The Shared Socio-Economic Pathways (SSP) framework

Franziska Piontek
IPCC 2000/TAR 2001: SRES

Figure 2-1. Illustration of the SRES families along two dimensions that indicate the relative orientation of the storylines along the axes of global or regional development and economic or environmental concerns (reprinted from Nakićenović et al., 2000).
New scenarios for climate change research, developed by the community

- **WG I:** climate models
- **WG II:** impact, adaptation and vulnerability
- **WG III:** integrated assessment models

Franziska Piontek: SSP framework
Process

Representative concentration pathways
Forcing, concentrations, emissions, land use
complete (RCPs)

Socio-economic pathways
Emissions drivers, mitigative capacity
Exposure, sensitivity, adaptive capacity
ongoing (SSPs)

Earth-system model simulations
Climate change, climate variability
ongoing (CMIP5)

Integrated analyses
Mitigation, adaptation impacts
Started (IAMs)

Franziska Piontek: SSP framework
New process (Moss et al. 2010)

- **complete**
  - General characteristics
    - Broad range of forcing in 2100
    - Shape of radiative forcing over time
  - Representative concentration pathways (RCPs)
    - Four pathways from existing literature
    - Greenhouse gases
    - Short-lived gases and aerosols
    - Land cover/use

- **ongoing (SSPs, IAV indicators)**
  - New socio-economic and emissions scenarios; vulnerability storylines
    - Adaptation
    - Mitigation
    - Stabilization
    - Overshoots
    - ...
  - Consistent with RCPs
  - Independent of the RCPs

- **ongoing (CMIP5)**

- **started (IAMs)**
  - Integration of climate and socio-economic scenarios
    - Integrated scenarios
    - Pattern scaling (climate)
    - Downscaling of climate and socio-economic scenarios
    - ...

- **your task!**
  - New research and assessments
    - Impact, adaptation, and vulnerability studies
    - Climate change feedbacks
    - Model development
    - ...

Franziska Piontek: SSP framework
Representative concentration pathways (RCPs)

Moss et al. (2010)  
RCPs: 2.6, 4.5, 6.0, 8.5 W/m²
Process

**Representative concentration pathways**
- Forcing, concentrations, emissions, land use
- **complete (RCPs)**

**Earth-system model simulations**
- Climate change, climate variability
- **ongoing (CMIP5)**

**Socio-economic pathways**
- Emissions drivers, mitigative capacity
- Exposure, sensitivity, adaptive capacity
- **ongoing (SSPs)**

**Integrated analyses**
- Mitigation, adaptation impacts
- **Started (IAMs)**

O’Neill and Schweizer (2011)
CMIP5 - Coupled Model Intercomparison Project Phase 5 - Overview

At a September 2003 meeting involving 20 climate modeling groups from around the world, the WCRP's Working Group on Coupled Modelling (WGCM), with input from the IGEP AIMES project, agreed to promote a new set of coordinated climate model experiments. These experiments comprise the fifth phase of the Coupled Model Intercomparison Project (CMIP5). CMIP5 will notably provide a multi-model context for 1) assessing the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds, 2) examining climate “predictability” and exploring the ability of models to predict climate on decadal time scales, and, more generally, 3) determining why similarly forced models produce a range of responses.

It is expected that some of the scientific questions that arose during preparation of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) will through CMIP5 be addressed in time for evaluation in the Fifth Assessment Report (AR5, scheduled for publication in late 2013). The IPCC/CMIP5 schedule (pdf) is now available and the three key dates are as follows:

- **February 2011:** First model output is expected to be available for analysis.
- **July 31, 2012:** By this date papers must be submitted for publication to be eligible for assessment by WG1.
- **March 15, 2013:** By this date papers cited by WG1 must be published or accepted.

The IPCC’s AR5 is scheduled to be published in **September 2013**. Future timeline information can be found on [IPCC WG1 website](http://www.ipcc.org/wg1).

CMIP5 is meant to provide a framework for coordinated climate change experiments for the next five years and thus includes simulations for assessment in the AR5 as well as others that extend beyond the AR5. CMIP5 is not, however, meant to be comprehensive, it cannot possibly include all the different model intercomparison activities that might be of value, and it is expected that various groups and interested parties will develop additional experiments that might build on and augment the experiments described here.

CMIP5 promotes a standard set of model simulations in order to

- evaluate how realistic the models are in simulating the recent past,
- provide projections of future climate change on two time scales, near term (out to about 2036) and long term (out to 2100 and beyond), and
- understand some of the factors responsible for differences in model projections, including quantifying some key feedbacks such as those involving clouds and the carbon cycle.
CMIP5

CMIP5 data from 5 GCMs used in Inter-sectoral Impact Model Intercomparison Project
Socio-economics in RCPs

→ Not useful as complete set of new socio-economic scenarios
Process

Representative concentration pathways
Forcing, concentrations, emissions, land use
complete (RCPs)

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Climate change, climate variability
ongoing (CMIP5)

Integrated analyses
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Socio-economic pathways
Emissions drivers, mitigative capacity
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O’Neill and Schweizer (2011)

Franziska Piontek: SSP framework
Socio-economic pathways (SSPs)

• Series of workshops since 2010

• Papers:
  • Moss et al. 2010: The next generation of scenarios for climate change research and assessment
  • Kriegler et al. 2010: Socio-economic Scenario Development for Climate Change Analysis
  • Arnell et al. 2011: A framework for a new generation of socio-economic scenarios for climate change impact, adaptation, vulnerability, and mitigation research (framework paper draft)
  • Van Vuuren et al. 2012: A proposal for a new scenario framework to support research and assessment in different climate research communities
  • O’Neill et al. 2012: Workshop on the nature and use of new socioeconomic pathways for climate change research (meeting report on storylines)
  • Special Issue forthcoming
Aims

• Joined IAM-IAV activity
• Improve coordination and integration of assessments of all 3 WGs
• Support integrated analysis of mitigation, adaptation and residual impacts
• Simplify comparability among research projects
• Provide framework for regional and local research
• Tool for researchers, no straight communication to policy makers!
Concept of scenario architecture

Socio-economic pathways

<table>
<thead>
<tr>
<th>Climate pathways</th>
<th>SSP1</th>
<th>SSP2</th>
<th>SSP3</th>
<th>SSP4</th>
<th>SSP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP forcing level [W/m²]</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>4.5</td>
<td></td>
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<td></td>
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<tr>
<td>2.6</td>
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</tr>
</tbody>
</table>

Independent of but consistent with RCPs

Mitigation efforts

Climate impacts

Franziska Piontek: SSP framework
Possible application for analysis

Franziska Piontek: SSP framework
Shared climate policy assumptions (SPAs): Policy analysis wrt costs

- 3 components
  - Policy objective: RCP level or derivative
  - Policy instruments and measures: e.g. CO2 and energy taxes, cap & trade, regulatory approaches
  - Implementation obstacles & market distortions ("2nd best"): e.g. regional and sectoral fragmentation, trade barriers, technology failure
What is a Shared Socio-economic Pathway (SSP)?

- Narratives
- Quantitative population/GDP scenarios
- Quantitative elements coming from IAMs
- Quantitative IAV elements

Done and available at IIASA database upon request

Work in progress
SSP „space“ – range of socio-economic challenges for mitigation and adaptation

Franziska Piontek: SSP framework
SSP „space“ – range of socio-economic challenges for mitigation and adaptation

- **SSP5**: Conventional development
- **SSP2**: Continuation
- **SSP1**: Sustainability
- **SSP3**: Fragmentation
- **SSP4**: Inequality

Increasing socio-economic challenges for **adaptation**

Increasing socio-economic challenges for mitigation
SSP1 – low challenges - sustainability

- Rapid development of low-income countries
- Reduction of global and national inequalities
- Rapid technological development
- High level of awareness regarding environmental degradation
- Open globalized economy
- R&D, technology transfers
- Clean energy technologies
- Low material growth and energy intensity
- Low population growth, high education investments
- Good governance
- Achievement of MGDs in next decades
SSP2 – medium challenges – continuation of current trends

- Slowly decreasing fossil fuel dependency
- Reductions of resource and energy intensity
- Uneven development of low-income countries
- Few weak global institutions
- Slow continuation of globalization with some barriers remaining
- Well regulated information flow
- Medium economic growth, slow convergence
- High intra-regional disparities
- Medium population growth related to medium educational investments
- Delay of achievement of MDGs
SSP3 – high challenges - fragmentation

- Regions of extreme poverty, pockets of moderate wealth, bulk of countries struggling to maintain living standards for strongly growing population
- Little coordination between regional blocks of countries
- Energy and food security within regions
- De-globalization, severe restrictions on international trade
- Little international cooperation
- Low investments in technology development and education
- High population growth, low economic growth
- Lack of governance and institutions
SSP4 – high adaptation challenges - inequality

- High inequality within and across countries
- Small, rich elite responsible for emissions
- Large poor group highly vulnerable
- Low mitigation challenges due to low reference emissions and high latent mitigation capacities → energy cooperations develop alternative technologies as hedging strategies against climate policy or resource scarcity
- Governance and globalization controlled by elite, inefficient for poor population
- High adaptation challenges – low income, low human capital, ineffective institutions for poorer population
SSP5 – high mitigation challenges – conventional development

- Rapid development powered by cheap fossil fuel
- Strong globalization, high levels of international trade, high mobility
- High level of human development, strong build-up of human and social capacity
- Effective governance structures
- High economic growth, strong convergence
- High resource and energy intensity
- Global population peaks and declines
- Optimized infrastructure, high disaster preparedness
- Local environmental consciousness, end-of-pipe solutions

Franziska Piontek: SSP framework
Country level, 5 year time steps
Country level, 5 year time steps

OECD: GDP | PPP [billion US$2005/yr]

IIASA: GDP | PPP [billion US$2005/yr]

PIK: GDP | PPP [billion US$2005/yr]

32 regions

Franziska Piontek: SSP framework
Other more detailed assumptions

- Fossil energy supply
- Energy demand assumptions
- Energy conversion assumptions
- Land use and agricultural assumptions
## Land use and agriculture

<table>
<thead>
<tr>
<th>SSP element</th>
<th>Country income groupings</th>
<th>SSP1</th>
<th>SSP2</th>
<th>SSP3</th>
<th>SSP4</th>
<th>SSP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use change regulation</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weak</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td>Strong</td>
<td>Medium</td>
<td>Weak</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Strong</td>
</tr>
<tr>
<td>Land productivity growth</td>
<td>Low</td>
<td>Rapid</td>
<td></td>
<td></td>
<td>Slow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td>Rapid</td>
<td>Medium</td>
<td>Slow</td>
<td>Medium</td>
<td>Rapid</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Medium</td>
<td></td>
<td></td>
<td>Rapid</td>
<td></td>
</tr>
<tr>
<td>Environmental impact of food consumption</td>
<td>Med</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>International trade</td>
<td>Low</td>
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<td></td>
<td>Limited access</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td>Globalized</td>
<td>Regionalized</td>
<td>Regionalized</td>
<td>Globalized</td>
<td>Globalized</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td>Globalized</td>
<td></td>
</tr>
</tbody>
</table>
SSP storylines „agriculture and land use“

SSP1:
• Strongly regulated land use, strong reduction in tropical deforestation rates, rapid increase in crop yields in developing countries (catch-up), healthy diets, low waste, low animal calorie shares, open food trade

SSP2:
• Incomplete regulation of land use, slow decline in tropical deforestation, slow increase of crop yields, medium calorie consumption, regionalization of trade

SSP3:
• No regulation of land use change, decline of crop yield increase rates (little investment), high animal shares in diets, large waste, regionalized world (local food security)
SSP storylines „agriculture and land use“

SSP4:

- SSP1 for high income countries, SSP3 for low income countries, high vulnerability for non-connected population groups, limited market access for poor countries

SSP5:

- Incomplete regulation of land use change (slow decline of tropical deforestation), high animal share in diets, high waste, high globalization
Two levels of SSPs

- „basic“ SSP – locate scenario in the challenge space
- „extended“ SSP – extended global, sectoral, regional characteristics (e.g. RAPs)
Representative agricultural pathways (RAPs)

• Pathways of farming management development and adaptation capabilities
• Consistency across climate, economics and field level farming management practices
• Describing synergies and trade-offs between biophysical and social dimensions of global food production
• Can be translated into scenarios of farming intensification levels and world agriculture trade policies to meet future food demand
Consistent across scales

SSPs

global RAPs

Other higher level pathways and scenarios

regional RAPs

crop, livestock, economic and other model inputs and parameters

drivers

consistency

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RAP matrix

- RAP 4: (Econ-Env Tradeoffs)
  - Sustainable Low Growth

- RAP 3: (Win-Win Synergies)
  - Sustainable High Growth

- RAP 2: Moderate Sustainable Growth

- RAP 1: (Lose-Lose Synergies)
  - Unsustainable Low Growth

- RAP 5: (Econ-Env Tradeoffs)
  - Unsustainable High Growth

Antle et al., submitted
Example: coupled REMIND-MAgPIE system @ PIK

- Narratives + tables
- Identify switches in the model representing elements of narratives + tables
- Quantify switch positions for each SSP
- Include quantitative drivers (GDP, population)
- Ensure consistency in results!
- Combine with climate policy
### Example: coupled REMIND-MAgPIE system @ PIK

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Parameter</th>
<th>SSP1</th>
<th>SSP2</th>
<th>SSP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Resource extraction Coal/oil/gas</td>
<td>Low/low/low</td>
<td>Med/med/med</td>
<td>High/med/med</td>
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<tr>
<td></td>
<td>Renewables scenario</td>
<td>Optimistic</td>
<td>Reference</td>
<td>Pessimistic</td>
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<tr>
<td>Environment</td>
<td>Fossil subsidies</td>
<td>Phase out until 2030</td>
<td>Phase out until 2050</td>
<td>Constant</td>
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<tr>
<td></td>
<td>Fossil taxes</td>
<td>Convergence to 10 $/GJ by 2050</td>
<td>Constant</td>
<td>Constant</td>
</tr>
<tr>
<td></td>
<td>Energy intensity</td>
<td>Low</td>
<td>Reference</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Nature conservation</td>
<td>High</td>
<td>Low-medium</td>
<td>Low-medium</td>
</tr>
<tr>
<td>Behaviour</td>
<td>Total calorie per capita demand</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Per capita demand for livestock products</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Trade</td>
<td>Import / Export constraints</td>
<td>Free / Globalizing</td>
<td>Medium</td>
<td>Free / Globalizing</td>
</tr>
</tbody>
</table>
More information/steps

- Population/GDP/urbanization data: contact Keywan Riahi (riahi@iiasa.ac.at) or Detlef van Vuuren (Detlef.vanVuuren@pbl.nl) – also for any questions on SSPs!
Population, GDP, urbanization

- https://secure.iiasa.ac.at/web-apps/ene/SspDb
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- Papers on these and narratives
- IAM implementations → fall
- IAV indicators
- Joint IAV-IAM Committee - https://www.isp.ucar.edu/joint-iai-iam-committee
Joint IAM-IAV Committee – working groups

- Narratives for SSPs (Brian O’Neill, Elmar Kriegler)
- IAV-IAM handshake document and research community interactions (Jae Edmonds)
- IAM quantitative drivers and scenarios for SSPs (Detlef van Vuuren, Keywan Riahi)
- IAV quantitative elements and evaluation metrics (Marc Levy, Bas van Ruijven)
- Nested scenarios across geographies and time (Kate Calvin, Linda Mearns)
- Roadmap for future IAV-IAM collaboration on scenarios (Stephane Hallegatte)
More information/steps

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- RAPs: contact Delphine Deryng for information (D.Deryng@uea.ac.uk)

→ Apply framework!
Thank you!