Low Mitigation Scenarios in Second-Best Worlds

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July 29-30 2010

Snowmass
Outline

• How to overcome the discrepancy between political ambition and scientific underpinning?

• Low mitigation scenarios in a first-best world

• Low mitigation scenarios in second-best worlds

• Exploring the „feasibility frontier“ for AR5
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• How to overcome the discrepancy between political ambition and scientific underpinning?

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• Exploring the „feasibility frontier“ for AR5
2. We agree that deep cuts in global emissions are required [...] to hold the increase in global temperature below 2 degrees Celsius, ...

Proposal by the President

Copenhagen Accord

The Heads of State, Heads of Government, Ministers, and other heads of delegation present at the United Nations Climate Change Conference 2009 in Copenhagen,

In pursuit of the ultimate objective of the Convention as stated in its Article 2,

Being guided by the principles and provisions of the Convention.
12. We call for an assessment [that] would include consideration of strengthening the long-term goal [...] including [...] temperature rises of 1.5 degrees Celsius.
The Scientific Arena

Only 6 scenarios from 3 models in the lowest category...

Table 3.10: Properties of emissions pathways for alternative ranges of CO₂ and CO₂-eq stabilization targets. Post-TAR stabilization scenarios in the scenario database (see also Sections 3.2 and 3.3); data source: after Nakicenovic et al., 2006 and Hanaoka et al., 2006

<table>
<thead>
<tr>
<th>Class</th>
<th>Anthropogenic addition to radiative forcing at stabilization (W/m²)</th>
<th>Multi-gas concentration level (ppmv CO₂-eq)</th>
<th>Stabilization level for CO₂ only, consistent with multi-gas level (ppmv CO₂)</th>
<th>Number of scenario studies</th>
<th>Global mean temperature C increase above pre-industrial at equilibrium, using best estimate of climate sensitivity (°C)</th>
<th>Likely range of global mean temperature C increase above pre-industrial at equilibrium (°C)</th>
<th>Peaking year for CO₂ emissions</th>
<th>Change in global emissions in 2050 (% of 2000 emissions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.5-3.0</td>
<td>445-490</td>
<td>350-400</td>
<td>6</td>
<td>2.0-2.4</td>
<td>1.4-3.6</td>
<td>2000-2015</td>
<td>-85 to -50</td>
</tr>
<tr>
<td>II</td>
<td>3.0-3.5</td>
<td>490-535</td>
<td>400-440</td>
<td>16</td>
<td>2.4-2.8</td>
<td>1.6-4.2</td>
<td>2000-2020</td>
<td>-60 to -30</td>
</tr>
<tr>
<td>III</td>
<td>3.5-4.0</td>
<td>535-590</td>
<td>440-485</td>
<td>21</td>
<td>2.8-3.2</td>
<td>1.9-4.9</td>
<td>2010-2030</td>
<td>-30 to +5</td>
</tr>
<tr>
<td>IV</td>
<td>4.0-5.0</td>
<td>590-710</td>
<td>485-570</td>
<td>118</td>
<td>3.2-4.0</td>
<td>2.2-6.1</td>
<td>2020-2060</td>
<td>+10 to +60</td>
</tr>
<tr>
<td>V</td>
<td>5.0-6.0</td>
<td>710-855</td>
<td>570-660</td>
<td>9</td>
<td>4.0-4.9</td>
<td>2.7-7.3</td>
<td>2050-2080</td>
<td>+25 to +85</td>
</tr>
<tr>
<td>VI</td>
<td>6.0-7.5</td>
<td>855-1130</td>
<td>660-790</td>
<td>5</td>
<td>4.9-6.1</td>
<td>3.2-8.5</td>
<td>2060-2090</td>
<td>+90 to +140</td>
</tr>
</tbody>
</table>

Notes:
- a. Warming for each stabilization class is calculated based on the variation of climate sensitivity between 2°C – 4.5°C, which corresponds to the likely range of climate sensitivity as defined by Meehl et al. (2007, Chapter 10).
- b. Ranges correspond to the 70% percentile of the post-TAR scenario distribution.
- c. ‘Best estimate’ refers to the most likely value of climate sensitivity, i.e. the mode (see Meehl et al. (2007, Chapter 10) and Table 3.9

Fisher et al. (2007), AR4
Low Mitigation Scenarios Beyond AR4

• ...but already many more available for AR5
• Exploration of RCP3-PD within the scenario process

Knopf/Luderer/Edenhofer, subm.
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• How to overcome the discrepancy between political ambition and scientific underpinning?

• **Low mitigation scenarios in a first-best world**

• Low mitigation scenarios in second-best worlds

• Exploring the „feasibility frontier“ for AR5
Low Stabilization Pathways: Economic and Technical Feasibility

ADAM Model Comparison

**Members:**
- PIK (REMIND model): O. Edenhofer, M. Leimbach, L. Baumstark, B. Knopf
- PSI (MERGE model): T. Hal, S. Kypreos, B. Magné
- U Cambridge (E3MG model): T. Barker, S. Scrieciu
- ENERDATA (POLES model): A. Kitous, E. Bellevrat, B. Chateau, P. Criqui
- PBL (TIMER): D. van Vuuren, M. Isaac
- Compilation of comparison: B. Knopf
The Economics of Atmospheric Stabilisation

ADAM model comparison:
Analysis of 3 stabilisation targets with different probabilities to reach the 2° target: 550ppm-eq, 450ppm-eq, 400ppm-eq

Energy-related CO₂ emissions

Knopf, Edenhofer et al. (2009)
Transformation of the Energy System

The historical challenge

Example: REMIND

Baseline

550ppm-eq

400ppm-eq

Knopf, Edenhofer et al. (2009)
Transformation of the Energy System

Many different pathways to transform the energy system

- Different possibilities to reach low stabilisation
- 400ppm can be achieved by all models

Knopf, Edenhofer et al. (2009)
Costs of Low Stabilisation

Mitigation costs
as net present value of mitigation costs until 2100 relative to baseline, 3% disc.

Global costs are below 2.5% GDP losses for low stabilisation
One model reports gains as it assumes inefficiencies in the baseline

Knopf, Edenhofer et al. (2009)
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Statistical Analysis for Assessing Second Best Worlds

Green: with BECS
Blue: w/o BECS

Increasing strictness of target

Increasing strictness of target

Tavoni and Tol (2010)\textsuperscript{15}
Mitigation Costs: Technology Options, 550ppm

550ppm-eq

Mitigation costs [%GDP]

Abatement costs [%GDP]

Knopf, Edenhofer et al. (2009)
Technology Options for Low Stabilisation

- high biomass potential
- with all options
- no nuclear beyond baseline
- low biomass potential
- no CCS
- no renewables beyond baseline

Robust ranking of options

Knopf, Edenhofer et al. (2009)
Technology Options for Low Stabilisation

Mitigation potential of nuclear is limited (but high use in the baseline)
400 ppm neither achievable without CCS nor without extension of renew
Biomass potential dominates the mitigation costs of low stabilisation

Knopf, Edenhofer et al. (2009)
Influence of the CCS Potential

MERGE-ETL

- CCS potential does not only affect the costs, but also the strategy in the energy system

Magné, Kypreos, Turton (2010)
Influence of the Biomass Potential

- Competition between biomass+CCS with other renewables
- Longer use of fossil energy with higher biomass potential

Reference:

Knopf, Edenhofer et al. (2009)
International climate policy architectures: Overview of the EMF 22 International Scenarios

Leon Clarke, Jae Edmonds, Volker Krey, Richard Richels, Steven Rose, Massimo Tavoni

* The Pacific Northwest National Laboratory (PNNL), Joint Global Change Research Institute (JGCRI), at the University of Maryland College Park, USA
* International Institute for Applied Systems Analysis (IIASA), Austria
* Electric Power Research Institute (EPRI), USA
* Princeton Environmental Institute, Princeton University, USA
* Fondazione Ente Enrico Mattei (FEMI), Italy
* Centro Euro-Mediterraneo per i Cambiamenti Climatici (CMCC), Italy

**ABSTRACT**

This paper presents an overview of the study design for, and the results of, the EMF 22 International Scenarios. The EMF 22 International Scenarios engaged ten of the world’s leading integrated assessment (IA) models to focus on the combined implications of three factors integral to international climate negotiations: (1) the long-term climate-related target, expressed in this study in terms of the CO₂-equivalent (CO₂-e)
EMF 22: Overshoot or „Not to exceed“

• EMF 22: assessment of
  – Different targets
  – Overshoot (O.S.) or Not-to-exceed (N.T.E.) scenarios
  – Delayed participation

![Graph showing the number of models (out of 10) for different scenarios with 550 ppm and 450 ppm emissions.]
EMF22: Delayed Participation

Scenarios that could not be modeled under criteria of study.

Clarke et al (2009) 23
Proposal: EMF 24 Scenarios

<table>
<thead>
<tr>
<th>Technology Dimension</th>
<th>Ref</th>
<th>Low</th>
<th>Ref</th>
<th>Low</th>
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<tbody>
<tr>
<td>Energy intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCS</td>
<td>On</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Nuclear energy</td>
<td>On</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>Opt</td>
<td>Opt</td>
<td>Opt</td>
<td>Pess</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Dimension 2</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Baseline</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>450 CO2e</td>
<td>33</td>
<td>34</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>550 CO2e</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Idealized G8</td>
<td>37</td>
<td>38</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Muddling through</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>

**Purple:** Required scenarios for participation (14)
**Green:** Higher priority optional scenarios (12)
**Yellow:** Lower priority optional scenarios (14)
Second-Best Scenarios – Insights From RECIPE
If global climate agreement is delayed until 2030, stabilization at 450 ppm CO2 or below becomes infeasible.

If global climate agreement is delayed until 2020, costs are projected to increase by at least 46%.
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Costs of Low Mitigation Scenarios

Exceedence probability for 2°C [%]

Mitigation costs 2005-2050 [%GWP]

Cumulated CO₂ emissions 2000-2050 [GtCO₂]

Somewhere here starts the (model dependent) feasibility frontier

Knopf/Luderer/Edenhofer, subm.
Assessment of Differential Impacts

- Exploration of the feasibility frontier has to come from both sides: including impacts and limits of adaptive capacity.
Iteration Between Targets and Measures

Science: Scope of options

Goal-setting by policy makers

Data

1.5°C target
2°C target

Consideration of unintended side-effects
Exploring the Feasibility Frontier

3D assessment space for each model

Stringency of mitigation target

2nd best worlds and structural model uncertainties

Categories: uncertainty in baseline assumptions

feasible
infeasible

Knopf/Luderer/Edenhofer, subm.
Conclusion

Potsdam is the first-best place in the World…

…but Snowmass is definitely the second-best place
The Supply-side of Global Warming

Cumulative historic carbon consumption (1750-2004), estimated carbon stocks in the ground, and estimated future consumption (2005-2100) for business-as-usual (BAU) and ambitious 400-ppm-CO₂-eq. scenario

Source: Kalkuhl, Edenhofer and Lessmann, 2009