Fukushima’s impact on the European power sector: A long term policy analysis using TIAM-FR

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Outline

1) European nuclear and climate context
2) Objectives
3) A panorama of nuclear capacity and CCS projects in Europe
4) TIAM-FR model and scenarios
5) Results
Nuclear and climate context
Nuclear context

- March 2011: Fukushima Accident reactivate the debate on the future role of nuclear energy

- Contrasting energy policy responses in European countries

- European Commission’s energy roadmap:
  - Pre-Fukushima (2050): nuclear share in power generation 26.4%
  - Post-Fukushima (2050): nuclear share in power generation 20.5%
Climate context

- GHG emissions reduction target
  - 20% in 2020
  - 80% to 95% in 2050

- Low carbon electricity generation technologies will compete in the electricity mix
  - Nuclear
  - Renewable energies
  - CCS and BECCS
Objectives
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• To evaluate the impact of reducing and even slowly phasing out nuclear power on the electricity mix, while considering the availability of CCS and BECCS technological options

  – Are CCS on fossil and biomass power plants good substitutes for nuclear energy to decarbonize the electricity sector?

  – What is the cost of nuclear power reduction and nuclear phase-out in Europe under an emissions reduction policy?

  – What will happen if CCS technologies are not developed in Europe?
Nuclear capacity and CCS projects in Europe
## Nuclear capacity in Europe (IAEA, 2012)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Reactors operable (Nb)</th>
<th>Total net electricity capacity (MW) September 2012</th>
<th>Nuclear Electricity supplied (TWh) 2011</th>
<th>Nuclear share in the electricity mix (%) 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>58</td>
<td>63,130</td>
<td>423.5</td>
<td>77.7</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>16</td>
<td>9,246</td>
<td>62.6</td>
<td>17.8</td>
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<tr>
<td>Sweden</td>
<td>10</td>
<td>9,378</td>
<td>58.1</td>
<td>39.6</td>
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<tr>
<td>Germany</td>
<td>9</td>
<td>12,068</td>
<td>102.3</td>
<td>17.8</td>
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<tr>
<td>Spain</td>
<td>8</td>
<td>7,560</td>
<td>55.1</td>
<td>19.5</td>
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<tr>
<td>Belgium</td>
<td>7</td>
<td>5,927</td>
<td>45.9</td>
<td>54</td>
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<tr>
<td>Czech Republic</td>
<td>6</td>
<td>3,766</td>
<td>26.7</td>
<td>33</td>
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<tr>
<td>Switzerland</td>
<td>5</td>
<td>3,263</td>
<td>25.7</td>
<td>40.8</td>
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<tr>
<td>Finland</td>
<td>4</td>
<td>2,736</td>
<td>22.3</td>
<td>31.6</td>
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<tr>
<td>Hungary</td>
<td>4</td>
<td>1,889</td>
<td>14.7</td>
<td>43.2</td>
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<tr>
<td>Slovakia</td>
<td>4</td>
<td>1,816</td>
<td>14.3</td>
<td>54</td>
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<tr>
<td>Bulgaria</td>
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<td>1,906</td>
<td>15.3</td>
<td>32.6</td>
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<td>Romania</td>
<td>2</td>
<td>1,300</td>
<td>10.8</td>
<td>19</td>
</tr>
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<td>Netherlands</td>
<td>1</td>
<td>482</td>
<td>3.9</td>
<td>3.6</td>
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<tr>
<td>Slovenia</td>
<td>1</td>
<td>688</td>
<td>5.9</td>
<td>41.7</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>137</strong></td>
<td><strong>125155</strong></td>
<td><strong>887</strong></td>
<td></td>
</tr>
</tbody>
</table>
Nuclear reactors’ age (IAEA, 2012)
Large scale integrated CCS projects (Global CCS institute, 2013)

• 18 projects in Europe - 2 in operation (Sleipner – Snøhvit)
• 14 projects are related to the power sector
TIAM-FR model and scenarios
TIAM-FR

- **TIMES Integrated Assessment Model**
  - ETSAP (Energy Technology Systems Analysis Program) from IEA

- **Bottom-up model**
  - Detailed description of existing and future technologies
  - From extraction to energy services demands
  - Reference Energy System (RES)

- **Optimization model**
  - Minimization of the total discounted cost of the system
TIAM-FR: simplified RES

Inputs, exogenous
- Extraction costs
- Reserves of fossil
- Potential of biomass

Thousands of technologies for each region
TIAM-FR

- World integrated model in 15 regions
  Europe (EEU-WEU)
- Time horizon: 2005-2050
- GHG emissions (CO₂, CH₄ and N₂O)
- Carbon capture and sequestration technologies
  - 3 capture technologies (ETP)
  - Storage capacities (Geocapacity, 2009)
  - Storage and transport costs (ZEP, 2011)
Scenarios

- **BAU**: no climate policy

- **EU_PreFuku**:
  - Climate policies
    - **World**: CO₂ emissions decrease by 50% in 2050 by comparison with 2000
    - **Europe**: CO₂ emissions decrease by 20% in 2020 and by 80% in 2050, by comparison with 1990
  - Nuclear policies in Europe
    - Pre-Fukushima scenario: 26.5% in 2050 in power generation

- **EU_postFuku**
  - Climate policies: same as EU_PreFuku
  - Nuclear policies in Europe
    - Post-Fukushima scenario: 20.5% in 2030 and 2050 in power generation

2 scenarios on technology availability

- **EU_No nuclear**: Nuclear phase-out
- **EU_NoCCS**: CCS is not deployed over the period
European power generation (TWh)
European power generation by plants with carbon capture (TWh)

- Biomass+CCS
- Co-firing+CCS
- Gas+CCS

Comparison over years 2020, 2030, and 2050.
European power generation (TWh)
Carbon marginal cost (€/tCO₂)
Variation of the total energy system cost compare to the BAU (%)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Date</th>
<th>Cost increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU_NoCCS</td>
<td>2020</td>
<td>1.03</td>
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<td>2050</td>
<td>22.8</td>
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<tr>
<td>EU_NoNuclear</td>
<td>2020</td>
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<td></td>
<td>2050</td>
<td>14.5</td>
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<tr>
<td>EU_preFuku</td>
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<td>0.7</td>
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<tr>
<td></td>
<td>2050</td>
<td>13.0</td>
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<td>EU_postFuku</td>
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<td>0.8</td>
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<tr>
<td></td>
<td>2050</td>
<td>13.6</td>
</tr>
</tbody>
</table>
Conclusions
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- CCS technologies constitute a key carbon reduction option in case of stringent climate target and nuclear electricity limitation. Uncertainties regarding incentives, social acceptability.

- CCS unavailability involves:
  - Significant costs
  - A significant fuel shift from fossil to renewable energy sources, stable, reliable electricity system.
Thank you?