Global Energy Supply: Model-based Scenario Analysis of Resource Use and Energy Trade

Uwe Remme, Maryse Labriet, Richard Loulou, Markus Blesl

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Factors in long-term energy supply of fossil fuels

Supply side
Reserves and resources
- Uncertainty in estimation of geologically available resources
- Extraction technology (Conventional, unconventional)
- Geographic unequal distribution and induced dependencies/risks

Alternative supply options
- Substitution between fossil fuels (e.g. Coal- or Gas-to-liquids)
- Renewable energy carriers (e.g. biofuels)

Energy trade
- Transport technologies
- Geographic route
- Investment lead times
- Transit risks

Demand side
- Demand drivers
- Efficiency in conversion sector
- Efficiency/Energy savings in end-use sectors
- Substitution of fossil end-use fuels by renewables
Global resource base: Coal

Global reserves and resources (end of 2004) Global production 2004

Hard coal: 115000 EJ 112 EJ
Lignite: 10900 EJ 9 EJ

Source: Federal Institute of Geosciences and Natural Resources (BGR), Germany, 2006
## Global resource base: Gas

### Table: Global Gas Resources

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<tbody>
<tr>
<td></td>
<td>Reserves</td>
<td>Resources</td>
<td>Coal-bed methane</td>
<td>Tight gas</td>
</tr>
<tr>
<td>Reserves</td>
<td>122558</td>
<td>5310</td>
<td>2827</td>
<td>1694</td>
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Sources: BGR, WEC, USGS
Global resource base: Oil

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<tbody>
<tr>
<td>Reserves</td>
<td>Resources</td>
<td>Tar sand</td>
<td>Extra heavy oil</td>
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<tr>
<td>10083</td>
<td>3618</td>
<td>3117</td>
<td>1616</td>
</tr>
</tbody>
</table>

Sources: BGR, WEC, USGS
Major oil trade flows in 2004

Net trade between world regions:
- Oil: 76 EJ (global consumption 158 EJ)
- Gas: 22 EJ (global consumption 101 EJ)
- Coal: 12 EJ (global consumption 116 EJ)

Sources: BP, IEA
Comparison of transport costs

- Natural gas offshore (56 offshore)
- Natural gas onshore (30 inch)
- Coal rail
- LNG
- Natural gas onshore (56 inch)
- Oil pipeline
- Coal shipping
- Oil tanker
Ex: veh-km driven by car, tonnes aluminum, number apartments to heat, etc.
Scenario analysis

- **Base scenario (BAS)** oriented towards the IPCC A2 scenario:
  - **World GDP:**
    - 2000: 37 trillion US$\textsubscript{2000}, 2100: 235 trillion US$\textsubscript{2000} → average annual growth rate of 1.8 %
  - **World population:**
    - 2000: 6 billion, 2100: 9.8 billion
  - **Nuclear and renewables:**
    - slow growth of nuclear up to 2040, more rapid growth afterwards
    - coal and gas dominant energy carriers after 2050, low use of renewables

- **CO\textsubscript{2} mitigation scenario (CO2):**
  - Reducing annual CO\textsubscript{2} emissions to 18 Gt CO\textsubscript{2} by the year 2090 (corresponding to a stabilization of the atmospheric CO\textsubscript{2} concentrations at 550 ppm by 2090)

- **Variant to the base scenario (VAR):**
  - Assuming reduced unconventional resources for oil and gas (50% of base case):

<table>
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<tr>
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<th>Oil</th>
<th>Gas</th>
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<tbody>
<tr>
<td>Base (BAS)</td>
<td>12500 EJ</td>
<td>22000 EJ</td>
</tr>
<tr>
<td>Variant (VAR)</td>
<td>6200 EJ</td>
<td>11000 EJ</td>
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</table>
Final energy demand

- Solar thermal
- Biomass (solid, gas)
- Geothermal
- Bioliquids
- Synth. Fuels
- Refinery products
- Natural gas
- District heat
- Coal
- Electricity

Final energy demand [EJ]

Year: 2000, 2030, 2050, 2070, 2090
Emissions

CO\(_2\) emissions (Gt CO\(_2\))

- VAR
- BAS
- CO2

- 12 $/t CO\(_2\)
- 52 $/t CO\(_2\)
- 130 $/t CO\(_2\)
- 688 $/t CO\(_2\)
Oil production by world region
Oil trade flows in 2050 and 2090 (Base scenario in EJ)
Conclusions

• Coal:
  – Abundant resources comparably equally distributed
  – Coal-to-liquid becomes competitive supply option, as conventional oil reserves decline
  – CO₂ capture & storage required to keep coal competitive under climate protection policies
  – Major exporter in 2090: Australia, FSU, Africa
  – Volume of global coal trade depends on climate policies

• Natural gas:
  – Conventional natural gas production peaks around 2050
  – Increase in unconventional gas production (coal bed methane, tight gas) after 2030, accelerated by CO₂ mitigation targets
  – Major exporters in 2090: FSU, Australia, Canada, South America, Africa
  – Trade of Russian gas influenced by CO₂ reduction target

• Oil:
  – Conventional production peaks around 2030, substituted by unconventional oil (tar sands, oil shale) as well synthetic fuels (based on coal) and natural gas in the transport sector
  – Reduced amounts of unconventional oil trigger higher coal use
  – Major exporters in 2090: USA, Canada, CSA
  – Rather small influence of CO₂ reduction target on trade flows
Regions of the TIAM model

15 regions:
CAN, USA, MEX, CSA (Central South America), WEU (Western Europe), EEU (Eastern Europe), MEA (Middle East), FSU (Former Soviet Union), CHI, IND, SKO (South Korea), JPN, ODA (Other Developing Asia), AUS (Australia+New Zealand)