CCS Development Scenarios in the West Mediterranean Region

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High level meeting, Lisbon, December 13, 2012
CCS Perspectives in the Iberian Peninsula and Morocco Development of CO2 Transport Infrastructure Scenarios
Outline

1. Purpose
2. Functionality of the tool for analyses
3. Scenario drivers and scenarios
4. Results: CO2 emissions and energy systems development
   1. Spain
   2. Portugal
   3. Morocco
   4. Sensitivity
5. Conclusion
6. Reference web sites
1. – Purpose of scenario analyses

Scenarios built with the TIMES-COMET model explore whether CO2 capture and storage in the West Mediterranean region is economically viable \textbf{WHEN? \ WHERE? \ at \ WHAT LEVEL?}
depending on future:

- mitigation policies
- economic growth
- neighbourhood to permanent CO2 storage formations
- flexibility of pipelines network layout
- possibility to transport across countries
- technology costs and energy prices
2. – Functionality of the TIMES-COMET model

- The tool is quantitative, consistent, transparent, reproducible
- Needs detailed input data on the main system elements
- Integrates the elements in system analysis view (for instance: if there is more wind power, there is less power from some other source)
- Joins energy, environmental, technical and economic aspects (but not safety, legal, administrative, political, or other social aspects)
- Joins long term time developments and geographical aspects
- Joins energy system mitigation options and CCS options
- Compares options on the same 'level playing field'
- Results depend on development assumptions (drivers)
This analysis considered 6 scenario drivers

• 3 on general aspects (set 1):
  – Economic growth (exploratory),
  – National mitigation level (policy),
  – CCS availability (policy),

• 3 on CO2 transport and storage infrastructure aspects (set 2):
  – Storage capacities (exploratory),
  – National CO2 pipeline networks (exploratory), and
  – Possibility to transport across country borders (policy).
### 3.2. – List of the main scenarios

<table>
<thead>
<tr>
<th>DESCRIPTIVE NAME</th>
<th>CODE</th>
<th>GDP Growth</th>
<th>Mitigation level</th>
<th>Storage Potential</th>
<th>National Routes</th>
<th>Cross-Frontier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set 1: Emission side</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSERVATIVE CCS</td>
<td>HD.40-GAS.NAT.LS</td>
<td>HIGH</td>
<td>40%</td>
<td>LOW</td>
<td>GAS</td>
<td>NAT</td>
</tr>
<tr>
<td>HIGH MITIGATION</td>
<td>HD.80-GAS.NAT.LS</td>
<td>HIGH</td>
<td>80%</td>
<td>LOW</td>
<td>GAS</td>
<td>NAT</td>
</tr>
<tr>
<td>NO-CCS</td>
<td>HD.40-No.CCS</td>
<td>HIGH</td>
<td>40%-NO CCS</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LOW ECONOMIC GROWTH and HIGH MITIGATION</td>
<td>LD.80-GAS.NAT.LS</td>
<td>LOW</td>
<td>80%</td>
<td>LOW</td>
<td>GAS</td>
<td>NAT</td>
</tr>
<tr>
<td><strong>Set 2: Transport and storage infrastructures side</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>CONSERVATIVE CCS</td>
<td>HD.40-GAS.NAT.LS</td>
<td>HIGH</td>
<td>40%</td>
<td>LOW</td>
<td>GAS</td>
<td>NAT</td>
</tr>
<tr>
<td>CROSS-FRONTIER PIPELINES</td>
<td>HD.40-GAS.REG.LS</td>
<td>HIGH</td>
<td>40%</td>
<td>LOW</td>
<td>GAS</td>
<td>REG</td>
</tr>
<tr>
<td>FREE ROUTES</td>
<td>HD.40-FREE.NAT.LS</td>
<td>HIGH</td>
<td>40%</td>
<td>LOW</td>
<td>FREE</td>
<td>NAT</td>
</tr>
<tr>
<td>OPTIMISTIC STORAGE</td>
<td>HD.40-GAS.NAT.HS</td>
<td>HIGH</td>
<td>40%</td>
<td>HIGH</td>
<td>GAS</td>
<td>NAT</td>
</tr>
</tbody>
</table>

40% = the emissions in 2050 have be 40% lower than 2005; HD=High demand, vs. LD; GAS=pipelines follow the natural gas network where possible; NAT=pipelines cannot cross the frontiers, vs. REG; LS=Lower storage potential, vs. HS
4. – Results

1. Spain
2. Portugal
3. Morocco
4. Sensitivity
4.1.a – Spain: CO2 emission reduction

Reference year (2005)
- 56% CO2 emissions come from ETS sectors
- 56 emission clusters → 77% of the total MO+PT+SP CO2 emissions

31 sink clusters, 11 offshore not used

Prospective
- CCS timidly starting in 2020 in the Conservative CCS scenario, 120 Mt (31% of total gross emissions) captured by 2050
- The same amount when frontiers are crossed but 148 Mt are stored
- 106 Mt (34%) in the HM, and 62 Mt (33%) in the LEG

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4.1.b – Spain: the contribution of electricity to mitigation

- Share of RES growing (31% in 2011)
- Fossil fuels trend strongly dependent on policy
- 20% nuclear but no plans for new plants

By 2050
- Highest electricity production in HM
- Highest share of RES in LEG (97%), lowest in HM (66%)
- Coal power plants decommission
- Gas power plants production increase in CCCS and HM
4.1.c – Spain: the contribution of industry to mitigation

- Main sectors: electricity and cement
- New sectors at long term
4.2.a – Portugal: CCS starts in 2030

-40% CO₂ in 2050/2005 and CCS possibility

- Role of CCS: 10% in 2030 and 34% in 2050, of CO₂ emissions captured compared with total country emissions;
- Power and Heat production, CO₂ capture technology is cost-effective in 2030, capturing 69% of the sector emissions;
- Industry, CO₂ capture technology is cost-effective:
  - 2040 in cement sector, representing a capture of 12% of the industry emissions;
  - 2050 in other industry sectors, as glass, lime and refinery, capturing CO₂ emissions equivalent to 44% of the total industry emissions;
4.2.b – Portugal: high mitigation promotes CCS technology

Portugal net CO2 emissions

**Reference Year (2005)**
- 9 emission clusters → 38% of the total PT CO2 emissions
- 4 sink clusters, 3 offshore appear as solution for storage in the results

**High Mitigation (80% CO2 reduction):** 19% in 2030 and 39% in 2050, of CO2 emissions captured compared with total country emissions; CCS will enter a decade earlier in industry;

**Low Economic Growth:** 7% in 2030, 17% in 2040 and 25% in 2050, of CO2 emissions captured compared with total country emissions
4.2.c – Portugal: contribution of electricity to mitigation

- More electricity is produced under High Mitigation scenario (+26% in 2050 compared to the Conservative CCS case) as a decarbonization strategy;
- Coal fired power plants are not cost effective options in any of the scenarios. Restrictive emission caps induces higher electricity production from gas power plants.
- **No CCS scenario**: in 2050, all the electricity is produced from RES sources (mainly wind onshore, offshore and hydro).
- **Low Economic Growth**: 96% of the electricity produced in the country in 2050 is from RES.
- In the long term, Portugal is a net exporter of electricity to Spain.
4.3.a – Morocco: construction of the TIMES-Morocco model

• Developed during COMET project, same structure (reference energy system) as other TIMES country models
• International and national energy statistics, collaboration with national partners
• Takes into account:
  – Current characteristics of the energy system of Morocco, from end-use to supply-side, such as: efficiency and capacity of installed power plants, high solar and wind potentials, availability of oil shale reserves, possibility to build LNG terminal, industrial activity, etc.
  – Future socio-economic trends: pop and economic growth, high contribution of cement and phosphate sectors, future fossil fuel prices (harmonization with ES and PT)
  – Solar and wind plans: 1 GW each by 2020
4.3.b – Overview: emissions, capture and sinks opportunities

- **Main sources of emissions**: fossil power plants and cement plants
- **Around 1/3 of them** are candidate to capture

- Storage potential quite limited based on current knowledge

- No climate target imposed in Morocco, CDM is allowed: purchase of CO2 credits by ES+PT driven by lower mitigation costs in MO
4.3.c – Energy and emission developments in Morocco: driven by the prospective of selling permits to ES+PT

- ES+PT buy as many CO2 permits as possible from MO (max 20% from their own reduction)
- Cost efficient CDM portfolio:
  - Low carbon power plants w/o capture: solar and wind, gas (replacing coal)
  - CO2 capture at coal power plants only. No capture at cement plants: other options are more cost-efficient.
  - No increase of CCS even in cases of high demand for CO2 credits
  - Changes in end-use sectors (biofuels in transport, more electricity in buildings) only in cases of high demand for CDM

Technical Meeting, Lisbon, December 12, 2012 – The TIMES-COMET model
• Availability of cross-frontier pipelines:
  – CO2 capture (coal power plants) jumps up to 65% of the CDM permits
  – Storage of CO2 in Spain
  – More coal power plants (w CCS), less gas power plants (w/o CCS)

• Optimistic storage:
  – Also a CCS incentive, although less than cross-frontier opportunities
4.3.e – Conclusion for Morocco

- **TIMES-Morocco**: prospective analysis tool now available for energy planning and climate mitigation analysis (including Nationally Appropriate Mitigation Actions – NAMAs)
- Characteristics of **future power system of Morocco** driven by socio-economic factors, fossil energy prices and climate policies
- **Capture strongly depending on storage opportunities**: cross-frontier pipelines? better knowledge of domestic sinks, including off-shore opportunities?
- **Diversified mitigation portfolio** available in Morocco
- Remaining some uncertainties on the **role of CCS in CDM**
1. CCS yes/no: Mitigation options and emissions
   System costs and prices, table
   Electricity (animation)
2. -40% vs. -80%: (the same) + maps
3. Cross-frontier: maps
4. Storage, +/-: maps

If it works, live at
www.kanors.com/vedaviz/vwpresenter.aspx?prj=comet02dec
4.4.1 – Mitigation options by scenario

Spain and Portugal: net CO2 emissions

- Total ETS
- Total NETS
- Permits from ROW
- CDM from MA
- Total CCS
- Self-emissions

Years: 2005, 2020, 2030, 2040, 2050
Scenarios: CONSERVATIVE CCS, HIGH MITIGATION, LOW ECON. GROWTH, NO-CCS
4.4.1–Results: energy system mitigation options in transport residential & commercial, agriculture, small industry (NETS)
4.4.1 – Results: energy system mitigation options in the Emission Trading Scheme sectors (power, large industry)

Mitigation forces coal out; Renewables and gas in.

4.4.2 – System cost and prices by scenario

<table>
<thead>
<tr>
<th>In 2050</th>
<th>Central -40%</th>
<th>NoCCS -40%</th>
<th>HighM -80%</th>
<th>L.Dem -80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total system surplus, ES+PT+MO (B€’2005/a)</td>
<td>637</td>
<td>652</td>
<td>701</td>
<td>469</td>
</tr>
<tr>
<td>Share of CCS (%)</td>
<td>1.38</td>
<td>0</td>
<td>1.38</td>
<td>1.13</td>
</tr>
<tr>
<td>CO2 stored (MtCO2/a)</td>
<td>142</td>
<td>131</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Cost of CCS (B€’2005/a)</td>
<td>8.6</td>
<td>0</td>
<td>9.0</td>
<td>5.0</td>
</tr>
<tr>
<td>% Share: Capture</td>
<td>30</td>
<td>28</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Energy input</td>
<td>60</td>
<td>63</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>

- Reducing CO2 emission of 40% by 2050/2005 cost less if CCS is available
- The max deployment of CCS is around -60%
- Costs and amount stored strongly depend on the economic development assumptions
4.4.3 – Electricity production, with/out CCS

- Consumption are lower
- Natural gas fully replaces coal
- Renewable almost at 90%
4.4.3 – Electricity production, -40% vs. -80% in 2050/2005
4.4.4 – Regional vs. national perspective for CCS transport

Circles: Hollow = negative number
Solid = positive number

Arrows: Black = positive flows
Red = negative flows

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4.4.4 – Optimistic vs. conservative evaluation of the storage potential in Spain and Morocco

Circles: Hollow = negative number
Solid = positive number

Arrows: Black = positive flows
Red = negative flows
4.4.4 – CCS under extreme mitigation commitments, 2040

Circles: Hollow = negative number
Solid = positive number

Arrows: Black = positive flows
Red = negative flows
4.4.4 – CCS under extreme mitigation commitments, 2050

\[ \text{Difference} \]

\[ -40\% \quad \rightarrow -80\% \]

Circles: Hollow = negative number
Solid = positive number

Arrows: Black = positive flows
Red = negative flows
5. – Conclusion

- All mitigation options contribute to reaching strong mitigation commitments
- If there is enough storage potential, CCS is generally competitive and CO2 is captured to almost its maximum technical potential under wide assumptions about:
  - storage potentials and cost, transport routes and costs, capture technologies emissions and costs, cost of the main other mitigation technologies
- CCS can play a significant role in the Iberian Peninsula under intermediate and strong mitigation scenarios
- When the mitigation target becomes extreme, CCS needs to be complemented by more no-carbon options
- If CCS is not available more expensive mitigation options have to be adopted in order to emit less CO2 and more emission permits bought
- Capture potential and pipeline network constraints appear stronger determinants of deployment levels compared to engineering costs and storage potentials.
- Since the cost difference between the ‘free routes’ and the ‘mirror gas network’ scenarios is negligible in terms of cost and cumulative storage, it seems that there is large room for negotiating socially acceptable infrastructures layouts
6. – Reference web sites

COMET project: at http://comet.lneg.pt

Documentation on The Integrated MARKAL-EFOM System (TIMES): at www.iea-etsap.org

Scenario results, in VEDA-BE format: at http://kanors.com/dcm/Results.asp?Fl=ShowAll&tab=thisweek&model=COMET

results by scenario, scenario difference, year, country, cluster, in tables, graphs and animated ‘google’ maps: at www.kanors.com/vedaviz/Login.aspx?prj=comet02dec (or the older version http://www.kanors.com/vedaviz/vwpresenter.aspx?Prj=comet02dec )