz, Lorie Schmidt or Joel Beauvais at (202) 225-4407.

Sincerely,

Henry A. Waxman
Chairman

Edward J. Markey
Chairman
Subcommittee on Energy and Environment

- On March 31, 2009, the House Energy and Commerce Committee released the Waxman-Markey Discussion Draft of the American Clean Energy and Security Act of 2009.
- On April 20, 2009, EPA released a preliminary analysis of the Waxman-Markey Discussion Draft.
- On May 14, 2009, the House Energy and Commerce Committee Chairman Waxman and Energy and Environment Subcommittee Chairman Markey requested that EPA estimate the economic impacts of the Committee-reported bill.
- On May 21, 2009, the American Clean Energy and Security Act of 2009 (H.R. 2454) was passed by the House Energy and Commerce Committee.
- This document represents EPA's analysis of the American Clean Energy and Security Act of 2009 (H.R. 2454).

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

Contact: Allen A. Fawcett
Tel: 202-343-9436
Email: fawcett.allen@epa.gov

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

Major Findings

- The American Clean Energy and Security Act of 2009 (H.R. 2454):
  - Establishes an economy wide cap & trade program.
  - Creates other incentives and standards for increasing energy efficiency and low-carbon energy consumption.

- The analysis focuses on the economy wide cap & trade program, the energy efficiency provisions, and the competitiveness provisions.
  - Sensitivity analysis conducted for:
    - H.R. 2454 without Energy Efficiency Provisions
    - H.R. 2454 without Output Based Rebates
    - H.R. 2454 with Reference Level Nuclear
    - H.R. 2454 with No International Offsets
  - Several provisions outside of the cap & trade program are not modeled in this analysis (e.g. lighting standards are not in the analysis, and the renewable electricity standard is not included in economy-wide modeling but is modeled as a sensitivity in power sector analysis).
  - See Appendix 1 for a full description of the bill and which provisions are modeled in this analysis.

Major Findings

- H.R. 2454 transforms the structure of energy production and consumption.
  - Increased energy efficiency and reduced demand for energy resulting from the policy mean that energy consumption levels that would be reached in 2015 without the policy are not reached until 2040 with the policy.
  - The share of low- or zero-carbon primary energy (including nuclear, renewables, and CCS) rises substantially under the policy to 18% of primary energy by 2020, 26% by 2030, and to 38% by 2050, whereas without the policy the share would remain steady at 14%. Increased energy efficiency and reduced energy demand simultaneously reduces primary energy needs by 7% in 2020, 10% in 2030, and 12% in 2050.
  - Electric power supply and use, and offsets represent the largest sources of emissions abatement.
- Allowance prices are less than EPA's previous analysis of the Waxman-Markey discussion draft, $13 per metric ton CO_2 equivalent (tCO_2e) in 2015 and $16/$tCO_2e$ in 2020 in the core scenario.
  - This is primarily driven by the looser 2020 cap and the expanded amount of international offsets allowed.
  - Across all scenarios modeled without constraints on international offsets, the allowance price ranges from $13 to $15 per ton CO_2 equivalents (tCO_2e) in 2015 and from $16 to $19 / tCO_2e in 2020.
  - Across all scenarios modeled that vary constraints on international offsets, the allowance price ranges from $13 to $24 per ton CO_2 equivalents (tCO_2e) in 2015 and from $16 to $30 / tCO_2e in 2020.
- Offsets have a strong impact on cost containment.
  - The annual limit on domestic offsets is never reached.
  - While the limits on the usage of international offsets (accounting for the extra international offsets allowed when the domestic limit is not met) are not reached, the usage of international offsets averages over 1 billion tCO_2e each year.
  - Without international offsets, the allowance price would increase 89 percent relative to the core policy scenario. If international offsets were not available for only the first 10 years, the allowance price would increase by just 3%. If extra international offsets could not be used when the domestic offset usage was below one billion tCO_2e, then the allowance price would increase 11%.

Major Findings

- The cap & trade policy has a relatively modest impact on U.S. consumers assuming the bulk of revenues from the program are returned to households.
  - Average household consumption is reduced by 0.03-0.08% in 2015 and 0.10-0.11% in 2020 and 0.31-0.30% in 2030, relative to the no policy case.
  - Average household consumption will increase by 8-10% between 2010 and 2015 and 15-19% between 2010 and 2020 in the H.R. 2454 scenario.
  - In comparison to the baseline, the 5 and 10 year average household consumption growth under the policy is only 0.1 percentage points lower for 2015 and 2020.
  - Average annual household consumption is estimated to decline by $80 to $111 dollars per year* relative to the no policy case. This represents 0.1 to 0.2 percent of household consumption.
  - These costs include the effects of higher energy prices, price changes for other goods and services, impacts on wages and returns to capital. Cost estimates also reflect the value of some of the emissions allowances returned to households, which offsets much of the cap & trade program's effect on household consumption. The cost estimates do not account for the benefits of avoiding the effects of climate change.
  - A policy that failed to return revenues from the program to consumers would lead to substantially larger losses in consumption.

- While this analysis contains a set of scenarios that cover some of the important uncertainties when modeling the economic impacts of a comprehensive climate policy, there are still remaining uncertainties that could significantly affect the results.

*Annual net present value cost per household (discount rate = 5%) averaged over 2010-2050 under the core scenario

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H.R. 2454

Bill Summary

- Title III of the American Clean Energy and Security Act of 2009 (H.R. 2454) establishes a cap & trade system for greenhouse gas emissions.
  - The cap gradually reduces covered greenhouse gas emissions to 17 percent below 2005 levels by 2020, and 83 percent below 2005 levels by 2050.
  - 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.
  - 1-3% of allowances in each year will be set aside in a Strategic Allowance Reserve, from which allowances will be auctioned 4 times each year. Up to 20% of a covered entity's emissions may be purchased from the reserve in a given year.
  - Offsets are limited to 2,000 million metric tons CO_2 equivalent ($MtCO_2e$) per year.
  - Supplemental emissions reductions from reduced deforestation through allowance set-asides.

- Titles I & II of H.R. 2454 deal with clean energy and energy efficiency, and among other things establish a renewable electricity standard, and energy efficiency programs and standards for buildings, lighting, appliances.
  - Not all provisions in Titles I & II are explicitly modeled in this analysis.

- Title IV addresses competitiveness issues and the transition to a clean energy economy.
  - Creates an output-based allowance allocation mechanism based on H.R. 7146 (Inslee-Doyle bill).
  - Allows for the implementation of an international reserve allowance requirement.
  - The output-based allowance allocation mechanism is included in this analysis, but not in all scenarios. The rest of Title IV is not included in this analysis.

- See Appendix 1 for a discussion of the bill, and which provisions are modeled here.

Analytical Scenarios

EPA analyzed 7 different scenarios in this preliminary report. A full description of all scenarios is available in Appendix 1. The assumptions about other domestic and international policies that affect the results of this analysis do not necessarily reflect EPA's views on likely future actions. These scenarios do not account for the American Recovery and Reinvestment Act, which could further advance the deployment of clean energy technologies.

1) **EPA 2009 Reference Scenario**
   - This reference scenario is benchmarked to the AEO 2009 forecast (March release) and includes EISA but not ARRA.
     - Does not include any additional domestic or international climate policies or measures to reduce international GHG emissions
     - For domestic projections, benchmarked to AEO 2009 (March release) without the American Recovery and Reinvestment Act of 2009 (ARRA).
     - Does not include the recently announced federal greenhouse gas and fuel economy program for passenger cars, light-duty trucks, and medium-duty passenger vehicles.
     - For international projections, used CCSP Synthesis and Assessment Report 2.1 A MiniCAM Reference.
2) **H.R. 2454 Scenario**
   - This core policy scenario models the cap-and-trade program established in Title III of H.R. 2454.
     - The strategic allowance reserve is not modeled (i.e., these allowances are assumed to be available for use and not held in reserve).
   - Provisions explicitly modeled in this scenario:
     - CCS bonus allowances
     - EE provisions (allowance allocations, building energy efficiency codes, and energy efficiency standard component of CERES).
     - Output-based rebates (Inslee-Doyle)
     - Allocations to electricity local distribution companies (LDCs) (used to lower electricity prices)
   - 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.
3) **H.R. 2454 Scenario without Energy Efficiency Provisions**
4) **H.R. 2454 Scenario without Output-Based Rebates**
5) **H.R. 2454 Scenario with Reference Nuclear**
6) **H.R. 2454 Scenario without Energy Efficiency, Output-Based Rebates, or LDC Allocations***
7) **H.R. 2454 Scenario with No International Offsets**

* **Scenario 6 is most directly comparable to the core scenario of EPA's preliminary analysis of the Waxman-Markey discussion draft, which did not include energy efficiency provisions, output-based rebates, or LDC allocations.**

Key Uncertainties

- There are many uncertainties that affect the economic impacts of H.R. 2454.
- This analysis contains a set of scenarios that cover some of the important uncertainties.*
  - The degree to which new nuclear power is technically and politically feasible.
  - The availability of international offset projects.
  - The amount of GHG emissions reductions achieved by the energy efficiency provisions of H.R. 2454.
  - The impact of output based rebates to energy intensive and trade exposed industries.

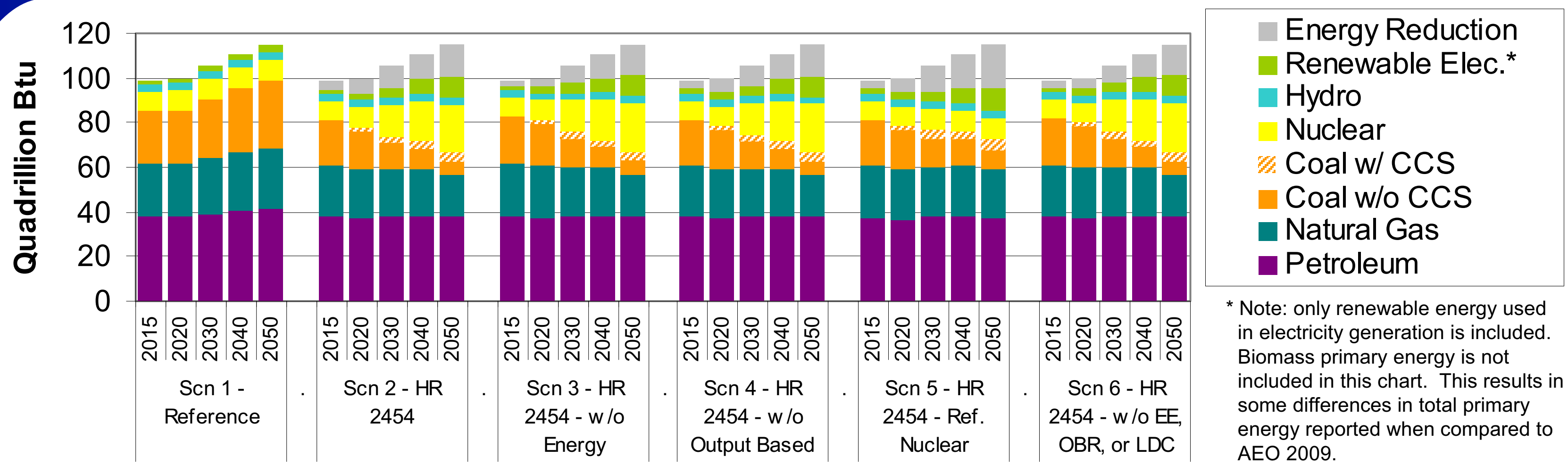
- Additional uncertainties include but are not limited to:
  - The impact of the Strategic Allowance Reserve (e.g., the extent to which it increases banking of allowances in the early years of the program).
  - The distributional consequences of H.R. 2454.
  - The extent and stringency of international actions to reduce GHG emissions by developed and developing countries.
  - The availability and cost of domestic offset projects.
  - The availability and cost of carbon capture and storage technology.
  - Long-run cost of achieving substantial GHG abatement.
    - Note that because of banking, uncertainty in long run abatement costs can have a significant impact on near term prices.
  - The pace of economic and emissions growth in the absence of climate policy.
  - Possible interactions among modeled and non-modeled policies.
  - The impact of the American Recovery and Reinvestment Act of 2009 on the cost of climate policy.
  - The impact of price reducing versus lump sum allocations to local electric distribution companies.
  - The responsiveness of household labor supply to changes in wages and prices (labor supply elasticity).
  - Other parameter uncertainty, particularly substitution elasticities (e.g., the abilities of firms to substitute capital, labor, and materials for energy inputs).

* Note that because of time limitations this analysis does not contain an extensive set of scenarios that would cover some of the additional uncertainties described above.

Economy Wide Impacts:
GHG Emissions & Economic Costs

Primary Energy

H.R. 2454 Scenario Comparison (ADAGE)

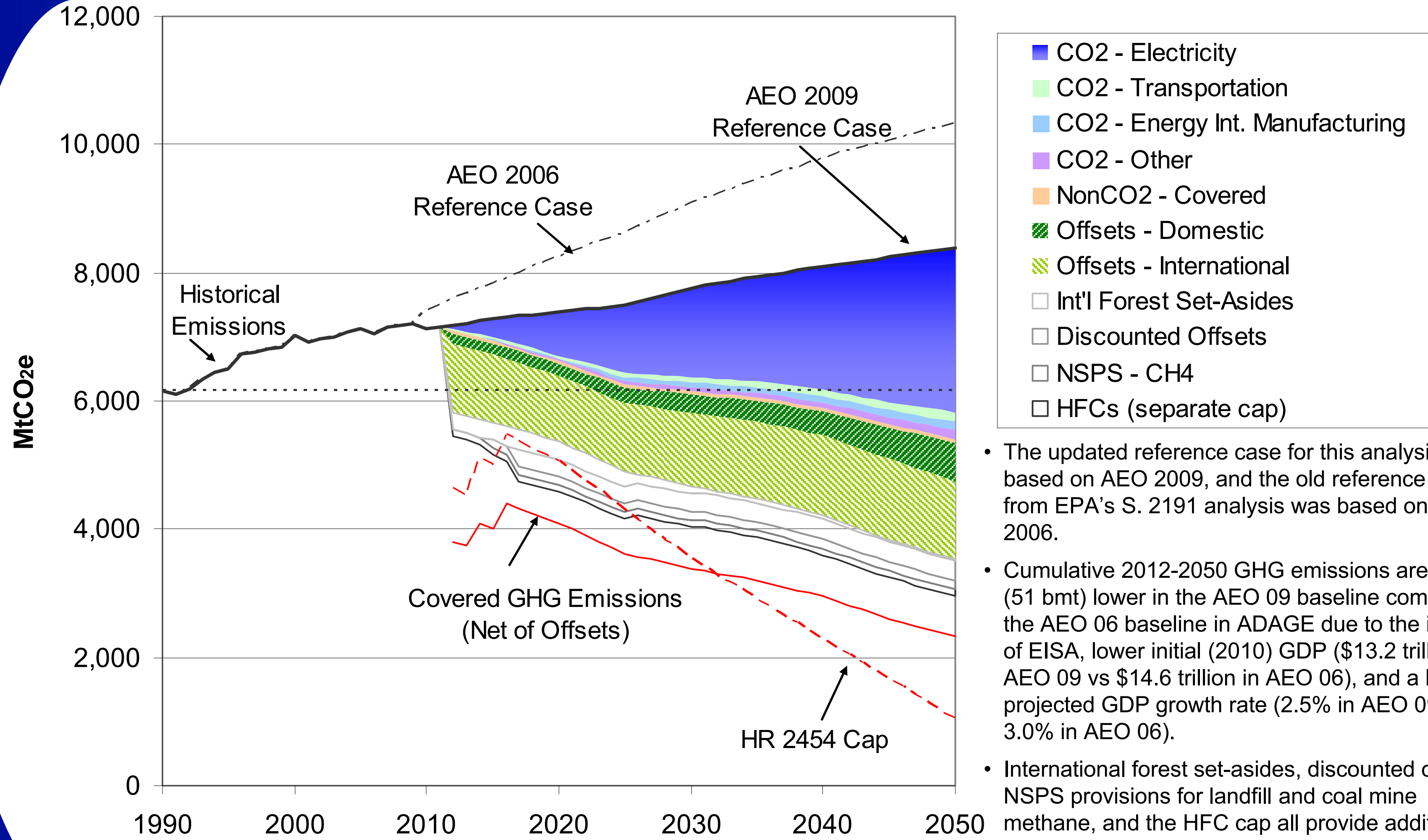


* Note: only renewable energy used in electricity generation is included. Biomass primary energy is not included in this chart. This results in some differences in total primary energy reported when compared to AEO 2009.

- The structure of energy consumption is transformed in the policy scenarios.
- In the reference scenario, primary energy use is 99 quadrillion Btu in 2015, and grows 7% by 2030 and 17% by 2050.
  - In scenario 2, primary energy use falls to 95 and 93 quadrillion Btu in 2015 and 2020 respectively, and rebounds to 2015 reference levels by 2040.
  - In scenario 5 with nuclear power constrained to reference case levels, primary energy use falls to 95 quadrillion Btu in 2015 and to 93 quadrillion Btu in 2020, and slowly rebounds to 95 quadrillion Btu by 2050.
- In the reference case, low- or zero- carbon energy (including nuclear, renewables, and CCS) makes up a steady 14% of total primary energy.
  - In scenario 2, low- or zero- carbon energy makes up 18% of primary energy by 2020, 26% by 2030, and 38% by 2050.
  - In scenario 5 with reference level nuclear, low- or zero- carbon energy makes up18% of primary energy by 2020, 22% by 2030, and 29% by 2050.
- See Appendix 3 for a discussion of the limitations and caveats associated with the methodology used to represent energy efficiency programs.
- Constraints on nuclear power growth are exogenous to the model (nuclear power generation is allowed to increase by ~150% from 782 bill. kWh in 2005 to 2,081 bill. kWh in 2050).
  - The reductions seen in primary energy from coal are somewhat driven by the model's representation of energy efficiency programs and the assumptions about nuclear power.
    - Compared to scenario 2, which includes energy efficiency programs, the reduction in primary energy from coal in scenario 3 without energy efficiency programs is 27% smaller in 2015 and 36% smaller in 2020. (In later years the two scenarios are more similar).
    - Compared to scenario 2, the reduction in primary energy from coal in scenario 5 with reference level nuclear is 18% smaller in 2030 and 17% smaller in 2050.

Total US GHG Emissions & Sources of Abatement

Scenario 1 - Reference & Scenario 2 – H.R. 2454 (ADAGE)

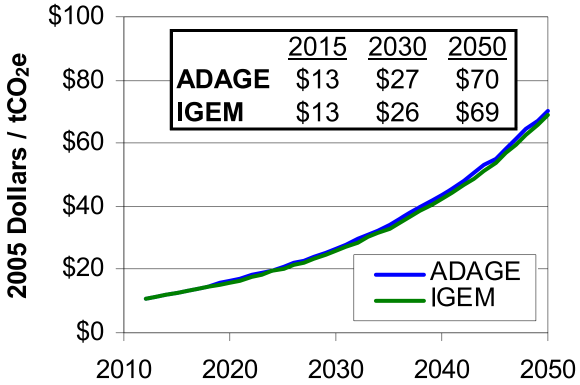


- The updated reference case for this analysis is based on AEO 2009, and the old reference case from EPA's S. 2191 analysis was based on AEO 2006.
- Cumulative 2012-2050 GHG emissions are 14% (51 bmt) lower in the AEO 09 baseline compared to the AEO 06 baseline in ADAGE due to the inclusion of EISA, 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).
- International forest set-asides, discounted offsets, NSPS provisions for landfill and coal mine methane, and the HFC cap all provide additional abatement that does not help to meet the main cap.

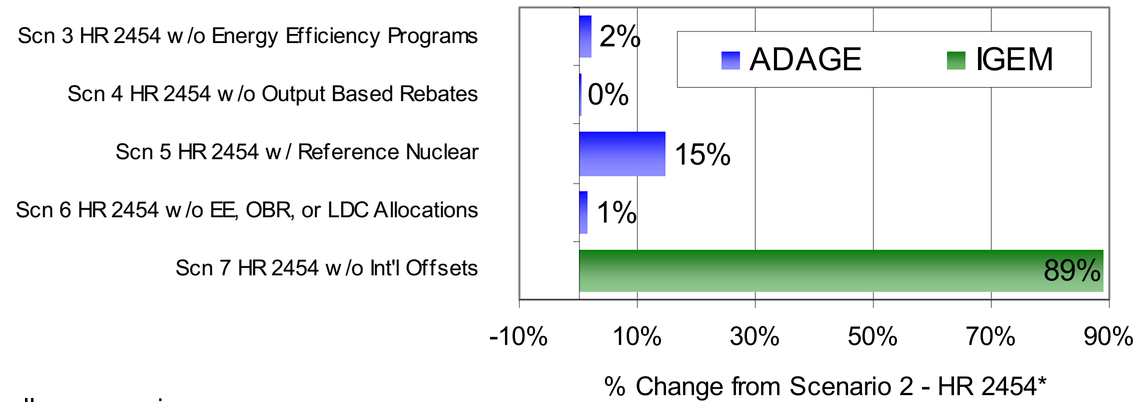
GHG Allowance Prices & Sensitivities

H.R. 2454 Scenario Comparison

Allowance Price



Marginal Cost of GHG Abatement Sensitivities

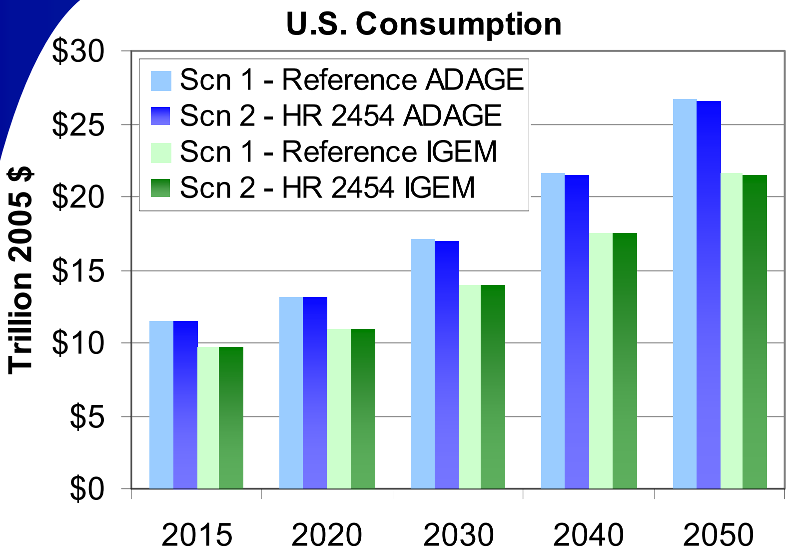


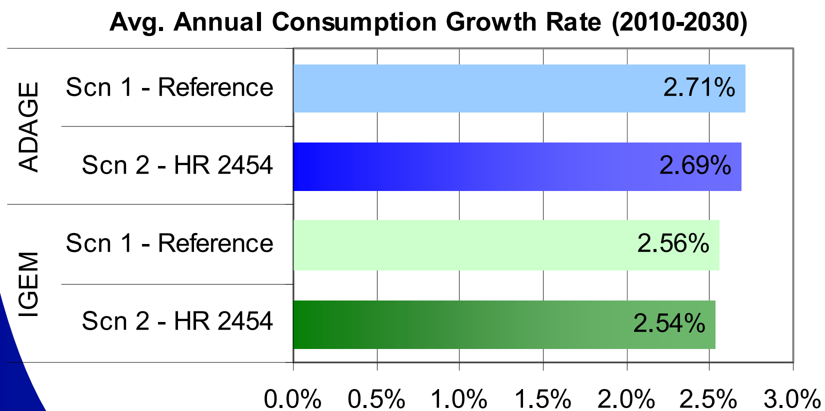
* Note that these percentage changes apply in all years.

- The marginal cost of GHG abatement is equal to the allowance price.
- Range of 2030 allowance price in *"scenario 2 – HR 2454"* across models is: $26 - $27. This range only reflects differences in the models and does not reflect other scenarios or additional uncertainties discussed elsewhere.
- The range of 2030 allowance prices across all scenarios that allow international offsets is: $26 - $31.
- In scenarios 2, 3, 4, and 6, the limit on international offsets usage is non-binding, and thus the domestic allowance price is equal to the international offset price (after discounting) and the international offset price acts a floor on the allowance price.
  - Because of this, the impact of these sensitivities on allowance prices is muted by the change in the usage of international offsets and the amount of abatement occurring within covered sectors (e.g. a change that would ordinarily lead to lower allowance prices instead would lead to decreased usage of international offsets.)
  - See the 'Offsets Usage & Limits' section below for information on how international offsets usage changes across scenarios.
- Without any international allowances, the allowance price would increase by 89% relative to the core scenario. See 'Offsets Usage & Limits' section below for a discussion of how varying degrees of international offsets availability impacts allowance prices.
- The availability of nuclear and carbon capture and sequestration (CCS) technologies have a significant impact on allowance prices. In particular, restricting nuclear power to reference case levels increases international offsets usage to the limit and results in a 15% increase in allowance prices relative to the core scenario.

Consumption

Scenario 1 – Reference & Scenario 2 – H.R. 2454





ADAGE	2015	2020	2030	2040	2050
Ref. Consumption per Household	$92,202	$99,888	$117,973	$140,233	$164,348
% Change (Scn. 2)	-0.08%	-0.11%	-0.31%	-0.55%	-0.78%
Consumption Loss per Household	-$70	-$105	-$366	-$771	-$1,287
NPV Cost per HH ($)	-$53	-$61	-$132	-$170	-$174

Average Annual NPV cost per Household	**-$111**

IGEM	2015	2020	2030	2040	2050
Ref. Consumption per Household	$75,531	$80,507	$91,686	$105,202	$119,168
% Change (Scn. 2)	-0.03%	-0.10%	-0.30%	-0.55%	-0.76%
Consumption Loss per Household	-$21	-$84	-$277	-$582	-$912
NPV Cost per HH	-$16	-$49	-$99	-$128	-$123

Average Annual NPV cost per Household	**-$80**

- The average annual cost per household is the 2010 through 2050 average of the net present value of the per household consumption loss in "*scenario 2 – H.R. 2454*."
- The costs above include the effects of higher energy prices, price changes for other goods and services, impacts on wages and returns to capital, and importantly, the above cost estimates reflect the value of emissions allowances returned lump sum to households, which offsets much of the cap-and-trade program's effect on household consumption. The cost does not include the impacts on leisure.
- 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 $80 - $111 average annual cost per household is the annual cost of achieving the climate benefits that would result from this bill.
- See Appendix 1 for a discussion of consumption accounting differences between ADAGE and IGEM and of composition of GDP.
- See Appendix 5 for a more detailed discussion of the average annual NPV cost per household calculation, and additional consumption cost metrics.

Total Abatement Cost

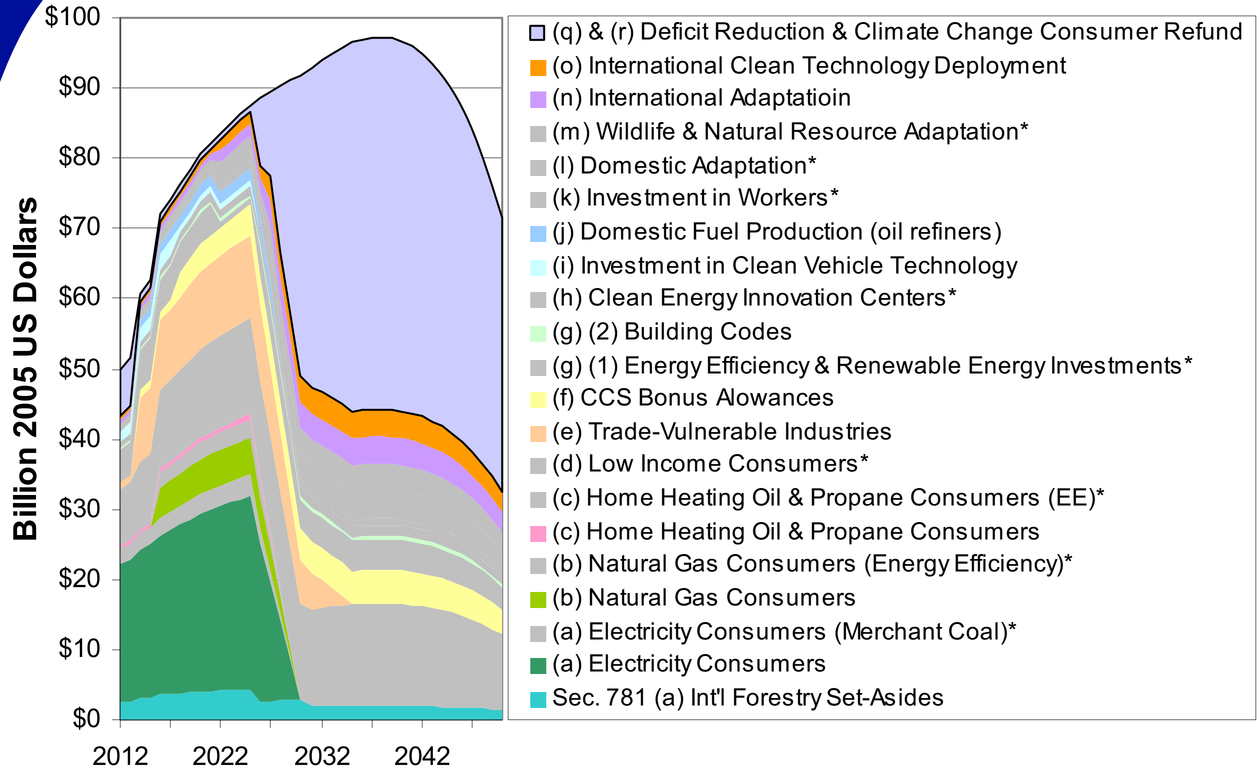
Scenario 2 – H.R. 2454

Table: **Total Abatement Cost Calculations**
Scenario 2 - HR 2454

	2015	2020	2030	2040	2050
Total Allowance Value (Billion 2005 Dollars)					
ADAGE	$62	$79	$94	$99	$73
IGEM	$63	$81	$92	$97	$71
Domestic Covered Abatement (MtCO2e)					
ADAGE	380	808	1,661	2,263	3,028
IGEM	728	1,028	1,421	1,912	2,628
Domestic Offset Abatement (MtCO2e)					
ADAGE	177	186	285	367	599
IGEM	172	176	287	370	643
International Offsets & Set-Asides (MtCO2e before discounting)					
ADAGE	1,340	1,571	1,552	1,632	1,550
IGEM	1,329	1,560	1,456	1,429	1,447
Allowance Price ($/tCO2e)					
ADAGE	$13	$16	$27	$43	$70
IGEM	$13	$16	$26	$42	$69
Offset Price ($/tCO2e)					
ADAGE	$13	$16	$27	$43	$70
IGEM	$13	$16	$26	$42	$69
International Offset/Credit Price ($/tCO2e before discounting)					
ADAGE	$10	$13	$21	$34	$55
IGEM	$10	$13	$21	$34	$55
Domestic Covered Abatement Cost (Billion 2005 Dollars)					
ADAGE	$2	$7	$22	$49	$107
IGEM	$5	$8	$18	$40	$91
Domestic Offset Abatement Cost (Billion 2005 Dollars)					
ADAGE	$1	$2	$4	$8	$21
IGEM	$1	$1	$4	$8	$22
International Offset Payments (Billion 2005 Dollars)					
ADAGE	$13	$20	$32	$55	$86
IGEM	$13	$20	$30	$48	$80
Total Abatement Cost (Billion 2005 Dollars)					
ADAGE	$17	$28	$58	$112	$213
IGEM	$19	$30	$52	$97	$193

- Total allowance value is the value of allowances issued in each year (i.e. allowance price multiplied by the cap level).
- The allowance price is equal to the marginal cost of abatement.
- The offset price is the marginal cost of abatement for uncovered sectors and entities in the U.S. When the limit on offset usage is non-binding, the offsets price is equal to the allowance price.
- The international offset price is the marginal cost of abatement outside of the U.S.
- Domestic covered abatement cost is approximated for each model as the product of domestic covered GHG emissions abatement and the allowance price divided by two.
  - Division by 2 is assumed to represent the fact that most reduction measures are not implemented at the marginal allowance price but at lower prices. In most cases, the relationship between emission reduction and the marginal price is a convex curve – which implies a value larger than 2. The value of 2, used here for simplicity leads to an overestimation of abatement costs.
- Domestic offset abatement cost is approximated for each model as the product of domestic offset abatement and the offset price divided by two.
- International offset payments are calculated for each model as the product of the amount of international offsets purchased and the international credit price.
  - Unlike the abatement costs associated with domestic covered abatement and domestic offsets, there is no need for dividing by two when calculating the costs of international offsets as they are all purchased at the full price of international allowances and those payments are sent abroad.
- Covered abatement occurs within the CGE models and thus the associated abatement cost is an ex-post general equilibrium cost.
- Offset abatement is generated by external MAC curves, and thus the associated abatement cost is an ex-ante partial equilibrium cost.
- Total abatement cost is simply the sum of domestic covered abatement cost, domestic offset abatement cost, and payments for international credits.

Value of Allocated & Auctioned Allowances (IGEM)



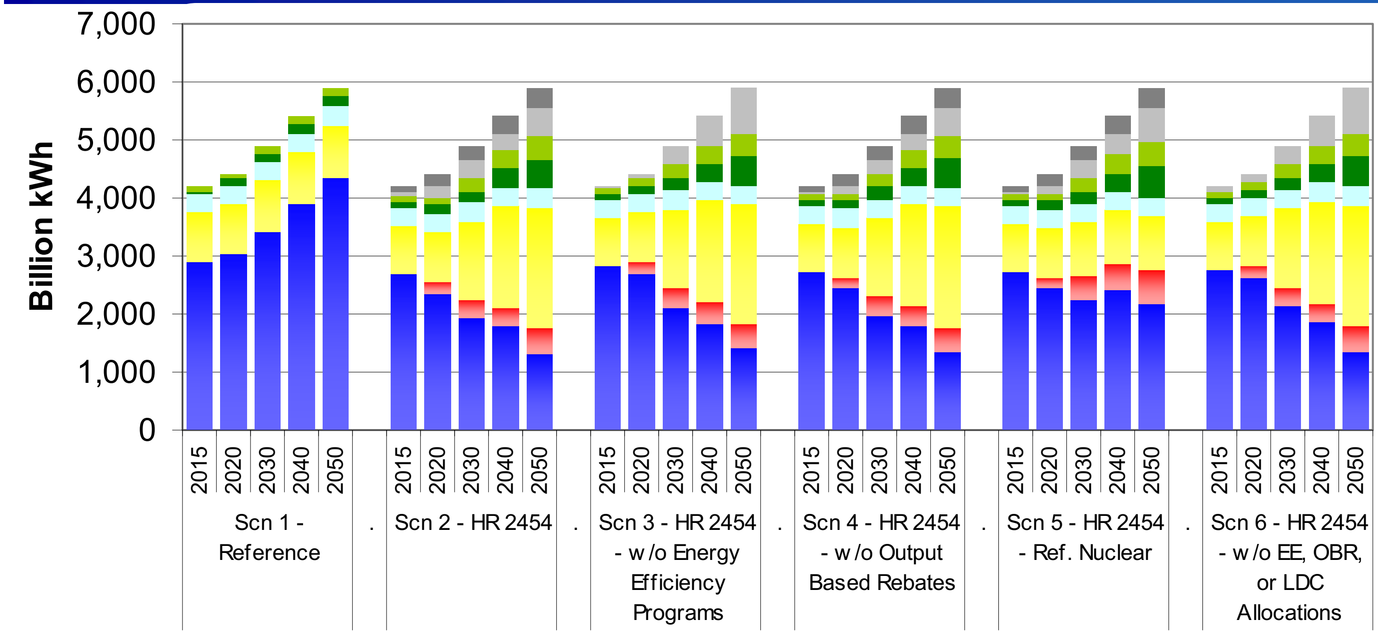
- H.R. 2454 Sec. 321 amends the Clean Air Act by inserting "Sec. 782. Allocation of Emissions Allowances." Parts (a) through (o) of this section allocate allowances for various purposes. Additionally, Sec. 781 (a) is added to allocate allowances for supplemental emissions reductions.
- The allowance price used in this figure is from the IGEM "*scenario 2 HR 2454.*"
- Except where noted by an *, the uses of allowances shown here are modeled within IGEM in that the appropriate sector receives the value of the allowances, although not all of the effects of the programs specified are modeled.
- * and shown in gray, indicates that the specified allocation is not explicitly modeled in IGEM. These allowances are instead allocated lump sum to households.
- ADAGE models all of the specified uses of allowances captured in IGEM, and also models the energy efficiency provisions in subsections (b), (c) and (g).

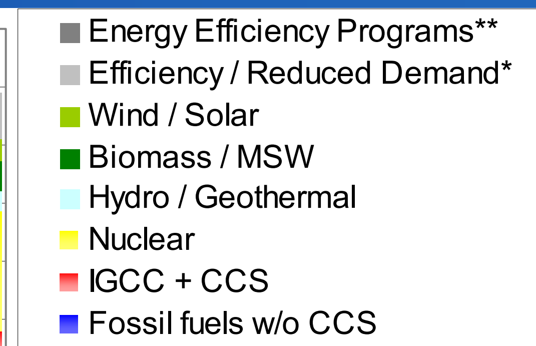
- Both of the computable general equilibrium models used in this analysis have a single representative agent household. Any auction revenue returned to households clearly accrue to households. Additionally, any private sector revenues from allocated allowances also accrue to the employee-shareholder households. Since the model only has a single representative agent household, the differing distributional impacts of various allocation schemes are not reflected in the models.
- If auction revenues that are modeled as being returned to households lump sum were instead directed to special funds, the reduction in household annual consumption and GDP would likely be greater. If these auction revenues were instead used to lower distortionary taxes, the costs of the policy would be lower.

Energy Sector Modeling Results from Economy-Wide Modeling

U.S. Electricity Generation

H.R. 2454 Scenario Comparison (ADAGE)





* *Efficiency / Reduced Demand* represents the energy savings from the consumer response to increased electricity prices (e.g. conservation, substitution to other goods/services from energy, etc.).

** *Energy Efficiency Programs* represents the energy savings achieved by the energy efficiency programs funded by allowance allocations or auction revenues, the energy efficiency portion of the RES, and the impact of revised building codes.

- Under the policy scenarios, both nuclear and renewable electricity generation expands above the reference levels.
  - Constraints on nuclear power growth are exogenous to the model (nuclear power generation is allowed to increase by ~150% from 782 bill. kWh in 2005 to 2,081 bill. kWh in 2050). EPA plans on revising these constraints for future analyses.
- The share of renewable electricity (as defined by the RES) in the reference scenario is 6% of generation in 2015, 8% in 2020, and 10% in 2030. In "*scenario 2 – HR 2454*" the renewable generation share increases to 8% in 2015, 12% in 2020, and 20% in 2030 (other policy scenarios have similar renewable shares).
- CCS deployment on fossil-fuel generation begins in 2020 with 25 GW of CCS capacity in "*scenario 2 – HR 2454*"; by 2030, 43 GW of new CCS capacity is projected to be built; and by 2050, 60 GW of new CCS capacity is projected to be built, which is the equivalent of 109 CCS units at 550 MW each. Through 2025, ADAGE projects a greater amount of CCS generation than IPM (328 billion kWh in ADAGE vs. 198 billion kWh in IPM in 2025).
- Previous modeling of the Waxman-Markey discussion draft showed that without a subsidy for CCS, the technology would not deploy until 2040.
- In scenario 5, nuclear power is held to reference levels, resulting in a 15% increase in allowance prices, and fossil generation in 2050 equal to 2010 levels.
- See the appendix 3 for a discussion of the limitations of the methodology used for representing energy efficiency programs.

Scenario 2 & 3

H.R. 2454 Energy Efficiency Provisions Discussion

Calculated demand impacts and costs

- Impacts on electricity and natural gas demand, and associated costs, were calculated for the following energy efficiency provisions: allowance allocations to energy efficiency, building codes, and the energy savings component of the Combined Efficiency and Renewable Electricity Standard. See appendix 3 for further detail.
- In '*scenario 2 – H.R. 2454*' total electricity demand reductions are estimated to grow to 5% of reference case demand by 2020 and increase to 5.6% of AEO reference case demand in 2050.
- In '*scenario 2 – H.R. 2454*' total natural gas demand reductions are estimated to grow to 4.4% of reference case demand by 2030, and decrease to 4.3% of reference case demand in 2050.
- Cost impacts were calculated, and applied to the manufacturing and services sectors within ADAGE.

Modeled economic impacts

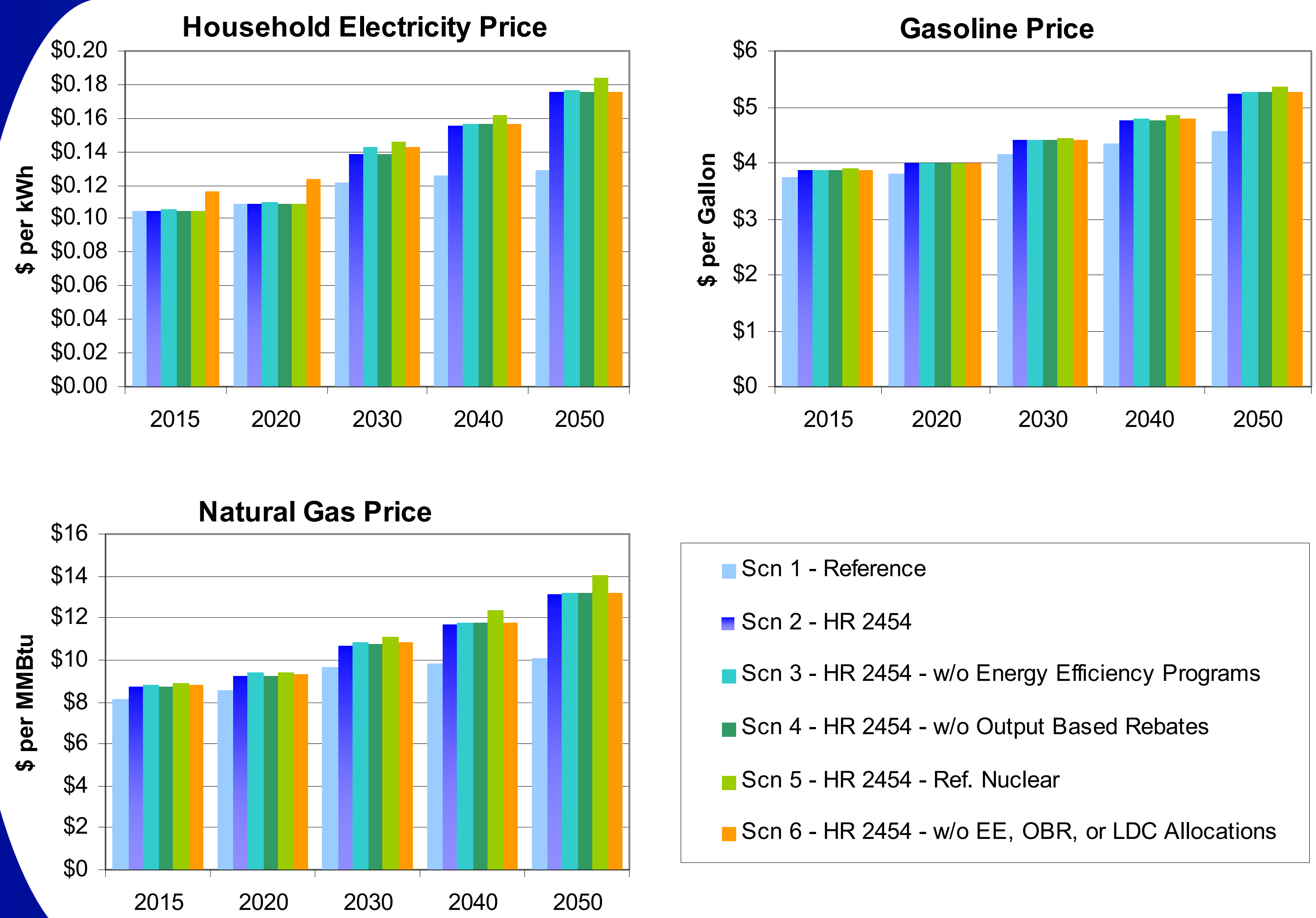
- Allowance prices are forecast to be slightly higher without energy efficiency provisions ('*scenario 3 – H.R. 2454 w/o Energy Efficiency Provisions'* relative to '*scenario 2 – H.R. 2454.')*
  - ~1.5% higher allowance prices estimated each year for 2015-2050
- Fossil fuel prices are forecast to be slightly higher for 2015-2050 without energy efficiency provisions (*scenario 3* relative to *scenario 2).*
  - Coal and Natural Gas ~1% higher
- Electricity prices are forecast to be slightly (<1%) higher for 2015-2050 without energy efficiency provisions (*scenario 3* relative to *scenario 2).*

Caveats on modeling of energy efficiency provisions

- A significant energy 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 energy demand reduction from energy efficiency provisions 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.
- While the costs of the energy efficiency programs are applied to the manufacturing and services sectors of ADAGE, the cost of saved energy for energy efficiency programs is not calculated by the model.

Energy Prices

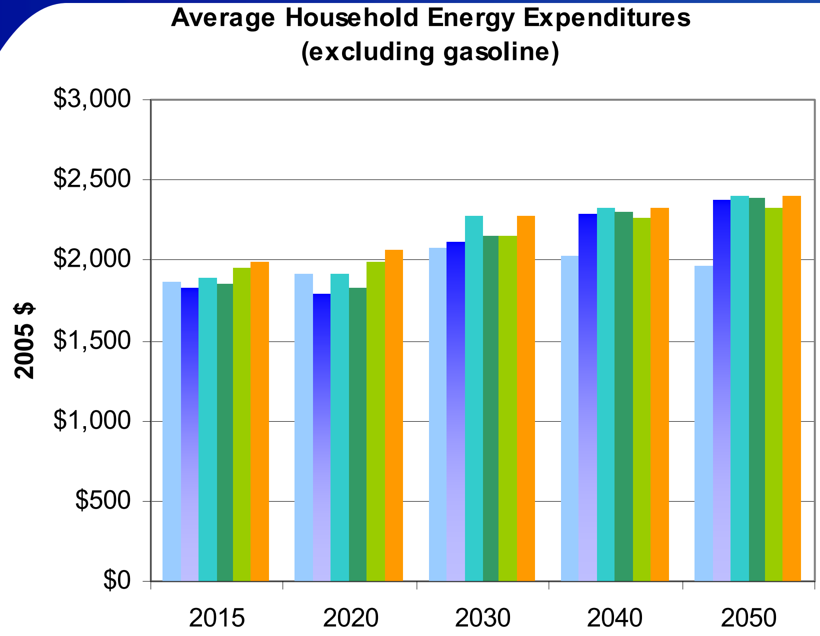
H.R. 2454 Scenario Comparison (ADAGE)

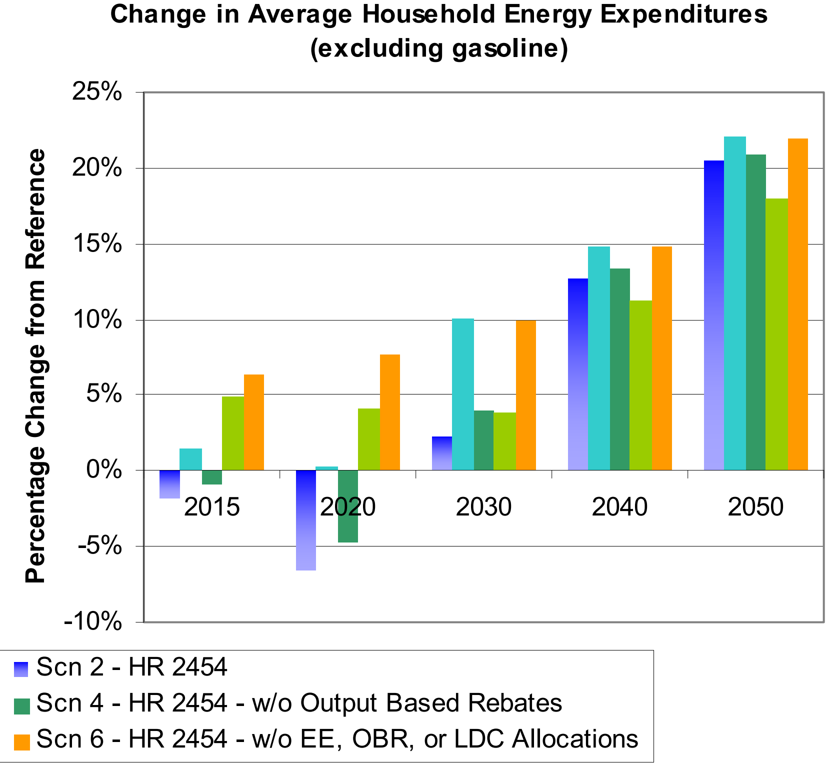


- Gasoline and natural gas prices are inclusive of the allowance price.
- The gasoline price is obtained by multiplying the petroleum price index in ADAGE by the 2010 price of gasoline from the AEO 2009 projection.
- See Appendix 3 for a discussion of the limitations and caveats associated with the methodology used for representing energy efficiency programs.

Household Energy Expenditures

H.R. 2454 Scenario Comparison (ADAGE)





- In 2020, electricity prices are unchanged in "*scenario 2 – H.R. 2454*" and increase by 13% in "*scenario 6 – H.R. 2454 w/o EE, OBR, or LDC Allocations*". In 2030, electricity prices increase by 13% in "*scenario 2 – H.R. 2454*" and increase by 17% in "*scenario 6 – H.R. 2454 w/o EE, OBR, or LDC Allocations*".
- Actual household energy expenditures increase by a lesser amount due to reduced demand for energy. In 2020, the average household's energy expenditures (excluding motor gasoline) decrease by 7% in *scenario 2 – H.R. 2454*" and increase by 8% in "*scenario 6 – H.R. 2454 w/o EE, OBR, or LDC Allocations*". In 2030, the increase is 2% in *scenario 2 – H.R. 2454*" and 10% in "*scenario 6 – H.R. 2454 w/o EE, OBR, or LDC Allocations*".
- In ADAGE, energy expenditures represent approximately 2% of total consumption in 2020, falling to 1% by 2050 in all scenarios.
- The energy expenditures presented here do not include any potential increase in capital or maintenance cost associated with more energy efficient technologies.

Detailed Near-Term Electricity Sector Modeling Results

Detailed Electricity Sector Modeling with IPM

Motivation for Using the Integrated Planning Model (IPM):

- The CGE models used for this analysis do not have detailed technology representations; they are better suited for capturing long-run equilibrium responses than near-term responses.
- Since the electricity sector plays a key role in GHG mitigation, EPA has employed the Integrated Planning Model (IPM) to project the near-term impact of H.R. 2454 on the electricity sector.

Power Sector Modeling (IPM 2009 ARRA Ref. Case):

- This version of IPM builds on the versions used previously to analyze the Waxman-Markey discussion draft, S. 280, S. 1766, and S. 2191.
- This version of the model incorporates key carbon-related options and assumptions, such as carbon capture and storage technology for new and existing coal plants, biomass co-firing options, and technology penetration constraints on new nuclear, renewable, and coal with CCS capacity.
- The model has been updated to include assumptions from the revised Energy Information Administration's Annual Energy Outlook 2009, taking into account the impacts of the American Recovery and Reinvestment Act (ARRA) of 2009. This update changes the reference case forecast for renewable energy considerably.

Modeling Approach:

For this analysis, IPM 2009 ARRA Ref. Case incorporated two sets of data from the ADAGE model:

- CO_2 allowance price projections*
- Percent change in electricity demand*

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.

* Allowance prices for the core IPM scenario are taken from the ADAGE core scenario (Scenario 2).

Key Model Updates and Major Power Sector Provisions Modeled in IPM

Updates to IPM 2009 ARRA Ref. Case:

- **Electricity Demand Growth:** Calibrated to AEO 2009 ARRA update (issued in April).
- **Cost of New Power Technologies:** Consistent with AEO 2009 ARRA update.
- **Biomass:** Supply curves and non-electricity demand for biomass are calibrated to AEO 2009 ARRA update.
- **Cost of Carbon:** An increase to the capital charge rate for new coal plants (consistent with AEO 2009).
- **State RPS and Climate Programs:** Calibrated to AEO 2009 with finalized regulations like RGGI.
- **CCS in Baseline:** Reflecting updated financial incentives including ARRA, 2 GW of CCS capacity are projected for 2015 in the baseline.

Major Bill Provisions:

CCS Demonstration and Early Deployment (Title I, Subtitle B, Sec. 114): Designed to "accelerate the commercial availability of carbon dioxide capture and storage technologies and methods."

- A Carbon Storage Research Corporation is created and administers funds generated through fees on electricity production by fuel type. The Corporation, organized through EPRI, will administer and distribute roughly $1 billion in annual funding for 10 years from date of enactment.
- IPM implementation: Assumed that this funding spurs 1 additional GW of CCS capacity by 2015 (beyond the baseline amount) and an additional 4 GW by 2020. These projects are "hard-wired" into IPM and are not a result of the model's economic analysis. The model may independently add CCS capacity after 2015 on an economic basis, subject to an upper-bound capacity development constraint. The funding amounts to about $2,000/kW for 5 GW of CCS.

CCS Bonus (Title I, Subtitle B, Sec. 115): Designed to provide additional economic incentive for coal with CCS through allocation of "bonus" allowances.

- A portion of allowances are reserved for incentivizing carbon capture and storage technology (starting at 1.75% of allowances and rising to 5% through 2050). The specific incentive is designed as a fixed monetary value for every ton of CO_2 sequestered, rather than a certain number of allowances. The value is specified as up to $100/ton for the first 6 GW and is unspecified (at no greater than $90/ton) for additional support until a maximum of 72 GW of CCS receives the bonus. A stream of specified bonus allowances are made into "current" allowances and made available to qualifying projects dependent upon allowance prices and the total quantity allocated. The bonus is administered as a reverse auction.
- IPM implementation: Similar to past IPM applications, CCS projects receive a subsidy equal to the bonus amount. The allowances are distributed on a first-come, first-serve basis and can be banked. Analysis was performed for a range of potential dollar-per-ton values after the initial $90/ton for the first 6 GW. In this analysis of H.R2454, $40/ton was used as the bonus amount for generation beyond the first 6 GW.

Note: See Appendix for more detail on updates to IPM. For more detail on the all of 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.

Major Power Sector Provisions of H.R. 2454 Modeled in IPM

Major Bill Provisions (cont.):

Combined Efficiency and Renewable Electricity Standard (Title I, Subtitle A, Sec. 101): Requires retail electricity providers to meet a minimum share of sales with electricity savings and qualifying renewable generation by holding tradable credits.

- Nominal targets begin at 6% in 2012 and rise to 20% by 2020. Up to 1/4 of the target may be met with electricity savings (Governors may petition to raise this amount to 2/5). Qualifying renewable resources include solar, wind, biomass, landfill gas, and geothermal. Sales of generation from new nuclear, new CCS†, and existing hydropower capacity are deducted from a retail provider's total sales for assessing the CERES requirement. The bill allows sources to bank federal Renewable Electricity Credits (RECs) for 3 years following generation. Retailers selling less than 4 million MWh a year are exempted from CERES.
- IPM implementation: Reductions in electricity consumption are assumed to meet 1/4 of the standard's targets, which are reduced accordingly.* Estimated sales from hydro generation, new CCS† generation, and new nuclear generation (as projected by IPM in the main H.R. 2454 policy case) are deducted from total sales to establish the qualifying sales levels for meeting CERES. Banking is not explicitly modeled but is implicitly included because the model runs roughly every 5 years. The share of sales from exempted retailers is assumed to remain constant at about 23% (its 2007 level) and is removed from CERES assessment.

Allowance Allocation to Local Distribution Companies (Title III, Subtitle B, Sec. 783): Distributes allowances to electricity local distribution companies (LDCs) "for the benefit of retail ratepayers."

- LDCs collectively receive a declining share of allowances to 2030, beginning at about 39% in 2012 and ending with about 6% in 2029.‡ Half of those allowances are disbursed to LDCs based on historic GHG emissions. The remaining allowances are disbursed based on an updating measure of an LDC's population served (revised every 3 years). LDCs are required to direct allowance value toward "ratepayer benefit," which may range from energy efficiency improvements to consumer rebates. For the latter purpose, the bill encourages LDCs and their regulators to issue lump sum rebates.
- IPM implementation: Allowance prices and electricity demand response are taken from the core ADAGE H.R. 2454 Scenario (#2), which reflects the LDCs allocation as rebates based on electricity consumption.

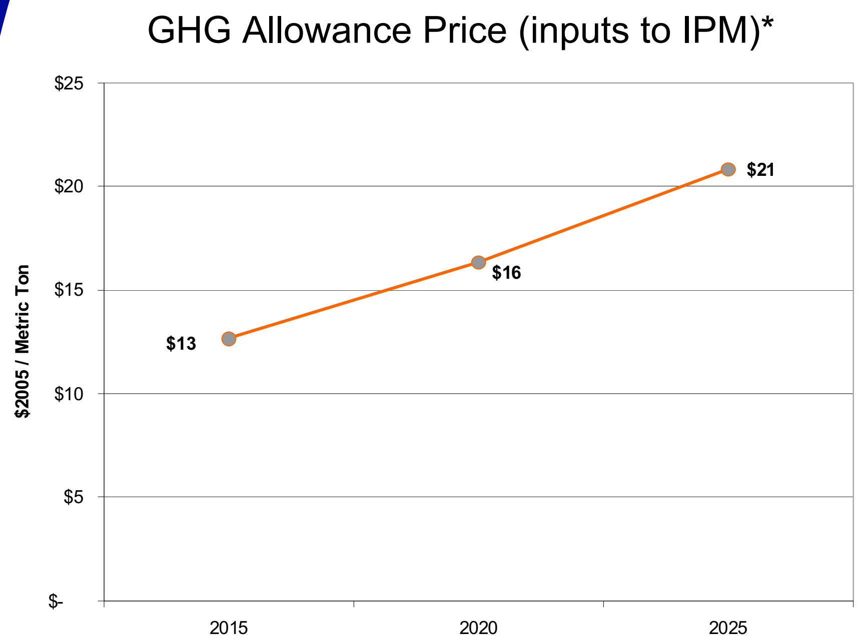
* Assumptions for energy efficiency are detailed earlier in this presentation and are taken from the ADAGE model.

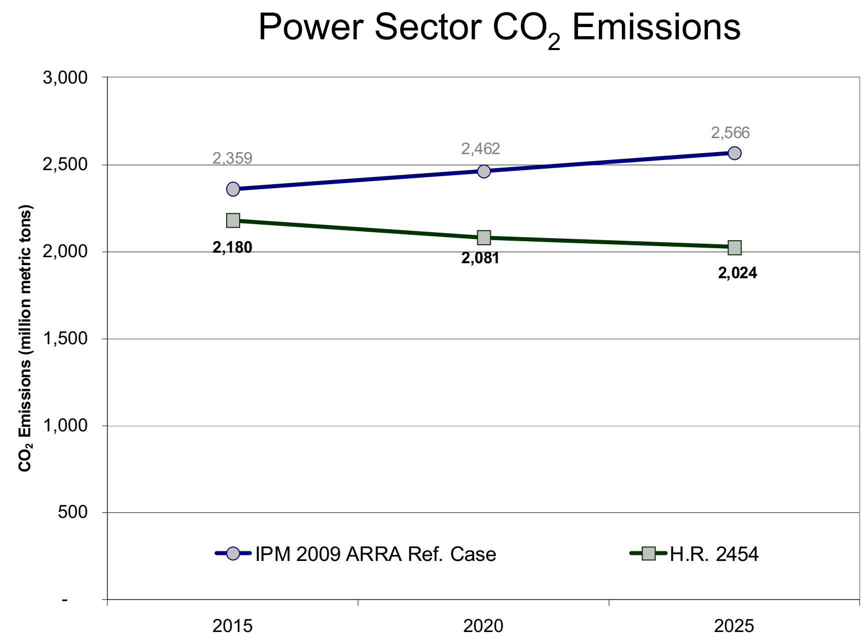
† Sales of generation from CCS is only deducted from the CERES baseline equivalent to the percentage of carbon capture achieved, which is assumed to be 90% in this analysis.

‡ The bill directs EPA to reserve up to 10% of the electricity consumer allocation for distribution to generators subject to long-term contracts and to merchant coal generators. The remaining amount is estimated here for LDCs.

Note: See Appendix for more detail on updates to IPM. For more detail on the all of 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.

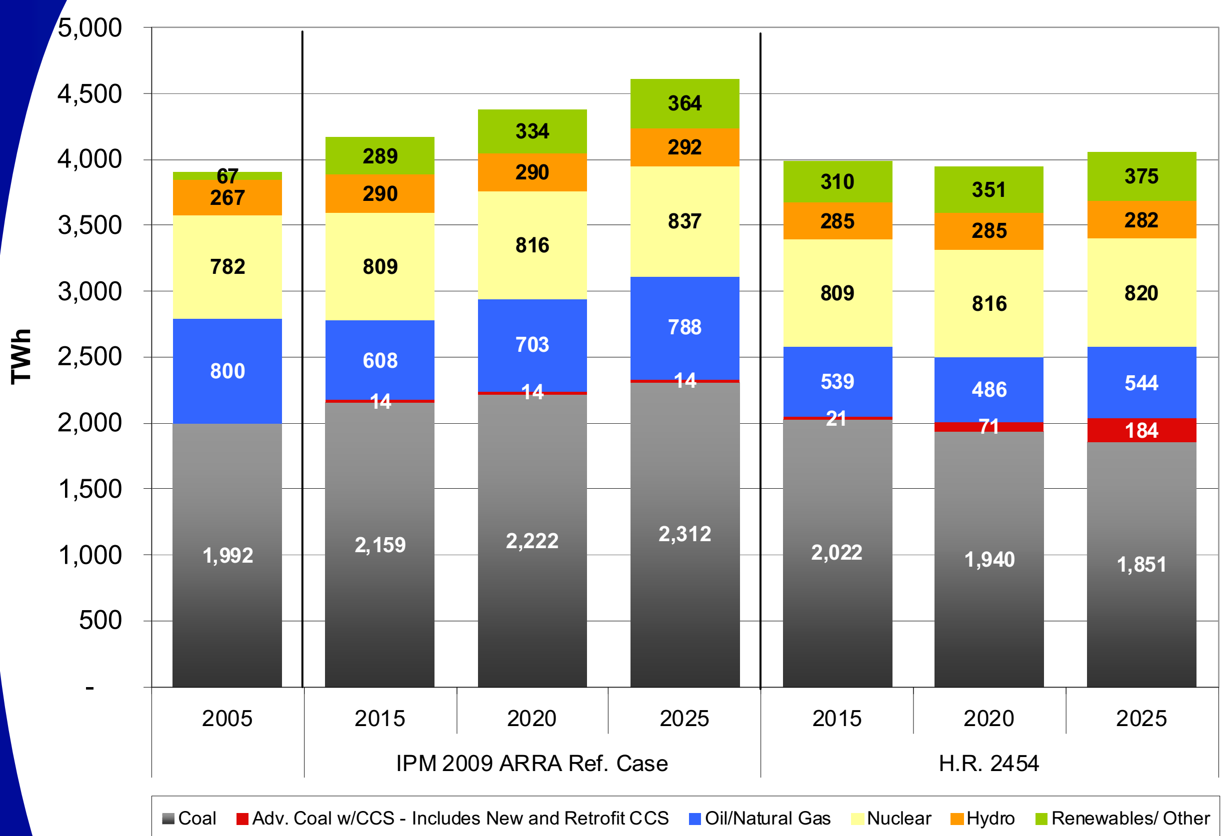
GHG Allowance Prices and Power Sector CO_2 Emissions (IPM)*





* Allowance prices for the core IPM scenario are taken from the ADAGE core scenario (Scenario 2). IPM 2009 ARRA Reference Case is generally consistent with AEO 2009 (ARRA update), although projections are not identical because IPM is a power sector model and has different treatment of key assumptions and variables.

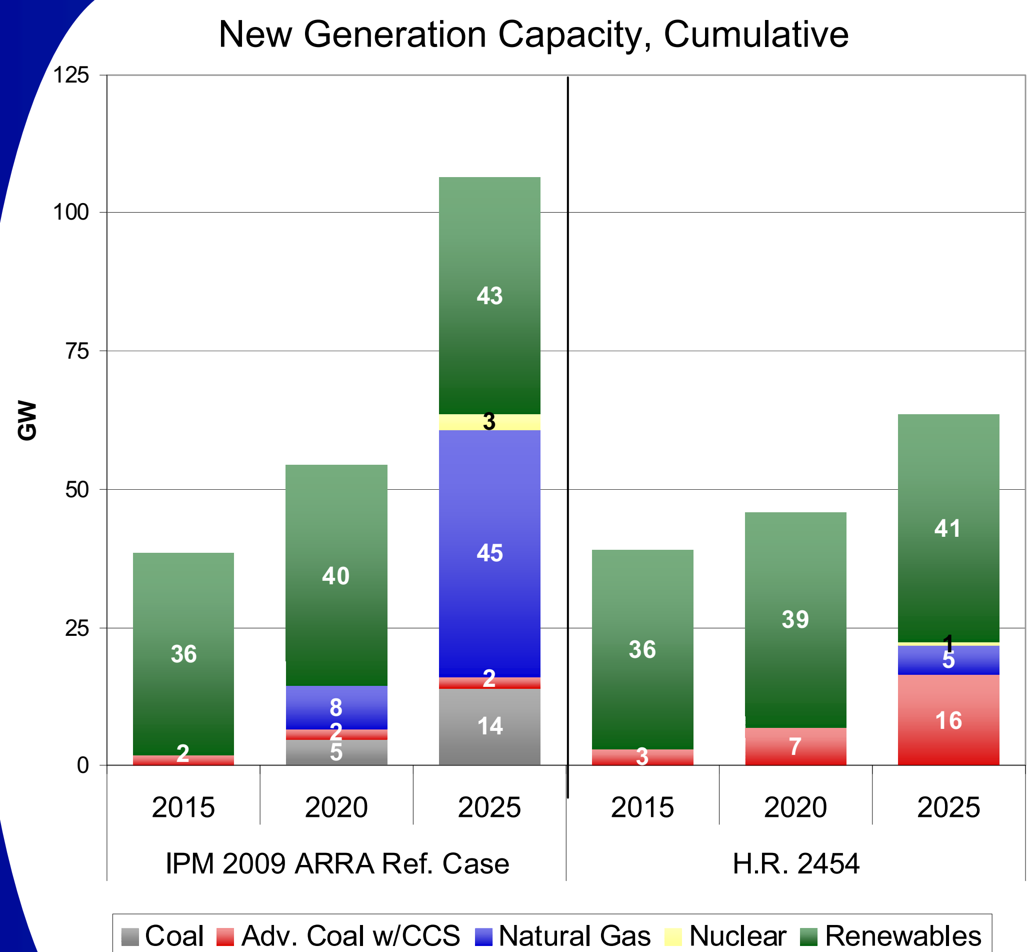
Electricity Generation Mix (IPM)



- The electricity demand forecast is lower than past EPA analyses, reflecting economic and policy-related adjustments.
- Due to a large increase in renewable energy largely driven by ARRA provisions, there is excess electricity generating capacity projected through 2015 in the reference case and H.R. 2454 scenario.
  - This tends to drive generation away from existing natural gas.
- The difference in electricity generation between the reference case and policy case due to energy efficiency and demand response is around 550 TWh in 2025. This difference is equivalent to the amount of electricity used by over 40 million (50% of the total) single family homes in the US annually.*
- There is greater renewable generation in the H.R.2454 scenario even though less new renewable generation is built because of greater reliance on bio-mass co-firing at existing coal plants.

2005 data from EIA's Electric Power Annual (for electric utilities, independent power producers, and CHP electric power). IPM 2009 ARRA Reference Case is generally consistent with AEO 2009 (ARRA update), although projections are not identical because IPM is a power sector model and has different treatment of key assumptions and variables.
*EIA. 2005 Residential Energy Consumption Survey. Table 3. http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html.

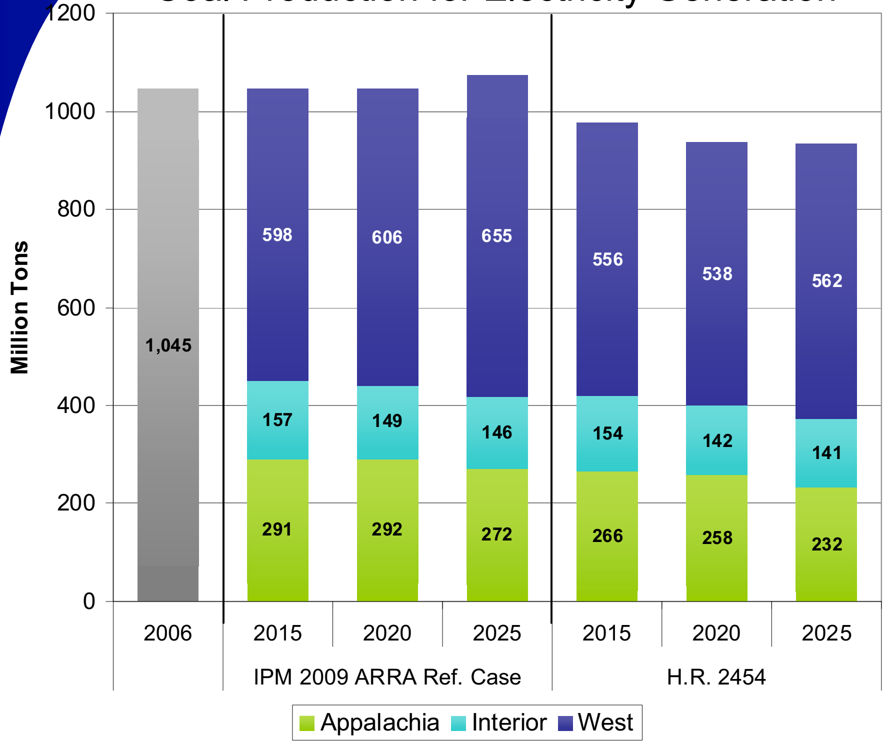
New Generation Capacity (IPM)

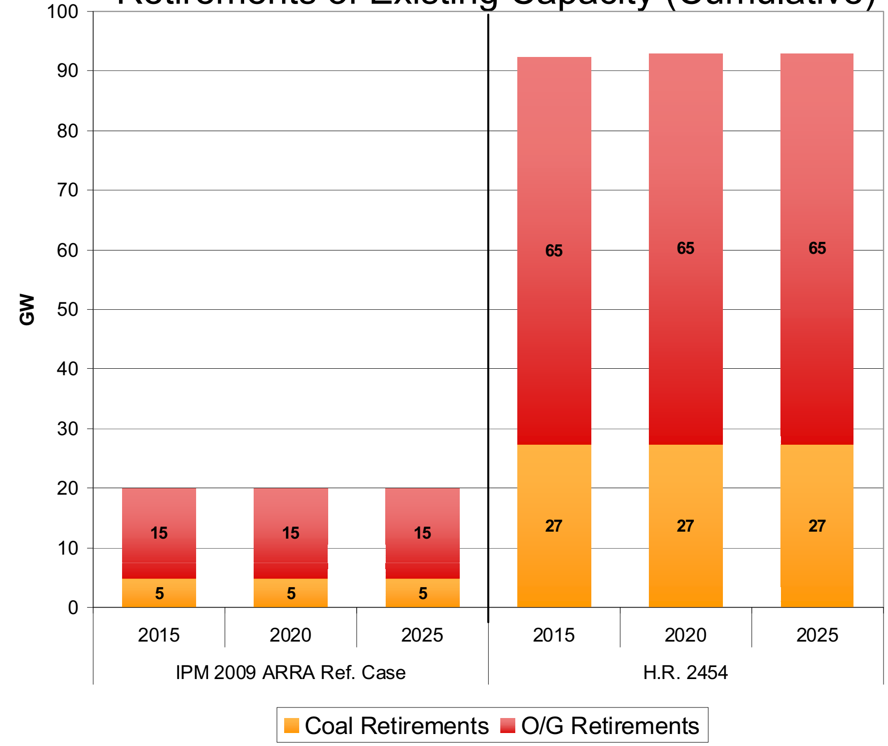


- A major change to the IPM 2009 ARRA reference case is the amount of new renewables expected to be built in the short-term in response to additional ARRA incentives. Overall electricity demand is also lower, necessitating fewer new power plants than past EPA modeling with IPM.
- Under H.R. 2454, electricity demand is reduced significantly and allowance prices are not high enough to drive a significant amount of additional low- or zero- carbon energy (including nuclear, renewables, and CCS) in the shorter-term, excluding the technologies with specific financial incentives (e.g., CCS).
- H.R. 2454 contains early deployment funding and a bonus allowance provision for CO_2 emissions that are captured and sequestered, resulting in some penetration of *new* coal capacity with CCS technology.
  - The policy results in a total of 14 GW of additional new capacity with CCS by 2025. Of that amount, 5 GW is forced in IPM beyond the reference case by 2020 to reflect early deployment funding. The other 9 GW becomes economic due to the bonus allowance allocation (see later slide).
  - CCS retrofits to the *existing* coal fleet are also economic, facilitated by the bonus (retrofits to existing facilities are not reflected in the graphic).
    - There are about 9 GW in 2025 of post-retrofit capacity, which meets IPM's CCS retrofit penetration limit (while the limit on new CCS capacity penetration is not reached).*
- The amount of new nuclear capacity is well below the penetration limit throughout the entire modeling period.

Note: New capacity additions less that 1 GW of capacity are not indicated. IPM 2009 ARRA Reference Case is generally consistent with AEO 2009 (ARRA update), although projections are not identical because IPM is a power sector model and has different treatment of key assumptions and variables. IPM projects less new nuclear and slightly less new renewable capacity compared to AEO 2009 ARRA. * See appendix for more detail on EPA's technology penetration limits applied in IPM.

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

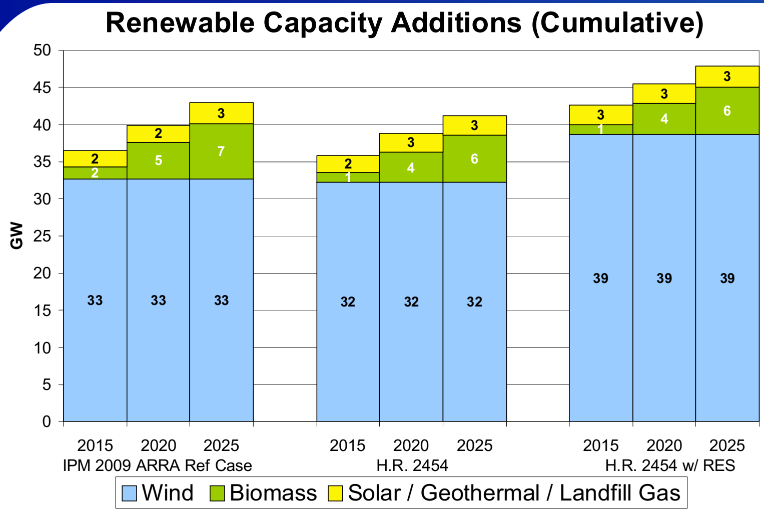


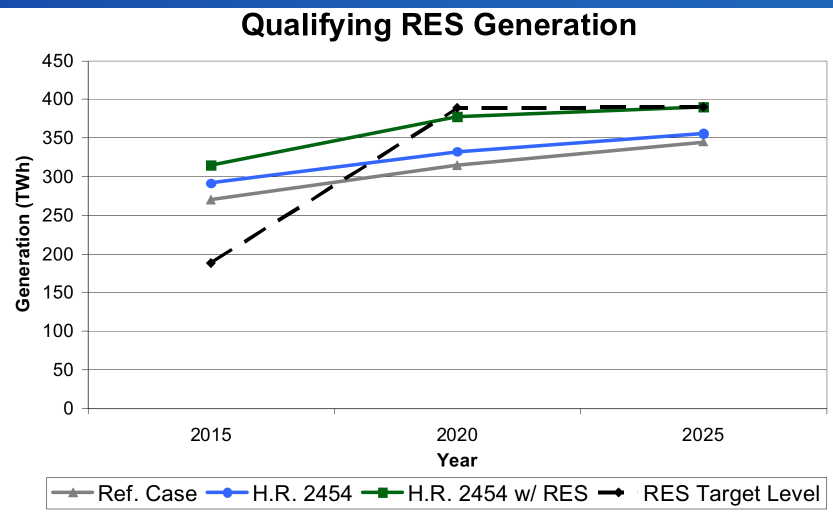


- Roughly 22 GW of additional existing coal capacity and 70 GW of additional oil/gas capacity is projected to retire under H.R. 2454. The lower allowance prices and higher costs to build new technology make existing coal cost-competitive in the shorter-term.
- In reality, uneconomic units may be “mothballed,” retired, or kept running to ensure generation reliability. The model is unable to distinguish among these potential outcomes. Most of these are marginal units with low capacity factors.
- Most uneconomic units are part of larger plants that are expected to continue generating. Currently, there is roughly 120 GW of oil/gas steam capacity and 320 GW of coal capacity.

Note: Regional coal production data includes coal production for power generation only. Historical data is from EIA’s AEO 2008. Coal production (in terms of tons) does not correlate to generation perfectly because different grades of coal have greater heat content (e.g. bituminous coal has greater heat content than sub-bituminous coal). In addition, coal production data shown here does not include coal imports, which increase over time in IPM. IPM 2009 ARRA Reference Case is generally consistent with AEO 2009 (ARRA update), although projections are not identical because IPM is a power sector model and has different treatment of key assumptions and variables.

Effects of the Combined Efficiency and Renewable Electricity Standard (CERES)





- The core case for H.R. 2454 illustrates how the bill's provisions for increased energy efficiency reduce the need for new capacity additions (including renewables), even as renewable generation rises. The RES portion of CERES is shown here to increase deployment of renewable capacity, and it results in a more substantial increase in renewable generation than the cap-and-trade system yields on its own.
  - The RES also reduces average natural gas prices, gas consumption, and wholesale electricity prices by about 1-2% throughout the model's time horizon. Initial analysis indicates that retail electricity prices rise slightly relative to the core H.R. 2454 scenario in later years. The impact on a household's electricity bill, however, would be offset to the extent that efficiency gains would reduce overall power consumption.
  - The share of renewable electricity (as defined by the RES) in the IPM reference scenario is roughly 7% of generation in 2020 and 2025. In Scenario 2 (H.R. 2454), the renewable generation share increases to 8% in 2020 and 9% in 2025. And in Scenario 2 with the RES, renewable generation is 9% in 2020 and 10% in 2025.
- The power sector is projected to reach the bill's RES targets through 2015 in the reference case (with 25% from electricity savings assumed).
- H.R. 2454 includes an alternative compliance payment (ACP) of $25 per MWh. This analysis projects that the federal Renewable Electricity Credit (REC) price reaches that level in 2020 but falls back to about $11 per MWh in 2025.
  - Use of the ACP in 2020 is very limited (accounting for only 2% of total CERES compliance).
  - H.R. 2454 also allows States to petition for the right to meet up to 40% of the CERES with electricity savings. Additional use of efficiency to meet the standards would lower federal Renewable Electricity Credit (REC) prices, potentially reducing use of the ACP.
  - This analysis does not take into account the effect of ACP payments, which H.R. 2454 reserves for States to increase the deployment of renewables or increase electricity savings.
- By increasing the share of renewable generation, the RES would likely lower power sector GHG emissions and could lower the economy-wide allowance price, although this effect was not modeled in the analysis. To the degree that the RES requires generation or capacity deployment that is not most cost effective otherwise, total system costs increase. RES would not impact the achievement of the emission caps under H.R. 2454.

Note: IPM 2009 ARRA Reference Case is generally consistent with AEO 2009 (ARRA update), although projections are not identical because IPM is a power sector model and has different treatment of key assumptions and variables. For more detail on natural gas impacts of the RES, see slide 93 of the Appendix.

Effects of Allocating Allowances to Electricity Local Distribution Companies

- Under lump sum rebate allocation, consumers pay higher electricity rates but receive payments irrespective of their consumption; therefore, the payments do not dampen the price incentive for more efficient use of electricity.

- Where allowance value is rebated to consumers on the basis of quantity consumed, electricity prices will be lower and thus consumption will be higher than would have occurred otherwise. Higher consumption yields higher GHG emissions from the power sector, which means other reductions will be needed that could lead to higher economy-wide allowance prices. EPA is doing additional analysis to examine the extent to which LDC allocation value impacts power prices, emissions, allowance prices, and developments in power sector generation and capacity.

- Note that any evaluation of the impact on consumers must examine electricity prices and total electric power consumption (e.g., monthly bills) together with other costs (e.g., efficiency investments) to get the full picture.

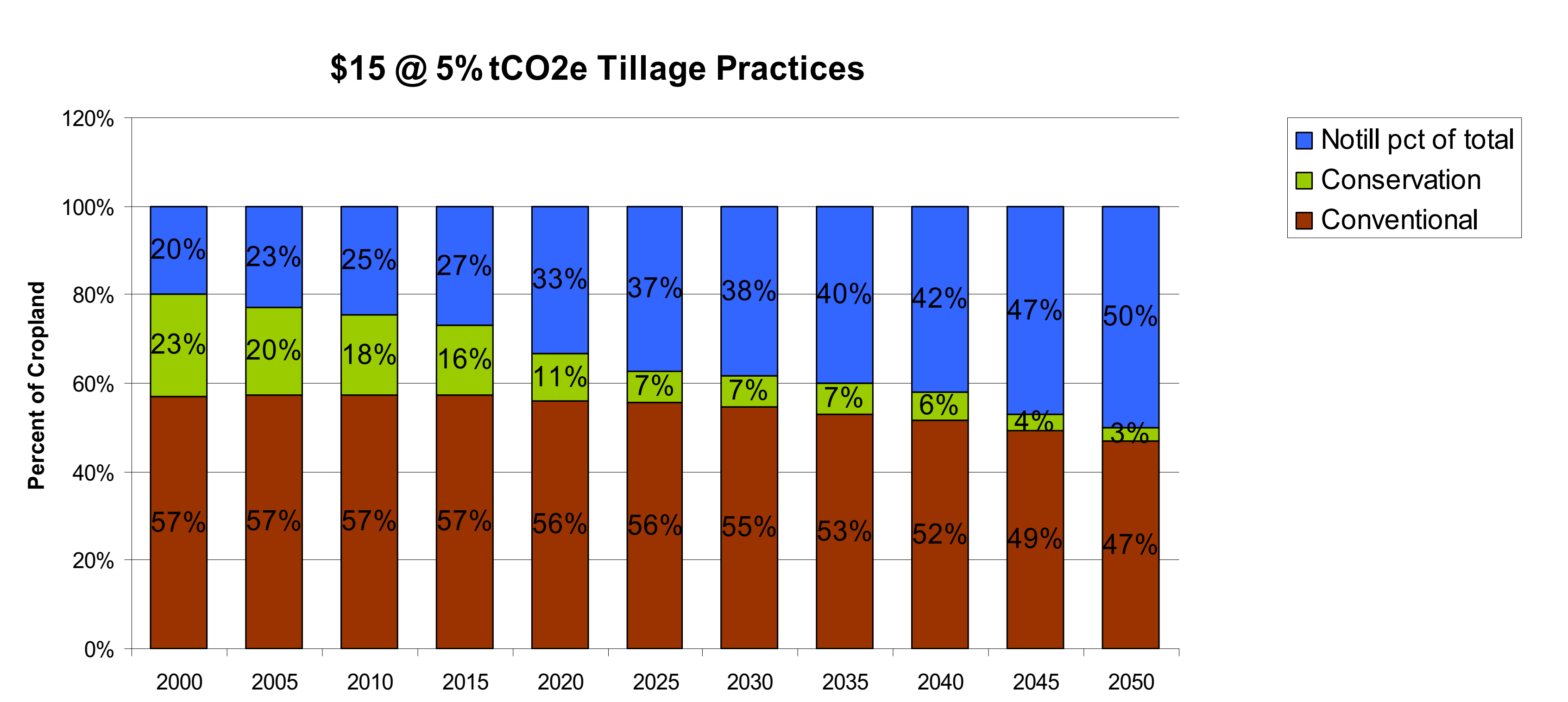
Offsets Usage & Limits

Factors Influencing Domestic Offset Supply

- The analysis of domestic forest and agriculture offsets is based on the FASOM marginal abatement cost curves used in the April 20th analysis of the Waxman-Markey Discussion Draft.
- The modeling of domestic offsets evaluates changes in greenhouse gases against a projected baseline. If offsets are evaluated against historic or current baselines, the overall volume of offsets would increase.
- The sources of domestic offsets modeled here represent sources that have significant supply in the FASOM model at the relevant allowance prices. The exclusion of other sources in the modeling results does not imply that those sources would not be eligible to receive offsets credits.
- The FASOM modeling did not account for several categories of potential agricultural GHG reductions, including:
    - Improvements in organic soil management;
    - Advances in feed management of ruminants;
    - Changes in the timing, form, and method of fertilizer application; and
    - Alternative manure management systems – other than anaerobic digesters
- Because of how it is handled in the model, agricultural soil sequestration does not show significant supply. However, detailed FASOM output indicates a 50% increase in the percent of cropland using conservation-tillage and no-till by 2020 in response to a \$15/ton CO_2 incentive payment. Because overall land area in crops declines due to afforestation, the modeling indicates a net decrease in total agricultural soil carbon storage as carbon is transferred from the agricultural soils pool to the afforestation carbon pool.
- Within the model, reductions in fertilizer use result in declines in yields. To the extent fertilizer application can be improved without yield penalties, the potential for this category of emissions reductions will be higher.
- EPA is working with USDA to review the analysis of the forestry and agricultural sectors.

Increased Use of No-Till Under Increasing Carbon Prices

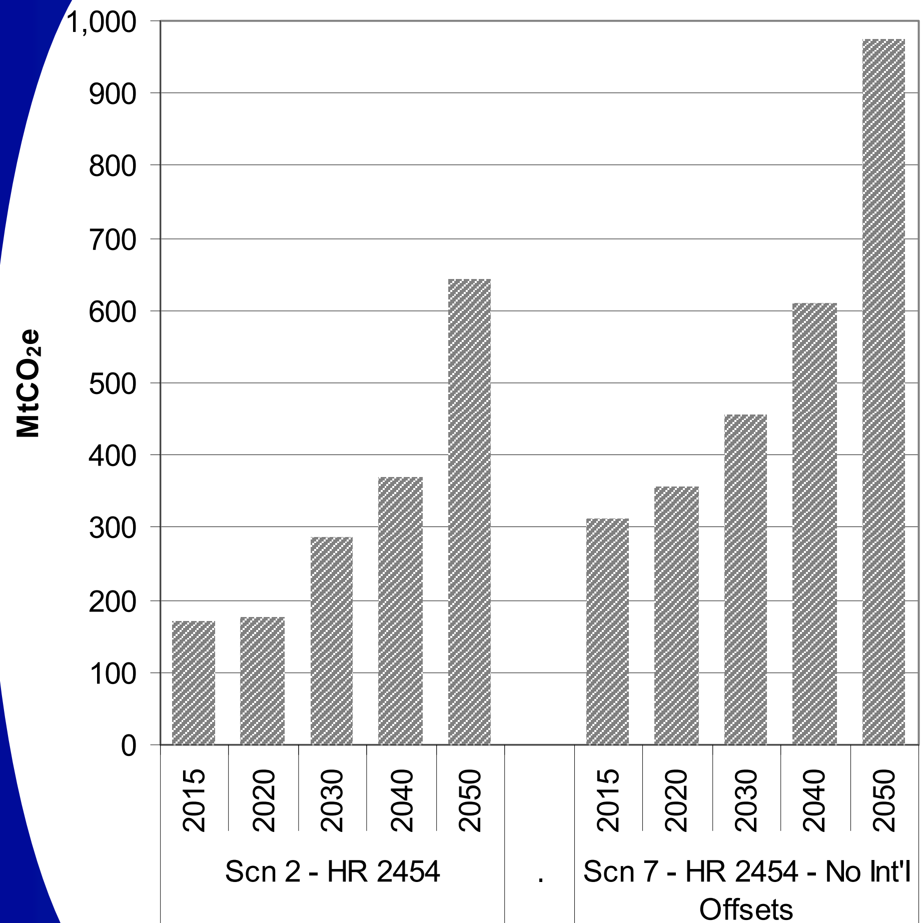
FASOM



- The above graphic represents the share of cropland under different tillage practices in one of the FASOM runs that contribute to the marginal abatement cost curves used for representing domestic offsets abatement potential. The specific run is based on an initial allowance price of $15/tCO_2e$ rising at five percent.
- Because of how it is handled in the model, agricultural soil sequestration does not show significant supply. However, detailed FASOM output indicates a 50% increase in the percent of cropland using conservation-tillage and no-till by 2020 in response to a $15/ton CO_2 incentive payment. Because overall land area in crops declines due to afforestation, the modeling indicates a net decrease in total agricultural soil carbon storage as carbon is transferred from the agricultural soils pool to the afforestation carbon pool.

Domestic Offsets Usage

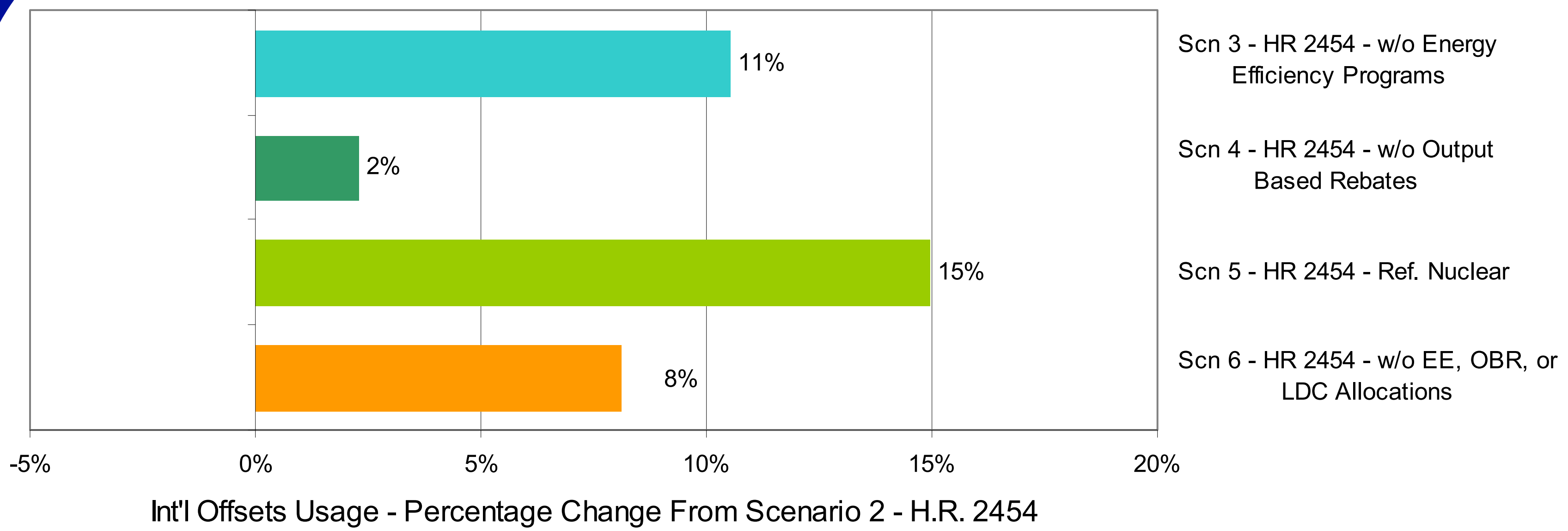
H.R. 2454 Scenario Comparison (IGEM)



- The annual limit on the usage of domestic offsets is non-binding.
  - H.R. 2454 Sec 722 (d) (1) (A) allows covered entities to collectively use offset credits to demonstrate compliance for up to a maximum of 2 billion tons of GHG emissions annually.
  - This section also attempts to share the 2 billion tons of offsets allowed pro rata among covered entities. However, the formula specified for pro rata sharing among covered entities does not result in 2 billion tons of offsets in total.
  - H.R. 2454 Sec 722 (d) (1) (C) modifies the pro rata sharing to allow more international offsets if fewer than 0.9 GtCO2e are expected to be used.
  - See appendix 2 for a detailed discussion of the offsets provisions in H.R. 2454.
- 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.
  - EPA's previous analysis of the Waxman-Markey discussion draft showed that allowing landfill and coal mine methane as offset projects instead of covering them under NSPS would increase cumulative domestic offsets usage by 45%.
- Restricting the use of international offsets, as in "*scenario 7 – H.R. 2454 No Int'l Offsets*" has a large impact on allowance prices (89% increase relative to '*scenario 2 – H.R. 2454'*).

International Offsets Usage Sensitivities

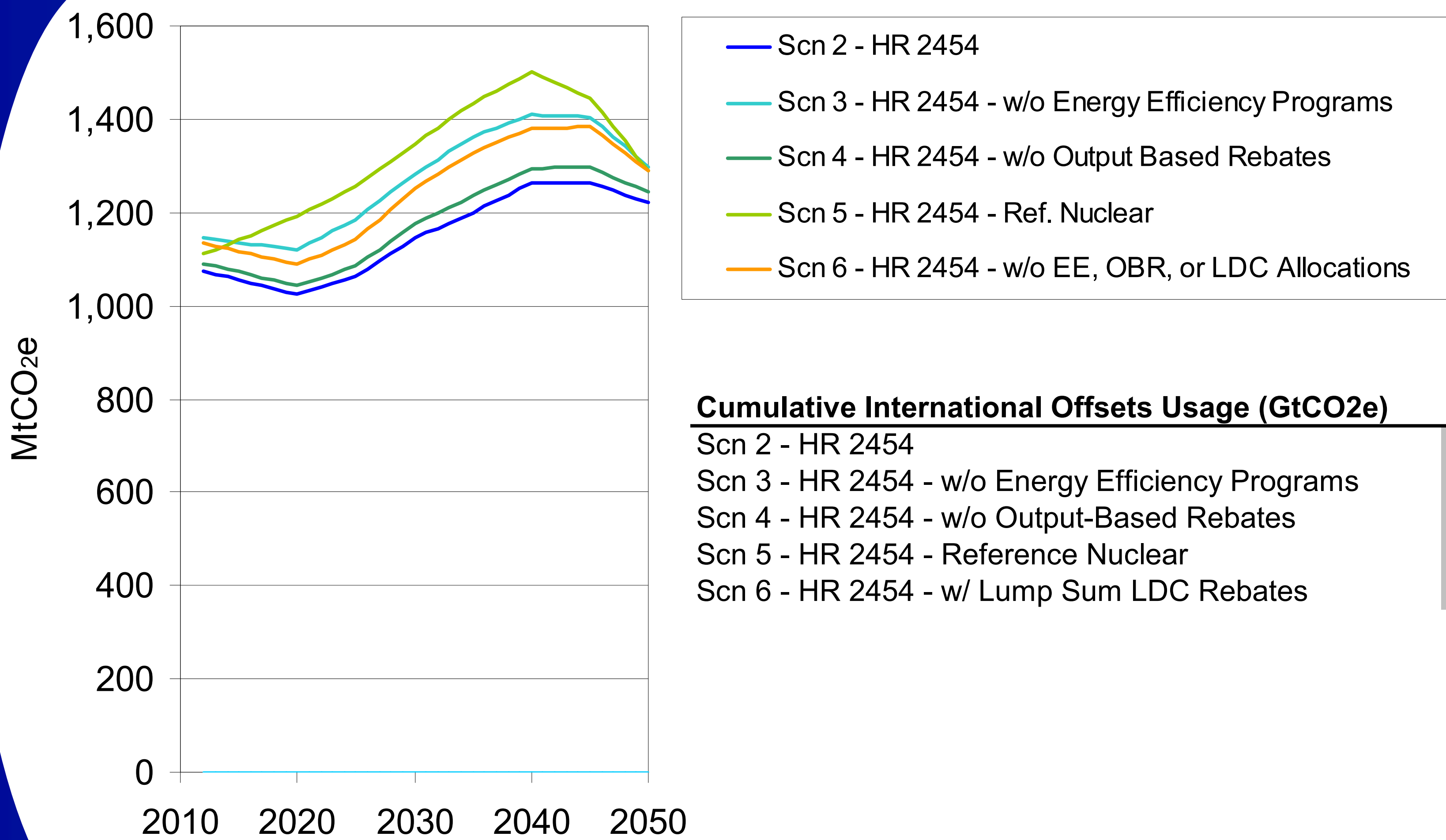
H.R. 2454 Scenario Comparison (ADAGE)



- Since the annual limit on the usage of international offsets is non-binding in most scenarios, sensitivities that would be expected to impact allowance prices, instead impact the usage of international offsets (and thus the amount of abatement within covered sectors).
- For example, in EPA's analysis of the Waxman-Markey discussion draft (WM-draft), the sensitivity case adding in the energy efficiency programs resulted in a 9% decrease in allowance prices. In this analysis of H.R. 2454, the sensitivity case removing the energy efficiency programs only increases allowance prices by 2%. The difference is that in the WM-draft analysis the cumulative U.S. covered emissions were the same in the two scenarios; whereas, in the H.R. 2454 analysis, removing the energy efficiency programs increases the marginal cost of abatement, but instead of allowance prices increasing to achieve the same level of abatement, the usage of international offsets increases and the amount of abatement decreases so cumulative U.S. covered emissions increase.

International Offsets Usage

H.R. 2454 Scenario Comparison (ADAGE)



Cumulative International Offsets Usage (GtCO2e)	
Scn 2 - HR 2454	45
Scn 3 - HR 2454 - w/o Energy Efficiency Programs	50
Scn 4 - HR 2454 - w/o Output-Based Rebates	46
Scn 5 - HR 2454 - Reference Nuclear	52
Scn 6 - HR 2454 - w/ Lump Sum LDC Rebates	48

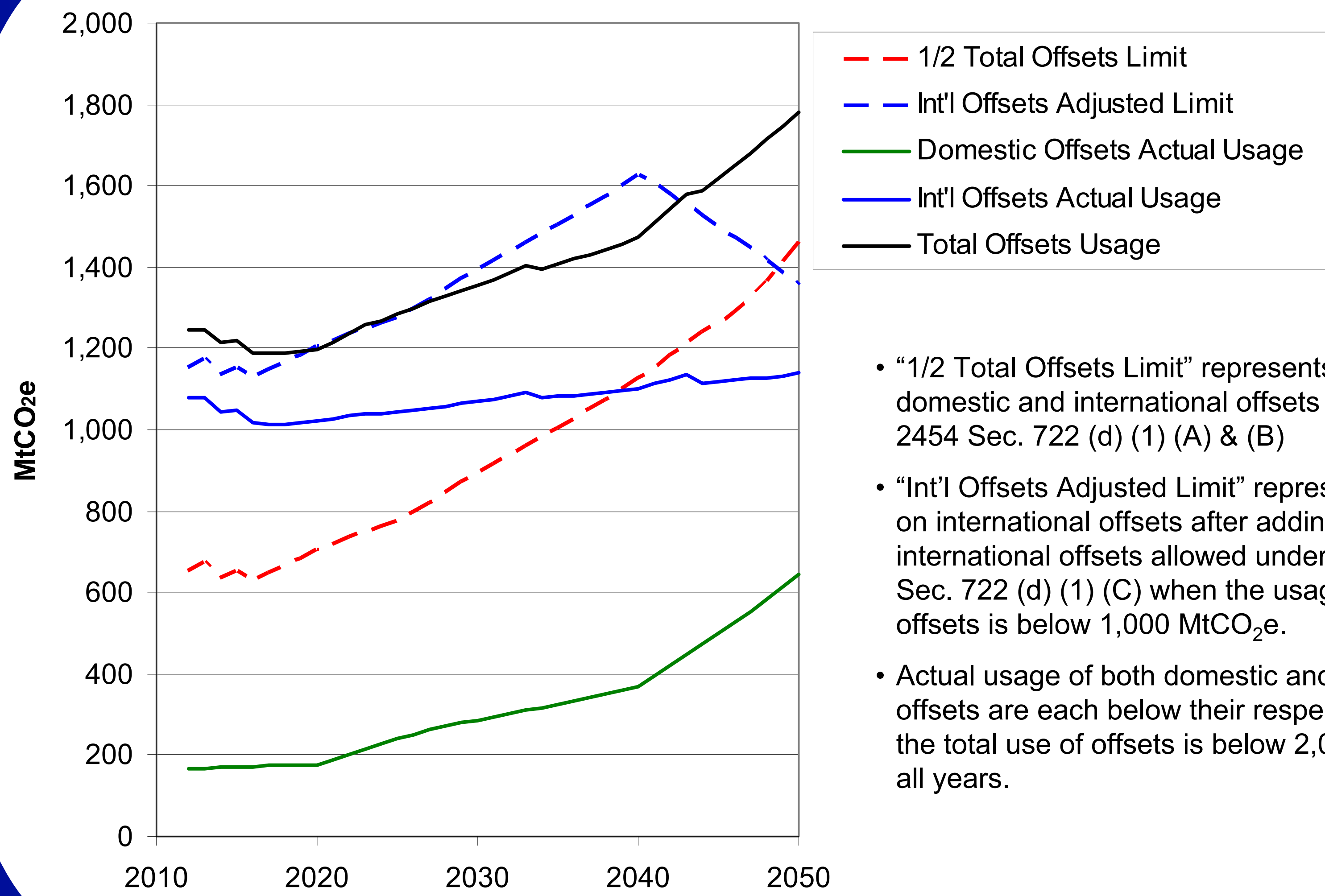
H.R. 2454 Offsets Provisions

Sec. 722 (d) (1)

- H.R. 2454 Sec 722 (d) (1) (A) allows covered entities to collectively use offset credits to demonstrate compliance for up to a maximum of 2 billion tons of GHG emissions annually.
- This section also attempts to share the 2 billion tons of offsets allowed pro rata among covered entities. However, the formula specified for pro rata sharing among covered entities does not result in 2 billion tons of offsets in total.
  - Covered entities are allowed to satisfy a specified percentage of the number of allowances required to be held for compliance with offsets credits.
  - H.R. 2454 Sec 722 (d) (1) (B) shows that for each year, the specified percentage is calculated by dividing two billion by the sum of two billion and the annual tonnage limit for that year. For example, in 2012, when the cap level is 4.627 GtCO2e, the percentage would be 30.20%; and in 2050, when the cap level is 1.035 GtCO2e the percentage would be 65.90%.
  - The number of allowances required to be held for compliance is equal to the amount of covered emissions, so for any given firm the amount of offsets they are allowed to use is equal to the product of their covered emissions and the percentage specified above.
  - The total amount of offsets allowed is equal to the product of the total amount of covered emissions and the specified percentage. In order for this to be equal to the 2 billion ton limit on offsets specified above, total covered GHG emissions would have to be equal to the cap level plus 2 billion tons. There are several reasons why this is unlikely to be the case.
    - First, even if covered emissions remain at reference levels, in the early years of the policy they will not be 2 billion tons over the cap level.
    - Second, if firms bank allowances, their covered GHG emissions will be reduced, which will reduce the amount of offsets they are allowed to use.
    - Third, in the later years when firms are drawing down their bank of allowances, it is possible for covered GHG emissions to be more than 2 billion tons above the cap, which means that the pro rata sharing formula can be in conflict with the overall 2 GtCO2e limit on offsets usage. However, if the domestic limit is non-binding, then the pro-rata sharing would allow for the international limit to exceed 1 GtCO2e, so long as the sum of domestic and international offsets were still below 2 GtCO2e.
- H.R. 2454 Sec 722 (d) (1) (C) modifies the pro rata sharing to allow more international offsets if fewer than 0.9 GtCO2e are expected to be used.
  - In years when this provision triggers, an additional amount of international offsets are allowed equal to the lesser of: 1 GtCO2e less the actual amount of domestic offsets used; or 0.5 GtCO2e.
  - This has the potential in later years to allow more than 2 GtCO2e of offsets into the system, so our interpretation is that the actual amount of extra international offsets allowed would be equal to the lesser of the amount calculated above, or 2 GtCO2e less the sum of the international offsets limit and the actual usage of domestic offsets.
  - Because the pro-rata sharing limits domestic offsets in the early years to well below 0.9 GtCO2e, this provision will automatically trigger, even if the actual limit on domestic offsets were binding.

Domestic & International Offsets Usage & Limits

Scenario 2 – H.R. 2454 (IGEM)



- "1/2 Total Offsets Limit" represents the limits on domestic and international offsets based on H.R. 2454 Sec. 722 (d) (1) (A) & (B)
- "Int'l Offsets Adjusted Limit" represents the limit on international offsets after adding in the extra international offsets allowed under H.R. 2454 Sec. 722 (d) (1) (C) when the usage of domestic offsets is below 1,000 $MtCO_2e$.
- Actual usage of both domestic and international offsets are each below their respective limits, and the total use of offsets is below 2,000 $MtCO_2e$ in all years.

International Offsets Sensitivities

Side Scenarios (IGEM)

Because of the importance of international offsets, several side scenarios are included here to further explore the relationship between the availability of international offsets and the price of domestic allowances. A reduced form version of the IGEM model was used for these side scenarios.

Scenario 2 – H.R. 2454

- One of the main scenarios.

Scenario 7 – H.R. 2454 with No International Offsets

- One of the main scenarios.

Scenario 7a – H.R. 2454 with Delayed International Offsets

- Side scenario.
- No international offsets are allowed in the first 10 years.

Scenario 7b – H.R. 2454 with No Extra International Offsets

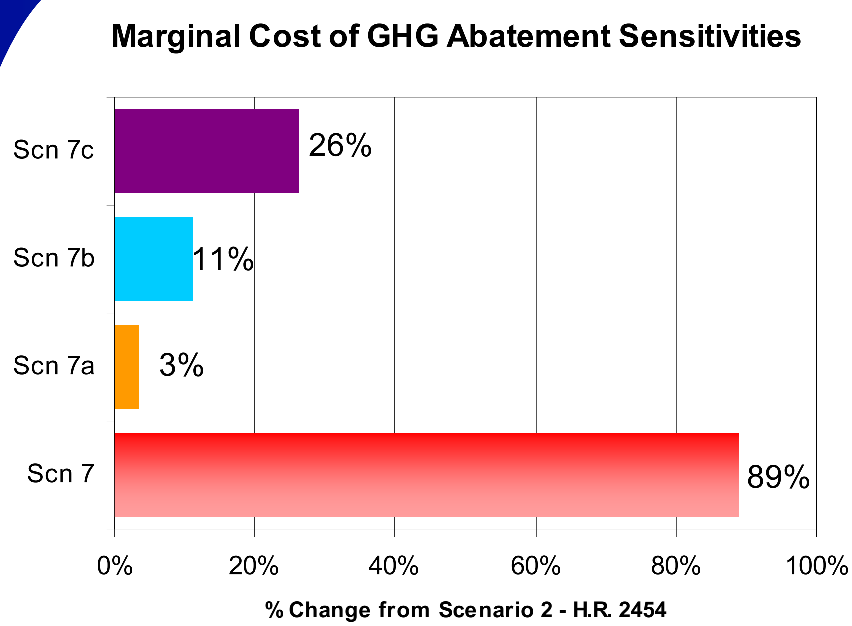
- Side scenario
- No extra international offsets from H.R. 2454 Sec 722 (d) (1) (C) when domestic offset usage is below 900 $MtCO_2e$.

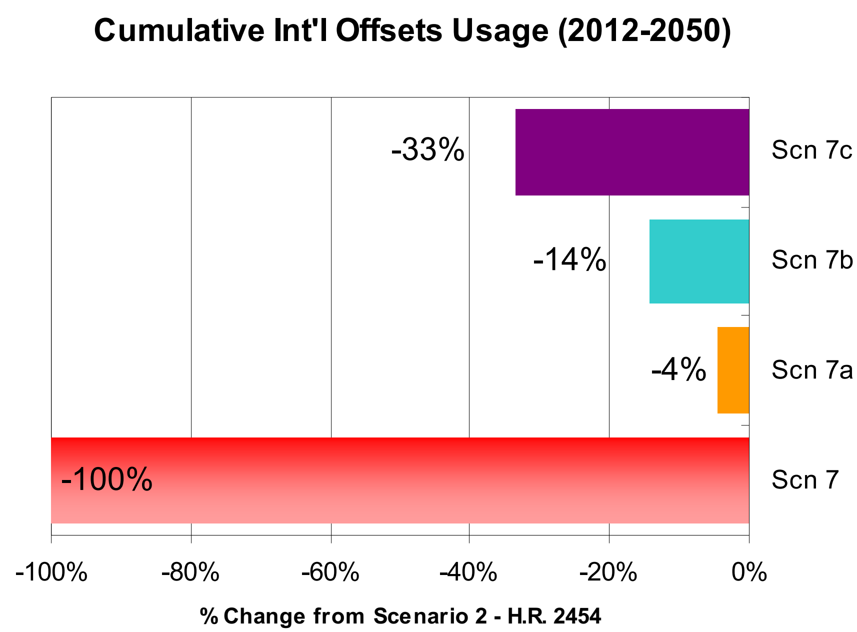
Scenario 7c – H.R. 2454 with Delayed International Offsets & No Extra International Offsets

- Side scenario
- No international offsets are allowed in the first 10 years.
- No extra international offsets from H.R. 2454 Sec 722 (d) (1) (C) when domestic offset usage is below 900 $MtCO_2e$.

International Offsets Sensitivities

Allowance Prices & Cumulative International Offsets (IGEM)



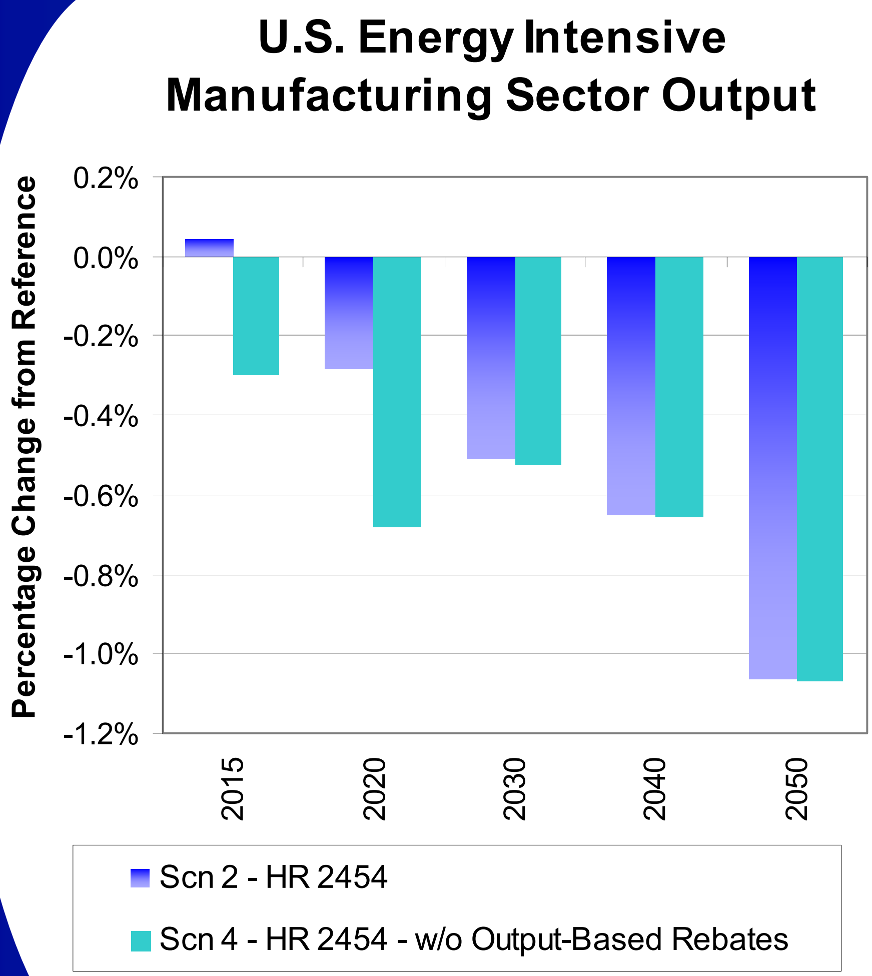


Cumulative International Offsets Usage (GtCO2e)	
Scn 2 - H.R. 2454	42
Scn 7 - H.R. 2454 - No Int'l Offsets	0
Scn 7a - H.R. 2454 - Delayed Int'l Offsets	40
Scn 7b - H.R. 2454 - No Extra Int'l Offsets	36
Scn 7c - H.R. 2454 - Delayed & No Extra Int'l Offsets	28

Global Results:
Trade Impacts and
Output-Based Rebate Provisions

Summary of Trade Impacts and Output-Based Rebate Provisions

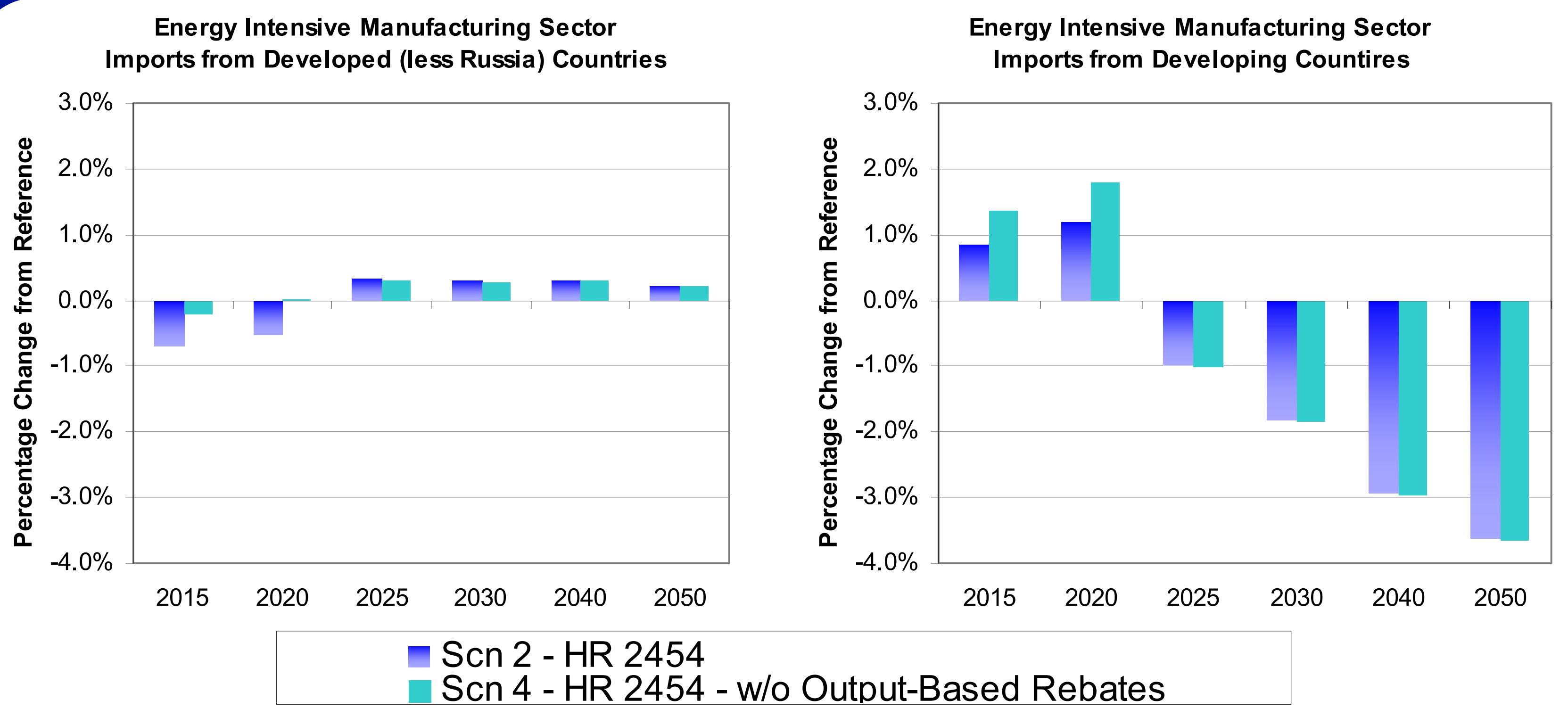
(ADAGE)



- The output-based rebate provision specified in Title IV of H.R 2454 is similar to H.R. 7146 (Inslee - Doyle).
  - Applies to energy- or GHG-intensive industries that are also trade-intensive.
  - Rebates on average 100 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 2025 and 2035, or when other countries take comparable action on climate change.
- Without output-based rebate provision, energy intensive manufacturing output decreases by 0.3% in 2015 and by 0.7% in 2020. With the output-based rebates, energy intensive manufacturing output *increases* by 0.04% in 2015 and only falls by 0.3% in 2020.
- The output-based rebate provisions have little impact on allowance prices, and thus, in later years after the rebates are phased out, the energy intensive manufacturing sector output losses are similar in the two scenarios.
- More detailed results are presented in Appendix 5.

Summary of Trade Impacts and Output-Based Rebate Provisions

(ADAGE)

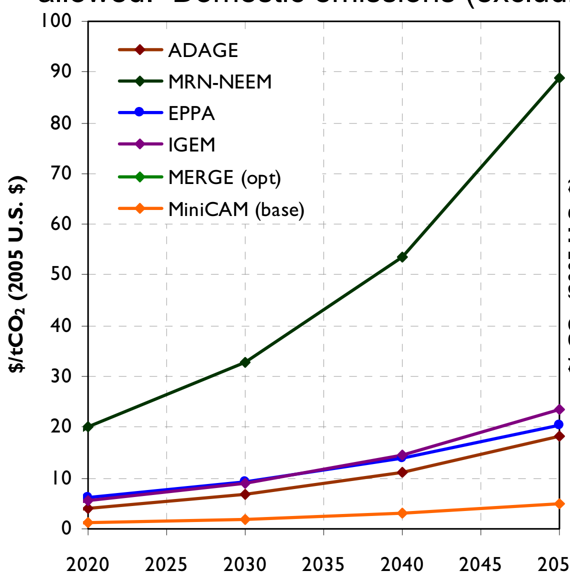


- Imports of energy intensive manufacturing goods from developing countries increase in 2015 and 2020, then decrease in 2025 and after as the developing countries are assumed to adopt climate policies.
- In 2015 and 2020, the output-based rebate provisions decrease imports from both developed and developing countries.
- More detailed results are presented in Appendix 5.

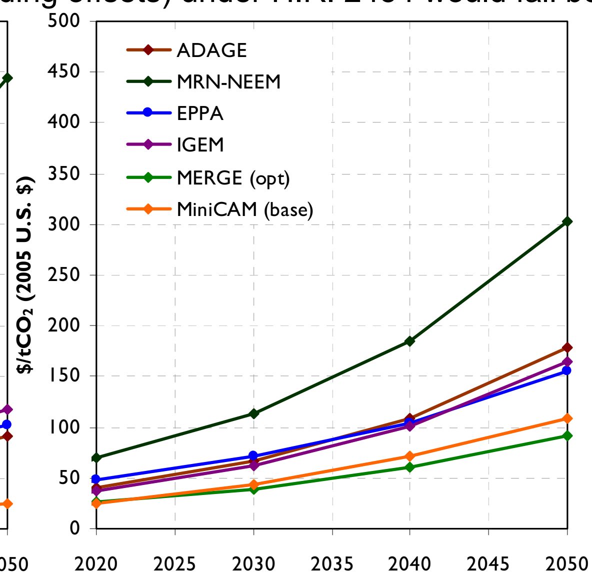
Literature Review

Comparing Costs of Three Possible U.S. Emissions Targets through 2050

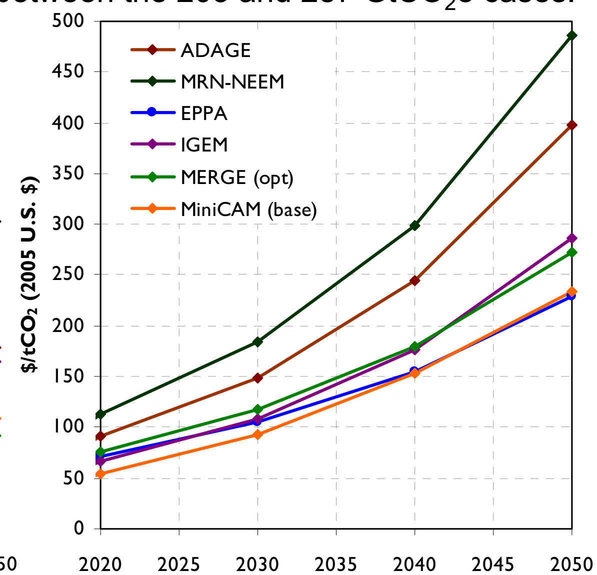
To put the EPA models (ADAGE and IGEM) in context, we compare the results of EMF's analysis of three emission goals that span a wide range of possible U.S. 2050 targets. Caps are based on CO_2-equivalents (CO_2-e), covering all Kyoto gases. These scenarios were not intended to represent any specific bill, and no domestic or international offsets are allowed. Domestic emissions (excluding offsets) under H.R. 2454 would fall between the 203 and 287 $GtCO_2$e cases.



287 $GtCO_2$-e



203 $GtCO_2$-e



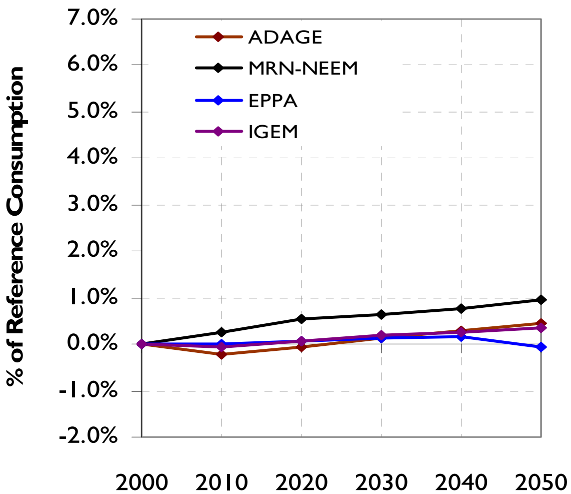
167 $GtCO_2$-e

- 287 bmt CO_2-e: ADAGE, IGEM and EPPA predict a similar rise in allowance prices. The cost of allowances rises from approximately $4-$6 per ton in 2020 to $20-$25 in 2050, however MiniCAM predicts only a small increase in allowance prices ($1 to $5), while NEEM predicts allowance prices will rise from $20 in 2020 to nearly $90 in 2050.
- 203 bmt CO_2-e: All models predict similar allowances prices in 2020 ($25-$70 per ton), but predict different growth rates resulting in a relatively wide range of allowance prices ($90 to $180; NEEM over $300) in 2050 .
- 167 bmt CO_2-e: All models predict relatively similar allowances prices in 2020 ($55-$115 per ton), but predict different growth rates resulting in a relatively wide range of allowance prices ($230 to $485) in 2050

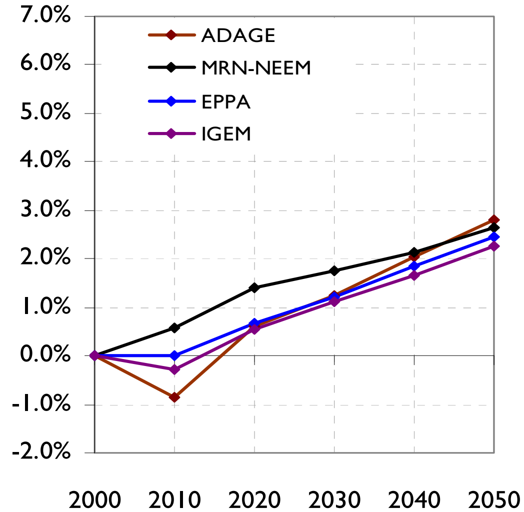
Comparing Costs of Three Possible U.S. Emissions Targets through 2050

Changes in consumption approximate changes in consumer welfare

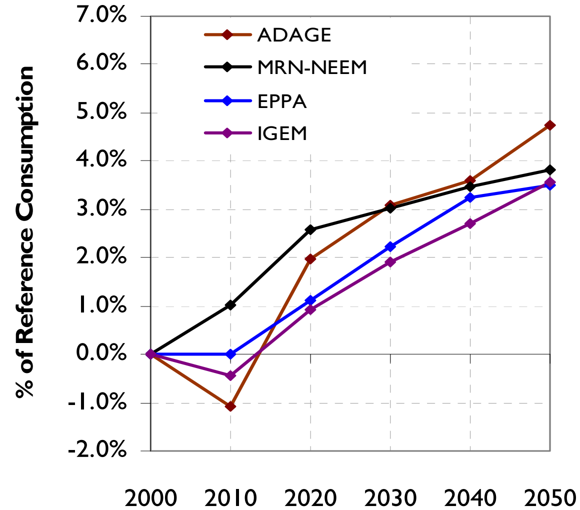
Annual Consumption Losses across Scenarios



287 bmt CO_2-e



203 bmt CO_2-e



167 bmt CO_2-e

- 287 bmt CO_2-e: Annual consumption losses remain below 1% for all models through 2050.
- 203 bmt CO_2-e: Annual consumption losses are all 1.4% or below in 2020 and rise to between 2.25% to 2.8% in 2050.
- 167 bmt CO_2-e: Annual consumption losses are between 1% and 2.6% in 2020 and rise to between 3.5% to 4.75% in 2050.

Comparing Costs of Three Possible U.S. Emissions Targets through 2050

- **Different Models, Different Baselines and Assumptions**

	EPA	MIT	CRA	EPRI	PNNL
Model	ADAGE,IGEM	EPPA	MRN-NEEM	MERGE	MiniCAM
Baseline	AEO 2008 Early Release*	AEO 2009 Early Release	AEO 2008 Early Release	Own baseline	Own baseline
Nuclear Assumptions	Capacity grows at 150% 2005 levels	Not permitted to expand in the base case (Advanced Nuclear available in 2020)	Capacity limited but growing over time (3 GW in 2015; 100 GW in 2050)	New capacity in 2020: capacity limited but growing over time subject to uranium supply constraints	Soft constraints in 2020; after 2020 allowed to grow unconstrained (Advanced nuclear case)
CCS Assumptions	Available in 2020	Available in 2020	Available in 2015 but with capacity limits	Available in 2020; allowed to triple each decade	Available in 2020

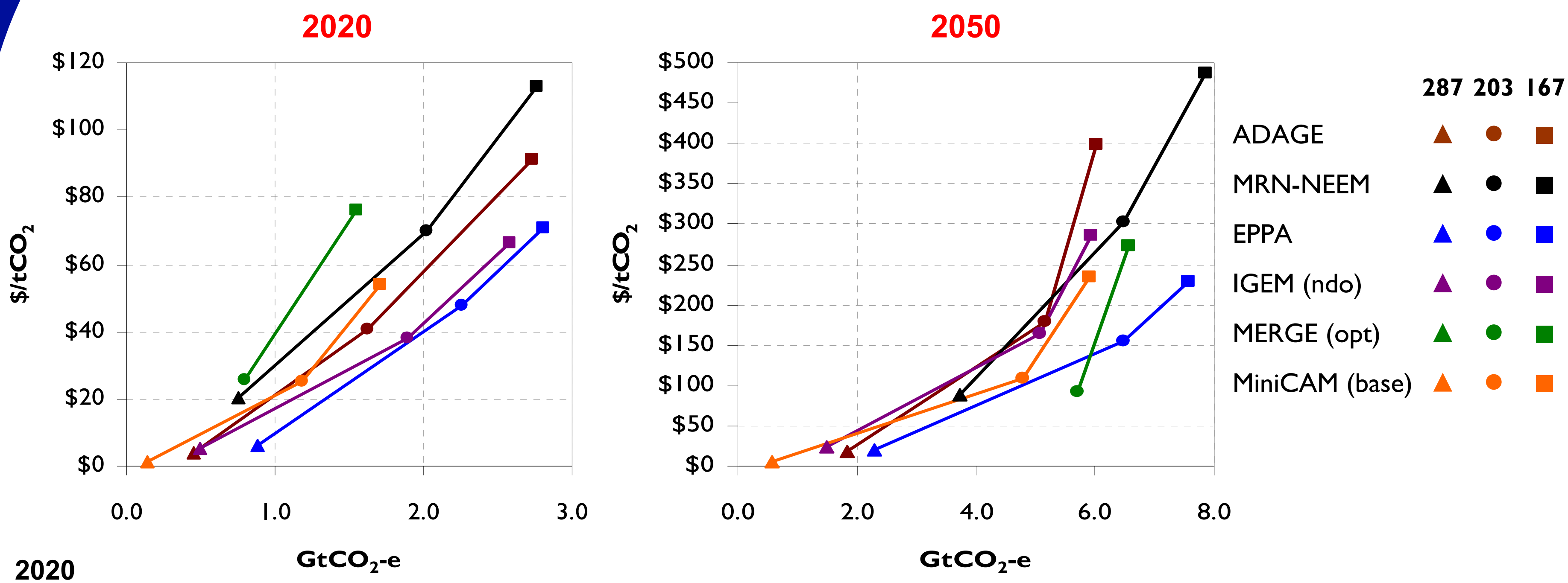
*** AEO 2008 Early release was used by the EPA models for EMF-22. The baseline in EPA's H.R. 2454 analysis is AEO 2009 (March release).**

Common messages from the models

- The majority of the cost-effective reductions come from the electricity sector.
- Greater expansion in nuclear power reduces the costs
- CCS is an important enabling technology

Comparing Costs of Three Possible U.S. Emissions Targets through 2050

Marginal Abatement Cost Functions (MACs) in 2020 and 2050



2020

- All models, except MERGE, require abatement of less than 1 $GtCO_2$-e to reach 287 bmt – MACs range from $1-$6, except for NEEM, which reaches $20
- All models require abatement between 0.8-2.25 GtCO2-e to reach the 203 bmt – MACs range from $25-$70
- All models, except MERGE and MiniCAM, require abatement between 1.55-2.8 GtCO2-e to reach 167 bmt – MACs range from $55-$113

2050

- All models, except MERGE, require abatement between 0.6-3.75 GtCO2-e to reach 287 bmt – MACs range from $5-$25, except NEEM which reaches $90
- All models require abatement between 4.8-6.5 GtCO2-e to reach 203 bmt – MACs range from $90-$180, except NEEM, which reaches $300
- All models require 6-8 GtCO2-e to reach 167 bmt – MACs range from $230-$485.

Household Distributional Issues

- There is relatively little analysis in the economics literature on how benefits from a domestic GHG or carbon cap-and-trade policy are distributed across U.S. households. There are more analyses of the distribution of the costs associated with a cap-and-trade policy.
  - These studies' findings are briefly summarized here (Fullerton, forthcoming; Parry 2004; Dinan and Lim Rogers 2002; Rose and Oladosu 2002).
- A cap-and-trade policy increases the price of energy-intensive goods. The majority of this price increase is ultimately passed onto consumers.
- Before accounting for the way in which allowances are allocated or revenues are redistributed, lower income households are disproportionally affected by a GHG cap-and-trade policy because they spend a higher fraction of their incomes on energy-intensive goods.
- The way in which allowances are allocated (auctioned or given away) and how any revenues collected are utilized affects the distribution of costs across households.
- Freely distributed allowances to firms tends to be very regressive.
  - Higher income households may actually gain at the expense of lower income households under this policy. This is because the asset value of the allowances flow to households in the form of increased stock values or capital gains, which are concentrated in higher-income households.
  - The government would collect some additional revenue via a tax on profits; the stringency of the profit tax and the use of this revenue may have distributional effects. For instance, lump sum distribution of revenues makes the policy look less regressive than lowering of payroll or corporate taxes.
- If allowances are auctioned, revenues can be used to influence the regressivity of the policy.
  - Revenues can be redistributed in the form of lower payroll or corporate taxes. These options tend to look less regressive when paired with auctioned allowances then when combined with free allocation but more regressive than equal lump-sum rebates to households.
  - Auctioned allowances with lump-sum distribution of revenues to households is the least regressive cap-and-trade policy analyzed and has been shown to be progressive in some cases.
- Returning the allowance value to consumers of electricity via local distribution companies in a non-lump sum fashion prevents electricity prices from rising but makes the cap-and-trade policy more costly overall.
  - This form of redistribution makes the cap-and-trade more costly since greater emission reductions have to be achieved by other sectors of the economy.
  - Resulting changes in prices of other energy-intensive goods also influence the overall distributional impacts of the policy.

Household Distributional Issues

- As way of illustration, Metcalf (2007) examines the distributional implications of a \$15/ton CO_2 tax.
  - This is equivalent to a cap-and-trade policy with full auctioning.
  - This price is roughly equivalent to what is predicted to occur in this EPA analysis under Waxman-Markey in 2015.
- Metcalf's main case redistributes the revenue via an earned income tax credit
  - The tax credit is equal to total (employer and employee) payroll taxes paid in the current year, up to a maximum of \$560.
  - This is equivalent to exempting the first \$3,660 of wages per covered worker.
- Before the tax credit, the policy is regressive. After accounting for the tax credit, the policy is progressive.
- Metcalf also illustrates how the distributional impacts may change if the revenue is redistributed in others ways.
  - Including social security lowers the maximum tax credit available to \$420 and makes the policy more progressive. A per capita lump sum rebate of \$274 further increases progressivity relative to an earned income tax credit.

	\$15/ton Tax		**Earned Income**		**Earned Income and Social Security**		**Lump Sum**	
Income group (decile)	Net (\$)	Net (%)	Net (\$)	Net (%)	Net (\$)	Net (%)	Net (\$)	Net (%)
1 (lowest)	-\$276	-3.4	-\$68	-0.7	\$112	1.4	\$166	2.1
2	-\$404	-3.1	-\$120	-1	\$125	1.0	\$128	1.0
3	-\$485	-2.4	-\$57	-0.2	\$114	0.6	\$120	0.6
4	-\$551	-2	\$6	0.1	\$70	0.3	\$103	0.4
5	-\$642	-1.8	\$26	0.1	\$54	0.1	\$108	0.3
6	-\$691	-1.5	\$115	0.3	\$66	0.1	\$26	0.1
7	-\$781	-1.4	\$135	0.2	\$35	0.1	-\$32	-0.1
8	-\$883	-1.2	\$99	0.2	-\$61	-0.1	-\$52	-0.1
9	-\$965	-1.1	\$70	0	-\$95	-0.1	-\$171	-0.2
10 (highest)	-\$1,224	-0.8	-\$130	0	-\$332	-0.2	-\$355	-0.2

* Metcalf uses 2003 Consumer Expenditure Survey data and assumes payroll tax rules from 2005.

Household Distributional Issues

- Recent, but still unpublished, studies have explored regional differences in the distributional effects of many allowance allocation and revenue distribution options for a carbon cap-and-trade policy (Burtraw et al. 2009, Hassett et al. 2007).
  - Regional differences result from differences in pre-existing policies, consumption levels, pricing of electricity, and the inputs used to produce energy goods (e.g. coal, natural gas).
  - For instance, a cap-and- (taxable) dividend policy that results in a \$20.87/metric ton CO_2 price is estimated to result in an average welfare gain of 3.6% for the 20% poorest households. However, regionally, this varies from 1.9% to 5.4%.
- Most of these studies use annual household expenditures as a proxy for income. When a wealth measure is used instead, the distributional difference between low and high income households is less pronounced (Dinan and Lim Rogers 2002; CBO 2003).
  - However, lower income households are still disproportionately impacted relative to higher income households.
- These analyses do not consider how expenditure patterns and demand for energy goods may change over time as a result of the policy. Furthermore, they do not always consider the effect of the policy on the prices of non-energy goods.
- Providing lump-sum compensation to households – or other economic entities – has an opportunity cost in the form of foregone efficiency gains.
  - The government cannot use the revenue to reduce other distortions in the economy, which would reduce the overall cost of the cap-and-trade policy (Fullerton forthcoming; CBO 2003).

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U.S. Environmental Protection Agency
Office of Atmospheric Programs

EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the *111th Congress*

Appendix

6/23/09

Appendix 1: Bill Summary, Modeling Approach and Limitations

H.R. 2454 – Bill Summary
Title I

- *Title I – Clean Energy*
  - *Subtitle A* - Combined Efficiency and Renewable Electricity Standard
    - Sec. 101 requires utilities that sell more than 4 million megawatt hours of electricity to consumers to meet a certain percentage (6% in 2012 rising to 20% in 2020) of their load electricity generated from renewable resources and energy savings. Up to one quarter (or two-fifths upon petition) of the requirement can be met with energy savings.
      - This provision is modeled in IPM. In ADAGE, the energy savings portion of the RES is modeled, but not the renewable electricity portion. IGEM does not model this provision.
  - *Subtitle B* - Carbon Capture and Sequestration
    - Sec. 114 creates a Carbon Capture and Sequestration (CCS) demonstration early deployment program.
      - This provision is modeled in IPM, but not in ADAGE or IGEM.
    - Sec. 115 promotes the commercial deployment of CCS technologies through a bonus allowance program.
      - This provision in modeled in ADAGE, IGEM, and IPM.
  - *Subtitle C* - Clean Transportation
  - *Subtitle D* - State Energy and Environmental Deployment Accounts
    - Sec. 131 establishes SEED Accounts to serve as a state-level repository for managing and accounting for all emissions allowances designated primarily for renewable energy and energy efficiency purposes.
    - Sec. 132 distributes emission allowances among states for energy efficiency and renewable energy deployment and manufacturing support.
      - The energy efficiency portions of Sec 131 and 132 are modeled in ADAGE and IPM, but not in IGEM.
  - *Subtitle E* - Smart Grid Advancement
  - *Subtitle F* - Transmission Planning
  - *Subtitle G* - Technical Corrections to Energy Laws
  - *Subtitle H* - Energy and Efficiency Centers
  - *Subtitle I* - Nuclear and Advanced Technologies
  - *Subtitle J* - Miscellaneous

- Title I, Subtitles C, E, F, G, H, I, and J are not modeled in this analysis.

H.R. 2454 – Bill Summary
Title II

- *Title II – Energy Efficiency*
  – *Subtitle A* - Building Energy Efficiency Programs
    - Sec. 201 establishes energy efficiency targets of 30% reduction below 2006 IECC by enactment, 50% reductions by Jan 1, 2014 (residential) and 2015 (commercial) and increasing 5% every three years thereafter until 2029 (residential) and (commercial)
      - This provision is modeled in ADAGE. IGEM does not model this provision.
    - Sec. 202 establishes the Retrofit for Energy and Environmental Performance (REEP) program for residential buildings, and another for commercial, funded by allowances, to provide loans certification, and other support
      - This provision is modeled in ADAGE. IGEM does not model this provision.
    - Sec 203 assistance for homeowners living in manufactured homes built before 1976 to purchase new energy efficient manufactured homes
      - This provision is modeled in ADAGE. IGEM does not model this provision.
    - Sec 204 creates a building energy performance labeling program
      - This provision is modeled in ADAGE. IGEM does not model this provision.
  – *Subtitle B* - Lighting and Appliance Energy Efficiency Programs
  – *Subtitle C* - Transportation Efficiency
  – *Subtitle D* - Industrial Energy Efficiency Programs
  – *Subtitle E* - Improvements in Energy Savings Performance Contracting
  – *Subtitle F* - Public Institutions
  – *Subtitle G* - Miscellaneous

- Title II, Subtitles B, C, D, E, F, and G are not modeled in this analysis.

H.R. 2454 – Bill Summary
Title III

- *Title III – Reducing Global Warming*
- Amends the Clean Air Act by adding "*Title VII – Global Warming Pollution Reduction Program*" that 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
    - Any stationary source (any size) in 13 special sectors incl. adipic acid, primary aluminum, ammonia, cement, HFCs, lime, nitric acid, petroleum refining, phosphoric acid, silica carbide, soda ash, titanium dioxide, coal-based liquids or gaseous fuels.
    - 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 2008 *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: 4,627 $MtCO_2e$ (3% below 2005 emissions levels for covered sectors)
    - 2020: 5,056 $MtCO_2e$ (17% 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)

H.R. 2454 – 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 international offsets to submit 1.25 tons of offsets credits for each ton of emissions being offset after the first five years.
  - 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

* See appendix 2 for a discussion of how the pro rata sharing specified in Sec 722 (d) alters these limits.

H.R. 2454 – 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 100 percent of the direct and indirect cost of allowances to eligible industries
      - Gradually phases out between 2025 and 2035.
    - 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

H.R. 2454 – Bill Summary
Allowance Allocations

- Sec. 782 includes the following allocation of allowances, which were modeled in IGEM:
  - Electricity consumers: 43.75% in 2012, declining to 7% by 2029
  - Natural gas consumers: 9% beginning in 2016, declining to 1.8% in 2029
  - Heating oil and propane consumers: 1.875% in 2012, declining to 0.3% in 2029
  - CCS Bonus Allowances: 2% from 2014-2017; 5% from 2018-2050
  - International Forest Carbon: 5% through 2025, 3% through 2030, 2% through 2050
  - Energy Efficiency: 9.5% from 2012-2015, declining to 4.5% from 2026-2050
  - Clean vehicle technology: 3% from 2012-2017, 1% from 2018-2025
  - Domestic refiners: 2% from 2014-2026
  - International adaptation: 1% from 2012-2021, rising to 4% from 2027-2050
  - International clean technology deployment: 1% from 2012-2021, rising to 4% from 2027-2050
  - Output-Based Rebate: 15% through 2025, declines thereafter at 10% per year to phase out by 2035.
  - Necessary allowances for deficit neutrality
  - Remaining allowance value is recycled to households lump sum

- Sec 782 also includes the following allocations, not modeled in IGEM:
  - Low-income consumers: 15% from 2012-2050 (auctioned with revenue returned through Title IV C)
  - Trade-vulnerable industries: 2% in 2012, 2013, 15% in 2014, declining through 2050
  - Clean energy innovation centers: 1% from 2012-2050
  - investment in workers: 0.5% from 2012- 2021, 1% from 2022-2050
  - Domestic adaptation: 0.9% from 2012-2021, rising to 3.9% through 2050
  - Climate change health protection and promotion fund: 0.1% from 2012-2050
  - Wildlife and natural resource adaptation: 1% from 2012-2021, rising to 4% from 2027-2050

Analytical Scenarios

EPA analyzed 7 different scenarios in this report. 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 AEO 2009 forecast (March release) and includes EISA but not ARRA.
     - Does not include any additional domestic or international climate policies or measures to reduce international GHG emissions
     - For domestic projections, benchmarked to AEO 2009 (March release) without the American Recovery and Reinvestment Act of 2009 (ARRA).
     - Does not include the recently announced federal greenhouse gas and fuel economy program for passenger cars, light-duty trucks, and medium-duty passenger vehicles.
     - For international projections, used CCSP Synthesis and Assessment Report 2.1 A MiniCAM Reference.
2) **H.R. 2454 Scenario**
   - This core policy scenario models the cap-and-trade program established in Title III of H.R. 2454.
     - The strategic allowance reserve is not modeled (i.e., these allowances are assumed to be available for use and not held in reserve).
   - Provisions explicitly modeled in this scenario:
     - CCS bonus allowances
     - EE provisions (allowance allocations, building energy efficiency codes, and energy savings component of CERES (or RES)).
     - Output-based rebates (Inslee-Doyle)
     - Allocations to electricity local distribution companies (LDCs) (used to lower electricity prices)
   - 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) H.R. 2454 Scenario without Energy Efficiency Provisions

- Removes the energy efficiency provisions included in scenario 2 (allowance allocations, building energy efficiency codes, and energy efficiency standard component of CERES).

4) H.R. 2454 Scenario without Output-Based Allocations

- Removes the output-based allocations specified in *Title IV – Subtitle A – Part 1 Preserving Domestic Competitiveness,* which is similar to H.R. 7146 (Inslee / Doyle).

5) H.R. 2454 Scenario with Reference Nuclear

- Holds nuclear electricity generation to reference case levels.

6) H.R. 2454 Scenario without Output-Based Allocations or Energy Efficiency Provisions

- Removes the energy efficiency provisions included in scenario 2 (allowance allocations, building energy efficiency codes, and energy efficiency standard component of CERES).
- Removes the output-based allocations specified in *Title IV – Subtitle A – Part 1 Preserving Domestic Competitiveness,* which is similar to H.R. 7146 (Inslee / Doyle).
- Comparable to scenario 2 in EPA's analysis of the Waxman-Markey discussion draft.

7) H.R. 2454 Scenario without International Offsets

- International offsets are not allowed.

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 H.R. 2454 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 H.R. 2454.
- 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 21^{st} 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 H.R. 2454 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 H.R. 2454 (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 H.R. 2454, 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 H.R. 2454.
  - 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 cannot 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: Additional Information on Offsets Usage & Limits

Domestic Offsets & International Credits Methodology Highlights

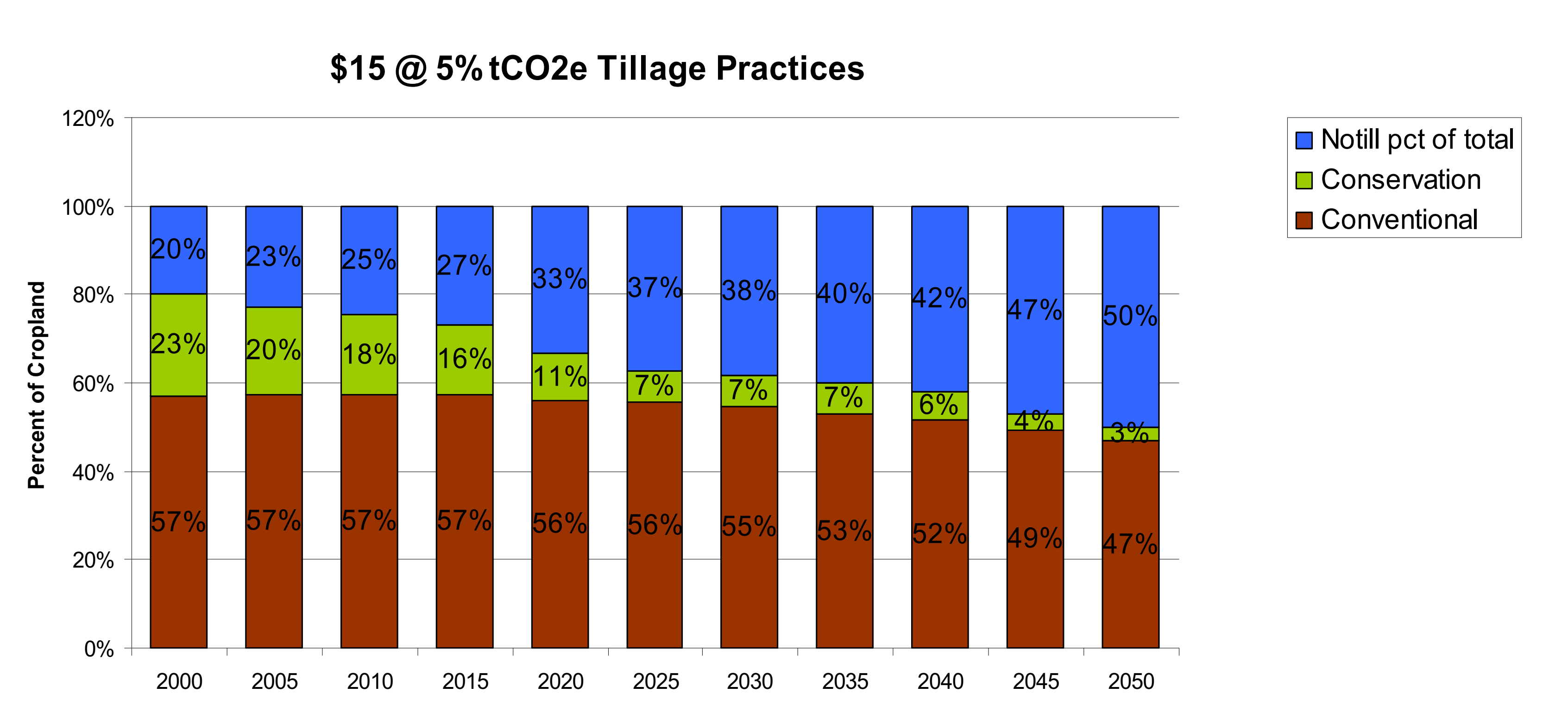
- EPA developed mitigation cost schedules for 24 offset mitigation categories, covering the following mitigation types:
  - Domestic non-CO_2 GHG emissions reductions
  - International non-CO_2 GHG emissions reductions
  - Domestic and international increases in terrestrial carbon sinks (soil and plant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

Factors Influencing Domestic Offset Supply

- The analysis of domestic forest and agriculture offsets is based on the same modeling analysis used in the April 20th analysis of the Waxman-Markey Discussion Draft.
- The modeling of domestic offsets evaluates changes in greenhouse gases against a projected baseline. If offsets are evaluated against historic or current baselines, the overall volume of offsets would increase.
- The sources of domestic offsets modeled here represent sources that have significant supply in the FASOM model at the relevant allowance prices. The exclusion of other sources in the modeling results does not imply that those sources would not be eligible to receive offsets credits.
- The FASOM modeling did not account for several categories of agricultural GHG reductions, including:
  - Improvements in organic soil management;
  - Advances in feed management of ruminants;
  - Changes in the timing, form, and method of fertilizer application; and
  - Alternative manure management systems – other than anaerobic digesters
- Because of how it is handled in the model, agricultural soil sequestration does not show significant supply. However, detailed FASOM output indicates a 50% increase in the percent of cropland using conservation-tillage and no-till by 2020 in response to a \$15/ton CO_2 incentive payment. Because overall land area in crops declines due to afforestation, the modeling indicates a net decrease in total agricultural soil carbon storage as carbon is transferred from the agricultural soils pool to the afforestation carbon pool.
- Within the model, reductions in fertilizer use result in declines in yields. To the extent fertilizer application can be improved without yield penalties, the potential for this category of emissions reductions will be higher.
- EPA is working with USDA to review the analysis of the forestry and agricultural sectors.

Increased Use of No-Till Under Increasing Carbon Prices

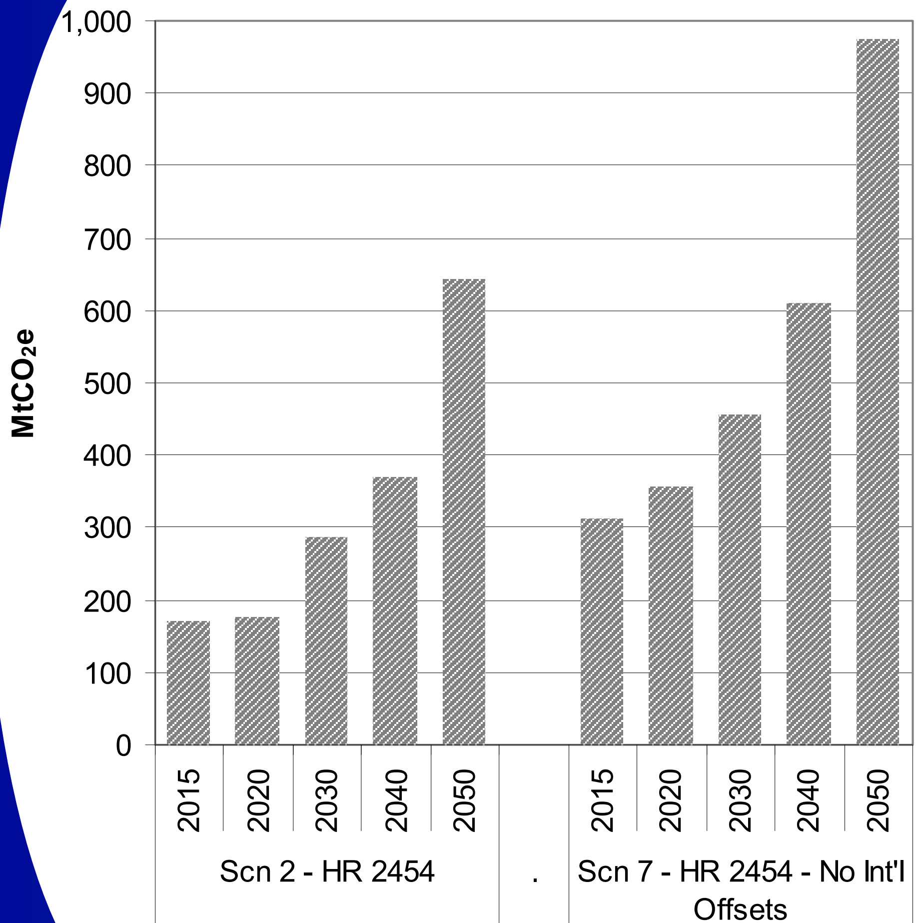
FASOM



- The above graphic represents the share of cropland under different tillage practices in one of the FASOM runs that contribute to the marginal abatement cost curves used for representing domestic offsets abatement potential. The specific run is based on an initial allowance price of \$15/tCO2e rising at five percent.
- Because of how it is handled in the model, agricultural soil sequestration does not show significant supply. However, detailed FASOM output indicates a 50% increase in the percent of cropland using conservation-tillage and no-till by 2020 in response to a \$15/ton CO2 incentive payment. Because overall land area in crops declines due to afforestation, the modeling indicates a net decrease in total agricultural soil carbon storage as carbon is transferred from the agricultural soils pool to the afforestation carbon pool.

Domestic Offsets Usage

H.R. 2454 Scenario Comparison (IGEM)



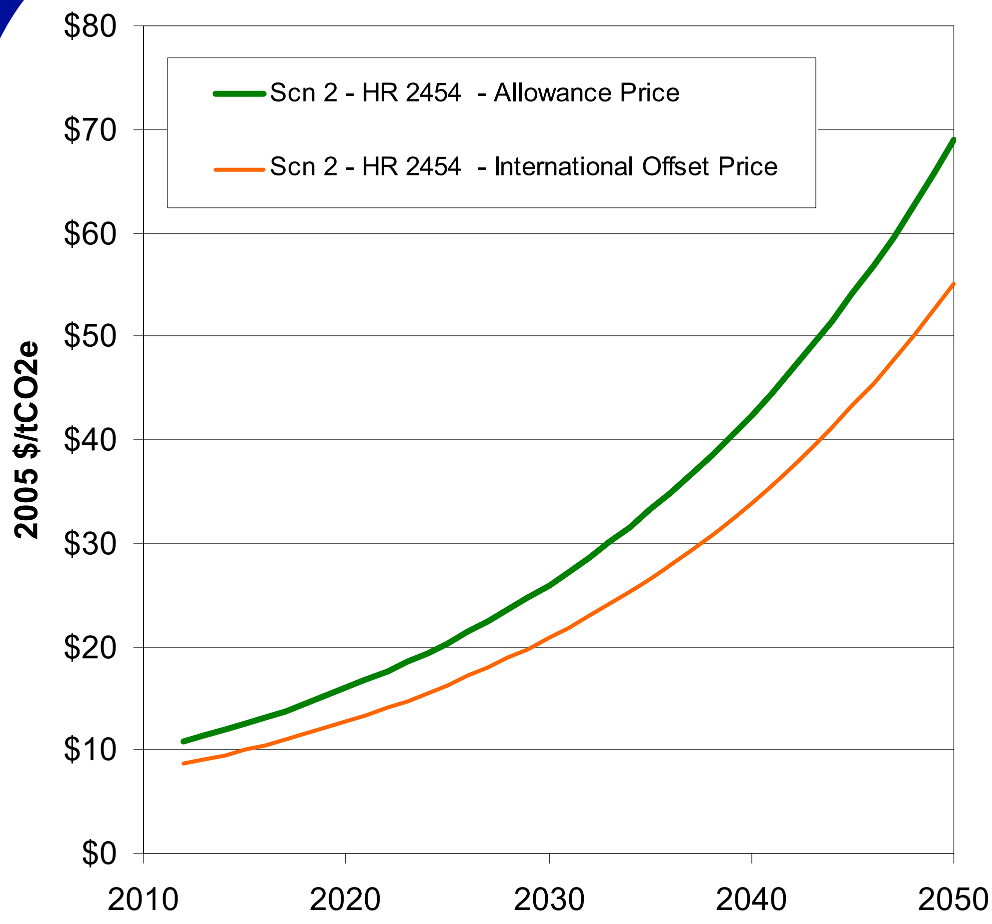
- The annual limit on the usage of domestic offsets is non-binding.
  - H.R. 2454 Sec 722 (d) (1) (A) allows covered entities to collectively use offset credits to demonstrate compliance for up to a maximum of 2 billion tons of GHG emissions annually.
  - This section also attempts to share the 2 billion tons of offsets allowed pro rata among covered entities. However, the formula specified for pro rata sharing among covered entities does not result in 2 billion tons of offsets in total.
  - H.R. 2454 Sec 722 (d) (1) (C) modifies the pro rata sharing to allow more international offsets if fewer than 0.9 GtCO2e are expected to be used.
  - See appendix 2 for a detailed discussion of the offsets provisions in H.R. 2454.
- 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.
  - EPA's previous analysis of the Waxman-Markey discussion draft showed that allowing landfill and coal mine methane as offset projects instead of covering them under NSPS would increase cumulative domestic offsets usage by 45%.
- Restricting the use of international offsets, as in "*scenario 7 – H.R. 2454 No Int'l Offsets*" has a large impact on allowance prices (89% increase relative to '*scenario 2 – H.R. 2454*').

Stationary Source Standards

- H.R. 2454 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.
- EPA's previous analysis of the Waxman-Markey discussion draft showed that allowing landfill and coal mine methane as offset projects instead of covering them under NSPS would increase cumulative domestic offsets usage by 45%.

Offset and Allowance Prices

H.R.2454 Scenario Comparison (IGEM)



- H.R.2454 limits the use of domestic and international offsets; however, in '*scenario 2 – H.R. 2454*' the limits are non-binding in all years.
- The domestic offset price is equal to the allowance price.
- International offsets are subject to a turn-in-ratio so that after the first five years 5 tons of offsets must be turned in for every 4 offsets credits received.
- The price shown here is the price before applying the turn-in-ratio. Since 1.25 allowances must be purchased for each ton of covered emissions being offset, the price to use international offsets to offset one ton of domestic emissions is equal to the product of 1.25 and the price shown here. When the limit on international offsets usage is non-binding, this product is equal to the domestic allowance price.

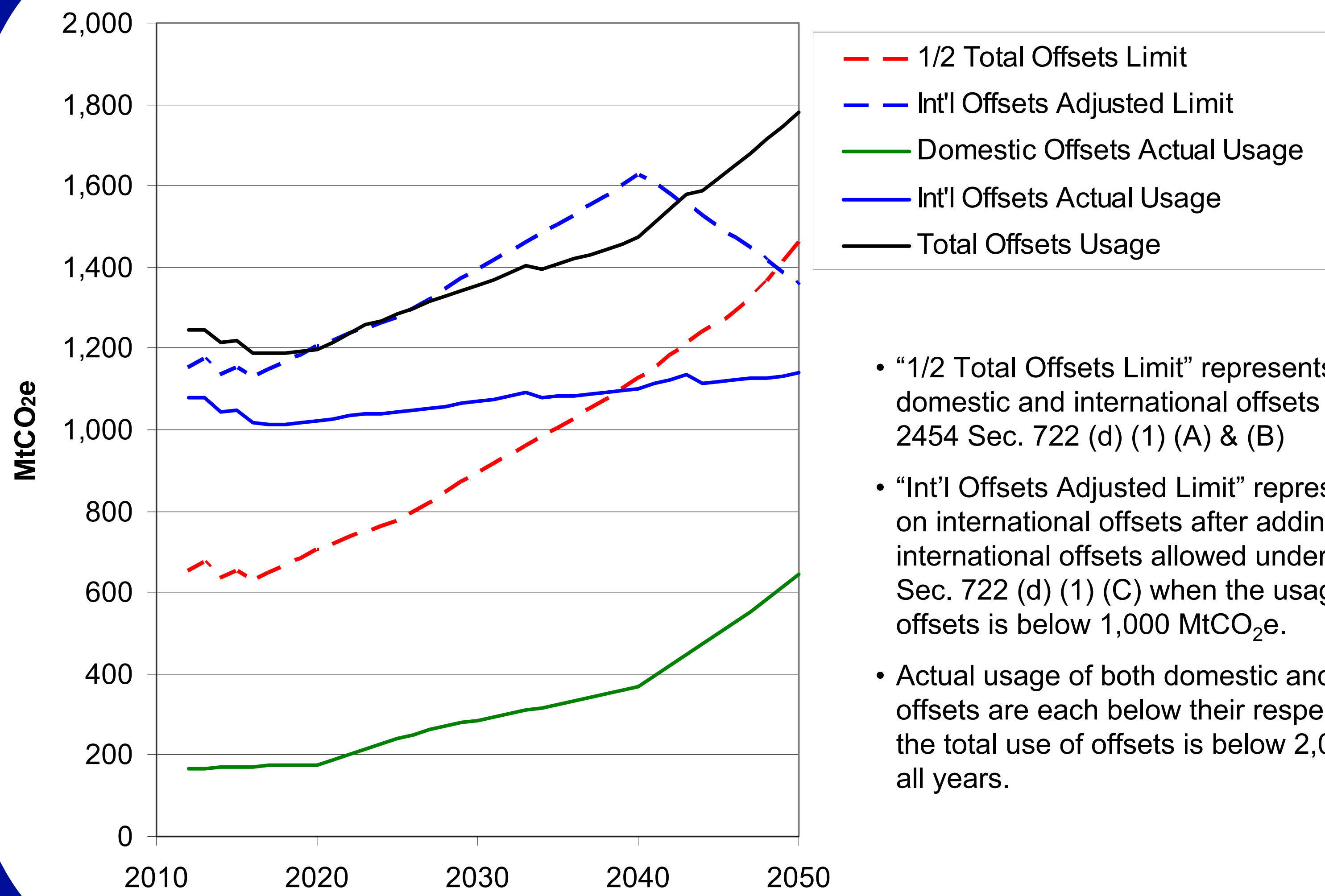
H.R. 2454 Offsets Provisions

Sec. 722 (d) (1)

- H.R. 2454 Sec 722 (d) (1) (A) allows covered entities to collectively use offset credits to demonstrate compliance for up to a maximum of 2 billion tons of GHG emissions annually.
- This section also attempts to share the 2 billion tons of offsets allowed pro rata among covered entities. However, the formula specified for pro rata sharing among covered entities does not result in 2 billion tons of offsets in total.
  - Covered entities are allowed to satisfy a specified percentage of the number of allowances required to be held for compliance with offsets credits.
  - H.R. 2454 Sec 722 (d) (1) (B) shows that for each year, the specified percentage is calculated by dividing two billion by the sum of two billion and the annual tonnage limit for that year. For example, in 2012, when the cap level is 4.627 $GtCO_2e$, the percentage would be 30.20%; and in 2050, when the cap level is 1.035 $GtCO_2e$ the percentage would be 65.90%.
  - The number of allowances required to be held for compliance is equal to the amount of covered emissions, so for any given firm the amount of offsets they are allowed to use is equal to the product of their covered emissions and the percentage specified above.
  - The total amount of offsets allowed is equal to the product of the total amount of covered emissions and the specified percentage. In order for this to be equal to the 2 billion ton limit on offsets specified above, total covered GHG emissions would have to be equal to the cap level plus 2 billion tons. There are several reasons why this is unlikely to be the case.
    - First, even if covered emissions remain at reference levels, in the early years of the policy they will not be 2 billion tons over the cap level.
    - Second, if firms bank allowances, their covered GHG emissions will be reduced, which will reduce the amount of offsets they are allowed to use.
    - Third, in the later years when firms are drawing down their bank of allowances, it is possible for covered GHG emissions to be more than 2 billion tons above the cap, which means that the pro rata sharing formula can be in conflict with the overall 2 $GtCO_2e$ limit on offsets usage. However, if the domestic limit is non-binding, then the pro-rata sharing would allow for the international limit to exceed 1 $GtCO_2e$, so long as the sum of domestic and international offsets were still below 2 $GtCO_2e$.
- H.R. 2454 Sec 722 (d) (1) (C) modifies the pro rata sharing to allow more international offsets if fewer than 0.9 $GtCO_2e$ are expected to be used.
  - In years when this provision triggers, an additional amount of international offsets are allowed equal to the lesser of: 1 $GtCO_2e$ less the actual amount of domestic offsets used; or 0.5 $GtCO_2e$.
  - This has the potential in later years to allow more than 2 $GtCO_2e$ of offsets into the system, so our interpretation is that the actual amount of extra international offsets allowed would be equal to the lesser of the amount calculated above, or 2 $GtCO_2e$ less the sum of the international offsets limit and the actual usage of domestic offsets.
  - Because the pro-rata sharing limits domestic offsets in the early years to well below 0.9 $GtCO_2e$, this provision will automatically trigger, even if the actual limit on domestic offsets were binding.

Domestic & International Offsets Usage & Limits

Scenario 2 – H.R. 2454 (IGEM)



- "1/2 Total Offsets Limit" represents the limits on domestic and international offsets based on H.R. 2454 Sec. 722 (d) (1) (A) & (B)
- "Int'l Offsets Adjusted Limit" represents the limit on international offsets after adding in the extra international offsets allowed under H.R. 2454 Sec. 722 (d) (1) (C) when the usage of domestic offsets is below 1,000 $MtCO_2e$.
- Actual usage of both domestic and international offsets are each below their respective limits, and the total use of offsets is below 2,000 $MtCO_2e$ in all years.

International Offsets Sensitivities

Side Scenarios (IGEM)

Because of the importance of international offset, several side scenarios are included here to further explore the relationship between the availability of international offsets and the price of domestic allowances. A reduced form version of the IGEM model was used for these side scenarios.

Scenario 2 – H.R. 2454

- One of the main scenarios.

Scenario 7 – H.R. 2454 with No International Offsets

- One of the main scenarios.

Scenario 7a – H.R. 2454 with Delayed International Offsets

- Side scenario.
- No international offsets are allowed in the first 10 years.

Scenario 7b – H.R. 2454 with No Extra International Offsets

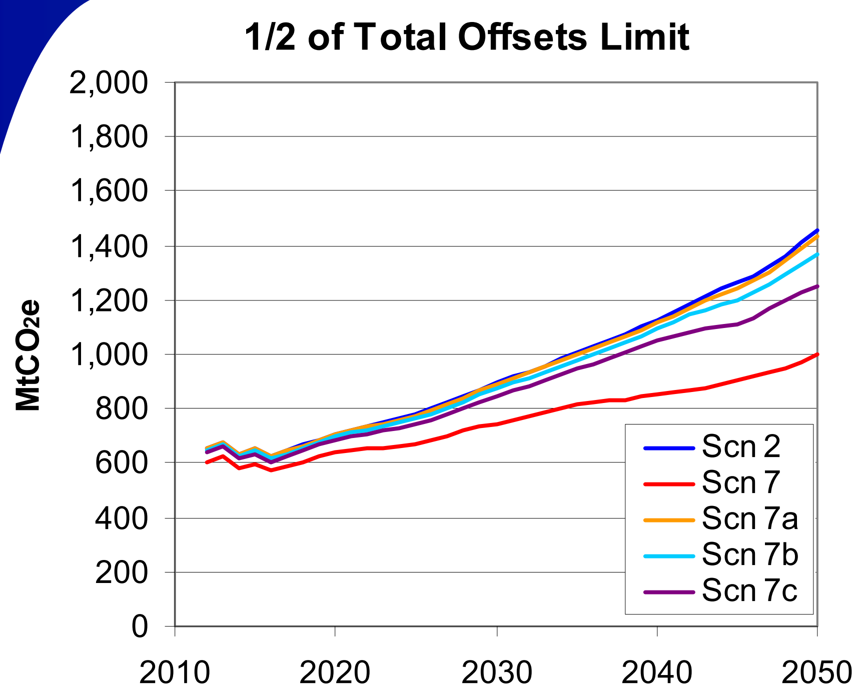
- Side scenario
- No extra international offsets from H.R. 2454 Sec 722 (d) (1) (C) when domestic offset usage is below 900 $MtCO_2e$.

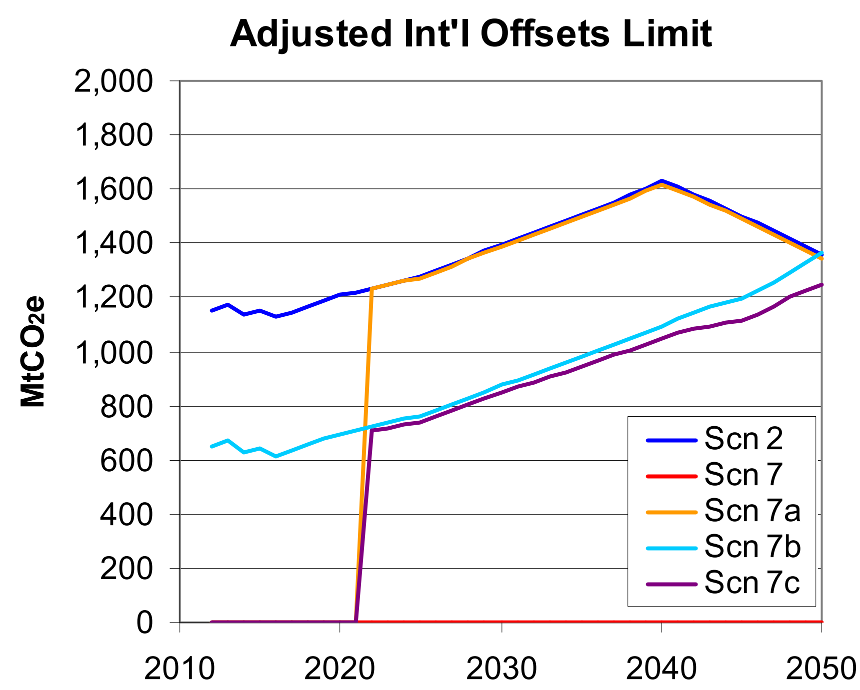
Scenario 7c – H.R. 2454 with Delayed International Offsets & No Extra International Offsets

- Side scenario
- No international offsets are allowed in the first 10 years.
- No extra international offsets from H.R. 2454 Sec 722 (d) (1) (C) when domestic offset usage is below 900 $MtCO_2e$.

International Offsets Sensitivities

International Offsets Limits (IGEM)

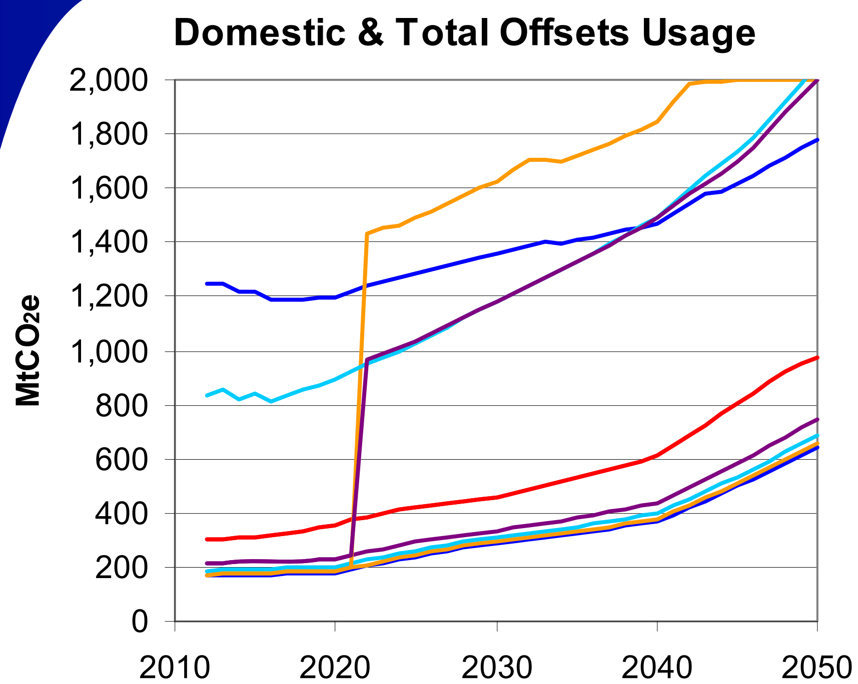


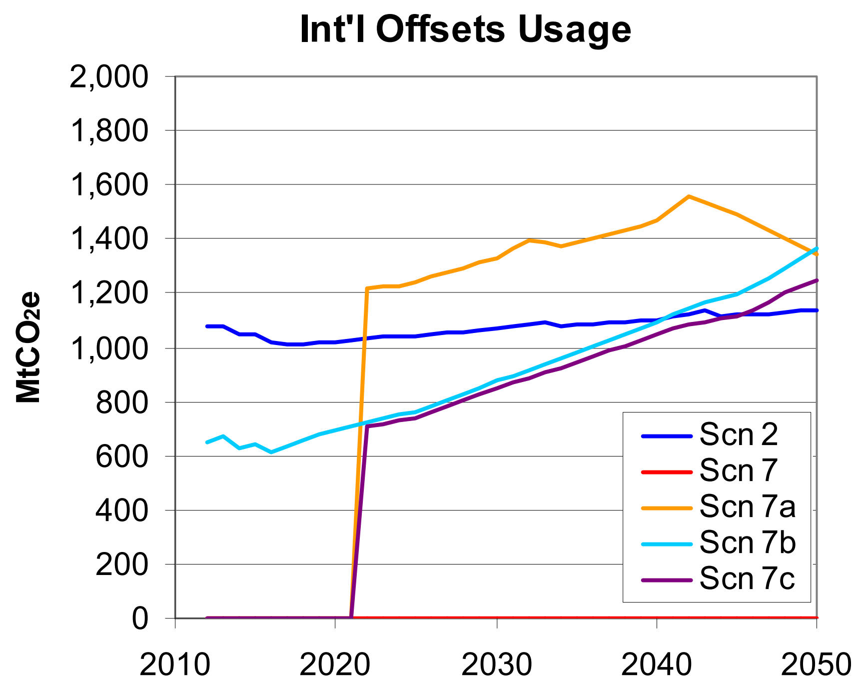


- "1/2 Total Offsets Limit" represents the limits on domestic and international offsets from H.R. 2454 Sec. 722 (d) (1) (A) & (B)
- "Int'l Offsets Adjusted Limit" represents the limit on international offsets after adding in the extra international offsets allowed under H.R. 2454 Sec. 722 (d) (1) (C) when the usage of domestic offsets is below 1,000 $MtCO_2e$.
  - Scenario 7a sets the limit on international offsets to zero for the first ten year.
  - Scenario 7b does not allow any extra international offsets from Sec. 722 (d) (1) (C).
  - Scenario 7c sets the limit on international offsets to zero for the first ten year, and does not allow any extra international offsets from Sec. 722 (d) (1) (C).

International Offsets Sensitivities

Offsets Usage (IGEM)

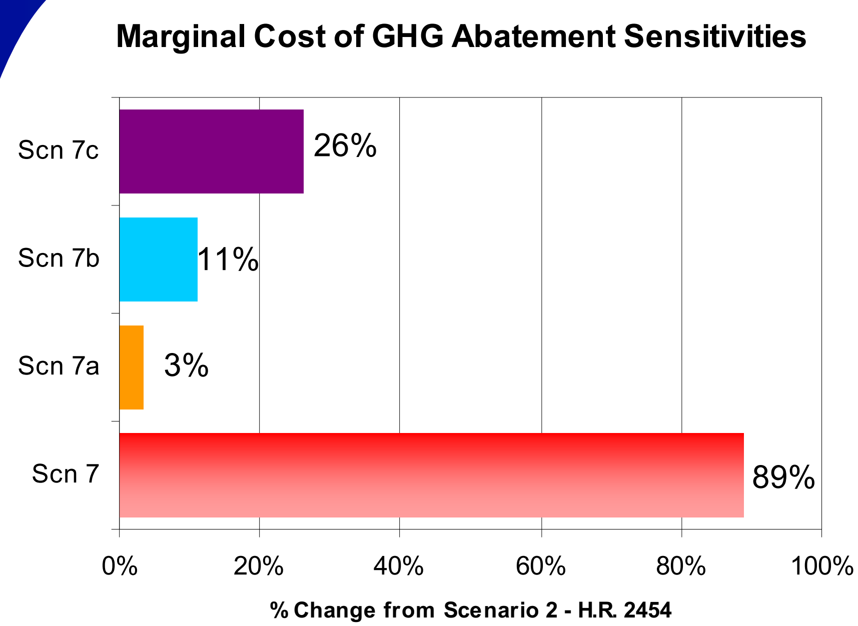


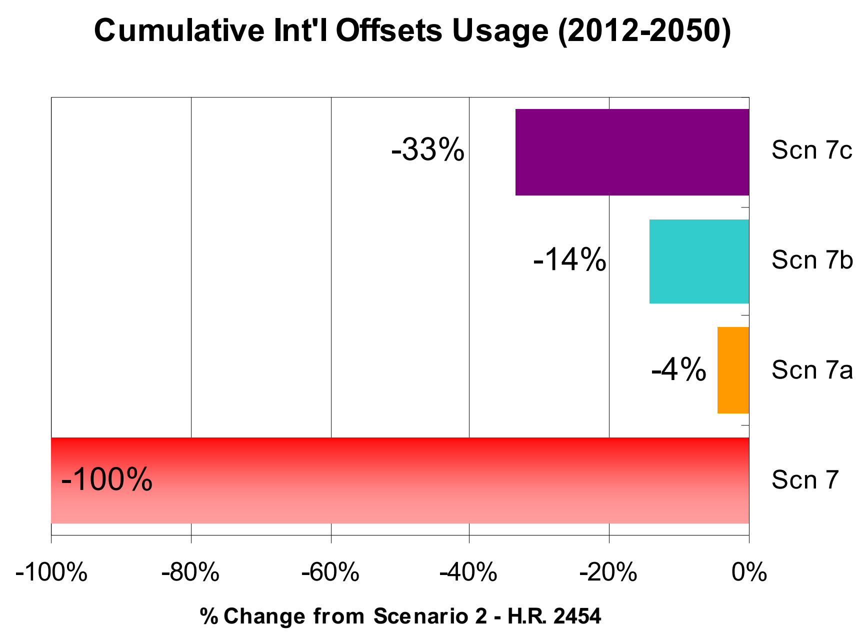


- Scenario 7a sets the limit on international offsets to zero for the first ten year.
- Scenario 7b does not allow any extra international offsets from Sec. 722 (d) (1) (C).
- Scenario 7c sets the limit on international offsets to zero for the first ten year, and does not allow any extra international offsets from Sec. 722 (d) (1) (C).

International Offsets Sensitivities

Allowance Prices & Cumulative International Offsets (IGEM)

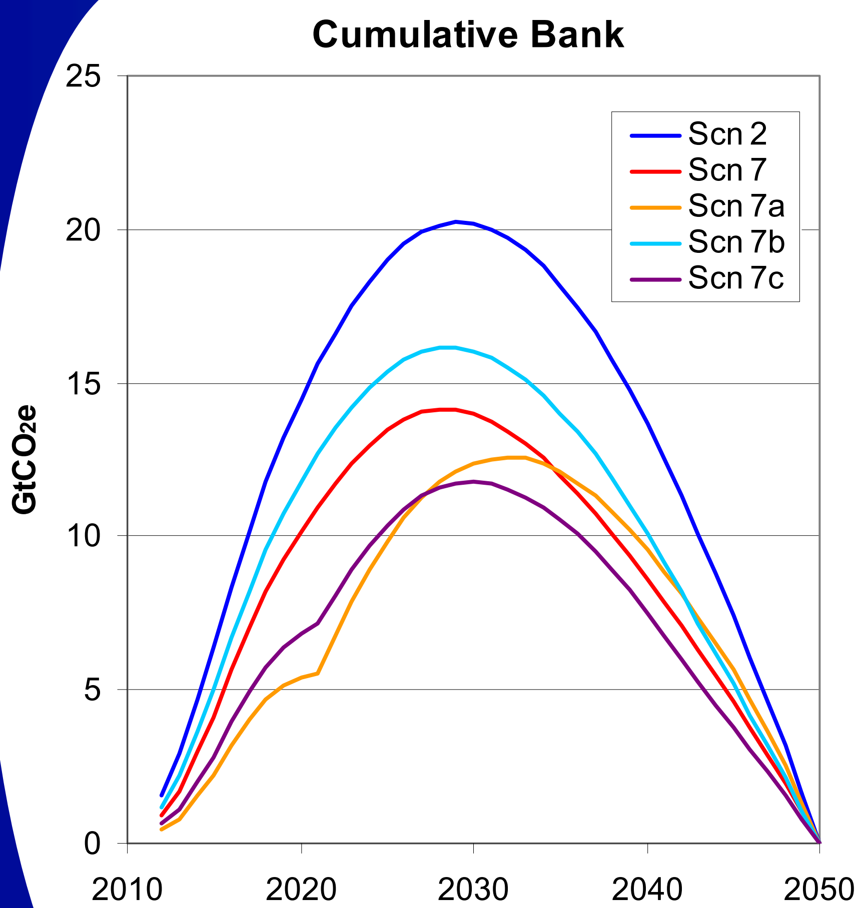




Cumulative International Offsets Usage (GtCO2e)	
Scn 2 - H.R. 2454	42
Scn 7 - H.R. 2454 - No Int'l Offsets	0
Scn 7a - H.R. 2454 - Delayed Int'l Offsets	40
Scn 7b - H.R. 2454 - No Extra Int'l Offsets	36
Scn 7c - H.R. 2454 - Delayed & No Extra Int'l Offsets	28

Cumulative GHG Allowance Bank

Scenario Comparison (IGEM)



- H.R. 2454 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, H.R. 2454 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.

Appendix 3: Modeling of Energy Efficiency Provisions

Modeling of Energy Efficiency Provisions

Provisions represented in Scenario 2 (HR 2454)

- Title I – Clean Energy
  - Subtitle A—Combined Efficiency and Renewable Electricity Standard (Sec. 101-102)
  - Subtitle D—State Energy and Environment Development Accounts (Sec. 131-132)
- Title II – Energy Efficiency
  - Subtitle A—Building Energy Efficiency Programs (Sec. 201-204)
- Title III – Reducing Global Warming Pollution
  - Subtitle B—Disposition of Allowances (Sec. 321)
    - Specifically, accounted for allocation of emission allowances for energy efficiency to
      - Natural gas consumers (Sec. 782 and 784),
      - Home heating oil and propane consumers (Sec. 782 and 785), and
      - Energy Efficiency and Renewable Energy (Sec. 782)

Provisions not represented in Scenario 2 (HR 2454)

- Title I – Clean Energy
  - Subtitle E—Smart Grid Advancement (Sec. 141-146)
  - Subtitle H—Energy and Efficiency Centers (Sec. 171-173)
- Title II – Energy Efficiency
  - Subtitle A—Building Energy Efficiency Programs (Sec. 205-206)
  - Subtitle B—Lighting and Appliance Energy Efficiency Programs (Sec. 211-219)
  - Subtitle D—Industrial Energy Efficiency Programs (Sec. 241-245)
  - Subtitle E—Improvements in Energy Savings Performance Contracting (Sec. 251)
  - Subtitle F—Public Institutions (Sec. 261-264)
  - Subtitle G—Miscellaneous (Sec. 271-274)

Modeling of Energy Efficiency Provisions

Three types of energy efficiency provisions represented

1. Building codes
2. Allowance allocations for energy efficiency programs
   - To natural gas local distribution companies
   - To states
3. Energy savings contribution to Combined Efficiency and Renewable Electricity Standard

- Estimated annual impacts (energy savings and costs) of EE provisions
- Accounted for impacts using ADAGE by adjusting energy demand and including costs

For #2 and #3, analysis based upon

- Cost of saved energy (CSE) at rate of $35/MWh (electric) and $3/mmBTU (natural gas), and average measure lives of 10 and 15 years, respectively. CSE includes "program administrator" and "participant" costs. CSE escalated at 1%/year.
- 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 (Nov. 2007)

Modeling of Energy Efficiency Provisions
Building Codes

Building Codes

- Title II – Energy Efficiency, Subtitle A—Building Energy Efficiency Programs,

  Sec. 201. Greater Energy Efficiency in Building Codes
  - Establishes targets for improvement and implementation of residential and commercial building codes to achieve 30%, 50%, and, ultimately, 75% reductions in energy use in buildings, phasing in from enactment through 2030.
  - Defines state/local compliance, establishes reporting requirements, provides allowances to states/locals to support compliance/enforcement efforts, and provides for federal enforcement under certain conditions
- Estimated energy impacts and associated economic costs
  - Used bill provisions for energy reductions, timing, and compliance
  - Used AEO 2009 forecasts of new construction in residential/commercial sectors and HUD data for residential demolitions, and AEO forecasts of building energy intensity
  - Accounted for code-affected building end-uses and applied estimated realization rates
  - Estimated costs using EIA energy price forecasts and 10-year simple payback

Modeling of Energy Efficiency Provisions
Allowance Allocations for EE Programs

Allowance Allocations for EE Programs

- Title I – Clean Energy, Subtitle D—State Energy and Environment Development Accounts (Sec. 131-132)
- Title II – Energy Efficiency, Subtitle A—Building Energy Efficiency Programs (Sec. 202-204)
- Title III – Reducing Global Warming Pollution, Subtitle B—Disposition of Allowances (Sec. 321)

- **Specifically, accounted for allocation of emission allowances for EE programs to
  - Natural gas consumers (Sec. 782 and 784)
    - 33% of total for EE w/ allowances going to natural gas LDCs
  - Home heating oil and propane consumers (Sec. 782, 785)
    - 50% of total for EE w/ allowances going to States
  - Energy Efficiency and Renewable Energy (Sec. 782)
    - 75% of total for EE w/ allowances going to States

- Estimated energy impacts using
  - Cost of saved energy (CSE) at rate of $35/MWh (electric) and $3/mmBTU (natural gas), and average measure lives of 10 and 15 years, respectively
  - CSE includes “program administrator” and “participant” costs
  - CSE escalated at 1%/year

- **<u>Note</u>: savings from these EE programs do not count towards CERES requirements

Modeling of Energy Efficiency Provisions

Combined Efficiency & Renewable Electricity Standard

Combined Efficiency & Renewable Electricity Standard (CERES)

- Title I – Clean Energy, Subtitle A—Combined Efficiency and Renewable Electricity Standard (Sec. 101-102)
  - Allows for electricity savings to meet 25% to 40% of standard
  - Savings must be achieved through measures implemented after enactment
- Accounted for electricity savings
  - Met 25% of standard using electricity savings; left standard at 20% from 2040-2050
  - Adjusted for affected entity size cutoff of 4 million MWh
  - Adjusted for exclusion from base amount of non-qualified hydro, new nuclear, and CCS
  - Adjusted for BAU energy savings from utility DSM programs
- Estimated energy impacts and associated economic costs using
  - Cost of saved energy (CSE) at rate of \$35/MWh (electric) and \$3/mmBTU (gas) and average measure lives of 10 (electric) and 15 (gas) years
  - CSE escalated at 1%/year

Modeling of Energy Efficiency Provisions Caveats

- A significant energy 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 energy demand reduction from energy efficiency provisions 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.
- While the costs of the energy efficiency programs are applied to the manufacturing and services sectors of ADAGE, 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)

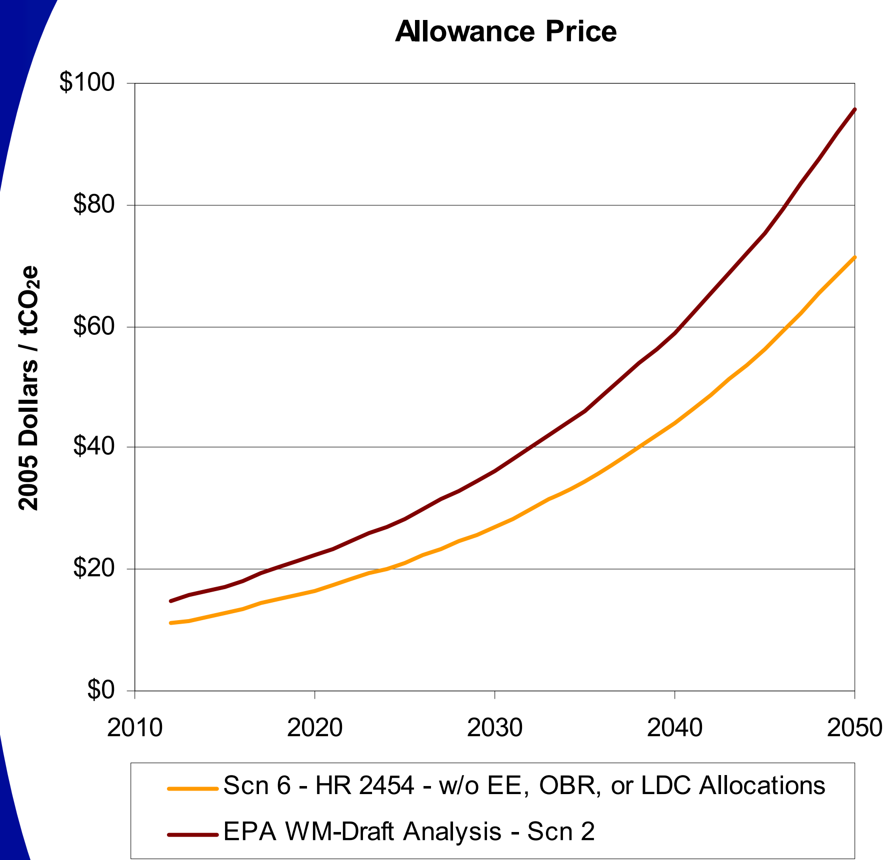
Appendix 5 Contents

- Comparison to EPA's preliminary analysis of the Waxman-Markey Discussion Draft
- Additional Economy-Wide Impacts:
  GHG Emissions & Economic Costs
- Global Results: Trade Impacts and Output-Based Rebates
- U.S. Regional Modeling Results

Comparison to EPA's preliminary analysis of the Waxman-Markey Discussion Draft

Comparison to EPA Analysis of WM-Draft

Allowance Prices (ADAGE)



	2015	2030	2050
H.R. 2454 - Scn. 6	$13	$27	$70
WM-Draft - Scn. 2	$17	$36	$96

- Because the core scenario of EPA's preliminary analysis of the Waxman-Markey discussion draft did not model the effects of specific allowance allocations, such as the output-based rebate provisions or the energy efficiency provisions, the scenario in the current analysis most comparable to the core scenario of the previous analysis is scenario 6, which does not include the output-based rebate provisions, the energy efficiency provisions, or the LDC allocations.
- The primary differences between WM-Draft as modeled in the core scenario of EPA's preliminary analysis, and H.R. 2454 as modeled here in scenario 6 are:
  - The change in the 2020 target for the cap level from 80% of 2005 covered sector emissions to 83% of 2005 covered sector emissions.
  - Allowing extra international offsets when domestic offset usage is below one billon metric tons CO_2e.*
- The allowance price is 27% lower in 'scenario 6 – H.R. 2454' compared to the allowance price in EPA's scenario 2 of EPA's analysis of the Waxman-Markey discussion draft.

* H.R. 2454 sec. 722 (d) (C)

Comparison to EPA Analysis of WM-Draft

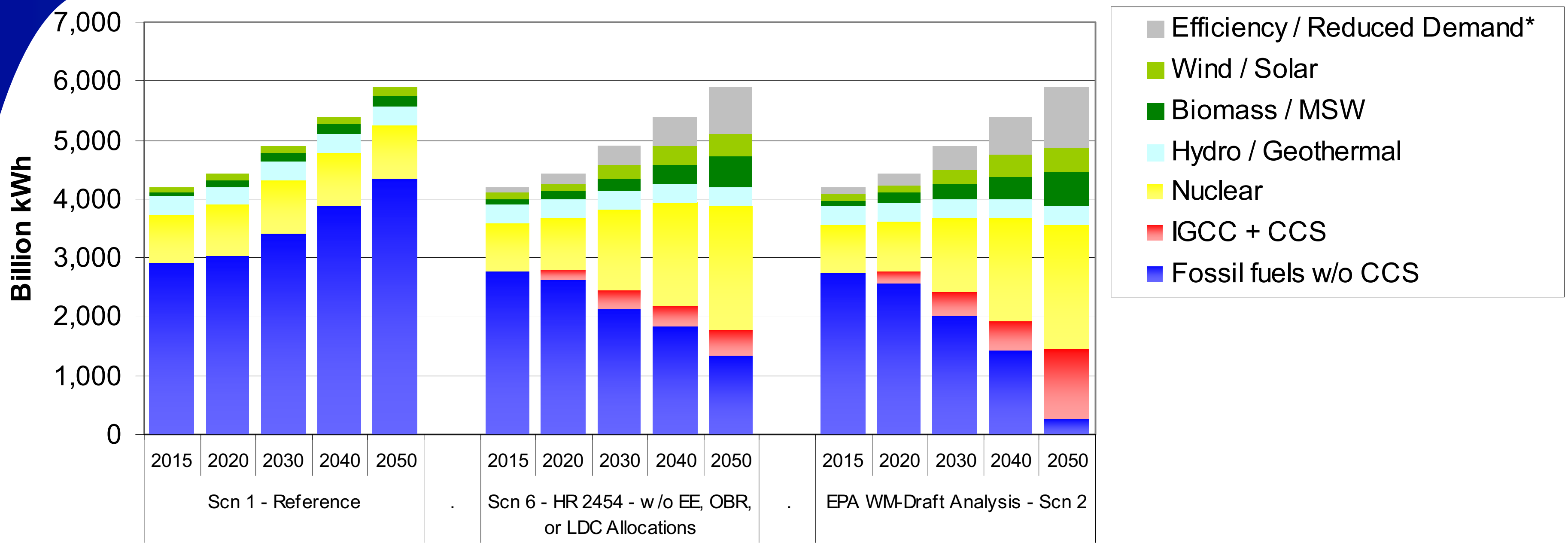
Consumption Impacts (ADAGE)

	ADAGE	2015	2020	2030	2040	2050
Scn. 1	Ref. Consumption per Household	$92,202	$99,888	$117,973	$140,233	$164,348
	% Change	-0.08%	-0.11%	-0.31%	-0.55%	-0.78%
H.R. 2454	Consumption Loss per Household	-$70	-$105	-$366	-$771	-$1,287
Scn. 6	NPV Cost per HH ($)	-$53	-$61	-$132	-$170	-$174
	Average Annual NPV cost per Household			**-$113**		
	% Change	-0.10%	-0.17%	-0.29%	-0.51%	-0.75%
WM-Draft	Consumption Loss per Household	-$90	-$172	-$347	-$714	-$1,231
Scn. 2	NPV Cost per HH ($)	-$67	-$101	-$125	-$157	-$166
	Average Annual NPV cost per Household			**-$140**		

- The average annual cost per household is the 2010 through 2050 average of the net present value of the per household consumption loss.
- The costs above include the effects of higher energy prices, price changes for other goods and services, impacts on wages and returns to capital, and importantly, the above cost estimates reflect the value of emissions allowances returned lump sum to households which offsets much of the cap-and-trade program’s effect on household consumption. The cost does not include the impacts on leisure.
- 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.

Comparison to EPA Analysis of WM-Draft

Electricity Generation (ADAGE)

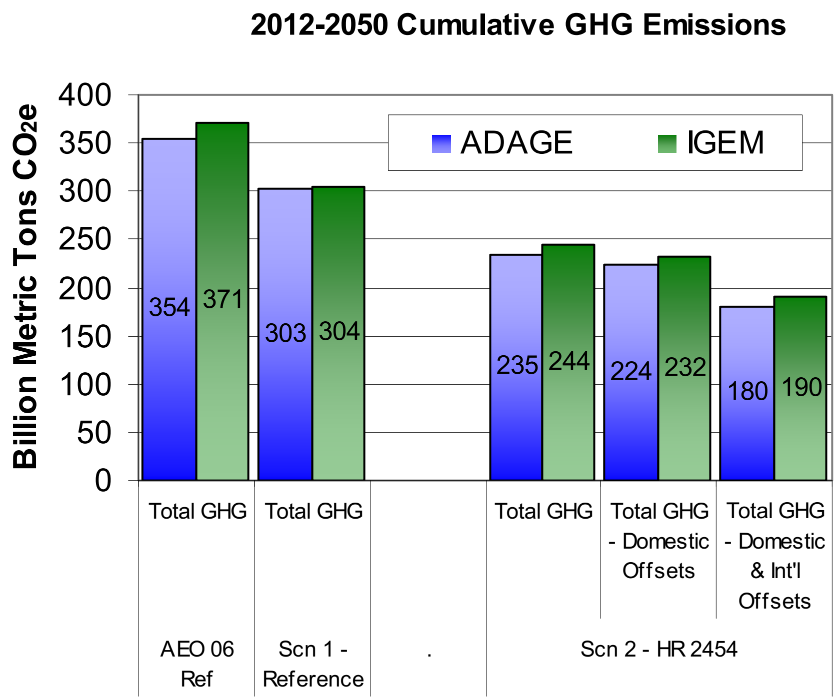


- The primary differences in the electricity generation mix between scenario 6 in the H.R. 2454 analysis and scenario 2 in the WM-Draft analysis is the amount of CCS generation. In both scenarios CCS is deployed in 2020 in response to the CCS bonus allowance provisions, and in both scenarios construction of new CCS capacity ceases after the bonus allowances run out in 2025.
- In the WM-Draft analysis, the allowance price in 2040 rose high enough that additional CCS capacity was projected to be installed, and by 2050 the projection was for 162 GW of total CCS capacity.
- In the H.R. 2454 analysis, the allowance price in scenario 6 is projected to be 27% lower than in the WM-Draft analysis, and thus after the CCS bonus allowances are exhausted, additional CCS capacity is not installed until 2045, and by 2050 total installed CCS capacity is projected to be 62 GW.

Additional Economy-Wide Impacts: GHG Emissions & Economic Costs

2012 – 2050 Cumulative GHG Emissions

Scenario 1 - Reference & Scenario 2 – H.R. 2454



- Discounted offsets would provide an additional 9 to 10 $GtCO_2e$ of cumulative abatement in IGEM and ADAGE respectively.
- International forestry set-asides would provide an additional 6 $GtCO_2e$ of cumulative abatement in IGEM and ADAGE respectively.
- New source performance standards (NSPS) for CH_4 are estimated to provide an additional 5 $GtCO_2e$ of cumulative abatement.*
- The separate cap for HFC's is estimated to provided an additional 19 $GtCO_2e$ of cumulative abatement.*
- Cumulative emissions net of offsets, and all abatement described above is 141 and 150 $GtCO_2e$ in ADAGE and IGEM respectively.
- 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.

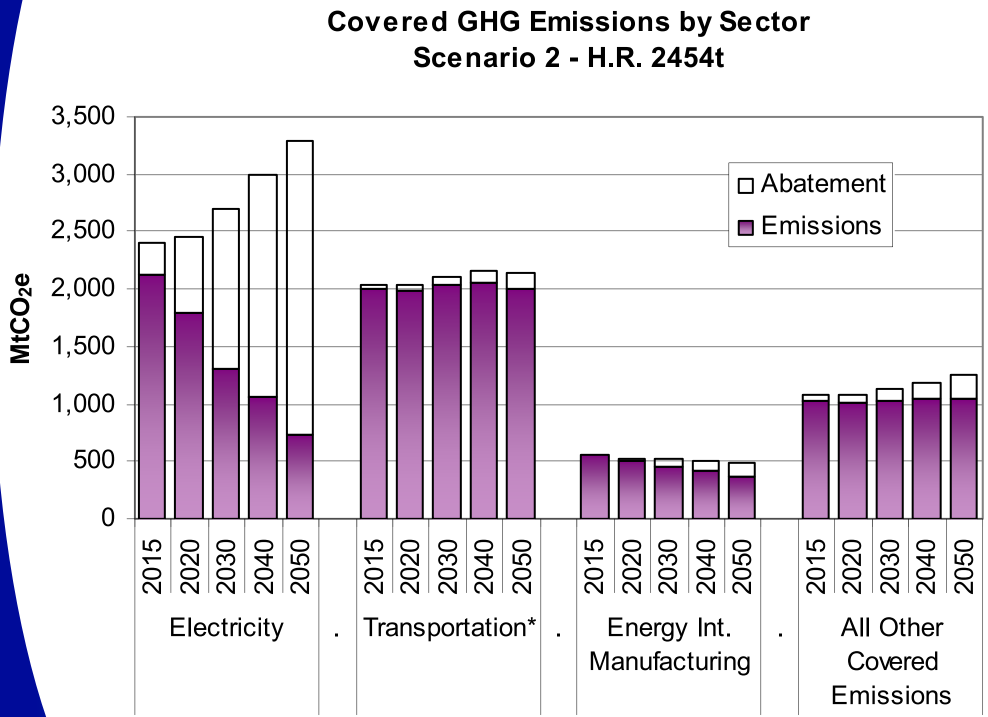
% Reduction from Scenario 1 - Reference

	ADAGE	IGEM
Total GHG Emissions	-22%	-20%
Total GHG Emissions - Domestic Offsets (sinks)	-26%	-24%
Total GHG Emissions - Domestic Offsets - International Offsets	-40%	-37%

Total US GHG Emissions & Sources of Abatement

Scenario 1 - Reference & Scenario 2 – H.R. 2454 (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 ($0.13 in 2015, $0.25 in 2030, and $0.69 in 2050 under Scenario 2 – H.R. 2454) 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.

Consumption

Scenario 1 – Reference & Scenario 2 – H.R. 2454

ADAGE	2015	2020	2030	2040	2050
Ref. Total C (Billion 2005 $)	$11,575	$13,168	$17,079	$21,655	$26,752
Change in Total C (Billion 2005 $)	-$9	-$14	-$53	-$119	-$209
Ref. Consumption per Household	$92,202	$99,888	$117,973	$140,233	$164,348
% Change (Scn. 2)	-0.08%	-0.11%	-0.31%	-0.55%	-0.78%
Consumption Loss per Household ($)	-$70	-$105	-$366	-$771	-$1,287
NPV Cost per HH ($)	-$53	-$61	-$132	-$170	-$174

Average Annual NPV cost per Household	**-$111**
Total NPV Cost per Household (2010-2050)	**-$4,564**

IGEM	2015	2020	2030	2040	2050
Ref. Total C (Billion 2005 $)	$9,705	$10,990	$13,962	$17,567	$21,642
Change in Total C (Billion 2005 $)	-$3	-$11	-$42	-$97	-$166
Ref. Consumption per Household	$75,531	$80,507	$91,686	$105,202	$119,168
% Change (Scn. 2)	-0.03%	-0.10%	-0.30%	-0.55%	-0.76%
Consumption Loss per Household	-$21	-$84	-$277	-$582	-$912
NPV Cost per HH	-$16	-$49	-$99	-$128	-$123

Average Annual NPV cost per Household	**-$80**
Total NPV Cost per Household (2010-2050)	**-$3,270**

- 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 $80 - $111 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

H.R. 2454 Scenario Comparison

	ADAGE	2015	2020	2030	2040	2050
Scn. 1	Ref. Consumption per Household	$92,202	$99,888	$117,973	$140,233	$164,348
Scn. 2	% Change	-0.08%	-0.11%	-0.31%	-0.55%	-0.78%
	Consumption Loss per Household (	-$70	-$105	-$366	-$771	-$1,287
	NPV Cost per HH ($)	-$53	-$61	-$132	-$170	-$174
	Average Annual NPV cost per Household			-$111		
Scn. 3	% Change	-0.06%	-0.09%	-0.31%	-0.52%	-0.76%
	Consumption Loss per Household (	-$53	-$93	-$369	-$735	-$1,255
	NPV Cost per HH ($)	-$40	-$54	-$132	-$162	-$170
	Average Annual NPV cost per Household			-$103		
Scn. 4	% Change	-0.09%	-0.13%	-0.33%	-0.56%	-0.79%
	Consumption Loss per Household (	-$84	-$133	-$388	-$787	-$1,303
	NPV Cost per HH ($)	-$63	-$78	-$139	-$173	-$176
	Average Annual NPV cost per Household			-$119		
Scn. 5	% Change	-0.14%	-0.18%	-0.43%	-0.67%	-0.92%
	Consumption Loss per Household (	-$131	-$180	-$506	-$934	-$1,507
	NPV Cost per HH ($)	-$98	-$105	-$181	-$206	-$204
	Average Annual NPV cost per Household			-$151		
Scn. 6	% Change	-0.10%	-0.17%	-0.29%	-0.51%	-0.75%
	Consumption Loss per Household (	-$90	-$172	-$347	-$714	-$1,231
	NPV Cost per HH ($)	-$67	-$101	-$125	-$157	-$166
	Average Annual NPV cost per Household			-$113		

	IGEM	2015	2020	2030	2040	2050
Scn. 1	Ref. Consumption per Household	$75,531	$80,507	$91,686	$105,202	$119,168
Scn. 2	% Change	-0.03%	-0.10%	-0.30%	-0.55%	-0.77%
	Consumption Loss per Household (	-$26	-$104	-$356	-$775	-$1,257
	NPV Cost per HH ($)	-$16	-$49	-$99	-$128	-$123
	Average Annual NPV cost per Household			-$80		
Scn. 7	% Change	2.29%	3.37%	4.65%	7.07%	10.03%
	Consumption Loss per Household (	$2,116	$3,369	$5,485	$9,920	$16,479
	NPV Cost per HH ($)	-$34	-$81	-$168	-$227	-$223
	Average Annual NPV cost per Household			-$140		

Consumption

Scenario 1 – Reference & Scenario 2 – H.R. 2454

Table: Impacts on Average HH Consumption

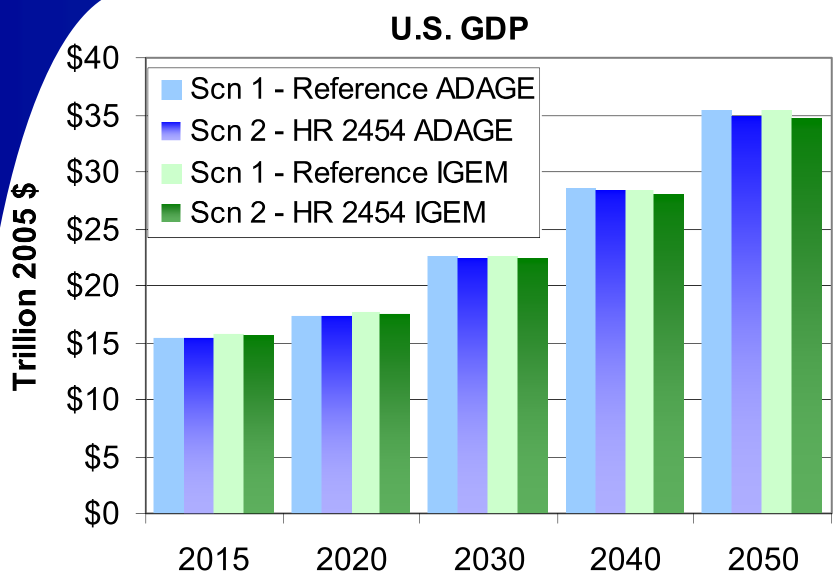
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Current Average HH Consumption (2010)									
ADAGE	$83,909								
IGEM	$69,814								
Average HH Consumption in *Scenario 1 - Reference*									
ADAGE		$92,202	$99,888	$107,898	$117,973	$128,895	$140,233	$151,989	$164,348
IGEM		$75,531	$80,507	$85,734	$91,686	$98,389	$105,202	$112,166	$119,168
Average HH Consumption in *Scenario 2 - H.R. 2454*									
ADAGE		$92,132	$99,783	$107,743	$117,606	$128,360	$139,462	$150,958	$163,062
IGEM		$75,510	$80,424	$85,567	$91,410	$97,949	$104,621	$111,427	$118,257
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		8.2%	15.3%	22.8%	31.3%	40.9%	50.7%	60.7%	70.7%
Increase in Average HH Consumption in *Scenario 2 - H.R. 2454* Compared to 2010									
ADAGE		9.8%	18.9%	28.4%	40.2%	53.0%	66.2%	79.9%	94.3%
IGEM		8.2%	15.2%	22.6%	30.9%	40.3%	49.9%	59.6%	69.4%
Benefits from Reduced Climate Change									
		Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated	Not Estimated

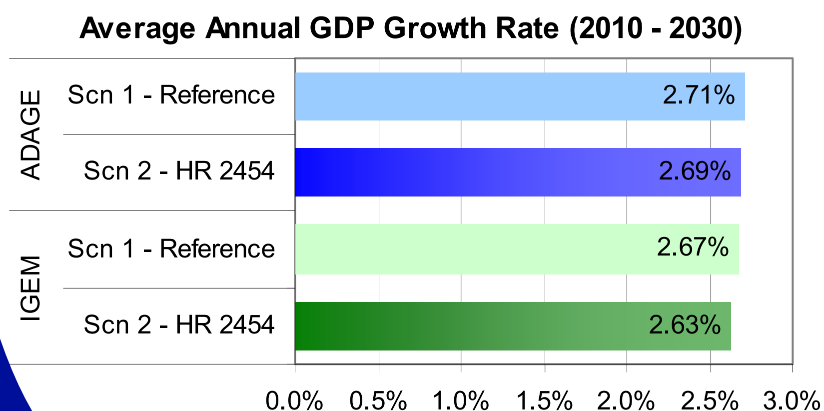
- This analysis is a cost-effectiveness analysis, not a cost-benefit analysis. As such, the benefits of reducing GHG emissions were not determined in this analysis.
- The consumption loss is the cost of achieving the climate benefits that would result from this bill.

- 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.

GDP

Scenario 1 – Reference & Scenario 2 – H.R. 2454





ADAGE

	2015	2020	2030	2040	2050
Reference	$15.4	$17.4	$22.6	$28.6	$35.4
Scn 2 - H.R. 2454	$15.4	$17.5	$22.5	$28.4	$34.9
Absolute Change	$0.013	$0.023	-$0.083	-$0.208	-$0.459
% Change	0.08%	0.13%	-0.37%	-0.73%	-1.30%

IGEM

	2015	2020	2030	2040	2050
Reference	$15.7	$17.7	$22.7	$28.5	$35.4
Scn 2 - H.R. 2454	$15.7	$17.6	$22.5	$28.0	$34.7
Absolute Change	-$0.067	-$0.101	-$0.241	-$0.425	-$0.727
% Change	-0.43%	-0.57%	-1.06%	-1.49%	-2.05%

- Other ways to frame these GDP reductions are as follows:
  - In the reference case, GDP in ADAGE is $22.6 trillion in 2030. In "*scenario 2 – H.R. 2454"* GDP reaches $22.6 trillion approximately two months later than in the reference case.
  - In IGEM the reference case GDP is $22.7 trillion in 2030. In *"scenario 2 – H.R. 2454"* GDP reaches $22.7 trillion five months later than in the reference case.
  - Under "*scenario 2 – H.R. 2454*", average annual GDP growth between 2010 and 2030 is approximately 2 basis points lower in ADAGE and 4 basis points lower in IGEM than in the reference scenario.

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 H.R. 2454 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.

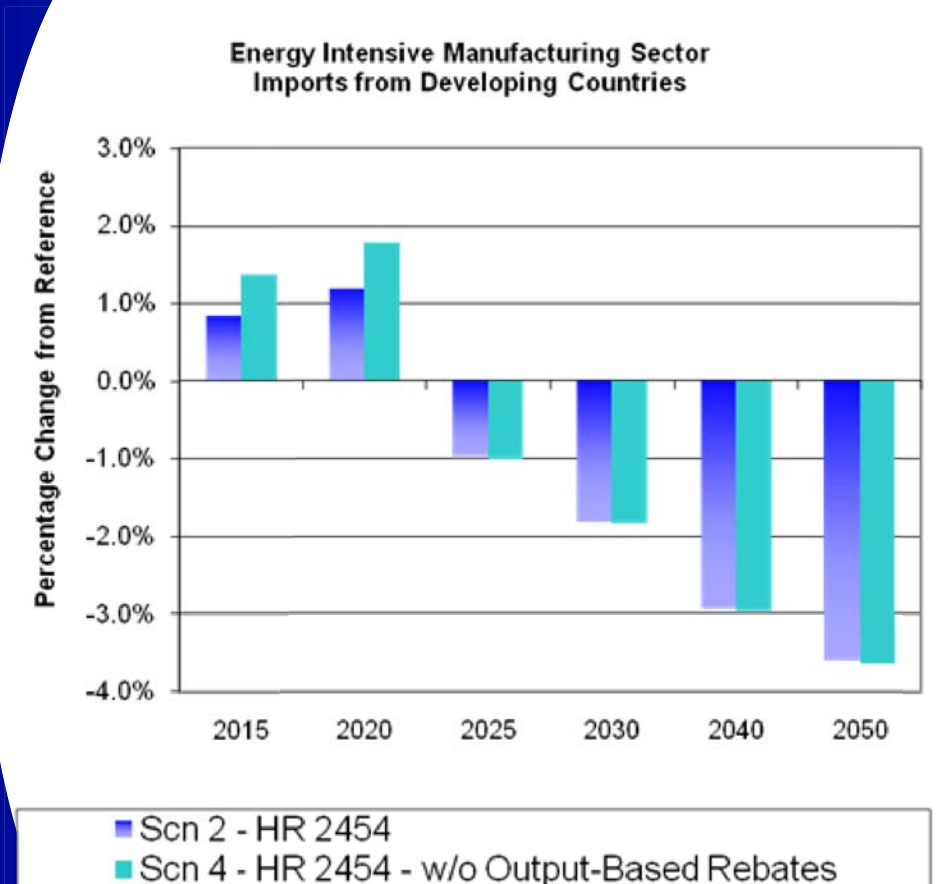
Jorgenson, D.W., Goettle, R.J., Wilcoxen, P.J. and Ho, M.S. (2008). The Economic Costs of a Market-based Climate Policy. Arlington, VA: Pew Center on Global Climate Change. June.

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.

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

Summary of Trade Impacts and Output-Based Rebate Provisions

(ADAGE)



- GHG emissions leakage may occur when a domestic GHG policy causes a relative price differential between domestically produced and imported goods. This can cause domestic production, which embodies the GHG allowance price, to shift abroad, which would thus 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.
- The figure shows developing country energy-intensive manufacturing sector emissions leakage. In scenarios 2 and 4, developing countries adopt climate policies in 2025, so their emissions fall in later years.
- In both scenarios, energy-intensive manufacturing sector emissions from developing countries increase slightly before 2025, and fall after policy is adopted. The effect of output-based rebates is shown in higher leakage in scenario 4 before 2025.

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.

- HR 2454 *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, and the sector average emissions intensity. Non-covered entities receive rebates according to indirect compliance costs using a similar formula.
- The rebates are phased out after 2025 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

HR 2454

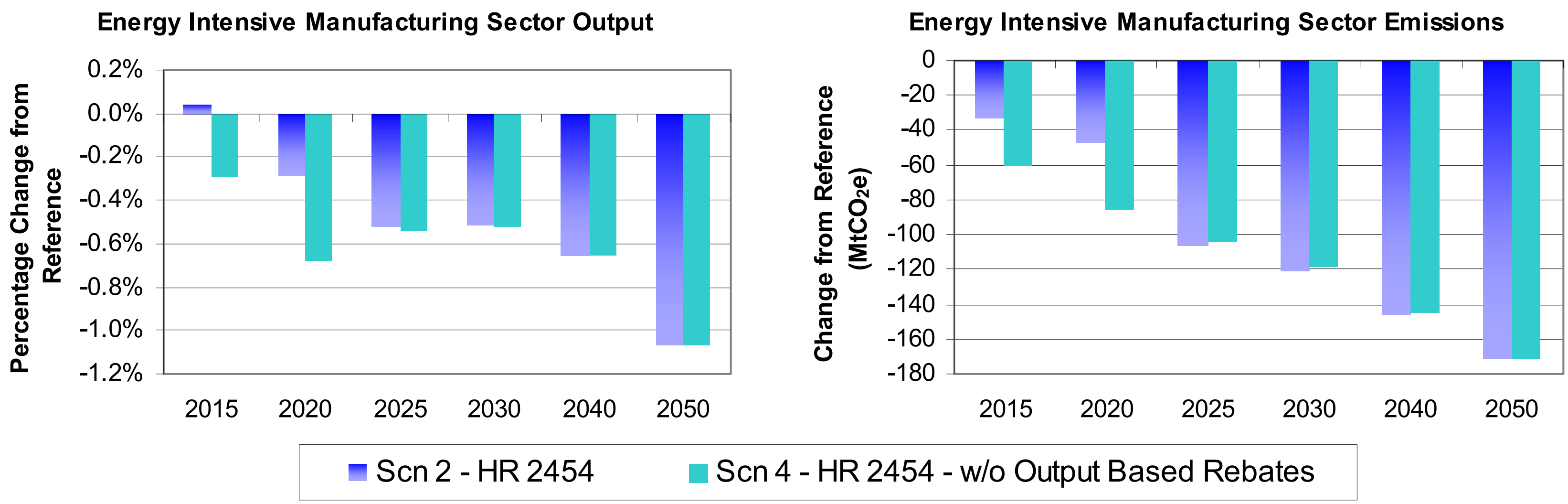
- If comparable polices are not adopted globally, the prices of U.S. exports rise relative to prices in the rest of the world, and export volumes fall. Since exports are price-elastic, the volumes fall proportionally more than the price rises and thus the value of exports declines. Imports are reduced 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.

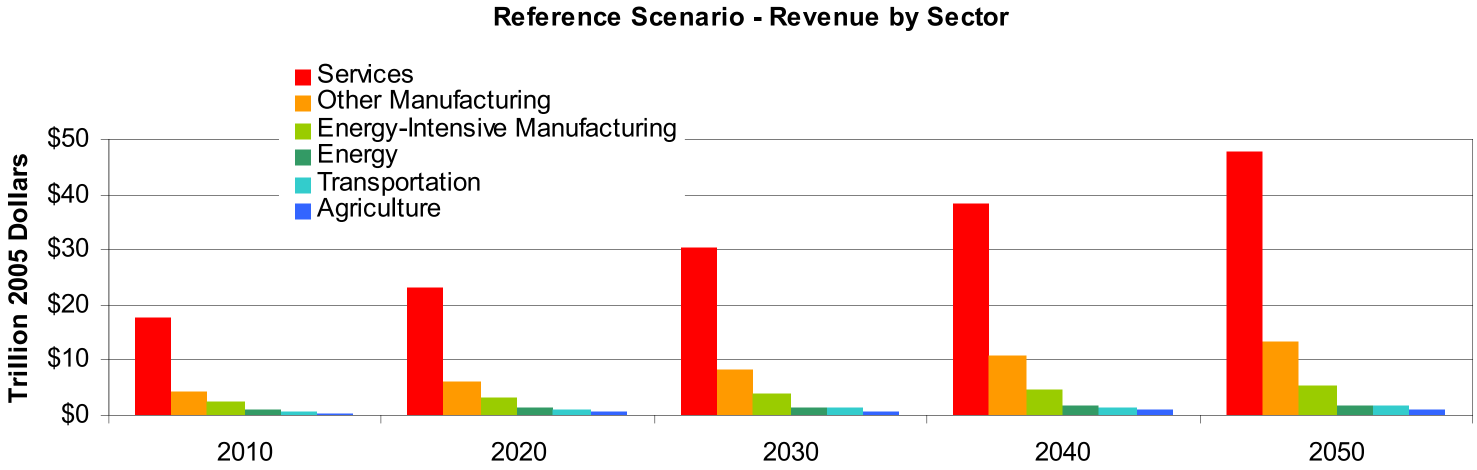
Scenarios

- Scenario 2 - HR 2454
  - 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 - H.R. 2454 without Output-Based Allocations
  - Removes the output-based allocations specified in *Title IV – Subtitle A – Part 1 Preserving Domestic Competitiveness,* which is similar to H.R. 7146 (Inslee / Doyle).

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

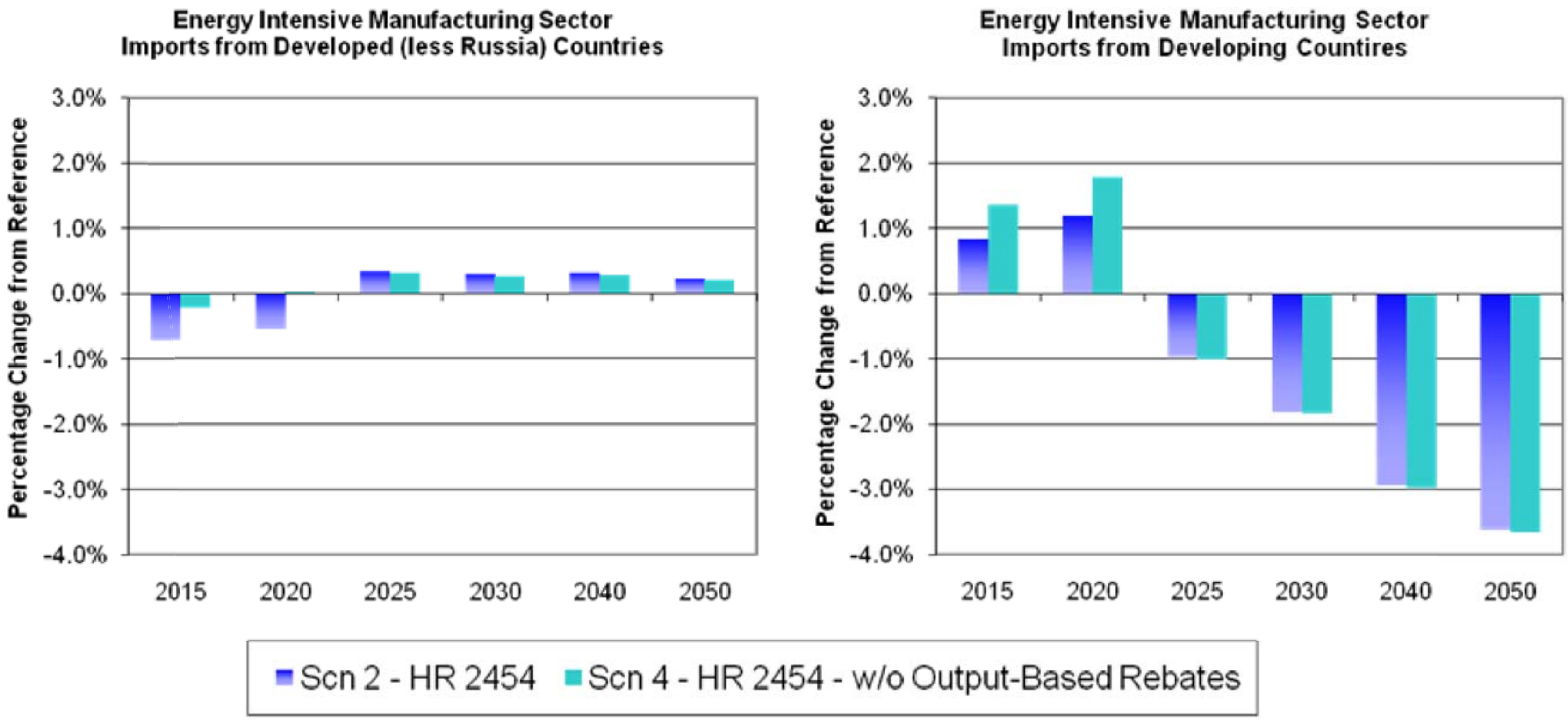
- Under the "*scenario 2* – HR 2454" assumptions, the energy-intensive manufacturing sector (EIS) reduces emissions by 33 $MtCO_2e$ in 2015 and 47 $MtCO_2e$ in 2020. Reductions from EIS are 9% and 6% of total covered emissions reductions in 2015 and 2020 respectively.

- In *scenario 2*, EIS output increases by 0.04% in 2015 and declines by 0.28% in 2020 from the reference case as eligible entities receive rebates tied to the level of output. Emissions and output are higher, and imports from Groups 1 and 2 are lower with rebates than in scenario 4.

- Under the "*scenario 4* - HR 2454 *w/o output based rebates*" assumptions, EIS output decreases by 0.3% in 2015 and 0.68% in 2020. EIS emissions are reduced by considerably more than in *scenario 2* (61 $MtCO_2e$ in 2015 and 85 $MtCO_2e$ in 2020).

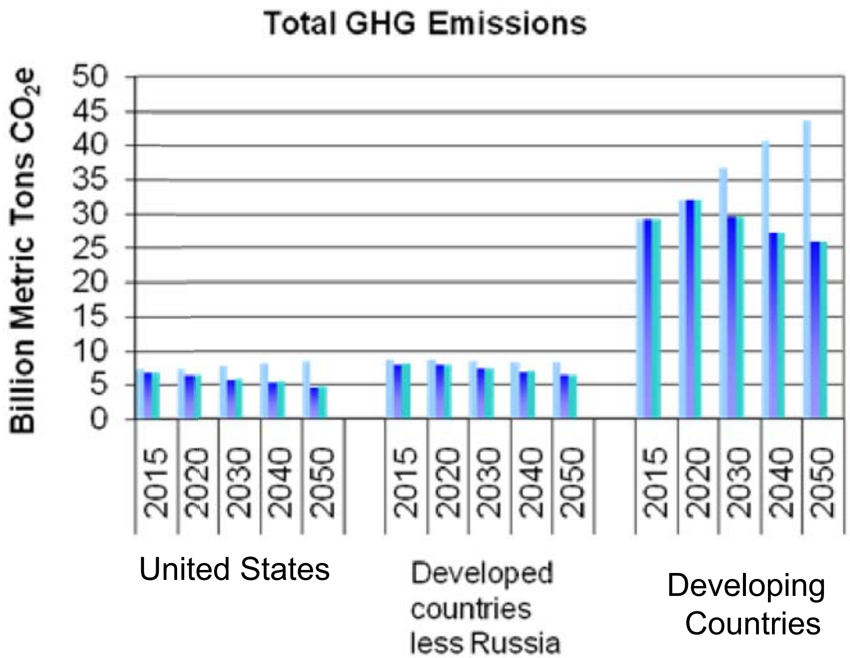
Energy Intensive Manufacturing – Imports

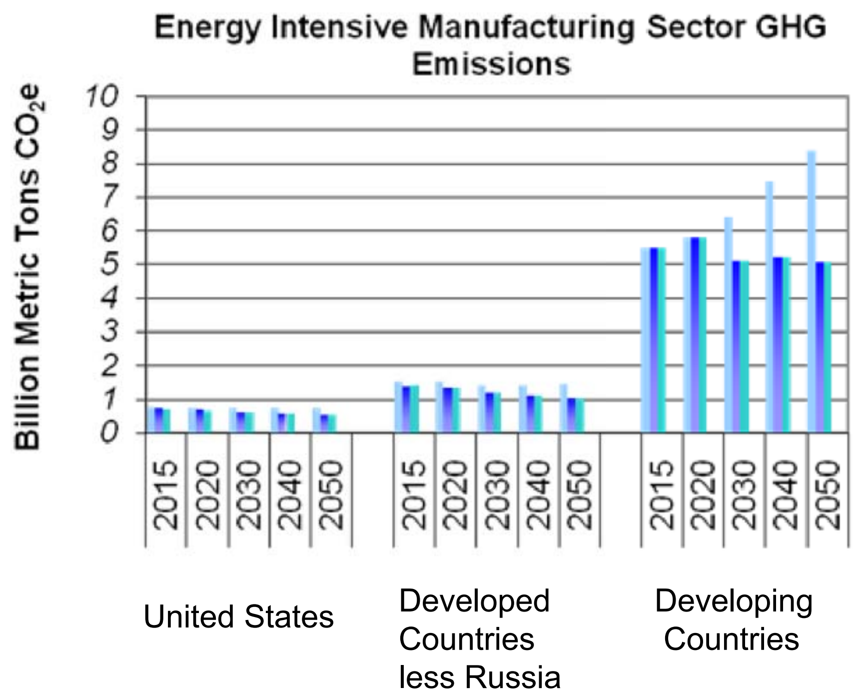
(ADAGE)



World Emissions

(ADAGE)





Scn 1 - Reference
Scn 2 - HR 2454
Scn 4 - HR 2454 - w/o Output-Based Rebates

ADAGE Energy Intensive Manufacturing Sector and HR 2454 Output-Based Rebate Eligible Sectors (with Value of Shipments by 6-digit NAICS Sectors)

HR 2454 Eligible Sectors			ADAGE EIM Sector		
NAICS6	Name	2007 VOS	NAICS4	Name	2007 VOS
			3111	Animal food mfg	38,610,736
311221	Wet Corn Milling	12,117,145	3112	Grain and oilseed milling	59,169,992
			3113	Sugar and confectionery product mfg	27,445,487
			3114	Fruit and vegetable preserving and specialty food mfg	60,885,934
			3115	Dairy product mfg	90,318,028
			3116	Animal slaughtering and processing	159,564,738
			3117	Seafood product preparation and packaging	11,434,416
			3118	Bakeries and tortilla mfg	55,181,117
			3119	All other food mfg	74,731,445
314992	Tire Cord and Tire Fabric Mills	1,069,765			
321219	Reconstituted Wood Product Manufacturing	6,896,468			
322110	Pulp Mills	5,027,395	3221	Pulp, paper and paperboard mills	80,114,225
322121	Paper (except Newsprint) Mills	46,291,440			
322122	Newsprint Mills	3,440,645			
			3222	Converted paper products mfg	95,904,020
			3231	Printing and rel supp act	103,210,365
325110	Petrochemical Manufacturing	77,661,772	3251	Basic chemical mfg	229,179,243
325131	Inorganic Dye and Pigment Manufacturing	5,689,517			
325132	Synthetic Organic Dye and Pigment Manufacturing	2,381,398			
325181	Alkalies and Chlorine Manufacturing	6,370,780			
325182	Carbon Black Manufacturing	1,487,557			
325188	All Other Basic Inorganic Chemical Manufacturing	22,828,592			
325191	Gum and Wood Chemical Manufacturing	1,266,090			
325192	Cyclic Crude and Intermediate Manufacturing	5,947,517			
325193	Ethyl Alcohol Manufacturing	14,005,115			
325199	All Other Basic Organic Chemical Manufacturing	81,997,462			
325211	Plastics Material and Resin Manufacturing	85,231,585	3252	Resin, synthetic rubber, and artificial and synthetic fibers	101,374,358
325212	Synthetic Rubber Manufacturing	8,253,660			
325221	Cellulosic Organic Fiber Manufacturing	925,820			
325222	Noncellulosic Organic Fiber Manufacturing	6,963,293			

ADAGE Energy Intensive Manufacturing Sector and HR 2454 Output-Based Rebate Eligible Sectors

HR 2454 Eligible Sectors			ADAGE EIM Sector		
NAICS6	Name	2007 VOS	NAICS4	Name	2007 VOS
325311	Nitrogenous Fertilizer Manufacturing	5,524,151	3253	Pesticide, Fertilizer, and other agricultural chemical mfg	29,560,163
			3254	Pharmaceutical and Medicine mfg	188,534,202
			3255	Paint, coating and adhesive coating mfg	33,507,929
			3256	Soap, cleaning compound, and toilet preparation mfg	97,239,397
			3259	Other chemical product and preparation mfg	45,031,231
			3261	Plastics product mfg	171,885,456
			3262	Rubber product mfg	39,634,400
327111	Vitreous China Plumbing Fixture and China and Earthenware Bathrc	867,553	3271	Clay product and refractory mfg	8,235,104
327112	Vitreous China, Fine Earthenware, and Other Pottery Product Manu	783,594			
327113	Porcelain Electrical Supply Manufacturing	737,282			
327122	Ceramic Wall and Floor Tile Manufacturing	1,126,093			
327123	Other Structural Clay Product Manufacturing	243,009			
327124	Clay Refractory Manufacturing	1,062,133			
327125	Nonclay Refractory Manufacturing	1,372,439			
327211	Flat Glass Manufacturing	3,420,860	3272	Glass and glass product mfg	23,419,188
327212	Other Pressed and Blown Glass and Glassware Manufacturing	4,316,979			
327213	Glass Container Manufacturing	4,899,025			
327310	Cement Manufacturing	10,619,945	3273	Cement and concrete product mfg	66,999,294
327410	Lime Manufacturing	1,875,567	3274	Lime and gypsum product mfg	7,600,487
327992	Ground or Treated Mineral and Earth Manufacturing	2,826,839	3279	Other nonmetallic mineral product mfg	21,119,149
327993	Mineral Wool Manufacturing	6,147,076			
			3311	Iron and steel mills and ferroalloy product mfg	103,505,983
			3312	Steel product mfg from purchased steel	20,426,985
331311	Alumina Refining	1,337,014	3313	Alumina and aluminum production and processing	44,039,046
331312	Primary Aluminum Production	6,657,285			
331419	Primary Smelting and Refining of Nonferrous Metal (except Copper	5,987,185	3314	Nonferrous metal (ex. Al) production and processing	57,424,173
			3315	Foundries	34,181,788
335991	Carbon and Graphite Product Manufacturing	2,795,262			

ADAGE Energy Intensive Manufacturing Sector and HR 2454 Output-Based Rebate Eligible Sectors

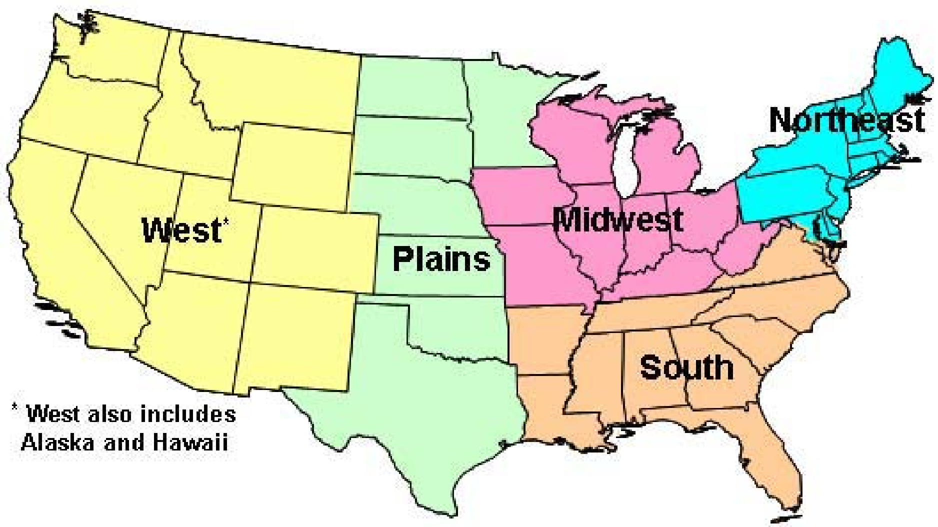
- Chart compares sectors believed eligible to receive allowances according to the criteria in H.R. 2454 with sectors in the ADAGE Energy Intensive Manufacturing (EIM) sector. H.R. 2454 uses data at the 6-digit NAICS level of definitions, while ADAGE is compiled from 4-digit NAICS data. Value of shipments data from the 2007 Economic Census is included.
- ADAGE EIM encompasses all but three 6-digit sectors believed eligible to receive allowances: Tire cord and tire fabric mills, Reconstituted wood product manufacturing, and Carbon and graphite product manufacturing. These 3 sectors represent about 2 percent of the output of all sectors believed eligible.
- ADAGE EIM includes many more 6-digit and 4-digit energy intensive manufacturing sectors. For example, at the 6-digit level, ADAGE EIM includes all grain and oilseed processing mills in addition to the corn wet milling sector. ADAGE EIM also includes other energy intensive food manufacturing sectors, such as dairy, frozen seafood, and bakeries.
- Overall, ADAGE EIM encompasses 163 6-digit NAICS, with 2007 Value of Shipments of about $2.2B. This is almost five times larger than the 39 6-digit NAICS believed eligible for rebates, with 2007 VOS of $458M.

U.S. Regional Modeling Results

Introduction to Regional Results

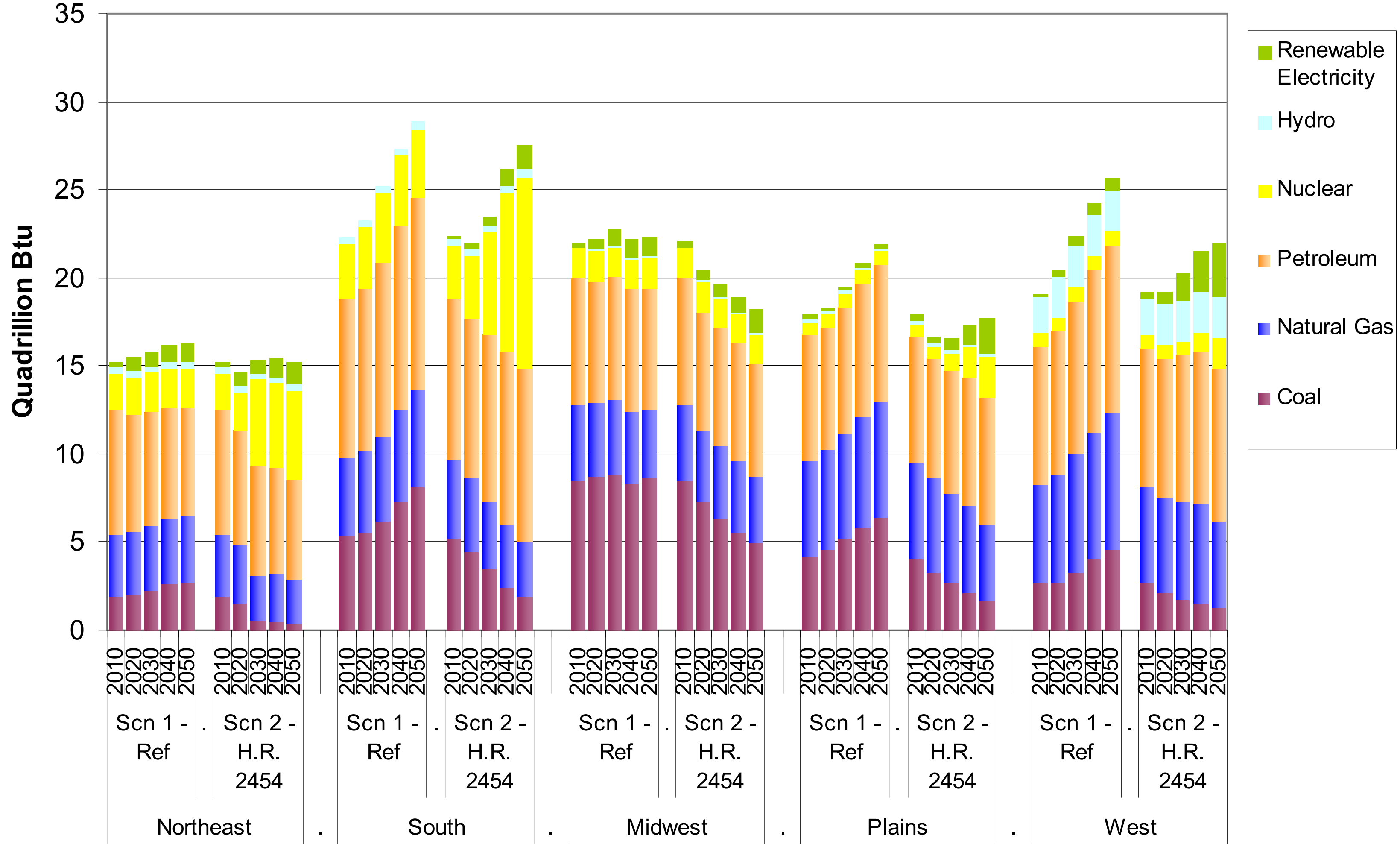
(ADAGE)

- 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



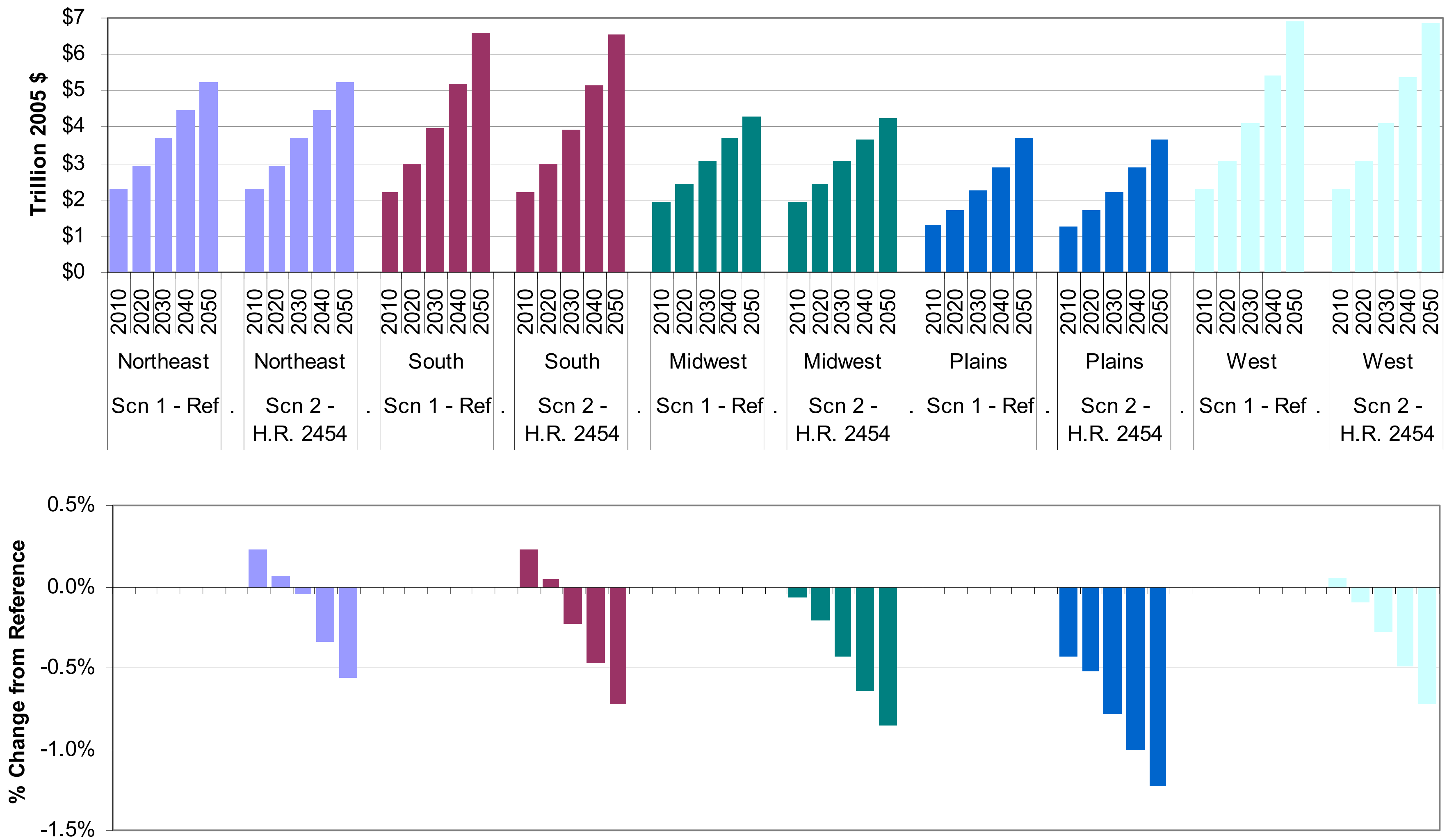
Regional Primary Energy Use

Scenario 1 - Reference and Scenario 2 – H.R. 2454 (ADAGE)



Regional Consumption

Scenario 1 - Reference and Scenario 2 – H.R. 2454 (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 IPM 2009 ARRA Ref. Case

- **Electricity Demand Growth:**
  - EPA uses the AEO 2009 ARRA update as the basis for future electricity demand projections for the reference case (roughly 0.9%).
  - ARRA lowered the AEO 2009 projection of electricity demand growth slightly, but not as significantly as the decline in projected electricity demand growth between AEO 2008 (~1.5%) and AEO 2009 (~1%).
- **Cost of New Power Technologies:**
  - The capital charge rate for new coal-fired capacity construction has been increased by 3 percentage points in the reference case – an adjustment that AEO 2009 introduced to reflect the implicit cost being added to GHG-intensive projects to account for additional risk associated with future climate regulation. The adjustment factor was removed in the policy scenarios.
- **Renewable Capacity and Biomass Supply:**
  - Renewable capacity prior to 2012 is calibrated to the AEO 2009 ARRA update, which shows substantially increased near-term renewable deployment in reaction to ARRA's extension and revision of financial incentives such as production and investment tax credits.
  - New supply curves and non-power-sector demand for biomass were adopted from the AEO 2009 ARRA update.
- **CCS in Reference Case Projection:**
  - The AEO 2009 ARRA forecasts 2 GW of CCS capacity in the reference case for the year 2017. 1 GW is ascribed to the financial incentives for CCS included in the Emergency Economic Stabilization Act of 2008, and 1 GW is added to reflect ARRA 2009 appropriated funding to DOE for CCS deployment.
  - In IPM 2009 ARRA Ref. Case, 2017 is included in the results mapped to the reported year 2015, and correspondingly, 2 GW of CCS are reported for 2015 in the reference case analysis.

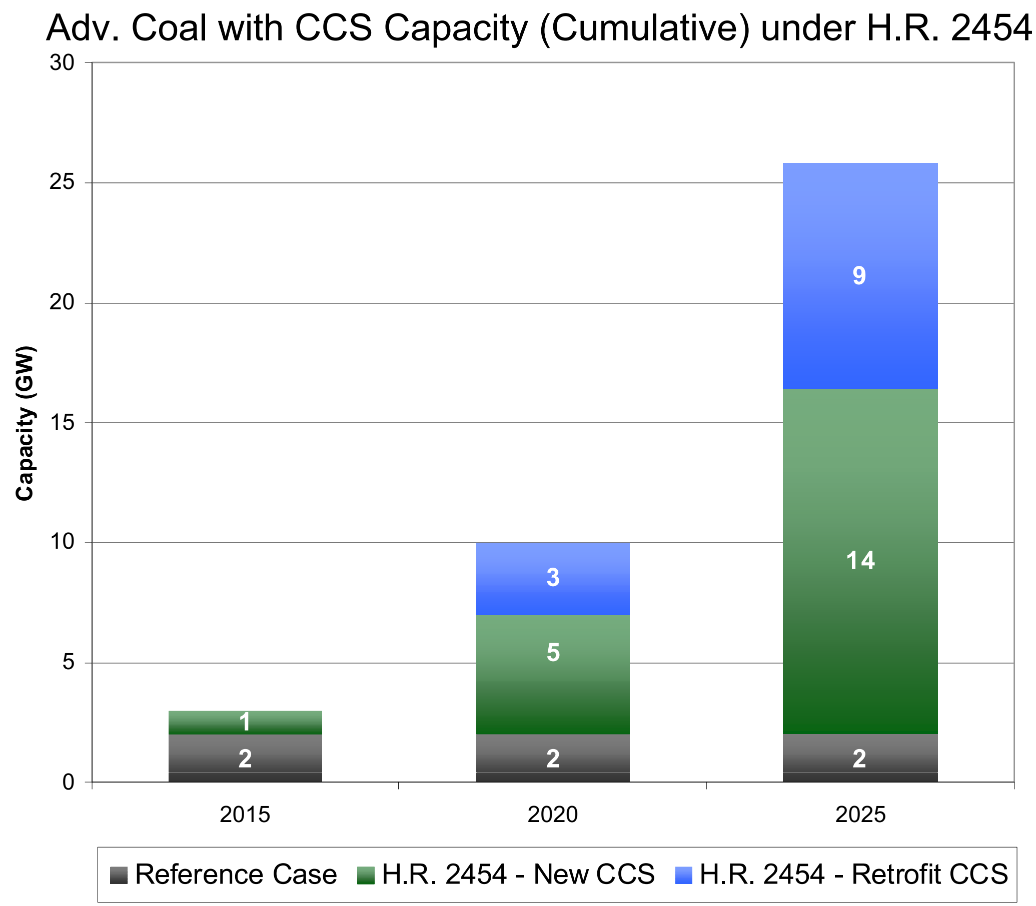
Note: For more detail on the assumptions used in EPA's application of IPM, please see more detailed documentation for IPM at http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html.

Key Insights from IPM Results for the Near-Term

- The price of carbon emissions under H.R. 2454 in conjunction with complementary measures (e.g., energy efficiency, technology incentives) leads to reduced electricity demand and a shift towards lower emitting technologies.
  - The electricity demand reduction includes allowance allocations, building energy efficiency codes, and energy savings component of CERES.
- The shifts in electricity production away from GHG-intensive facilities are somewhat modest in the shorter-term, due primarily to lower emissions in the baseline, increased capital costs for new power generating technologies, lower allowance prices, additional renewable energy, and lower overall electricity demand.
- The carbon price incurred by various emitting technologies (e.g., coal) does not result in a notable increase in new nuclear plants, due primarily to large reduction in electricity demand.
- The CCS early deployment provisions, along with the bonus allowance provision for CCS, incentivize penetration of *new* coal capacity with CCS technology.
  - New coal with CCS is projected to penetrate in 2015 and continue deploying through 2025 in response to the bill's early deployment program and the financial incentives as part of the bonus.
  - Some *existing* coal plants find it economic to retrofit with CCS starting in 2020, assisted by the CCS bonus.
- 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 uncertainty regarding technology cost and performance, the reverse auction approach for CCS would help determine the appropriate incentive for the technology without over or under incentivizing.

Analysis of CCS Technology for New and Existing Facilities

- EPA has modeled the CCS early deployment program and has assumed that a total of 7 GW of *new* coal with CCS is built by 2020, driven by existing technology funding provisions, the early deployment program in H.R. 2454, and the CCS bonus incentive.
  - 3 GW of retrofit CCS is also built by 2020.
- New capacity with CCS is economic with a bonus of greater than $40. However, it is difficult to project the precise bonus given the considerable uncertainty surrounding the future costs of technologies. EPA did not explicitly model the reverse auction provision contained in H.R. 2454.



Note: CCS retrofit capacity projections reflect a post-retrofit capacity energy-parasitic penalty of roughly 30%. IPM reference case projection is based on EIA AEO 2009 ARRA.

Analysis of CCS Technology

- The CCS bonus provision is modeled as a fixed incentive in IPM. H.R. 2454 directs EPA to conduct a reverse auction to set the per-ton value of bonus allocations beyond the first 6 GW, which could potentially optimize the incentive necessary to spur additional deployment of CCS. The total bonus is set as a portion of all allowances, starting at 1.75% of allowances and rising to 5% through 2050.
- EPA also has discretion to set the value of additional bonus allocation if a reverse auction is infeasible. For purposes of this analysis, the model assumed a range of fixed values to reflect possible values of CCS bonus support.
- Allowance prices are lower in this analysis relative to past EPA analyses of other bills, resulting in more allowances that must be distributed as part of the fixed incentive.
- H.R. 2454 also contains complementary measures for renewable energy, which were not modeled in ADAGE. This provision could dampen allowance prices, which would lessen the economic incentive for CCS in the longer term (both by displacing the fossil share of new necessary generation and by reducing the cost of emitting).
- Because of considerable uncertainty regarding technology cost and performance, the reverse auction approach for CCS would help determine the appropriate incentive for the technology without over or under incentivizing.
- 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.*

* 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.

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.

Assumed Deployment of CCS

- IPM 2009 ARRA Ref. Case assumes 2 GW of new capacity with CCS in 2015.
  - This assumption is based on tax incentives and research and development funding enacted in the Emergency Economic and Stabilization Act of 2008 and the American Recovery and Reinvestment Act of 2009.
- The H.R. 2454 policy analysis assumes 1 additional GW of new capacity with CCS in 2015 and 4 additional GW in 2020.
  - This assumption is based on Sec. 114 of the bill, which authorizes utilities to raise between $10-11 billion from ratepayers to fund commercialization of CCS.
  - This deployment level represents an informed estimate based on the costs of demonstrating new technology. The amount of capacity which $10-11 billion of funding would successfully deploy will depend in large part on the actual technology costs, which are uncertain.
- There are over 4 GW of projects in the early phases of planning, design, and/or construction that could potentially capitalize on the funding opportunities available.

Project Name	Developer	Size MW	Capture Process	CO2 Fate	Start-up
Pleasant Prairie	Wisconsin Electric	5	Post	Seq	2008
AEP Alstom Mountaineer	AEP	30	Post	Seq	2009
Williston	PCOR	450	Post	EOR	2009-15
Kimberlina	CES	50	Oxy	Seq	2010
AEP Alstom Northeastern	AEP	200	Post	EOR	2011
Plant Barry	MHI	25	Post	Seq	2011
Antelope Valley	Basin Electric	120	Post	EOR	2012
WA Parish	NRG Energy	125	Post	EOR	2012
Appalachian Power	AEP	629	Pre	Undecided	2012
Wallula Energy Resource Center	Wallula Energy	600-700	Pre	Seq	2013
Tenaska	Tenaska	600	Post	EOR	2014
AMPGS	AMP	1000	Post	EOR	2015
Restructuring / Dormant					
FutureGen	FutureGen Alliance	275	Pre	Seq	Re-Structuring

Source MIT's Carbon Dioxide Capture and Storage Project Database (http://sequestration.mit.edu/tools/projects/index.html). Pleasant Prairie site is temporary test site.

Delayed CCS Technology Scenario (IPM)

- H.R. 2454 provides considerable incentives for early development and deployment of coal power with CCS technology.
- Nonetheless, there is uncertainty surrounding the precise timing of the first set of projects due to technical and financial considerations, either in response to the bill's funding mechanisms or other funding mechanisms like ARRA and past energy bills.
- To reflect this uncertainty, a scenario was run with IPM without CCS technology deployed until after 2015.
- A delay in the CCS deployment pattern does not alter the results in any fundamental way in IPM.
  - The 3 GW of CCS capacity that was delayed is a very small amount relative to total generation capacity. The power sector currently has almost of 1,000 GW of total capacity.
  - The power sector can adapt and shift power in the shorter-term if CCS technology is delayed past 2015.

Representation and Effects of the CCS Bonus Allowances

- H.R. 2454 requires EPA to establish a reverse auction that would yield an appropriate financial incentive to spur deployment of CCS, neither over- or under-incentivizing the technology. A fixed portion of allowances are reserved for incentivizing carbon capture and storage technology (starting at 1.75% of allowances and rising to 5% through 2050).
- The reverse auction was not specifically included in IPM. Instead, some scenarios were modeled with a range of bonus values to simulate a spectrum of incentives that could result in an actual reverse auction.
- In all scenarios, the first 3 GW of CCS capacity receive a $100 per ton bonus and the next 3 GW receive $90 per ton, since H.R. 2454 sets the bonus level for the first 6 GW of CCS deployed.
- For subsequent capacity, the core IPM H.R. 2454 scenario has a bonus of $40 per ton. The capacity assumed to be built due to other sources of funding (such as the bill's early deployment provisions) also receives the bonus allowance value. A total of up to 72 GW of capacity is eligible for bonus allowances in this bill.
- There is significant uncertainty with regards to CCS technology availability and cost, thus making it difficult to ascertain the precise level of incentive that will lead to any given level of CCS deployment. The reverse auction approach for CCS bonus allowances is designed to elicit from market participants the minimum per-ton bonus value necessary to incentivize CCS deployment.

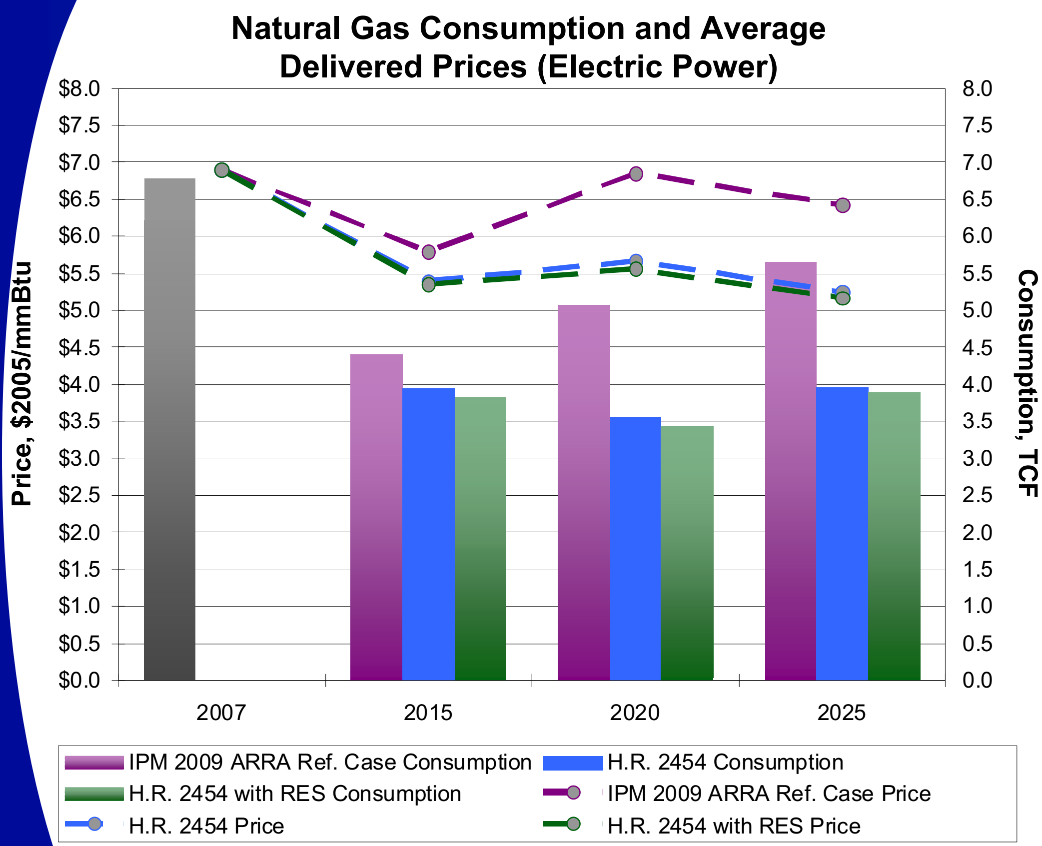
Key Results and Insights:

- In IPM, a price of $40 per ton of CO_2 sequestered resulted in the highest penetration of new CCS capacity (of the bonus values modeled). The bonus allowance pool was fully expended.
- Lowering the amount to $30 per ton yields a lower deployment of CCS, with allowances remaining in the pool. Funds thus go unclaimed because the per-ton incentive is insufficient to incentivize the technology.
- Raising the amount to $50 per ton reduces deployment for a different reason: it depletes the total funds earlier by spending more per ton than was necessary to make deployment economic.
- These findings apply to any range of potential bonus amounts, not specifically to the values used here. A reverse auction would theoretically elicit the optimal value for maximizing deployment with dedicated funds.
- The total value of financial incentive available for the CCS bonus is a function of the allowance price.

CCS Bonus Sensitivity to Alternative Capital Costs

- To reflect the uncertainty surrounding future technology costs, an IPM scenario was run with higher capital costs for new capacity additions.
  - When capital costs were increased, IPM showed less nuclear capacity and advanced coal with CCS built compared to the core policy case.
  - There was an increase in the amount of natural gas and renewable capacity that was added by 2025.
- The core IPM scenario included a CCS bonus of $40/ton of CO_2 sequestered to approximate the effect of the reverse auction (this bonus applies after the first 6 GW are built), which was unchanged for the alternative capital cost sensitivity.
  - Under alternate (higher) assumptions for power technology capital costs, a higher bonus would be needed to promote greater deployment of CCS.
  - As mentioned previously, there is significant uncertainty with regards to CCS technology availability and cost - hence the efficiency of the reverse auction approach for CCS bonus allowances. The reverse auction would yield the appropriate bonus level and would reflect some of the technology cost uncertainty that exists.

Power Sector Natural Gas Consumption and Prices (IPM)



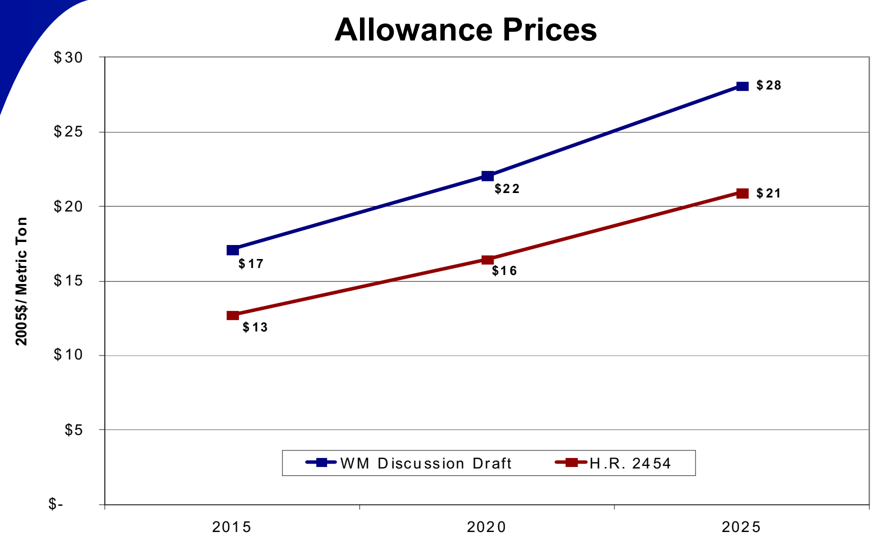
		N. Gas Consumption and Prices			
		2007	2015	2020	2025
Nat. Gas Consumption (TCF)	Ref. Case	6.8	4.4	5.1	5.6
	H.R. 2454		3.9	3.6	4.0
	H.R. 2454 w/ RES		3.8	3.4	3.9
Nat. Gas Price, Delivered ($2005/mmBtu)	Ref. Case	$6.90	$5.79	$6.85	$6.42
	H.R. 2454		$5.40	$5.67	$5.25
	H.R. 2454 w/ RES		$5.35	$5.56	$5.16

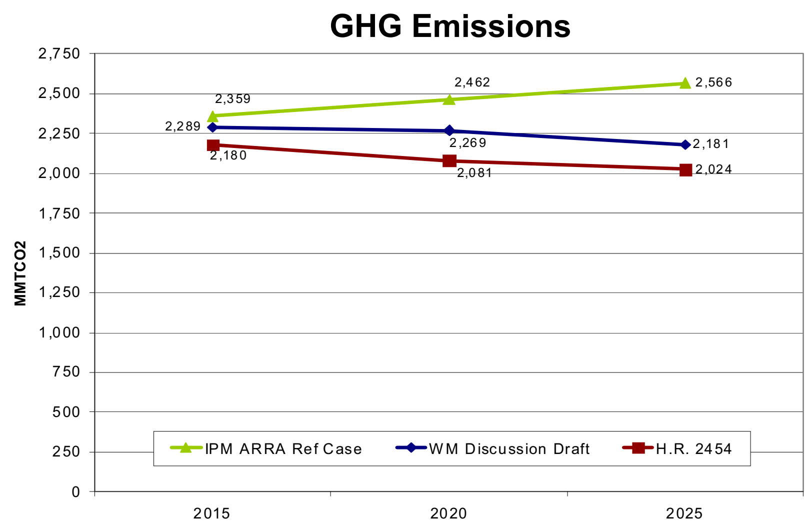
Lower producer natural gas prices are the result of decreases in natural gas demand. This is due, in part, to the power sector’s response to the emissions cap and CERES in H.R. 2454.

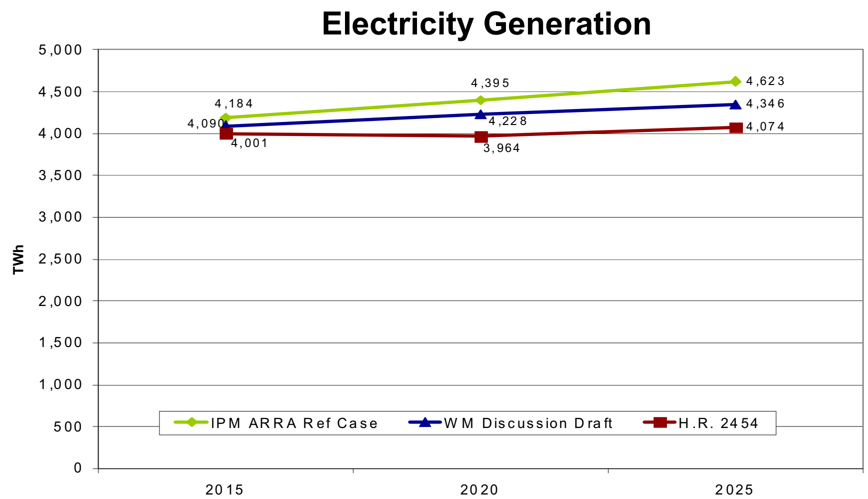
Source: 2007 data is from EIA, projections are from IPM 2009 ARRA Ref. Case and analysis of Waxman-Markey using IPM.

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.

Comparisons to Waxman-Markey Discussion Draft Analysis







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.
- *In this analysis, only CCS retrofit penetration limitations were reached.*

Incremental / Cumulative New Capacity Limitations in IPM for Renewables

GW	2015	2020	2025
Wind	30 / 30	45 / 75	65 / 140
Other Renewables	10 / 10	15 / 25	20 / 45
All Renewables	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
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

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).

* Post 2015 new CCS constraints exclude the 4 GW of hardwired capacity. CCS retrofit capacity reflects pre-retrofit capacity (e.g., before CCS parasitic load is taken into account).

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 focuses on the near-term impacts and only produces reportable results through 2025.
  - Model does not see longer term changes in electricity demand and CO_2 allowance prices (due to lowering of the cap over the entire timeframe of the bill).
  - 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) or enhanced energy efficiency that could lead to demand reductions.
  - The model provides a good sense over the next 15 to 20 years of how the power sector could operate with expected demand, fuel prices, technologies, and other factors, based on EPA's best information available.
- 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.
  - There is an option in IPM for nuclear plants to extend their operating life beyond 60 years at an additional cost.

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 was also used in the development of the Regional Greenhouse Gas Initiative (RGGI).
- 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.

Contact: Allen A. Fawcett
Tel: 202-343-9436
Email: fawcett.allen@epa.gov

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