CLIMATE CHANGE 2014
Mitigation of Climate Change
IA Models and WGIII:
Lessons from IPCC AR5

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I. The IAM Success Story in WGIII AR5: Identifying Requirements for Low Stabilization Targets
   I. Emissions Reduction Pathways
   II. Technological Requirements
   III. Sectoral Requirements
   IV. Cost Estimations

II. Scenario Process – Closing the Loop across IPCC Working Groups

III. Future Challenges of Integrated Model Development – towards a Sustainability Diagnostics
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The WGIII Story of AR5: Identifying different pathways towards low stabilization targets

- Low stabilization targets require deep emissions cuts irrespective of the precise target.
- Delay of mitigation will cause costs and risks in the future.
- There is more than one technological pathway to achieve a low stabilization target.
- Reduction of energy demand is a crucial option to realize co-benefits and hedge against the supply-side risks.
- All sectors have to contribute to mitigation, without CCS the AFOLU sector has to contribute more.
- Economic growth and low stabilization targets can be reconciled.
- Carbon pricing is essential for low stabilization targets.
Low stabilization targets require deep emissions cuts irrespective of the precise target.
Delaying mitigation is estimated to increase the difficulty and narrow the options for limiting warming to 2°C.

„immediate action“
Delaying mitigation is estimated to increase the difficulty and narrow the options for limiting warming to 2°C.
Delivering mitigation is estimated to increase the difficulty and narrow the options for limiting warming to 2°C.
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Current Cancún Pledges imply increased mitigation challenges for reaching 2°C.
Delay of mitigation efforts can greatly influence mitigation costs.
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In ambitious mitigation scenarios, fossil fuel use without CCS is phased out in the long-term.

Based on Figure 7.15b
There is more than one technological pathway to achieve a low stabilization target – the wide ranges imply flexibility.
Energy demand reductions can increase this flexibility, hedge against risks, avoid lock-in and provide co-benefits.

Based on Figure 7.11
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Mitigation requires changes throughout the economy. Systemic approaches are expected to be most effective.

Based on Figure TS.17

450 ppm CO$_2$eq with Carbon Dioxide Capture & Storage

- Direct Emissions [GtCO$_2$eq/yr]
- Land-Use (net)
- Electricity
- Transport
- Buildings
- Industry
- Non-CO$_2$

- Max
- 75%
- Median
- 25%
- Min
Mitigation efforts in one sector determine efforts in others.

Based on Figure TS.17

450 ppm CO$_2$ eq without Carbon Dioxide Capture & Storage
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Global costs rise with the ambition of the mitigation goal.

Based on SYR Figure SPM.13
Lessons learnt from the IPCC assessment process

- IAMs played an important role in identifying the technological and sectoral requirements, evaluating mitigation costs
- Multiple pathways have been presented to the policy makers
- The IAM modelling community has been successfully providing maps to the navigators....
State of knowledge before AR5: Claudius Ptolemy World Map (1482)
A huge step forward with AR5: Gerhard Mercator Map (1569)

"Nova et aucta orbis terrae descriptio ad usum navigantium emendate accommodata"
Lessons learnt from the IPCC assessment process

.... Nevertheless, future challenges remain:

- Closing the loop across IPCC Working Groups in scenario process
- Integrated models should be able to speak to other sustainability concerns
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Consistency of temperature projections and likelihood qualifiers across WGs has been a major leap for the IPCC

<table>
<thead>
<tr>
<th>CO₂ eq Concentrations (CO₂ eq)</th>
<th>Subcategories</th>
<th>Cumulative CO₂ emission (GtCO₂)</th>
<th>Change in CO₂ eq emissions (%)</th>
<th>Temperature change (°C)</th>
<th>Likelihood of staying below temperature change over the 21st century</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5°C</td>
<td>2.0 °C</td>
</tr>
<tr>
<td>in 2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>Total range</td>
<td>630-1180</td>
<td>-72 to -41</td>
<td>1.5-1.7</td>
<td>Likely</td>
</tr>
<tr>
<td>500</td>
<td>No Overshoot</td>
<td>960-1430</td>
<td>-57 to -42</td>
<td>1.7-1.9</td>
<td>More likely than not</td>
</tr>
<tr>
<td></td>
<td>Overshoot</td>
<td>990-1550</td>
<td>-55 to -25</td>
<td>1.8-2.0</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>550</td>
<td>No Overshoot</td>
<td>1240-2240</td>
<td>-47 to -19</td>
<td>2.0-2.2</td>
<td>Unlikely</td>
</tr>
<tr>
<td></td>
<td>Overshoot</td>
<td>1170-2100</td>
<td>-16 to 7</td>
<td>2.1-2.3</td>
<td>More unlikely than likely</td>
</tr>
<tr>
<td>580-650</td>
<td>Total range</td>
<td>1870-2440</td>
<td>-38 to 24</td>
<td>2.3-2.6</td>
<td></td>
</tr>
</tbody>
</table>

For all parameters, the 10th to 90th percentile of the scenarios is shown. Based on Table SPM.1
This has been the basis for a deep integration of WGI and WGIII

Based on SYR Figure SPM.10
... but important gaps remain. Closing the loop remains the main challenge for AR6.

- SSPs were not finalized in time for the AR5
  - No systematic assessment of the socioeconomic uncertainties
  - No consistent link to the impacts
- Identifying differential mitigation costs, adaptation costs and residual climate impacts

<table>
<thead>
<tr>
<th>Forcing level (W/m²)</th>
<th>SSP1</th>
<th>SSP2</th>
<th>SSP3</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
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<td></td>
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<tr>
<td>4.5</td>
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<td></td>
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<tr>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Forcing level (W/m²)

<table>
<thead>
<tr>
<th>Mitigation costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
</tr>
<tr>
<td>high</td>
</tr>
</tbody>
</table>

Adaptation costs + residual impacts

From van Vuuren et al., 2014, Figure 6
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IAMs are criticized by many non-modellers because...

- They misrepresent the pace and the direction of technological change.
- They do not understand institutional challenges of policy instruments (e.g. carbon pricing).
- Therefore, they underestimate/overestimate the costs of mitigation.
- They underestimate damages from climate change.
- They underestimate co-benefits.
- They overestimate (implicitly or explicitly) the capacity to adapt.
Two main conclusions...

• They **overestimate** the costs of action and underestimate the costs of non-action: too optimistic about climate policy.

• They **underestimate** the costs of action and overestimate the costs of non-action: too pessimistic about climate policy.

• Both camps agree that IAM misrepresent economic and social reality and are therefore misleading.
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   IV. Representation of Damages in IAMs
• Some IAMs have a quite detailed representation of technologies.

• Some of them have components of endogenous technological change.

• However, the direction of technological change seems to be important but not very well understood.
  — Technological progress in the fossil sector
  — Technological progress in the low-carbon sector
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Determining the effect of mitigation on SD requires...

• Identifying synergies and tradeoffs between multiple objectives,
• Exploring the multiple externalities,
• Evaluating the interaction between different policy instruments.
Multiple policy instruments: There are large knowledge gaps on the interaction of multiple policy instruments

Need to understand interaction to evaluate welfare effects

<table>
<thead>
<tr>
<th>Government Provision of Public Goods or Services</th>
<th>Option Specific</th>
<th>Whole Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install Efficient Technology</td>
<td>Training, Education</td>
<td>Government Procurement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regulatory Approaches</th>
<th>Option Specific</th>
<th>Whole Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Standards</td>
<td>Energy Management</td>
<td>Benchmark Target</td>
</tr>
<tr>
<td>Control Retrofit/Replace, Mandated Technologies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic Instruments</th>
<th>Option Specific</th>
<th>Whole Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferential Loans</td>
<td>Specific Tax Credit, Exemption, Deduction</td>
<td></td>
</tr>
<tr>
<td>Subsidies</td>
<td></td>
<td>Tradable Allowances</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Information Programmes</th>
<th>Option Specific</th>
<th>Whole Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmarking</td>
<td>Data Collection, Auditing, Monitoring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partnership, Programme</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Promotion</td>
<td></td>
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</tbody>
</table>

Based on Figure 10.15
Multiple Policy Instruments

• Interaction between different policy instruments
  • Technology standards and price instruments

• Interaction between regulator and market agents
  • Second-best policies (e.g. Green Paradox)
  • Overcoming lock-in effects

• Interaction between different Jurisdictions
  • Vertical Federalism
  • Horizontal Federalism
Lessons for IAMs

• Social Planner perspective is not sufficient.
• Recursive CGE models will no longer work.
• Game theoretic representation is required.
• Integrated policy instrument assessment is required.
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The „value“ of co-benefits are largest when...

\[ \frac{dW}{dp_1} \gg 0 \]

\[ dW = \sum_{i=1}^{m} \frac{\partial W}{\partial z_i} \frac{\partial z_i}{\partial p_1} dp_1 \]

\[ dW = \sum_{i=1}^{m} (t_i - \mu_i) \frac{\partial z_i}{\partial p_1} dp_1 \]

- ... there are strong synergies between policy objectives (e.g. local air pollution) and climate policy instruments (e.g. carbon taxes) \( \frac{\partial z_i}{\partial p_1} \ll 0 \),

- ... the non-climate externalities (e.g. local air pollution) are not regulated \( t_i = 0 \),

- ... the social benefits (e.g. reduction of local air pollution) are huge \( \mu_i \gg 0 \).

\( W \): Social Welfare
\( z_i \): Objective i
\( p_1 \): Climate policy instrument
\( t_i \): Tax for good/bad i
\( \mu_i \): Shadow price for good/bad i
“Sustainable Development Diagnostics“ require new analytical tools

\[
dW = \sum_{i=1}^{m} (t_i - \mu_i) \frac{\partial z_i}{\partial p_1} dp_1
\]

- Identify all relevant social objectives \((z_i, \ldots z_n)\) and their possible trade-offs and synergies!

- Target the largest distortions \((t_i - \mu_i)\)!

- Focus on policies with the largest positive & negative impacts on societal goals \(\left(\frac{\partial z_i}{\partial p_1}\right)\)!

- Be comprehensive – all relevant interactions matter \((\sum_{i=1}^{m} )\)!
Towards a “Sustainable Development Diagnostic Tool“
Non-marginal changes of co-benefits

The core question of SD diagnostics:

Which combination of policy instruments leads to the highest welfare gains?

\[
\Delta W = \int_{p_1^l}^{p_1^h} dW dp_1
\]

\[
\Delta W_t = W^*(p_1^h, t) - W^*(p_1^l, t) \begin{cases} \geq 0 \\ < 0 \end{cases}
\]

Conjecture for 2050 co-benefits

Carbon tax and infrastructure policy

Air quality co-benefits

Mitigation goal \((dp_1)\)

Working Group III contribution to the IPCC Fifth Assessment Report
Challenges for IAMs in the context of SD

• Representation of multiple externalities: dynamic second-best setting.
• Representation of multiple objectives; a broader sustainability framework is required.
• Exploring the most promising policy packages.
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Representation of damages in IAMs

AR5 Chapter 2: “… the uncertainty surrounding the potential impacts of climate change, including possible irreversible and catastrophic effects on ecosystems, and their asymmetric distribution around the planet, suggests CBA may be inappropriate for assessing optimal responses to climate change in these circumstances”

- Overcoming the representative household: heterogeneity of actors and distributional challenges
- Impacts on capital, labor and fixed factors (e.g. land or capital with adjustment costs)
- Modeling damages as anticipated and non-anticipated shocks
- Exploring the limits of expected utility theory
Towards more policy realism...

Source: *The Economist* 2014
CLIMATE CHANGE 2014
Mitigation of Climate Change

www.mitigation2014.org