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Outline

• Scope
• Model and Modifications
• Policies evaluated
• Results
• Conclusions and Policy Implications
Scope

• Climate policies
  – Clean Energy Standard (CES)
  – Renewable Fuel Standard (RFS)
  – Corporate Average Fuel Economy Standard (CAFE)
• Equivalent Emission Tax Policy
• Implications of combining climate policies
  – Sectoral and over all emissions
  – Abatement amounts and costs
  – Resulting primary energy mix
  – Electricity price
  – Effect on the economy
Model

• MARKAL-Macro
  – Technology and sectoral detail rich bottom-up MARKAL
  – Use of a neoclassical growth model (Macro)
  – Incorporates macroeconomic feedbacks into an integrated bottom-up MARKAL model
  – Aggregated endogenous energy demand structure
  – Calculation of GDP, consumption, and investment.
Model (contd.)

• MARKAL (an acronym for MARKet ALlocation)
  – Developed by the Energy Technology Systems Analysis Program of the International Energy Agency (IEA), is a well known “bottom-up” techno-economic model

• MARKAL approach is “total cost optimization” for the total energy system over the modeling horizon.

• An integrated energy, environmental and economic model

• Deterministic, perfect foresight, dynamic linear programming
Model - Database

• A database that represents a particular energy system must be developed to use MARKAL.

• U.S. EPA MARKAL national database was used.
  – Calibrated according to AEO 2010
  – Modeling time horizon from 2005 to 2055
  – With 5 year time steps
US EPA MARKAL has been modified:

- to introduce the complete supply chain of biomass production including land for corn, corn stover, miscanthus, and switchgrass coupled with land data based from the GTAP model.
- Updated the cellulosic biofuel production technologies based on 2009 National Academies study.
- The biomass thermochemical conversion process (without CCS) was added to the data set.
- Ethanol blends up to 10% (E10) compatible with current infrastructure.
  - US EPA MARKAL model modified to capture required investments (*dispenser and storage*) for distributing the E15 and higher blends.
Model – MARKAL-Macro Calibration

• Macro constructed on top of US EPA MARKAL model.
• Annual Energy Outlook 2010 assumptions/outputs used for calibration process.
• Iterative calibration process has been carried out to match energy service demand levels and expected economic growth levels.
• Estimated growth rates beyond 2035 are taken as long term average values.
Policies (CAFE)

• Corporate Average Fuel Economy
  – Increases the fleet average fuel economy for new passenger car and light duty truck vehicles 5% per year between now and 2025 to reach the target of 54.5 mpg.
Policies (CES)

• Clean Energy Standard
  – Electricity sector would move from the current 40 percent clean to 80 percent clean by 2035
  – Clean electricity:
    • Coal with carbon capture and sequestration,
    • Nuclear electricity
    • Renewable electricity generation (Hydro, solar, wind, and biomass).
  – Natural gas is considered 50 percent clean.
Results (contd.)

Total Abatement Breakdown

<table>
<thead>
<tr>
<th>Year</th>
<th>CAFE</th>
<th>RFS</th>
<th>CES</th>
<th>Interaction effect</th>
<th>Total Abatement</th>
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Note: The data for each year is presented in terms of million tonnes of CO₂.
Results (Electricity)

Reference
Results (Electricity)
Results (Electricity)
Results (Transport)
Results (Transport)
Results (Transport)

Transportation - Energy Consumption Change

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<thead>
<tr>
<th>Year</th>
<th>CAFE</th>
<th>RFS</th>
<th>CES</th>
<th>Interaction Effect</th>
<th>CES - CAFE - RFS</th>
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billion gallon gasoline equivalent
Results (Transport)

Transportation - Abatement Breakdown

- CAFE
- RFS
- CES
- Interaction effect
- Total Abatement

2015: -100
2020: 0
2025: 100
2030: 200
2035: 300
2040: 400
2045: 500

Million tonne CO2
Results (Overall)

Net Decrease in Crude Oil Imports

- Policy case (CAFE)
- Policy case (RFS)
- Policy case (CES)
- Interaction Effect
- Policy case (CES + RFS + CAFE)
- Equivalent emission tax policy
Results (Overall)

Comparative cost oil import reduction

- Policy case (CAFE)
- Policy case (RFS)
- Equivalent emission tax policy
Results (Overall)

Impact of policies on GDP

GDP change compared to reference (%)

Policy case (CES)  Policy case (CAFE)
Policy case (RFS)  Interaction Effect
Policy case (CES + RFS + CAFE)  Equivalent emission tax policy
Conclusions

• Primary energy use is found to be the least with tax case.
• CES is found to be cost effective for reducing GHGs coupled with high electricity prices.
• RFS contributes significant amount of GHGs abatement coupled with reduction of oil imports at a low cost.
Conclusions (contd.)

• CAFE policy offers significant GHG abatement for a very high cost.
• CAFE is more effective (lower cost) than other policies (CES,RFS, equivalent emission tax) for oil import reduction.
• Combined policy set would reduce GDP by 2%, which is higher higher than tax case reduction of 1.2%.
• However, policy makers might be willing to pay that cost to use the regulatory instead of tax approach.
Questions?

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