Energy Scenarios, Technology Development and Climate Policy Analysis with the POLES Modelling System

LEPII-EPE
ENERDATA

April 2009
LEPII: research on Energy, Resources, Environment and Negotiations

Axe 1: International Energy Markets and Industries
1. Fundamentals of the oil gas and coal markets (demand, supply and prices)
2. Institutional reforms in network electricity and gas industries (liberalisation, deregulation and reregulation)

Axe 2: Economic Analysis of Climate Policies
1. Economic instruments for environmental policies (Carbon)
2. International negotiation for the post-2012 regime (concentration stab scenarios and equity issues)

Axe 3: Energy Technologies for Sustainable Development
1. Energy R&D policies and technology

The POLES world energy model:
Reference industries (liberalisation, deregulation)
Constraints
Markets under environmental constraints (concentration stab scenarios)
ITC
Energy technologies: Niche markets, Learning by Doing, Increasing Return

Environmentally induced technical change

POLES modelling system, April 2009
1. Description of the POLES model: specifications

i. **Type:** Partial equilibrium model of the world energy system to 2050, year by year simulation of supply, demand and price interactions

ii. **Input parameters:** Population, GDP by region, Oil and Gas resources, technology costs and performances (when exogenous)

iii. **Output parameters:** international and national energy prices, full IEA-type national energy balance with 13 final sectors, diffusion of about 30 key energy technologies (in TECHPOL db)

iv. **Theory:** applied simulation model with full interaction of demand and supply dynamics with price changes through lagged adjustments

vi. **Distinguishing features:** detailed energy model at world level with economic consistency provided by the central role of prices and technological change

vii. **Potential:** Capability of generating diversified energy scenarios and in particular to take full account of GHG abatement policies in a consistent economic framework (i.e. through carbon tax or emission quotas)

viii. **Limitations:** no explicit macro-economic model and built-in feed-back
1. POLES: information management system

- The POLES model projections are based on ENERDATA’s updated international energy databases that keep track of:
  - Short-term demand and supply trends in the key countries
  - Price changes on the main energy markets
  - Planned plants and infrastructures and as such of the corresponding future capacities (10 yr)

- Associated models and databases have been developed at LEPII-EPE in order to organise and process data on:
  - Future technology costs and performances (TECHPOL)
  - Emission quotas endowments in the European EQTS (ENDOW)
  - Supply and demand on CO2 trading systems (ASPEN 1-2-3)
  - Trends in the Intensity of Use of materials (TRANSMAT)
2. POLES: Examples of prior work

- 2004-2005: World Energy Technology Outlook to 2050, WETO-H2 for DG-RTD, with FPB-Belgium, IPTS-Sevilla (under printing)


- 2002-2004: Endogenous technical change in large scale world energy models (SAPIENT + SAPIENTIA) for DG-RTD, in FP5 and FP6, with NTUA, IIASA, ECN, KUL ...

- 2001-2003: Greenhouse emission Reduction Pathways (GRP) and international targets in the post-2012 perspective for DG-ENV with NTUA, RIVM, KUL

- 2001-2003: Economic analysis of the European Emission Quota Trading System and linking with the international market (Kyoto Protocol Implementation) for DG-ENV

- 2001-2003: World Energy Technology and Climate Policy Outlook to 2030, WETO-2030 for DG-RTD, with FPB-Belgium, IPTS-Sevilla
2. POLES: Examples of prior work

- The POLES model and projections are also used by large European companies, such as:
  - ARCELOR (ULCOS – Ultra Low CO2 Steelmaking project)
  - EDF (the European electricity system in the Emission Quota Trading System)
  - Companies in the FONDDRI (Research Foundation for Sustainable Development and International Relations) project on GHG-constrained scenarios for industry
The POLES model year-by-year recursive simulation process

Resources

International Energy Markets

Coal
Oil
Gas

Prices (t+1)

Imports / Exports (t)

Technologies

Emission Constraint

46 Regions

Regional Energy Balances

POP GDP

Emissions

Cons, Prod
Key economic assumptions in the WETO-H2 study

- While industrialised regions converge towards a less than 2%yr growth in the very long run …
- Asian economic growth significantly slows down, while growth accelerates in Africa and the Middle-East
Endogenous oil and gas price simulation in WETO-H2
The endogenous « oil plateau » in WETO-H2

- After 2030, the increase in oil consumption has to rely on « manufactured » non-conventional oil
### POLES : Large scale power technologies

<table>
<thead>
<tr>
<th>Large Scale Power Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Thermodynamic Cycle</td>
</tr>
<tr>
<td>Super Critical Pulverised Coal</td>
</tr>
<tr>
<td>Integrated Coal Gasif. Comb. Cycle</td>
</tr>
<tr>
<td>Coal Conventional Thermal</td>
</tr>
<tr>
<td>Lignite Conventional Thermal</td>
</tr>
<tr>
<td>Large Hydro</td>
</tr>
<tr>
<td>Nuclear LWR</td>
</tr>
<tr>
<td>New Nuclear Design</td>
</tr>
<tr>
<td>Gas Conventional Thermal</td>
</tr>
<tr>
<td>Gas Turbines Combined Cycle</td>
</tr>
<tr>
<td>Oil Conventional Thermal</td>
</tr>
<tr>
<td>Oil Fired Gas Turbines</td>
</tr>
</tbody>
</table>
# POLES: New and Renewable Technologies

<table>
<thead>
<tr>
<th>New and Renewable Technologies</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Incineration CHP</td>
<td>BF2</td>
</tr>
<tr>
<td>Biomass Gasif. with Gas Turbines</td>
<td>BGT</td>
</tr>
<tr>
<td>Combined Heat and Power</td>
<td>CHP</td>
</tr>
<tr>
<td>Photovoltaics (windows)</td>
<td>DPV</td>
</tr>
<tr>
<td>Proton Exch. Membr. Fuel Cell (Fixed)</td>
<td>MFC</td>
</tr>
<tr>
<td>Solid Oxide Fuel Cell (Fixed Cogen.)</td>
<td>SFC</td>
</tr>
<tr>
<td>Rural Photovoltaics</td>
<td>RPV</td>
</tr>
<tr>
<td>Solar Thermal Powerplants</td>
<td>SPP</td>
</tr>
<tr>
<td>Small Hydro</td>
<td>SHY</td>
</tr>
<tr>
<td>Wind Turbines</td>
<td>WND</td>
</tr>
<tr>
<td>Biofuels for transport</td>
<td>BF3</td>
</tr>
<tr>
<td>Fuel Cell Vehicle (PEM)</td>
<td>FCV</td>
</tr>
</tbody>
</table>
In 2050, the world 6 GHG emissions should be brought back to 2000 level +/- 25%, in place of a doubling in the Baseline.
Four key technology portfolios
(From J. Pershing, IFRI-RFF seminar, March 2003)

The Technology Approach

Deep cuts in emissions require advanced technologies SOON
No single technology can do it all

Hydrogen Fuel Cell Vehicles
Zero Net Emission Buildings
Nuclear Power Generation IV

Renewable Energy Technologies
Bio-Renewable Power

Carbon (CO₂) Sequestration
Vision 21: Zero-Emission Power Plant
POLES 2005: WETO-H2 Reference projection

- World total energy consumption is multiplied by 2.2
- The “peak oil” occurs between 2030 and 2040
POLES 2005: stabilisation at 450 ppmv CO₂

- World total energy consumption goes down from 22 Gtoe in the Ref to 13 in S450 CO₂ scenario

- 55% of total supply come from Renewables and Nuclear (3 + 4 Gtoe)
Low Energy Buildings in the France « Factor 4 » study

Référence

Facteur 4

- Standard
- Basse Consommation
- Très Basse Consommation

2000 2010 2020 2030 2040 2050

2000 2010 2020 2030 2040 2050
Low Emission Vehicles in the France « Factor 4 » study

Référence

Facteur 4
The Energy – Environment Nexus

- The world faces challenges rather than impending doom with oil supply. The challenges include a sequence of supply crises likely to develop not when production peaks – the subject of much recent controversy – but earlier, when widening gaps appear between demand and sources of supply upon which the world has come to rely.

  Peter R.A. Wells, O&GJ, Feb. 21, 2005

- The CE [Constant Emission] warming commitment has no limit even on a time scale of many centuries, primarily because, at CE, CO2 concentration continue to rise for a millennium or more […] The CE results reinforce the common knowledge that, in order to stabilize temperatures, we eventually need to reduce emissions to well below current levels.

  Tom M.L. Wigley, Science, 18 March 2005
Conclusions: policy trade-offs for a sustainable energy path

- In all cases, radical changes will be implied by the emerging oil and gas constraint …

- but leaving the solution to the sole resource constraints involves the come-back of coal …

- while implementing ambitious climate policies will help to enhance the sustainability of energy development from both perspectives:
  - The “upstream” oil and gas resource challenge
  - The “downstream” climate change challenge
Research on energy and climate:

- 2004-2005: World Energy Technology Outlook 2050 (WETO-H2, DG-RTD) with ENERDATA, FPB-Belgium, IPTS (on-going)
- 2003-2004: Emission reduction scenario for France (Factor 4 scenario, Min. of Ind.-F) with ENERDATA
- 2002-2004: **Endogenous technical change** in a world energy model (SAPIENT + SAPIENTIA, DG-RTD) with NTUA, IIASA, ECN, KUL …
- 2001-2003: **Greenhouse emission Reduction Pathways** and international endowments in the post-Kyoto perspective (GRP, DG-ENV) with NTUA, RIVM, KUL
- 2001-2003: Economic analysis of the linking of the European EQTS with the international market (Kyoto Protocol Implementation, DG-ENV)
- 2001-2003: World energy technology and climate policy framework scenario to 2030 (WETO, DG-RTD) with ENERDATA, FPB-Belgium, IPTS
  http://europa.eu.int/comm/research/energy/gp/gp_pu/article_1257_en.htm
- 2000-2002: Multigas assessment of greenhouse gas emission reduction strategies (GECS, DG-RTD) with NTUA, RIVM, KUL, IPTS
- 2000-2001: Economic assessment of climate negotiation options, before and after COP-6 (Blueprints for International Negotiation, DG-ENV)
- 1999-2001: ASPEN a software for the analysis of emission quota trading systems with MAC curves from the POLES model (Min. of Env.-F)
  http://www.upmf-grenoble.fr/iepe/Recherche/Aspen.html

POLES modelling system, April 2009