Managing the Transition to Climate Stabilization

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Participants in CCSP

• MIT (IGSM – Integrated Global Systems Model)
  – Henry (Jake) Jacoby
  – John Reilly
• PNNL (MiniCAM – Mini Climate Assessment Model)
  – James (Jae) Edmonds
  – Hugh Pitcher
• EPRI (MERGE Model for Evaluating Regional and Global Effects of greenhouse gas reductions)
  – Richard Richels
• Coordinator
  – Leon Clarke
CCSP Study Design

- All models assume existing climate mitigation programs (Kyoto, U.S. intensity target) but then assume perfect “what” “where” and “when” flexibility going forward.
- Assumptions (e.g., population, economic growth, technological change) developed individually by the modeling teams.
- No likelihoods assigned to any scenarios or parameters.
  - Teams directed to develop assumptions they consider “plausible” and “meaningful”.
  - These are not the only sets of assumptions that these three modeling teams could have developed.
CCSP Study Design

- Develop Reference (Business as Usual) Case
- Stabilize total radiative forcing from CO₂, N₂O, CH₄, HFCs, PFCs, and SF₆

Four stabilization scenarios roughly consistent with 450 ppmv through 750 ppmv CO₂, along with one reference case.

<table>
<thead>
<tr>
<th>Stabilization Level</th>
<th>Long-Term Radiative Forcing Limit (Wm⁻² relative to pre-industrial)</th>
<th>Approximate 2100 CO₂ Limit (ppmv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
<td>6.7</td>
<td>750</td>
</tr>
<tr>
<td>Level 3</td>
<td>5.8</td>
<td>650</td>
</tr>
<tr>
<td>Level 2</td>
<td>4.7</td>
<td>550</td>
</tr>
<tr>
<td>Level 1</td>
<td>3.4</td>
<td>450</td>
</tr>
</tbody>
</table>
Goal of Present Study

• To extend earlier work done as part of US Climate Change Science Program
• Provide sensitivity analysis focusing on:
  – Policy design
  – Near-term transition constraints
  – Coalition membership
  – Technology availability
Overview of MERGE 5.5

• Intertemporal optimization model with 200 year timeframe
• Each region maximizes its own utility
• Prices of each GHG determined endogenously, i.e. no GWPs
• Top down model of economic growth

• Process model of energy sector, with **new additions:**
  - CCS Technologies
    • Existing plants
    • New plants
  - Considers market *and* nonmarket costs of nuclear power
CAVEAT:

THIS IS NOT A COST BENEFIT ANALYSIS
Reference Case Radiative Forcing
Reference *without* Annex B Emissions

![Graph showing radiative forcing from OGG and CO2 emissions with targets for 2010-2100.](image)

- **3.4 Target**
- **4.7 Target**

**Legend:**
- Black: RF from OGG
- Blue: RF from CO2
- Green: 4.7 Target
- Red: 3.4 Target
Two Policy Scenarios

• “First Best” (1B):
  When and where flexibility (except in 2010)

• “Third Best” (3B):
  Near-term transition constraints on Annex B countries
  Non-Annex B does not participate in near-term

3B Designed to Reflect Realistic Policies
3B Transition Constraints for Annex B

Historic Emissions

Transition Constraints

"Hot Air"

Kyoto Commitments

Post-transition emissions cannot increase

USA

Kyoto Coalition

EEFSU
Two Technology Scenarios

• “Optimistic”: All technologies available

• “Pessimistic”: New nuclear and carbon capture and sequestration (CCS) are not available in electric sector
## Electricity Generation Technologies in MERGE 5.5

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDRO</td>
<td>Hydroelectric</td>
</tr>
<tr>
<td>NUC-R</td>
<td>Remaining initial nuclear</td>
</tr>
<tr>
<td>GAS-R</td>
<td>Remaining initial gas-fired</td>
</tr>
<tr>
<td>OIL-R</td>
<td>Remaining initial oil-fired</td>
</tr>
<tr>
<td>COAL-R</td>
<td>Remaining initial coal-fired</td>
</tr>
<tr>
<td>NUC-N</td>
<td>New nuclear</td>
</tr>
<tr>
<td>GAS-N</td>
<td>Advanced combined-cycle</td>
</tr>
<tr>
<td>COAL-N</td>
<td>Pulverized coal without CO₂ recovery</td>
</tr>
<tr>
<td>RNW-LC</td>
<td>Low-cost carbon-free technologies (quantity constrained)</td>
</tr>
<tr>
<td>RNW-HC</td>
<td>High-cost carbon-free technologies (unlimited quantity)</td>
</tr>
<tr>
<td>GAS-NCS</td>
<td>New gas with carbon capture and sequestration</td>
</tr>
<tr>
<td>COAL-NCS</td>
<td>New coal with carbon capture and sequestration</td>
</tr>
<tr>
<td>COAL-RCS</td>
<td>Remaining coal with carbon capture and sequestration</td>
</tr>
</tbody>
</table>
Non-electric Energy Supplies in MERGE 5.5

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLDU</td>
<td>Coal – direct uses</td>
</tr>
<tr>
<td>OILNON</td>
<td>Oil (10 cost categories)</td>
</tr>
<tr>
<td>GASNON</td>
<td>Gas (10 cost categories)</td>
</tr>
<tr>
<td>BFUEL</td>
<td>Biofuels (ethanol, biodiesel, etc.)</td>
</tr>
<tr>
<td>SYNF</td>
<td>Synfuels (coal to liquids)</td>
</tr>
<tr>
<td>RNW-NE</td>
<td>Non-electric high-cost carbon-free technologies (unlimited quantity)</td>
</tr>
</tbody>
</table>

**Reference Case Relies Heavily on Synfuels**
Scenario Design

TARGET

3.4 RF

3rd Best

First Best

Third Best

Opt.

Opt.

Opt.

Opt.

POLICY

4.7 RF

3rd Best

First Best

Third Best

Opt.

Opt.

Opt.

Opt.

TECHNOLOGY

8 SCENARIOS
Global Carbon Emissions

- 1B
- 3B

(Optimistic Technology)

BAU

4.7 RF

3.4 RF

Billion tons Carbon

2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Annex B Carbon Price with 3.4 RF Target

Transition: Non-Annex B OUT

3B

1B

2000$US per ton Carbon

Opt.
Pess.
USA GDP Loss from Reference with 3.4 RF Target

Opt.
Pess.

3B
1B

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Annex B Carbon Price with 4.7 RF Target

Transition:
Annex B Constrained
Non-Annex B OUT

Optimal

Opt.
Pess.
USA GDP Loss from Reference with 4.7 RF Target


3B

1B

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U.S. Electric Generation, Optimistic Technology
U.S. Electric Generation, Pessimistic Technology

![Graph showing electric generation for different technologies and scenarios.]

Reference, 4.7 RF Target, 3.4 RF Target (1B Policy)
Global Discounted Sum of Economic Cost
At 5% through 2200

2000$US Trillions

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Optimistic 3B

Pessimistic 3B

4.7 Target

1B

3B

Pessimistic 3B

1B

Optimistic 3B

3.4 Target

% GDP Loss from Reference

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