Technology and Climate Policy in the Post-Copenhagen World: GTSP Research

Jae Edmonds
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Overview of the Presentation

► Update on GCAM

► The Post-Copenhagen World
  ■ Multiple Motivations
  ■ The Importance of Technology
  ■ Comparability in a Mosaic World

► Interactions with Other Issues
  ■ Chinese local air quality and the rate of climate change
  ■ REDD policies in a Mosaic world

► An Uncertain Future
UPDATE ON GCAM
GCAM Human and Natural Earth Systems

The Energy System
- Energy Demand
- Energy Demand Technologies
- Energy Markets
- Energy Supply
- Energy Production, Transformation & Use
- GHG Emissions

The Economy
- Regional Labor Force
- Regional GDP

Agriculture and Land Use
- Supply
- Crop
- Livestock
- Forest products
- Biocrops
- Managed Forests
- Unmanaged
- Land Use
- Crop
- Livestock
- Managed Forests
- Unmanaged
- Land Use Change Emissions
- Production
- Crop
- Livestock
- Forest products
- Biomass

Terrestrial Carbon Cycle
- Terrestrial Carbon Cycle

Ocean Carbon Cycle

Atmospheric Composition, Radiative Forcing, & Climate

MAGICC
**Major new developments**

1. **Variable time steps**—(5-year time steps) and beyond 2095.
Major new developments

1. Variable time steps—(5-year time steps) and beyond 2095.

   GCAM-AEZ: USA Wheat Yields

2. GCAM 3—the new agriculture-land-use model GCAM-AEZ (more on this at the Technical Workshop)
Major new developments

1. Variable time steps—(5-year time steps) and beyond

2. GCAM 3—the new agriculture-land-use model GCAM-AEZ (more on this at the Technical Workshop)

Legend

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Major new developments

1. Variable time steps—(5-year time steps) and beyond

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Major new developments

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3. Fresh Water
THE POST-COPENHAGEN WORLD
A Post-Copenhagen World

- From the Framework Convention (1992 UNFCCC) to Kyoto (1997 COP3)—the dream was a unified, comprehensive, & global program to stabilize GHG concentrations.
  - Where, When and How flexibility ruled.

- In the decade between Den Haag (2000 COP6) and Copenhagen (2009 COP15)
  - that paradigm broke apart on the rocks of who and how much?

- The world is unlikely to assemble a unified program. What are the implications?
  - Messy policies
  - More expensive emissions mitigation
  - Technology is even more important
Technology is more valuable in a Mosaic world …

- Improving technology always lowers costs.
- Cost reductions are even larger with inefficient policies.
Technology is not a “Silver Bullet”

Range over 348 technology scenarios

- Range 348 Technology Scenarios
- Pre-industrial CO₂ Concentration

- Range 348 Technology Scenarios

PgC/year

2005 2020 2035 2050 2065 2080 2095

PPM CO₂

2005 2020 2035 2050 2065 2080 2095

Pre-industrial CO₂ Concentration

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MULTIPLE MOTIVATIONS
Climate Policy Will Be Designed in the Context of Other Motivations

- Economic Prosperity
- Security
- Fairness
- Justice and Morality
- Environmental Effectiveness
- Cost Effectiveness
Multi-track regimes lead to less efficient allocation of emissions mitigation, across regions, sectors, and technologies.

It becomes increasingly challenging to use these policy structures as mitigation becomes more stringent.
Stabilization in Three, Really Difficult, Steps

The original vision, going into the 1997 Kyoto Protocol negotiations, was that a comprehensive agreement would be negotiated based on the principle of cap-and-trade. Reality is turning out to be much more complicated.

1. Getting things started.
2. Global comprehensive regime.
3. Getting from 1 to 2.
REDD
REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION
REDD in a reference scenario

ASSUMPTIONS

- There is no price on carbon anywhere.

- We assume that some fraction of unmanaged forests are banked in carbon parks.

- Carbon parks cannot be converted to managed ecosystems.

- Carbon parks do not prevent land-use change emissions due to changes in carbon density of managed systems.
REDD in a reference scenario

- Carbon parks have almost no effect on bioenergy production.

- Carbon parks reduce cumulative land-use change emissions the more extensively they are deployed.
How much does a REDD program help?

<table>
<thead>
<tr>
<th>Fraction of Forest Included in the Program</th>
<th>Reduction in Land-Use Emissions 2005-2095 (PgC)</th>
<th>Marginal Rate of Emissions Mitigation for the Next 1% Added to the REDD System</th>
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<tbody>
<tr>
<td>0-10%</td>
<td>4</td>
<td>-0.4 PgC</td>
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<td>27</td>
<td>-0.6 PgC</td>
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<td>50-90%</td>
<td>101</td>
<td>-1.9 PgC</td>
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<td>90-95%</td>
<td>132</td>
<td>-6.2 PgC</td>
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</table>

Reference Case Cumulative Land-use Change Emissions ~ 350 PgC
How does one compare level of effort when emissions regimes are heterogeneous?

COMPARABILITY
The trouble with comparability

- The trouble with comparability is that if you force everyone to do the same thing in one dimension, they will have to be different in other dimensions.

- No agreement as to what the RIGHT metric of effort really is
  - equal percentage reduction from a historic year (which year?),
  - equal percentage reduction from a future year (How do we predict that?),
  - equal percentage reduction in GDP per capita,
  - not to be confused with what the right emissions allowance should be.

- If you change the metric for comparison, the nominal emissions mitigation can dramatically different.

- What if the US returned to 1990 emissions levels in 2020?
2020 CO2 Emission Reduction Targets
Measured Relative to 2020 BAU level

- equal reduction from baseline 1990
- equal reduction from baseline 2005
- equal MAC
- equal TAC/GDP
- equal TAC/GDP (no trade)

% change from 2020 emission level

USA  FSU  EU15+  Japan  Canada  Australia_NZ  EU27+  ANNEX I
2020 CO2 Emission Reduction Targets
Measured Relative to 2005 level

USA  FSU  EU15+  Japan  Canada  Australia_NZ  EU27+  ANNEX I
2020 CO2 Emission Reduction Targets
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% change from 1990 emission level

USA  FSU  EU15+  Japan  Canada  Australia_NZ  EU27+  ANNEX I
INTERACTIONS WITH OTHER ISSUES
Chinese Air Quality

- China is the largest fossil fuel CO$_2$ emitter.
- It has severe local air quality issues.
- It is also the world’s largest sulfur emitter.
True-color MODIS image from October 22, 2001

Source: http://earthobservatory.nasa.gov/IOTD/view.php?id=1934
Radiative Forcing: Aerosols are estimated to reduce radiative forcing by almost as much as CO$_2$ increases it!
CHINESE Sulfur Emissions

Without Additional Controls

CHINA Sulfur Emissions

TgSO₂/yr

2005 2015 2025 2035 2045 2055 2065 2075 2085 2095
CHINESE Sulfur Emissions and GLOBAL Mean Surface Temperature with Accelerated Sulfur Emissions Policies

CHINA Sulfur Emissions

Global Mean Surface Temperature Change from Preindustrial

[Graph showing CHINESE sulfur emissions and global mean surface temperature changes with and without additional controls.]
CHINESE Sulfur Emissions and GLOBAL Mean Surface Temperature with Accelerated Sulfur Emissions Policies
Rate of Climate Change With and Without Accelerated Chinese Sulfur Controls

Global Mean Surface Temperature Change

Reference CHINA Emissions Controls
Rate of Climate Change With and Without Accelerated Chinese Sulfur Controls

Global Mean Surface Temperature Change

With CHINA SULFUR Emissions Controls
Reference CHINA Emissions Controls
AN UNCERTAIN FUTURE
Into the Matrix: A New Scenario Architecture

 ► **The Scenario Matrix Architecture (SMA):**
   The concept of multiple scenarios to systematically explore key uncertainties, useful to IAV and IAM researchers, clustered into families defined by
   1. Shared socio-ecological pathway (SSP) assumptions,
   2. Shared policy assumptions (SPA) about mitigative stringency, and

 ► **The SSPs:** Assumptions about the state of global and regional society and ecosystems as they evolve over the course of the 21st century.
   - Systematically explore key uncertainties in mitigative and adaptive capacity.
Populations for the SSPs [billion]

(Based on UN World Population Prospects: The 2008 Revision – Long Range Projections, released in 2011)
 Constructed GDP Scenarios [trillion 2000 USD]
Reference Scenario 2100 Radiative Forcing

[W/m²]

SSP13   RCP8.5   SSP9   SSP6   RCP6.0   RCP4.5   RCP2.6

2005 level
Mitigation under the Three SSPs

- We assumed a common global price of carbon applied to ALL emissions (fossil fuel and land-use change).
  - RCP 2.6 is an overshoot scenario
  - Other stabilization scenarios are “not-to-exceed”.

- We observe difference in the initial price required to stabilize among the SSPs.

- Of course, the big difference in price is between stabilization goals.
Higher population leads to more rapid increase in energy prices, particularly for crude oil and bio-energy.
Greater population leads to greater crop land use, rapidly displacing the land use for forest, pasture, and bio-energy.
Land Use Change Emissions in Reference Scenarios

- SSP13 results in the dramatic increase in land use change emissions throughout the century.
Reprise

➤ Update on GCAM

➤ The Post-Copenhagen World
  ■ Multiple Motivations
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DISCUSSION
BACKUP SLIDES
Net Land Use Change Emissions & Fossil Fuel and Industrial CO$_2$ Emissions

For a given CO$_2$ concentration limit

- In the UTC regime ILUC disappears as an issue.
- In the FFICT regime high carbon prices drive bioenergy demands and ILUC

Lower FF emissions are needed in FFICT regime to offset land use change emissions.
Significant crop price escalation occurs if carbon is valued, even in the absence of purpose grown bioenergy production.

- Prior to 2040 the influence of bioenergy is negligible.
- Prior to 2040 crop price escalation, relative to the reference scenario, is predominantly driven by the value of carbon.
Policy without architecture

- An international regime built around independent actions, employing heterogeneous policy instruments
  - Inevitably yields less than optimal emissions mitigation,
  - Gets messy fast, and
  - Produces a very different global energy system.

- For the LinkS project we examined a hypothetical protocol in which emissions were controlled using a policy regime based on the EU 20/20/20 proposal.
  - 20% reduction in emissions
  - 20% reduction in primary energy use
  - 20% share of energy from renewables
  - In 2020

...with staggered participation.
Policies can get messy fast: Assumptions applying the EU20/20/20 proposal to the world

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
<th>2065</th>
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<td><strong>W. Europe</strong></td>
<td><strong>Australia/NZ</strong></td>
<td><strong>Canada</strong></td>
<td><strong>China</strong></td>
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<td>EE (20%)</td>
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<tr>
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<td>TE (50%)</td>
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<td>TE (50%)</td>
<td>TE (50%)</td>
</tr>
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Graphs showing emissions and renewable energy contribution over time.
Global Electricity Generation in Global 20/20/20+ and economically efficient

GHG Only

Global 20-20-20

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SSPs

SSP1

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

Quantitative Variables that define IAM reference “no-climate-policy” scenario 1.
E.g. reference scenario population by region by year.

Quantitative Variables that define reference “no-climate-policy” scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

SSP2

Storyline 2: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

Quantitative Variables that define IAM reference “no-climate-policy” scenario 2.
E.g. reference scenario population by region by year.

Quantitative Variables that define reference “no-climate-policy” scenario 2, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

Etc.
The Reference Scenario for an SSP

Our focus today will be on the quantitative assumptions that feed the GCAM IAM in terms of only TWO variables: Population & Economic Activity.

- **SSP1**
  - **Storyline 1:** The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

- **Quantitative Variables that define IAM reference "no-climate-policy" scenario 1:**
  - Regional Climate Change
  - Temperature, Precip, Storm intensity, Other
  - Present - 2100

- **Other IAM assumptions**

- **Regional Climate Change**
  - Temperature, Precip, Storm intensity, Other

- **Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.**

- **SSP1 Reference Scenario**

- **Regional**
  - GDP, Pop,
  - Energy prices, Energy mix,
  - Commodity prices, Land prices,
  - Crop prices, Trade, Land cover,
  - GHG Emissions, pollutant emissions,
  - Etc.

- **Present - 2100**

- **Proudly Operated by Battelle Since 1965**
The Five Shared Policy Assumptions (SPAs) and The Three Shared Climate Assumptions (SCAs)

- We explore three population pathways based on the NEW UN long-range projections (extension of 2008 revision)
  - High fertility rate scenario
  - Medium fertility rate scenario
  - Low fertility rate scenario

- 5 SPAs representing a range of mitigative stringency:
  - No policy case (Ref)
  - End-of-the-century radiative forcing reaching 6.0, 4.5, 3.7, and 2.6

- 3 SCAs representing a range of climate sensitivity:
  - Climate sensitivity of 2°C, 3°C, and 5°C per doubling of CO₂

- This gives 15 scenarios for each Shared Socio-ecosystem Pathway (SSP)