Deliverable 5.3 (WP5)

Scenario analysis: perspectives for energy, emissions and mitigation of climate change

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The study questions

• Energy security and climate change

• What are the challenges?
  – Quantify the challenges
  – Quantify the uncertainties
  – Are there synergies or trade-off between the two issues?

• 2030
  – How to study the two coming decades, in the light of two issues that are mainly longer-term?
The methodology

- Study horizon extended to 2050 (2100), with a “zoom” on the first two decades
  - What pathways over 2010-2030?
  - Detect long-standing implications of short-term development options (path-dependencies)
  - What legacy in 2030 for future decision-makers options?

- Scenarios to explore the uncertainty
  - “Scenario elicitation” methodology with Imaclim-R model
    - a few scenarios among numerous alternative visions of the future world
    - contrasted in terms of the question(s) of interest, here energy and environment outcome
    - internally consistent
  
  - Developed jointly in Cired for AUGUR WP5 and the framework of the new socioeconomic pathways for climate change research (IPCC)
    - AUGUR scenarios “mapped” into this framework (for relevance and comparability)
The framework of the new socioeconomic pathways for climate change research (IPCC AR5, and beyond)

• Last generation of scenarios (SRES) were developed at the end of the 90s and were mainly used as “emission scenarios”.

• We need new scenarios to:
  – Encompass recent socio-economic evolutions (e.g., China’s booming economy)
  – Have scenarios that can be used for the study of mitigation policies and adaptation and impacts in the same framework

• We build a product (scenarios), but also a process to organize research over the coming years/decades
The “scenario elicitation” methodology we applied

**Identify drivers**
- Identify *a priori* the main drivers of the issues studied

**Model scenarios**
- Translate drivers into model parameters
- Build a large number of model runs
- Add “quantitative narratives” when necessary

**Select scenarios**
- Build relevant indicators
- Select contrasted scenarios
Environmental stress (environmentally-stressed vs. environmentally-friendly)

Use of natural resource

Consumption behaviors

Urbanization

Industrial and commercial policies

Economic structure

Population

Capital markets

Globalization (convergence vs. fragmented)

Labor markets

Governance efficiency

Extreme poverty reduction

Social protection

Carbon dependence (high vs. low dependence)

Availability of fossil energy

Technologies

Equity (inclusive growth vs. growth-and-poverty)

Accademia Lincei, Rome, ITALY
The “scenario elicitation” methodology we applied

Identify drivers
- 4 dimensions
- 13 drivers

Model scenarios
- Translate drivers into model parameters
- Build a large number of model runs
- Add “quantitative narratives” when necessary

Select scenarios
- Build relevant indicators
- Select contrasted scenarios
Descriptors translated into input parameters of the IMACLIM-R model

- Consumption behaviors
- Use of natural resource
- Availability of fossil energy
- Technologies
- Governance efficiency
- Extreme poverty reduction
- Social protection
- Industrial and commercial policies
- Economic structure
- Urbanization
- Population
- Capital markets
- Labor markets

- Descriptors translated into input parameters of the IMACLIM-R model
288 scenarios with Imaclim-R
The “scenario elicitation” methodology we applied

- **Identify drivers**
  - 4 dimensions
  - 13 drivers

- **Model scenarios**
  - 288 scenarios

- **Select scenarios**
  - Build relevant indicators
  - Select contrasted scenarios
Choosing indicators

GDP per capita of the low income countries

CO2 emissions

challenges for mitigation

challenges for adaptation

SSP 1
SSP 2
SSP 3
SSP 4
SSP 5
The resulting uncertainty space
Selecting scenarios
Discovering SSP drivers (data-mining algorithm)

<table>
<thead>
<tr>
<th>SSP1 (15% of cases)</th>
<th>Equity (2 options)</th>
<th>Convergence (3 options)</th>
<th>Energy sobriety (2 options)</th>
<th>Availability of low C technologies (2 options)</th>
<th>Availability of fossil fuels (2 options)</th>
<th>Population (3 options)</th>
<th>Capital markets (2 options)</th>
<th>Coverage/Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>improved</td>
<td>Fast or medium</td>
<td>high</td>
<td>high</td>
<td>Medium or low</td>
<td></td>
<td></td>
<td></td>
<td>50%/80%</td>
</tr>
<tr>
<td>SSP2 (10% of cases)</td>
<td>improved</td>
<td>Medium or slow</td>
<td>low</td>
<td>low</td>
<td></td>
<td></td>
<td></td>
<td>30%/60%</td>
</tr>
<tr>
<td>SSP3 (14% of cases)</td>
<td>worsen</td>
<td>low</td>
<td>low</td>
<td>High or medium</td>
<td></td>
<td></td>
<td></td>
<td>55%/90%</td>
</tr>
<tr>
<td>SSP4 (8% of cases)</td>
<td>worsen</td>
<td>slow</td>
<td>high</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90%/85%</td>
</tr>
<tr>
<td>SSP5 (6% of cases)</td>
<td>improved</td>
<td>fast</td>
<td>low</td>
<td>Reduced imbalances</td>
<td></td>
<td></td>
<td></td>
<td>60%/45%</td>
</tr>
</tbody>
</table>
# Building AUGUR scenarios from SSPs

<table>
<thead>
<tr>
<th>SSP</th>
<th>Multipolar</th>
<th>Convergence</th>
<th>Energy Sobriety</th>
<th>Availability of low C technologies</th>
<th>Availability of fossil fuels</th>
<th>Population</th>
<th>Capital markets</th>
<th>Coverage/Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4</td>
<td>multipolar</td>
<td>Fast or medium</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>Medium or low</td>
<td>Reduced imbalances</td>
<td>50% / 80%</td>
</tr>
<tr>
<td>S2</td>
<td>US-China</td>
<td>Medium or slow</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>High or medium</td>
<td>Reduced imbalances</td>
<td>30% / 60%</td>
</tr>
<tr>
<td>S1</td>
<td>Reduced government</td>
<td>medium</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>Medium or low</td>
<td>Reduced imbalances</td>
<td>55% / 90%</td>
</tr>
<tr>
<td>S3</td>
<td>regionalization</td>
<td>slow</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>medium</td>
<td>Continued imbalances</td>
<td>90% / 85%</td>
</tr>
<tr>
<td></td>
<td>SSP5</td>
<td>improved</td>
<td>fast</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>medium</td>
<td>Reduced imbalances</td>
</tr>
</tbody>
</table>
Mapping AUGUR scenarios into the SSP framework

<table>
<thead>
<tr>
<th>AUGUR scenarios</th>
<th>SSP framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Reduced government</td>
<td>SSP4 – challenge for adaptation dominate</td>
</tr>
<tr>
<td>S2 China and US intervention</td>
<td>SSP3 – high challenges for mitigation and adaptation</td>
</tr>
<tr>
<td>S3 Regionalisation</td>
<td>SSP5 – challenges for mitigation dominate</td>
</tr>
<tr>
<td>S4 Multipolar collaboration</td>
<td>SSP1 – low challenges for mitigation and adaptation</td>
</tr>
</tbody>
</table>

Note: we assume climate policies are implemented only in S4 scenario, corresponding to “Copenhagen pledges” to 2020 and on a trajectory aiming at limiting global warming to 2°C afterwards.
Emissions and temperature increase: a story of inertias

2 layers of inertia:

- Carbon cycle: from emissions to atmospheric concentration
- Climate system: from radiative forcing to temperature change
Looking beyond 2030

**Global CO₂ emissions**

- S1 Reduced government
- S2 China and US intervention
- S3 Regionalisation
- S4 Multipolar

**Mean global temperature increase (/pre-industrial)**

- S1 Reduced government
- S2 China and US intervention
- S3 Regionalisation
- S4 Multipolar
The future legacy of the two coming decades and the 2°C target

<table>
<thead>
<tr>
<th></th>
<th>2010-2030 carbon budget</th>
<th>remaining budget to have 50% chances to reach the 2°C target in GtCO2</th>
<th>in number of years of 2030 emissions</th>
<th>annual decrease of emissions over 2030-2050 to reach the 2°C target</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Reduced government</td>
<td>912</td>
<td>318</td>
<td>6</td>
<td>16%</td>
</tr>
<tr>
<td>S2 China and US intervention</td>
<td>1005</td>
<td>225</td>
<td>4</td>
<td>26%</td>
</tr>
<tr>
<td>S3 Regionalisation</td>
<td>1077</td>
<td>153</td>
<td>2</td>
<td>42%</td>
</tr>
<tr>
<td>S4 Multipolar</td>
<td>722</td>
<td>508</td>
<td>15</td>
<td>3%</td>
</tr>
</tbody>
</table>

For comparison:

- highest rate of CO2 emissions reductions historically observed in any industrialized country over a five-year period: 4.6% (France, 1980-85)

- “committed” emissions due to existing infrastructure in 2010: for 3.2% to 5.7% depending on assumptions (Davis et al, 2010, Guivarch and Hallegatte, 2011), if early capital retirement is avoided.

➢ Once again, a story of inertia; here the inertia of technical systems, infrastructures, location choices, behaviors. But one should also consider the inertia of institutions.
Oil prices pathways: when the bad surprise comes after 2030
The risks of carbon/oil lock-ins of our economies

Share of oil imports in GDP (Europe)

- S1 Reduced government
- S2 China and US intervention
- S3 Regionalisation
- S4 Multipolar
The risks of carbon/oil lock-ins of our economies

Share of oil imports in GDP (China)

S1 Reduced government
S2 China and US intervention
S3 Regionalisation
S4 Multipolar

The risks of carbon/oil lock-ins of our economies
The risks of carbon/oil lock-ins of our economies

Share of oil imports in GDP (India)

- S1 Reduced government
- S2 China and US intervention
- S3 Regionalisation
- S4 Multipolar

Index 1=2010
Both climate change and energy security issues are long-term issues, for which the main challenges may arise after the 2030 horizon.

However, the two coming decades are crucial for these issues since the directions taken over this short-/medium-term risk to create lock-ins of the economies in carbon and/or oil dependency.

Indeed, inertias in the technical systems, the behaviors and the institutions make the transformations away from oil consumption and/or away from carbon intensive economies a slow process.

If these transformations are not started early, during the coming two decades, it creates the risks that (i) economies are vulnerable to oil prices shocks that may happen when producers reach depletion constraints (possibly after 2030, as in our scenarios), (ii) it would be unfeasible or extremely costly to limit climate change to the 2°C target.
• Linkages between the two issues of energy security and climate change:

  – In S2 “US and China intervention” and S3 “regionalization”, pathways are characterized by both oil lock-in and carbon lock-in.

  – In S1 “reduced government”, oil lock-in is avoided, but through substitution towards coal, which creates a carbon lock-in.

  – In S4 “multipolar”, climate policies, by putting a price on carbon, give a signal increasing the price of fossil fuels, including oil. Therefore they trigger technical change, structural change and changes in behaviors that improve energy efficiency and leads to substitutions away from fossil fuel, including oil.

  ➢ If policies are implemented early, they may be able to avoid the “carbon lock-in”, as well as the “oil lock-in” of the economies. The improvement of the energy security can thus be seen as a co-benefit of climate policies.
The links to other environmental issues (1)

- **Ocean acidification**
  - Same cause (CO2 emissions),
  - It will evolve in the same direction as radiative forcing in the scenarios.

- **Local air pollutants**
  - Emissions often have the same sources as greenhouse gases (e.g. black carbon from coal combustion, particles from gasoline combustion in thermal engine vehicles)
  - It is likely that local air pollution co-varies with CO2 emissions.
The links to other environmental issues (2)

• Water scarcity and biodiversity

2 linking elements with climate change:

• Climate change **impacts** will affect water availability (change in rainfall patterns, increase of occurrence and severity of droughts in some regions)

• Similarly, changing climate would affect ecosystems functioning, with potentially biodiversity loss.

• However, these effects will mostly happen on a longer time scale than 2030.

• **Bioenergy** production can be seen as an option to mitigate emissions from fossil fuel burning and/or an option to hedge against fossil fuel scarcity.

• Depending on the extent of biofuel production and its sustainability, it may have significant negative impacts on water scarcity and biodiversity.

• Especially relevant to scenarios in which climate change mitigation would (maybe) occur late (as in our “Reduced government”, “China and US intervention” and “Regionalization” scenarios).

• Indeed, one of the main options to still reach the 2°C target with high short-term emission would be to exploit the possibility to produce negative net global emissions on the longer-term, with large-scale combinations of bio-energy and carbon capture and storage (BECCS).
Conclusion (1)

• Inertia and irreversibility

  – Several “layers” of inertias
    • Technical systems and infrastructures
    • Behaviors and institutions
      – Constrains the possibilities - and speed - of evolutions of both energy supply and demand patterns
    • Carbon cycle
    • Climate system

  – Increasing returns, feedbacks and irreversibility → path-dependency

  – 2030 has to be analyzed in terms of its legacy for future decision-makers options
Conclusion (2)

- Carbon lock-in and oil lock-in
  - Identify the risks, synergies and trade-offs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Carbon lock-in</th>
<th>Oil lock-in</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 “reduced government”</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>S2 “US and China intervention”</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>S3 “Regionalization”</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>S4 “Multipolar”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion (3)

Further work (towards deliverable 4, final report)

• Investigate further the links between energy security and climate mitigation policies:
  – Using our database of scenarios to identify vulnerabilities in a Robust Decision Making framework

• Investigate links between energy prices and the macroeconomy (with WP1)

• Investigate further the influence of technology R&D and technology transfer on the energy intensity and carbon intensity pathways, and energy security and climate change mitigation issues (with WP3?)
  – Analyzing alternatives on the main technological developments (electric vehicles, nuclear, renewable, carbon capture and sequestration, bioenergy)