Sustainable energy supply in Germany – scenario analysis with different CO₂ certificate prices

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<table>
<thead>
<tr>
<th>Technology</th>
<th>CO₂ reduction costs [Euro / t CO₂]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>490</td>
</tr>
<tr>
<td>Hydro</td>
<td>120</td>
</tr>
<tr>
<td>Wind</td>
<td>75</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>240</td>
</tr>
<tr>
<td>Heat insulation roof</td>
<td>220</td>
</tr>
<tr>
<td>Heat insulation wall</td>
<td>400</td>
</tr>
<tr>
<td>Substitution (coal - gas)</td>
<td>35</td>
</tr>
<tr>
<td>Topping</td>
<td>50</td>
</tr>
<tr>
<td>Biomass</td>
<td>120</td>
</tr>
<tr>
<td>cc chp</td>
<td>97</td>
</tr>
<tr>
<td>Small chp</td>
<td>128</td>
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</tbody>
</table>
TIMES-D2

- Two regional model (West + East Germany)
- Approx. 135 conversion technologies per region
- Approx. 85 transport technologies per region
- Approx. 120 residential technologies per region
- Approx. 90 commercial technologies per region
- Approx. 90 industrial technologies per region

- Time horizon 1990-2030, 5 year periods
- Six time segments per year
- 17 sectors per region
Policy Measures

- Phase-out of nuclear energy
- Use of domestic hard coal will decline (1120 PJ in 2000 => 200 PJ in 2030)
- Use of domestic lignite
- Subsidies for renewable energy sources and CHP
- Efficiency improvement programme for buildings
- Self commitment of German car industry to reduce specific fuel consumption
- Starting from year 2007 stronger legislative measures concerning maximum SO2 and NOx emissions for conversion technologies exist
Scenario definition

- Reference case (REF)

- Scenarios with different CO2 certificate prices between 5 and 50 Euro per t CO2 in 2010, after 2010 increasing 4 % per year
  - Certificate prices for the total energy system (CT)
  - Certificate prices only for the electricity production (CE)

(CT30 Certificate price for the total energy system of 30 Euro /t CO2)

<table>
<thead>
<tr>
<th>Year</th>
<th>4%</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tbody>
<tr>
<td>CT10</td>
<td>0.00</td>
<td>10.00</td>
<td>12.17</td>
<td>14.80</td>
<td>18.01</td>
<td>21.91</td>
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<tr>
<td>CT30</td>
<td>0.00</td>
<td>30.00</td>
<td>36.50</td>
<td>44.41</td>
<td>54.03</td>
<td>65.73</td>
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</tbody>
</table>

Energy related greenhouse gas emissions in Germany in Mio. t CO2*

- THG
- REF
- CT10
- CT30
- CT50
- CE10
- CE30
- CE50
Energy related greenhouse gas emissions by sectors in Germany

Net electricity generation by energy carrier in Germany in TWh
Primary energy consumption by energy carrier in Germany in EJ

Greenhouse gas intensity of the energy consumption in t CO₂eq per GJ
Energy related greenhouse gas emissions reduction depending on the certificate price in Germany

NOx-Emissions by sector for the different scenarios
SO\textsubscript{x} Emissions by sector for the different scenarios

- Powerplant and district heating
- Industry
- Household, Commercial
- Transport

Considered monetary values for the external costs

For fossil conversion technologies and transport

<table>
<thead>
<tr>
<th>Cost per unit of pollutant</th>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{2}</th>
<th>Particulates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>station$</td>
<td>mobil$</td>
<td>station$</td>
</tr>
<tr>
<td></td>
<td>25290</td>
<td>620</td>
<td>4860</td>
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</tbody>
</table>

For special conversion technologies

- Fuel Cells: m\textsubscript{Euro}/kWh
- Nuclear: 5
- Wind: 1
- Hydro: 1
- Biomass: 3
- PV: 1
Conclusions

- Germany can achieve the Kyoto targets with given CO₂ certificate prices for the whole energy system of 10 €/t CO₂.
- Germany has also with certificate prices lower than 30 €/t CO₂ costs problems to achieve the national emission targets for air pollutants from the European commission.
- CO₂ certificates should be applied to the entire energy system to avoid leakage effects.
- CO₂ certificates can be used to realise hidden benefits and to realise a sustainable energy supply system in Germany.