High Oil and Gas Prices, Fuel Mix in Power Generation and Long Term CO2 Emissions

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- **The three dimensions of uncertainty in the inter-technology competition for power generation**
- **The electricity sector in a world long term energy scenario with high oil and gas prices**
- **High fossil prices with low carbon constraints or high carbon constraints with lower fossil prices ?**

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Increasing uncertainties in power generation costs

- **In the past twenty years, power generation "reference cost studies" (e.g. NEA-IEA, Min. de l' Industrie-Fr) have focussed on a limited number of technologies (Coal, GTCC, Nuclear) in a context of low energy prices**
- **The range for generation costs was relatively stable at 30-40 €/MWh**
- **Today uncertainty is growing along three directions:**
  - Technologies are more diverse, complex and novel (e.g. H2 and Fuel-Cells, CCS, distributed power systems…)
  - The price of primary fuels are higher and more unstable
  - Carbon tax/permits may have significant impacts (e.g. a 25 €/tCO2 almost doubles the price of coal)

The TECHPOL database: Power Generation

Large Scale Power Generation

- Hydroelectricity
- Light-water nuclear reactor (including EPR)
- New nuclear design (Generation 4)
- Pulverised coal, supercritical, with/without CO2 capture
- Integrated coal gasification in combined cycle, with/without CO2 capture
- Coal conventional thermal
- Lignite conventional thermal
- Gas conventional thermal
- Gas turbine
- Gas turbine in combined cycle, with/without CO2 capture
- Oil conventional thermal
- Oil gas turbine in combined cycle

Renewable Energy Sources

- Small hydro power (<10 MWe)
- Onshore wind power
- Offshore wind power
- Solar thermal power
- Biomass (woodfuels, electricity from wastes, biofuels)
- Biomass gasification for power generation

The TECHPOL db: H2 and distributed power

Hydrogen Production

- Gas steam reforming, with/without CO_2 capture
- Coal partial oxidation, with/without CO_2 capture
- Biomass pyrolysis
- Solar high-temperature thermolysis
- Nuclear high-temperature thermolysis
- Water electrolysis, dedicated nuclear power plant
- Water electrolysis, dedicated wind power plant
- Water electrolysis, baseload electricity

Distributed Power Generation

- Combined heat and power
- Stationary fuel-cells, natural gas
- Stationary fuel-cells, hydrogen
- Building integrated photovoltaic systems
- Photovoltaic systems for rural electrification

Very Low Emission Vehicles / Buildings

- Internal combustion engine (including hybrid)
- Pluggable hybrid
- Electric, battery
- Gas fuel-cell vehicle
- Hydrogen fuel-cell vehicle
- Hydrogen internal combustion engine
- Low energy building
- Very low energy building

A case study:

HYP		2000	2025	2050
Nat Gas	$/MBTU	3	8	12
Oil	$/bl	25	50	75
Coal	$/t	40	80	120
Carbon	€/tCO2	0	25	50

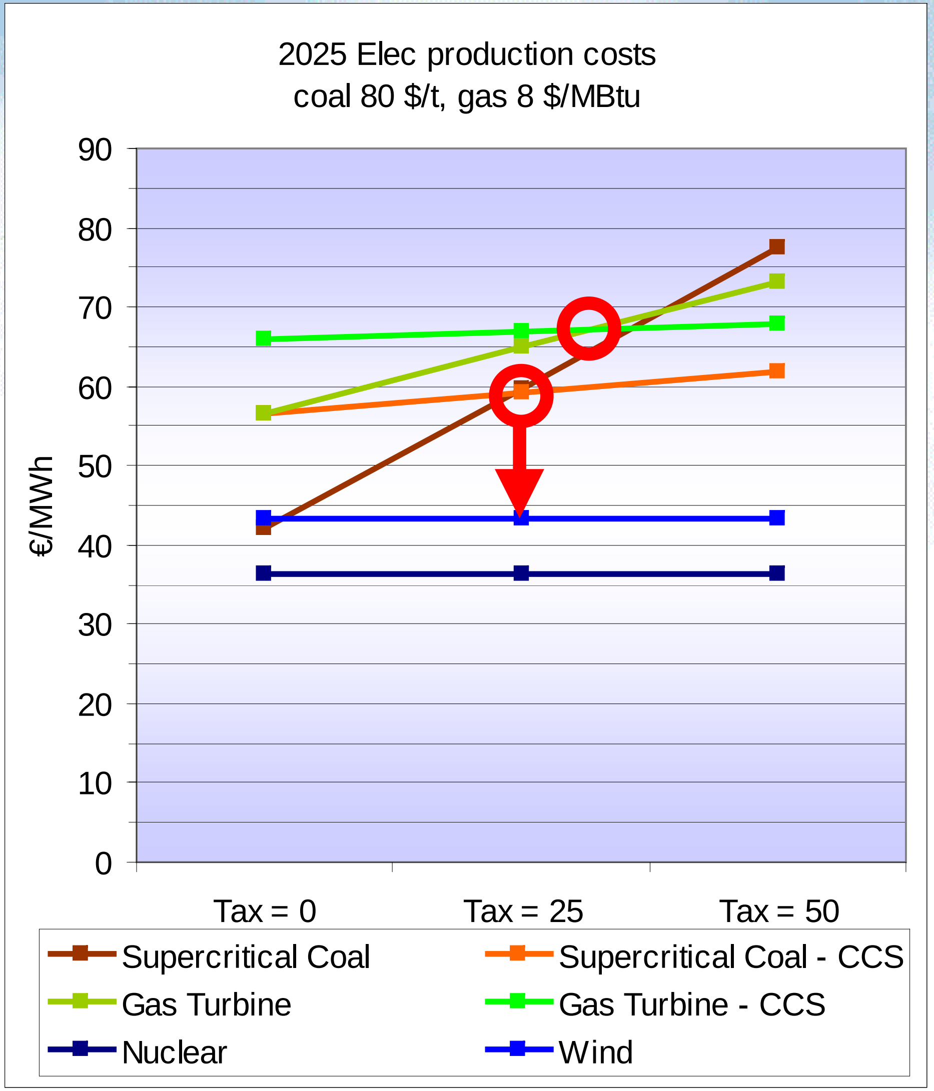
- **Total investment decreases by 25 % in 2050, but CCS is an extra investment of 50 %**
- **Fuel costs are multiplied by almost 3 between 2000 and 2050**
- **In the no-CCS option, carbon costs represent almost half of 2050 cost**
- **Supercritical coal with CCS in 2050 is still about twice the current generation cost**

SUPERCRITICAL COAL		Without CCS			With CCS		
99€ - 95$		2000	2025	2050	2000	2025	2050
Overn. Inv. Cost	€/kW	1200	1050	900	2153	1717	1328
Technical lifetime	Years	35	35	35	35	35	35
Construction time	Years	3	3	3	4	4	4
Interest rate	%	5%	5%	5%	5%	5%	5%
Decommission share	%	10%	10%	10%	10%	10%	10%
Discount rate (%)	%	8%	8%	8%	8%	8%	8%
Total investment Cos	**€/kW**	**1330**	**1164**	**997**	**2443**	**1948**	**1507**
Fixed annual cost	**€/kWy**	**114**	**100**	**86**	**210**	**167**	**129**
FOM cost	€/kWy	40	38	36	47	44	42
Load Factor	%	85%	85%	85%	85%	85%	85%
Uncertainty 1							
Fixed cost	**€/MWh**	**21**	**19**	**16**	**34**	**28**	**23**
Fuel price	**€/toe**	**57**	**114**	**171**	**57**	**114**	**171**
Carbon content	tCO2/toe	4	4	4	4	4	4
Carbon price	**€/tCO2**	**0**	**25**	**50**	**0**	**25**	**50**
Fuel efficiency	%	44%	48%	50%	35%	40%	42%
Fuel input	toe/kW	1,5	1,3	1,3	1,8	1,6	1,5
[illegible] rate	%				85,0%	88,0%	90,0%
[illegible] **Uncertainty 2**	tCO²/MWh	0,8	0,7	0,7	0,1	0,1	0,1
Fuel cost	**€/MWh**	**11**	**20**	**29**	**14**	**25**	**35**
Carbon cost	**€/MWh**	**0**	**18**	**34**	**0**	**3**	**4**
[illegible] **Uncertainty 3**	€/MWh	3,0	3,0	2,0	3,5	3,5	2,5
Variable cost	**€/MWh**	**14**	**41**	**66**	**17**	**31**	**41**
Capture cost	€/tCO²				27	24	21
Production cost	**€/MWh**	**35**	**60**	**82**	**52**	**59**	**64**

Power generation costs, 2025 - Europe

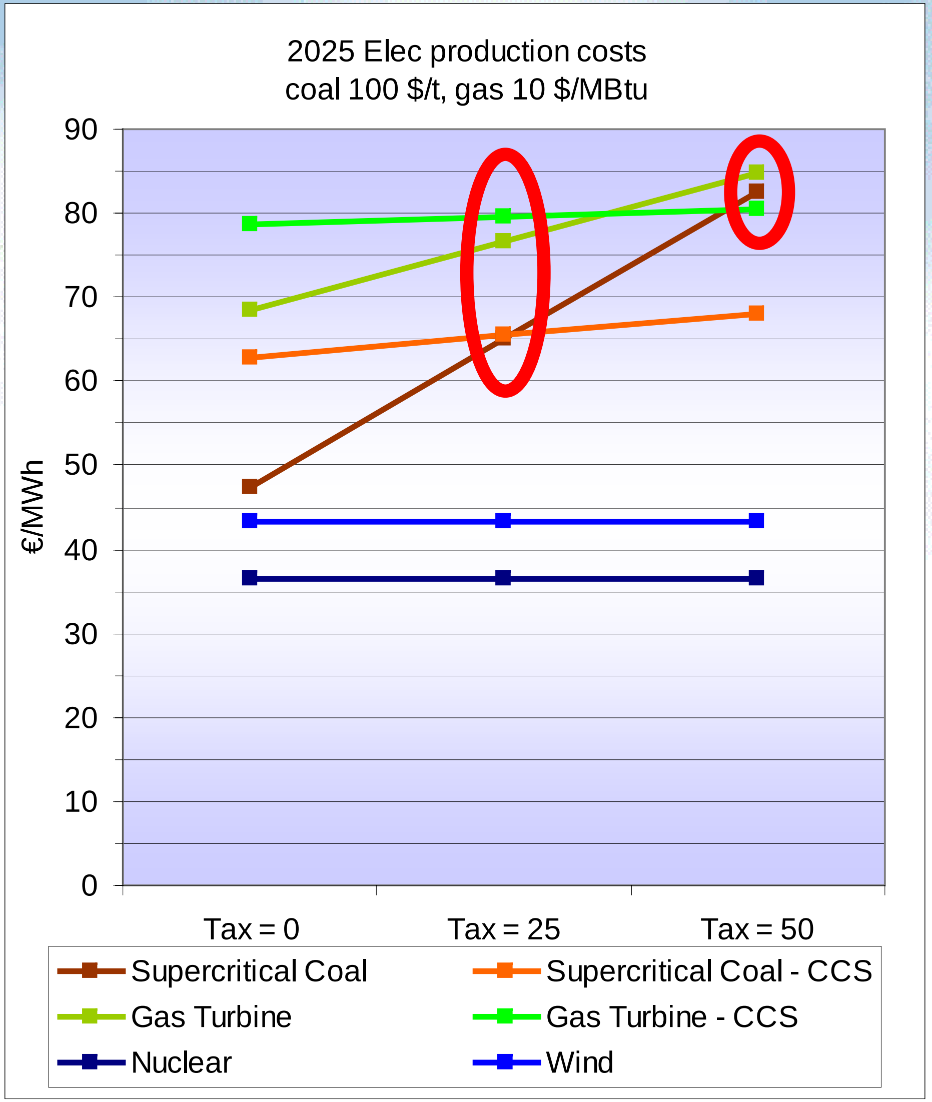
- **The breakeven point for CCS is at 25 €/tCO2 for coal technologies, 30 €/tCO2 for gas**

- **A 25 €/tCO2 tax/permit increases the cost of coal-based power by 50 %**



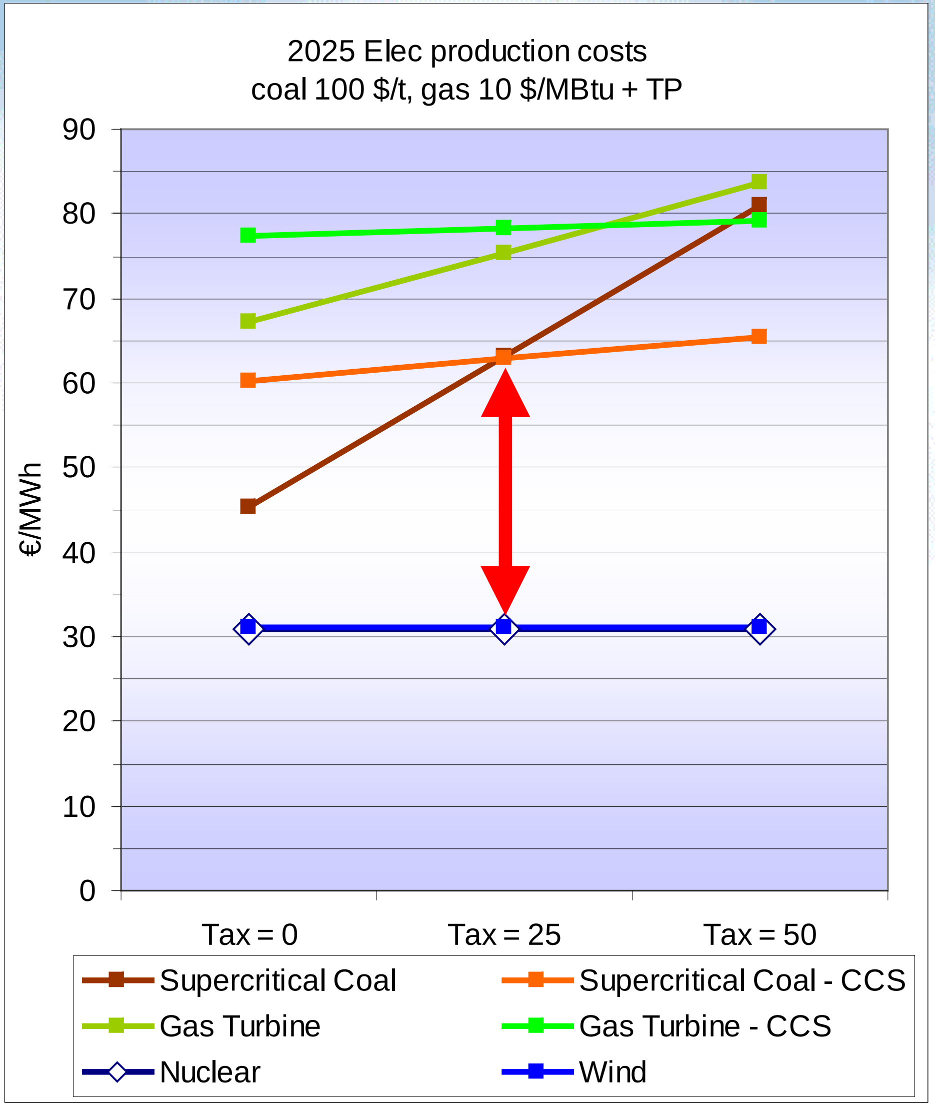
Power generation costs: high prices

- The same relative increase on coal and gas (+25%) has more impact on gas-powered generation (due to increased differential per toe)
- The cost of coal without CCS is not significantly different of that of gas with/out CCS



Power generation costs: technological progress

- Adopting the "optimistic" investment cost for all technologies favours more nuclear and wind …
- As the primary fuel and carbon component is at least one half of total cost for coal- or gas-based power



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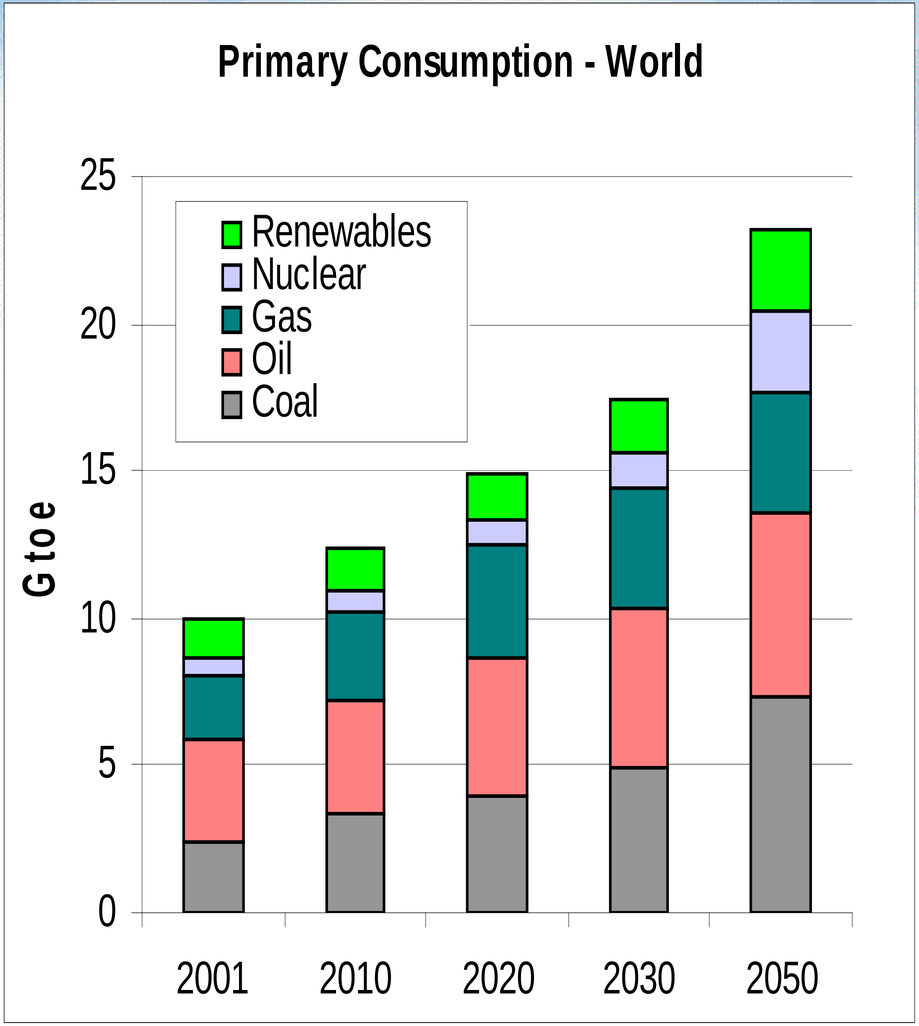
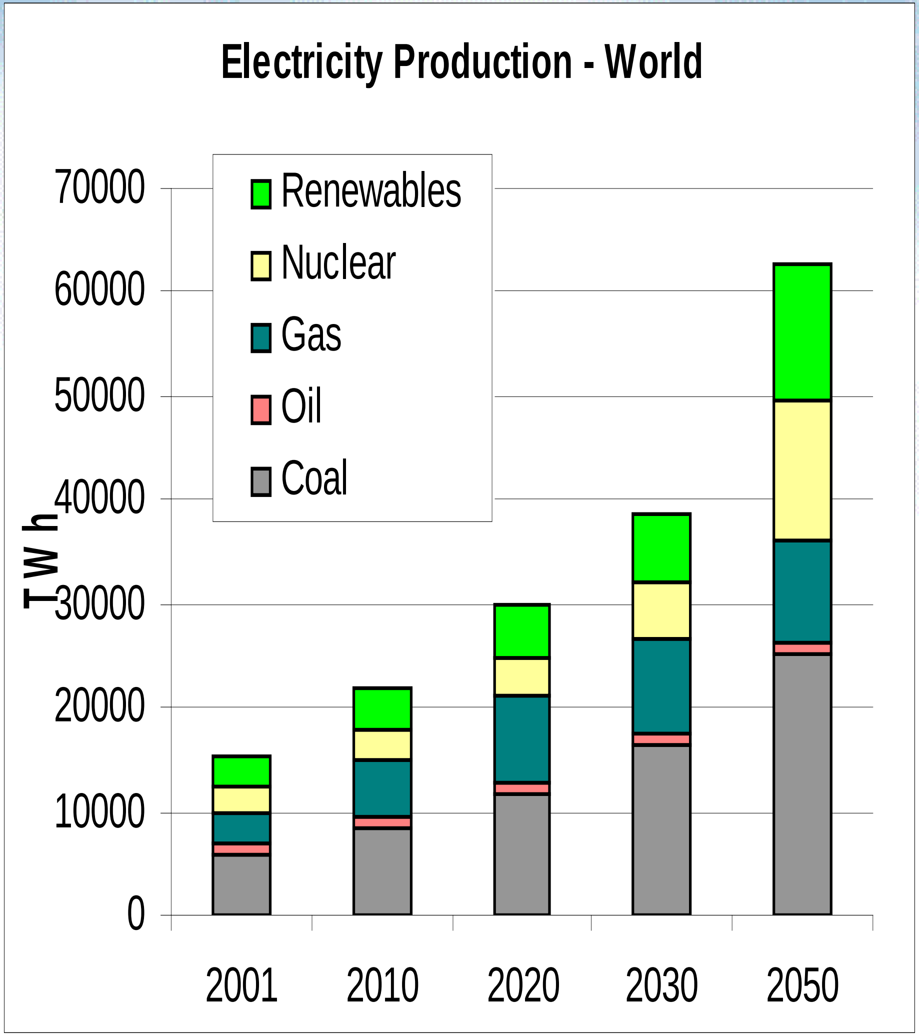
A world Baseline with the POLES model

- A quadrupling of world GDP, with oil prices at more than 110 $/bl in 2050
- World primary consumption amounts to 23.5 Gtoe
- An “oil plateau” at less than 110 Gbl for conventional oil (+25 Gbl for non-conventional)
- A stabilisation of gas production towards 2040
- The “comeback” of coal with more than 7 Gtoe in 2050, as the first primary energy source



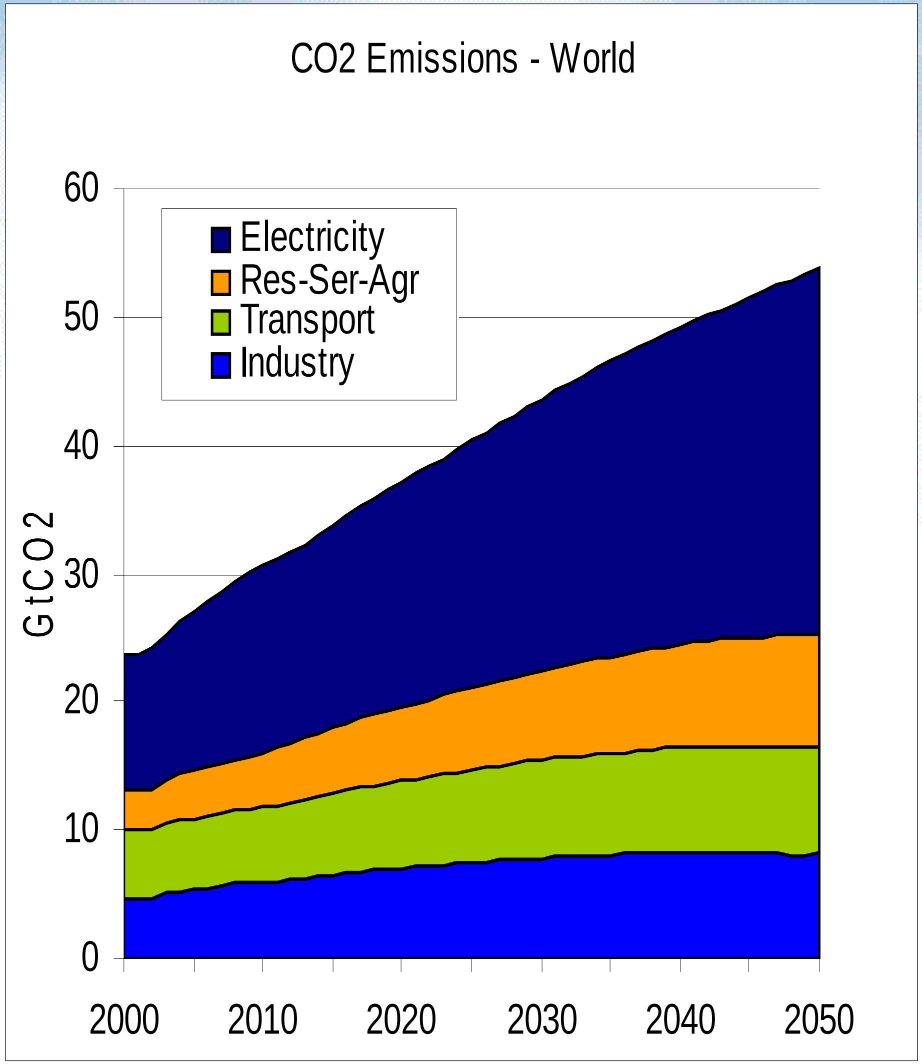
A world Baseline: electricity sector

- Electricity generation grows along with GDP, from 15 000 to more than 63 000 TWh in 2050
- In spite of a strong increase in nuclear and renewable electricity generation after 2030 …
- the share of coal-based generation is remarkably stable at about 40%
- and results in a total coal-based production that is almost twice total current production



A world Baseline: CO2 emissions

- The result of coal development without CCS is a multiplication of the power sector emissions by 2.6 until 2050 …
- against 2.3 for total world emissions …
- i.e. somewhere between the A1B (balanced) and A1T (technology) IPCC scenarios



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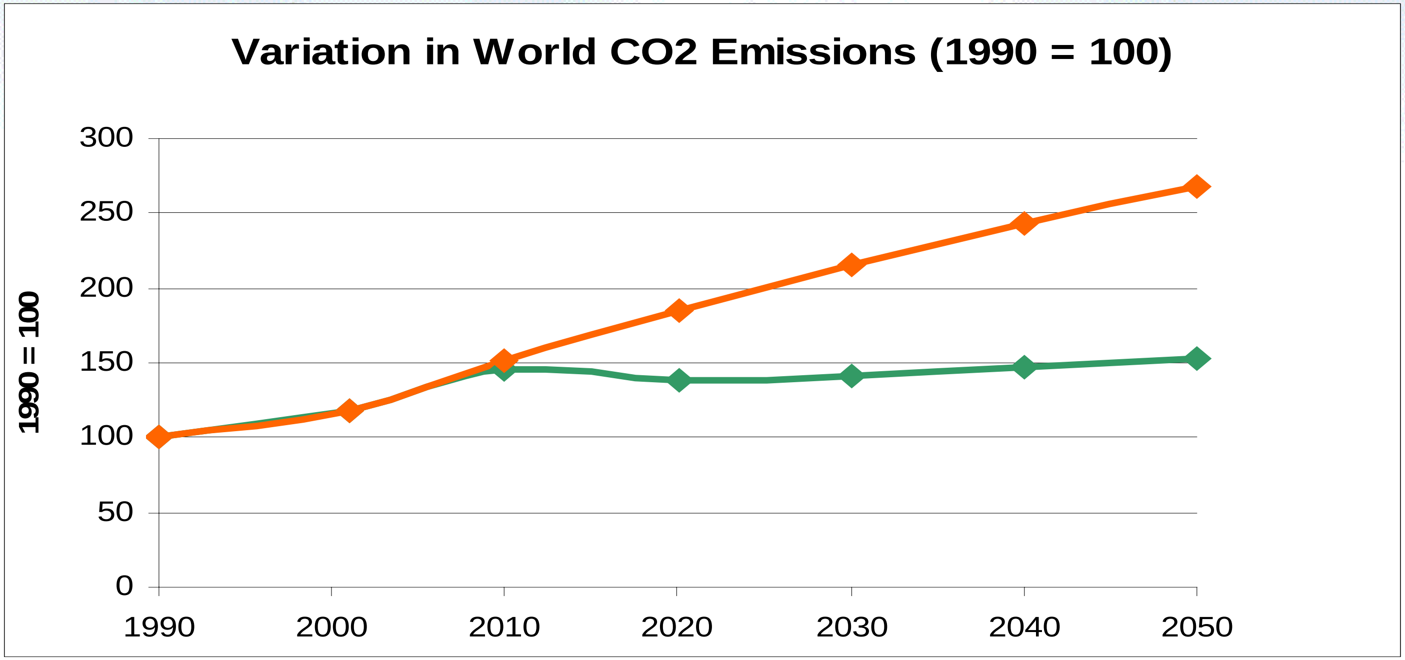
Sensitivity analysis for an Emission Stab Case

- The introduction of a linearly increasing carbon value, from 20 €t/CO2 in 2010 to 100 €t/CO2 in 2050 …
- Produces a “WEDGES-like” (Socolow & Pacala) world emission profile, with a rapid stabilisation



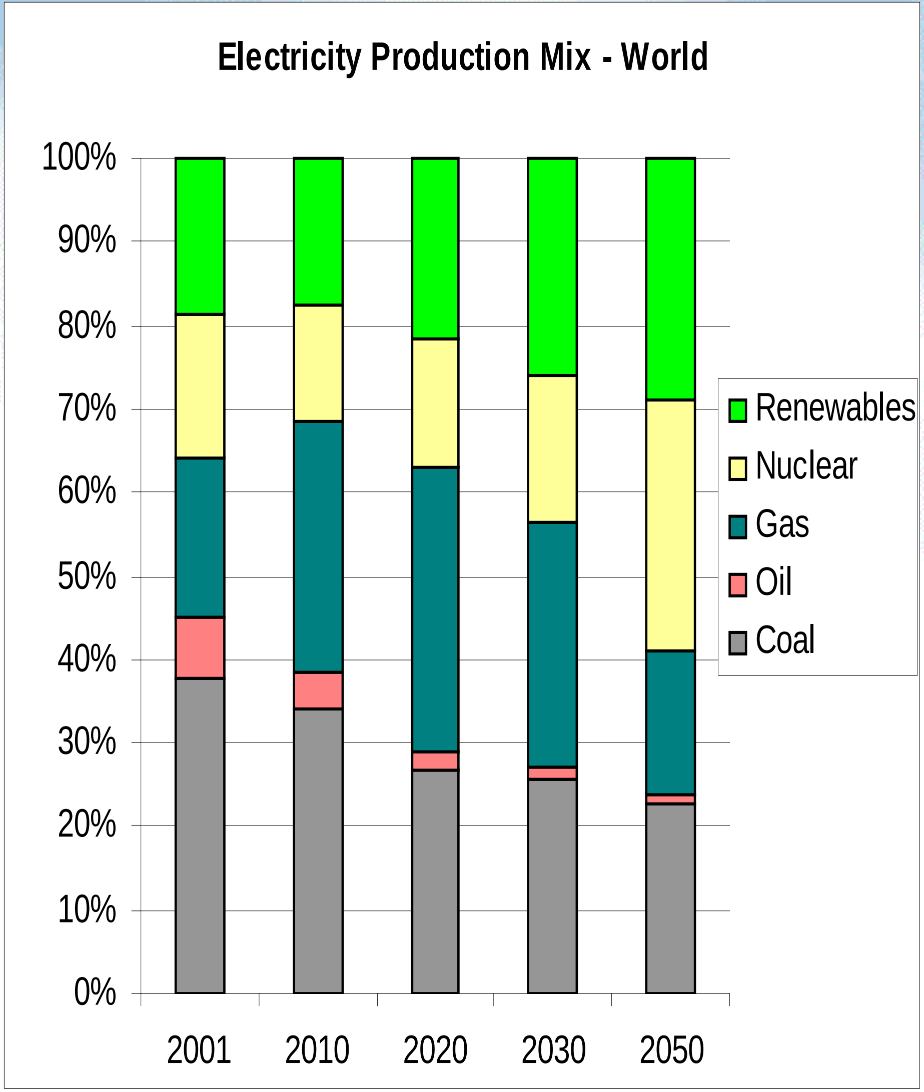
Emission Stab Case: changes in primary energy

- Both the Baseline and the Stabilisaton case are extreme scenarios
- The POLES system provides an economically consistent image of changes in the energy system
- With a reduction of only 10 % in primary energy, but 50 % in coal consumption
- While nuclear and renewable increase of about one third compared to Baseline

	2001	2010	2030	2050
Primary Production (Mtoe)	100	98	89	90
Coal, lignite	100	86	58	51
Oil	100	101	93	93
Natural gas	100	106	100	94
Nuclear	100	101	115	133
Hydro, geothermal	100	100	106	107
Biomass and wastes	100	100	123	141
Wind, solar	100	108	200	134

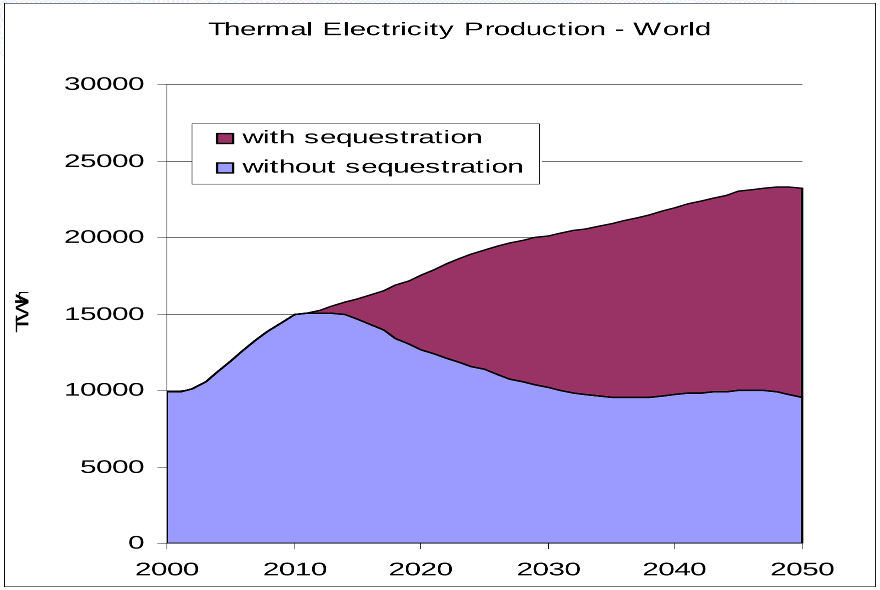
Emission Stab Case: fuel-mix in power generation

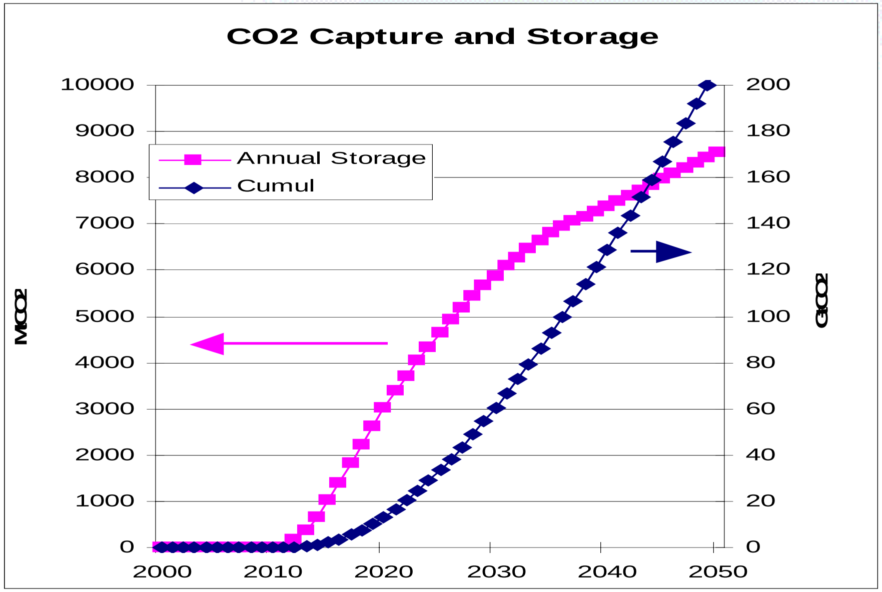
- **In the electricity sector the world fuel-mix is significantly altered**
- **As a consequence of changes in the relative cost-effectiveness identified in section 1:**
  - In spite of CCS, coal's share is down from 40 to 20 %
  - While renewables and nuclear represent about 30 % of total each



Emission Stab Case: CCS

- However fossil-based thermal production continues to increase, with CCS plants representing more than half of total in 2050
- With an annual storage of 8.5 $GtCO_2$, i.e. 21 % of gross emissions
- And more than 200 $GtCO_2$ cumulative storage in 2050





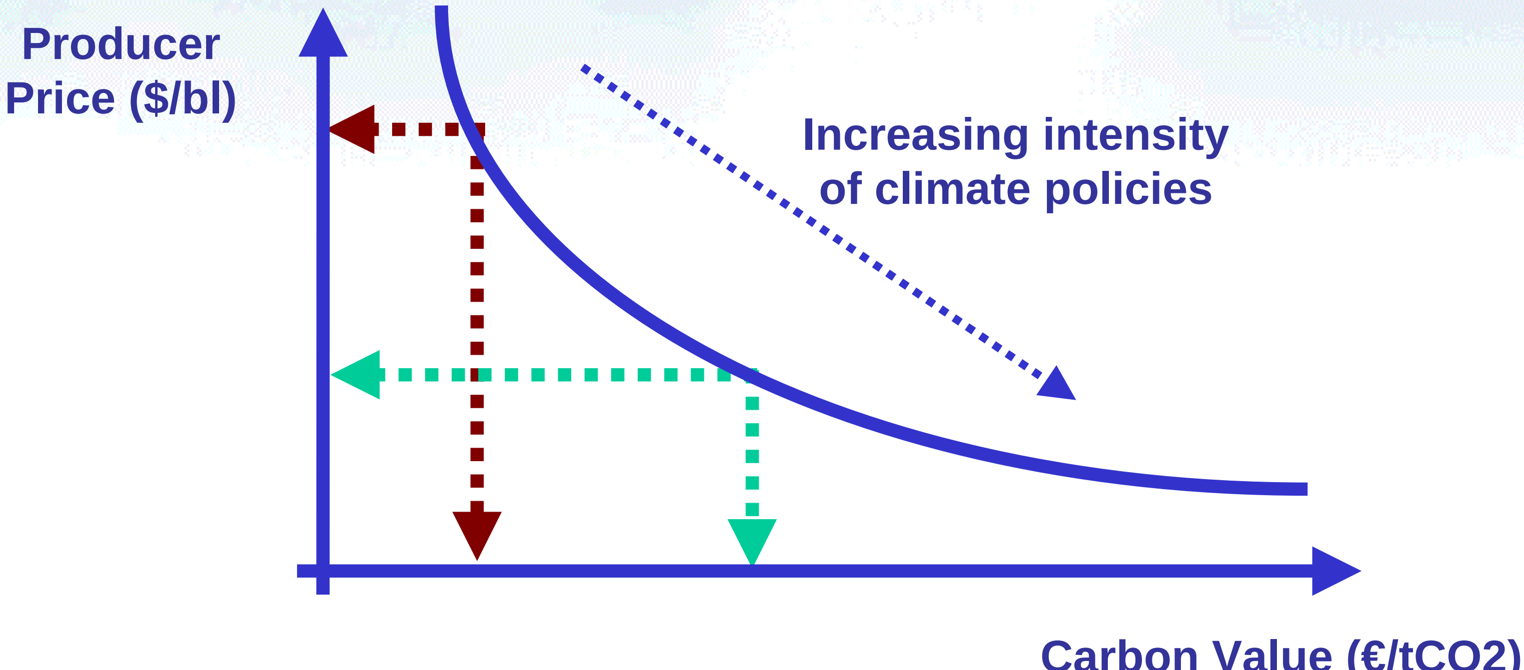
Emission Stab Case: sectoral abatement

	2001	2010	2030	2050	
CO2 Emissions (MtCO2)*, of which*	**0,0**	**-1,3**	**-15,2**	**-23,1**	
Electricity generation	0,0	-0,7	-11,2	-17,3	75%
Industry	0,0	-0,3	-2,2	-2,8	12%
Transport	0,0	0,0	-0,4	-0,4	2%
Household, Service, Agriculture	0,0	-0,1	-0,6	-1,0	4%

- **Three-fourths of emission reductions come from the electricity sector, while the contributions from transport and residential are very limited**
- **This is explained by the fact that 100 €/tCO2 only represents:**
  - 25 €c per litre of gasoline
  - but a doubling of the price of gas for electricity and industry
  - and a multiplication by four of the price of coal …

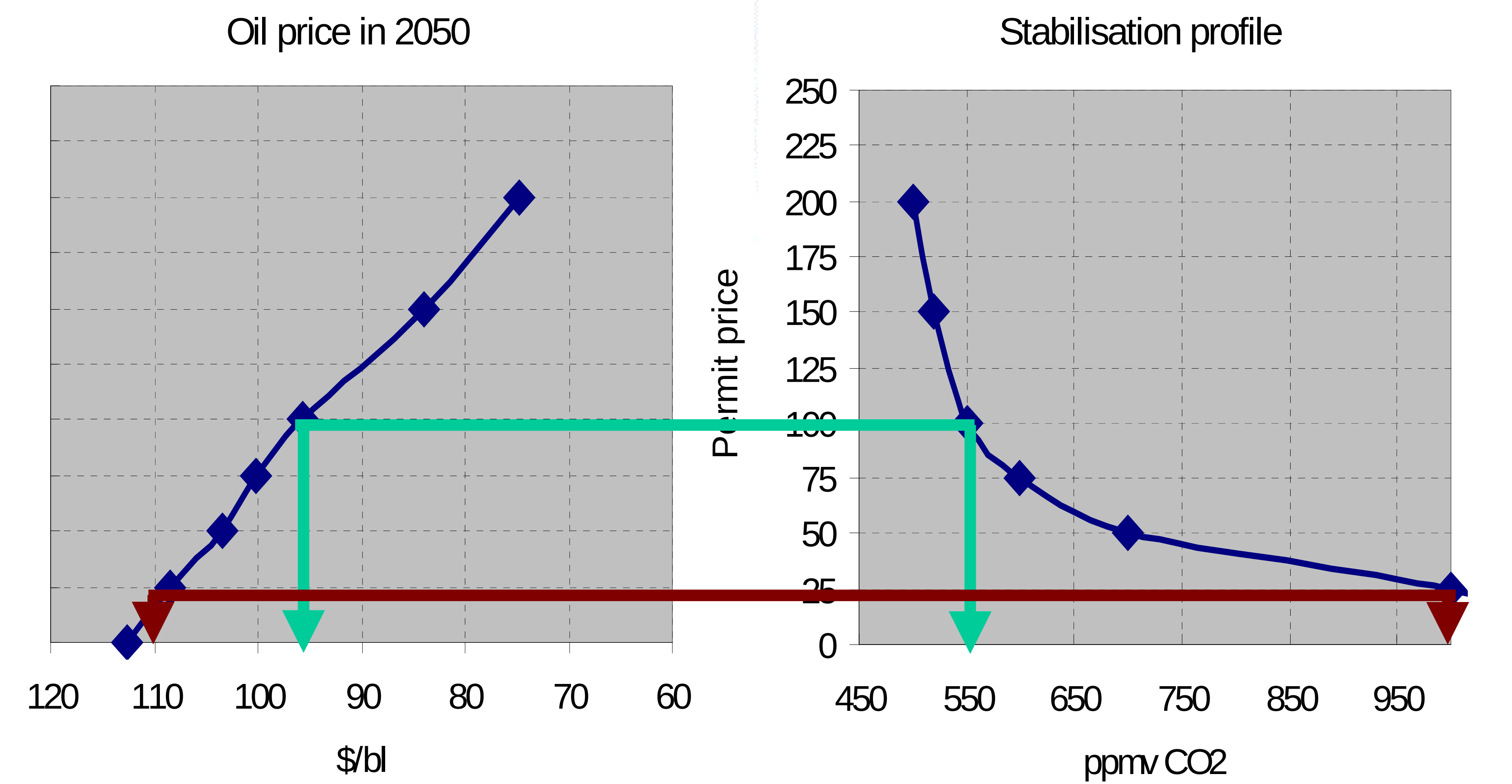
Carbon Value / Energy Prices

- Under climate policies, end use energy prices show different proportions in the carbon and the producer price component



Carbon Value, oil price and stabilisation profiles

- **Impacts on oil prices of increasing carbon constraint scenarios (permit price for 2050)**



Conclusion 1:

- If no emission constraint is adopted, the growing scarcity in oil and gas will spur the comeback of coal with heavy impacts on emissions
- The early emission stabilisation – “Wedges-like” scenario – shows the importance of the abatement to be realized at relatively low cost in the electricity sector
- If needed, abatements in the other sectors, particularly transport, will require adjusted incentive systems, as the pure price-signal is considerably dampened by existing taxes and lower (?) price-elasticities

Conclusion 2:

- On the one hand, the impacts of the Emission Stabilisation Case on the oil and gas markets exist but are limited
- On the other hand, the stabilisation in emissions is not sufficient for long term stabilisation in concentrations
- A sustainable energy development imposes to overcome both the oil and gas resource constraints and the challenge of reducing emissions in absolute terms
- This imposes new research on incentive systems, including differentiated carbon values across sectors …

Research on energy and climate: POLES studies on the Web

- 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

http://www.industrie.gouv.fr/energie/prospect/pdf/oe-facteur-quatre.pdf

- 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

http://europa.eu.int/comm/environment/climat/pdf/pm_summary2025.pdf

- 2001-2003: Economic analysis of the linking of the European EQTS with the international market (Kyoto Protocol Implementation, DG-ENV)

http://europa.eu.int/comm/environment/climat/pdf/kyotoprotocolimplementation.pdf

- 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: Multi-gas 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)

http://europa.eu.int/comm/environment/climat/pdf/blueprints.pdf

- 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