Low Carbon Scenarios: European Commission Development Method

POLES: A world energy model and its applications

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POLES: Model goals

- A **world** simulation model for the analysis of energy systems and their global environmental impacts to 2010 and 2030 :
  - scenarios and projections for energy demand, supply and prices
  - analysis of CO2 emission reduction options in an international perspective
  - impacts of technological change and R&D strategies

Policy Outlook on Long Term Energy Systems

CONTRIBUTIONS TO MODEL DEVELOPMENT

The model development has been initially funded under the JOULE II programme of EU-DG XII with the main contribution the CNRS-IEPE, ECOSIM, JRC-IPTS and the support of Enerdata, CEPII, ETSU, FhG-ISI and other partners.

- 1993-1995, a first **version**.
- 1996-1997, JOULE III programme CTS (Climate Technology Strategy) project :
  - complementarity with other models such as PRIMES and GEM-E3 new model
- 1998-1999, the POLES model improvement and utilisation continue in the EU-DG XII « JOULE III » programme, in the TEEM (Technology Endogenisation in Energy Models) project
- 1999-2001: SAPIENT
- 2000-2002: GECS
- 2001-2003: WETO, ACROPOLIS
- 2004-2006: EU New Member States, CIS, WETO-H2, EC Communication "Winning the Battle Agianst Climate Change"

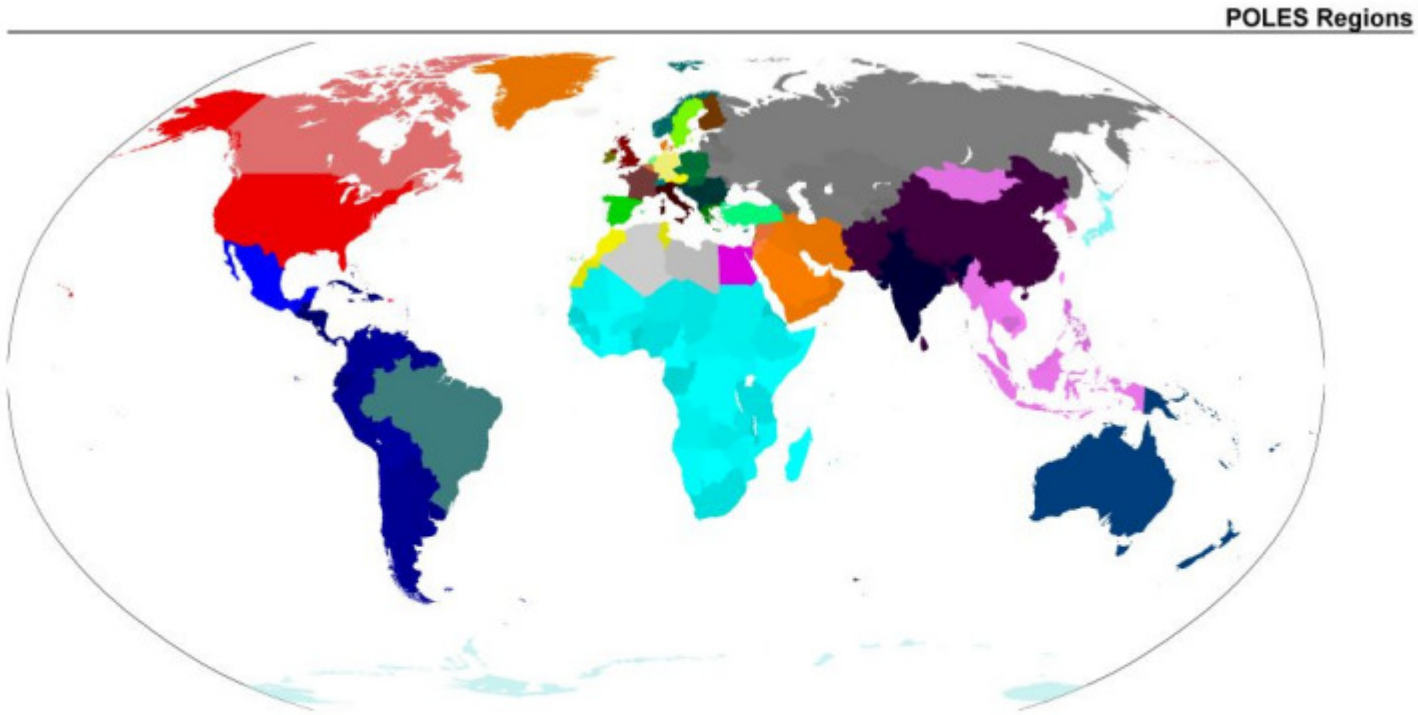
The POLES model

- The POLES 5 model is a recursive simulation model at world level, working on a year by year basis, from 1998 to 2030
- It incorporates more than 60 000 variables of which appr.:
  - 10 000 exogenous variables
  - 15 000 endogenous
- It is thus built of a system of >50 000 equations organised in modules for the different countries/regions and energy consuming sectors, activities and technologies
- The model provides a regularly updated Reference Case with associated CO2 reduction costs, Technology Stories and other cases or sensitivity analyses

POLES 5: Modelling Characteristics

- Economic analysis
  - Recursive year by year simulation process, with behavioural equations for energy demand, conversion, production and price-making processes
- Outputs
  - World long-term energy scenarios or projections
  - National-regional energy balance and CO_2 emissions simulation
  - Analysis of new energy technologies potentials, markets and diffusion
  - Test of energy policies and energy RTD strategies

POLES 5 : Geographical coverage



47 regions

POLES 5: Energy demand disaggregation

INDUSTRY	Steel Industry	STI
	Chemical industry (+feedstock)	CHI (CHF)
	Non metallic mineral industry	NMM
	Other industries (+non energy use)	OIN (ONE)
TRANSPORT	Road transport	ROT
	Rail transport	RAT
	Air transport	ART
	Other transports	OTT
RAS	Residential sector	RES
	Service sector	SER
	Agriculture	AGR

Reaction on price and income changes

Standard Demand Equation

Ln(FC) = RES_FC+Ln(FC[-1])

residual and lagged variable

+ES*(0.67*Ln(AP/AP[-1])+0,33*Ln(AP[-1]/AP[-2]))

short-term price effect, current year and year -**1**

+EL* Σ (i = -1to -DP : 6*DI[i-1]/(DP*(DP2-1))*(i**2+DP*i)*Ln(AP[i-1]/AP[i-2]))**

long-term price effect with distributed lag and asymmetry factor

+EY*Ln(VA/VA[-1])

income/activity elasticity

+Ln(1+TR/100)

autonomous technological trend

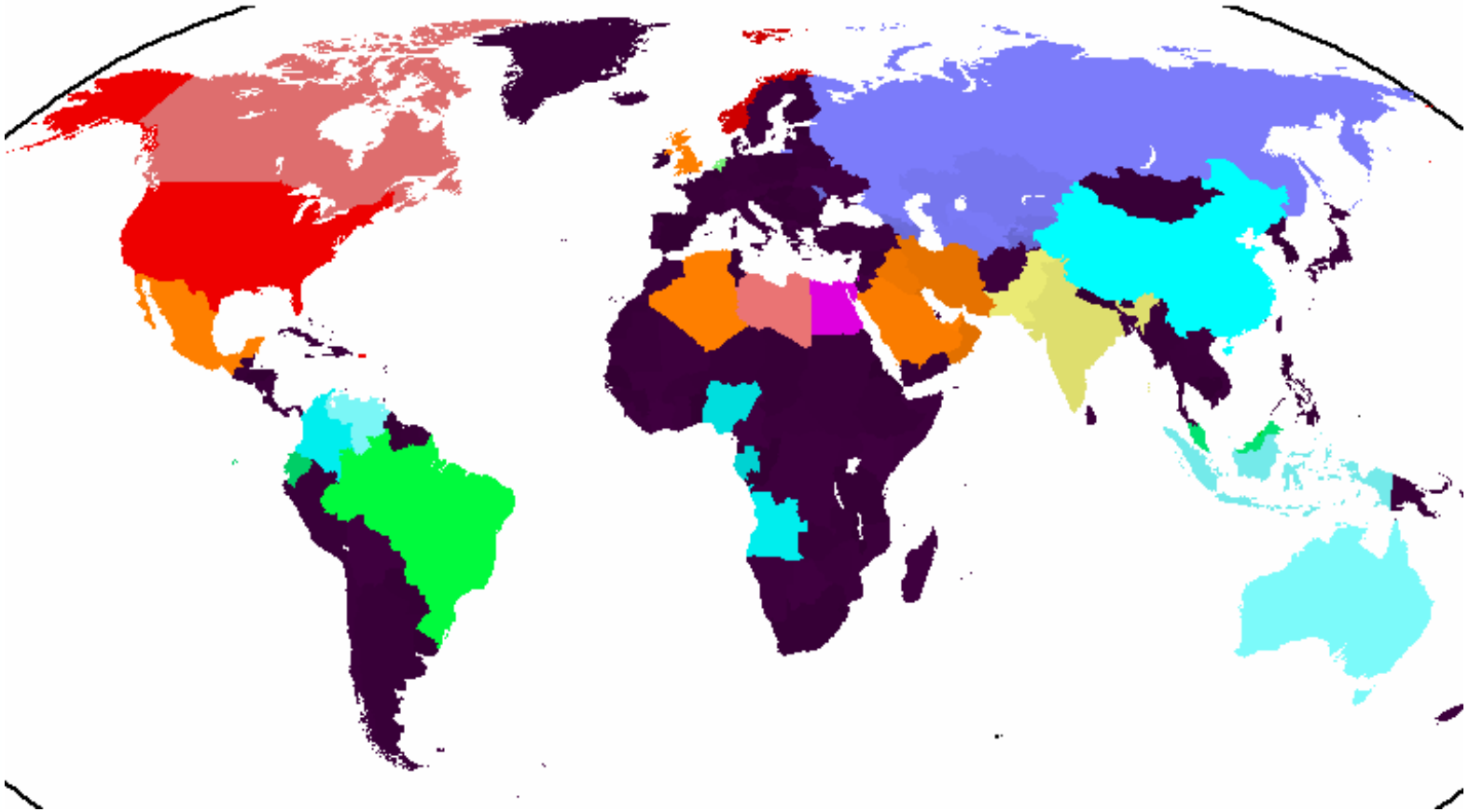
Technology Rich / Bottom-up Model: New and Renewable Energy Technologies

Small combined heat and power (cogeneration)	CHP
Small hydro power plants (<10 Mwe)	SHY
Wind power (grid connected)	WND
Solar thermal power plants (grid connected)	SPP
Decentalised roof integrated photovoltaic system	DPV
Rural electrification photovoltaic system	RPV
Low temperature solar heat in building	LTS
Conventional biomass (waste, electric., biofuels)	BF1, BF2, BF3
Biomass gasification in gas turbines	BGT
Fuel-cells (vehicles, stationary and cogen.)	FCV, MFC, SFC

Technology Rich / Bottom-up Model: Electricity generation technologies

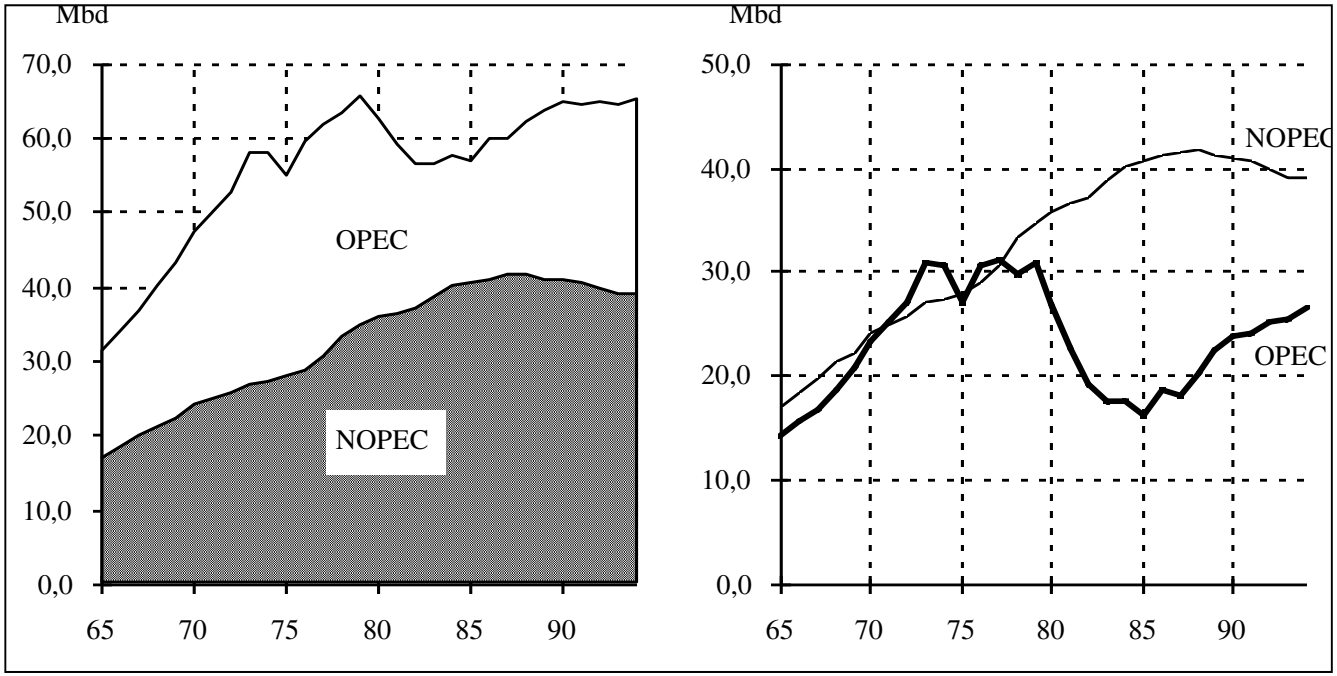
Conventional large size hydropower	HYD
Nuclear Light Water Reactor	LWR
New nuclear design	NND
Supercritical pulverised fuel combustion (coal)	PFC
Integrated coal gasification with CC	ICG
Advanced thermodynamic cycle (coal)	ATC
Lignite powered conventional thermal	LCT
Coal powered conventional thermal	CCT
Oil powered conventional thermal	OCT
Gas powered conventional thermal	GCT
Gas powered gas turbine in combined cycle	GGT
Oil powered gas turbine in combined cycle	OGT

POLES 5: 31 major Oil & Gas producers



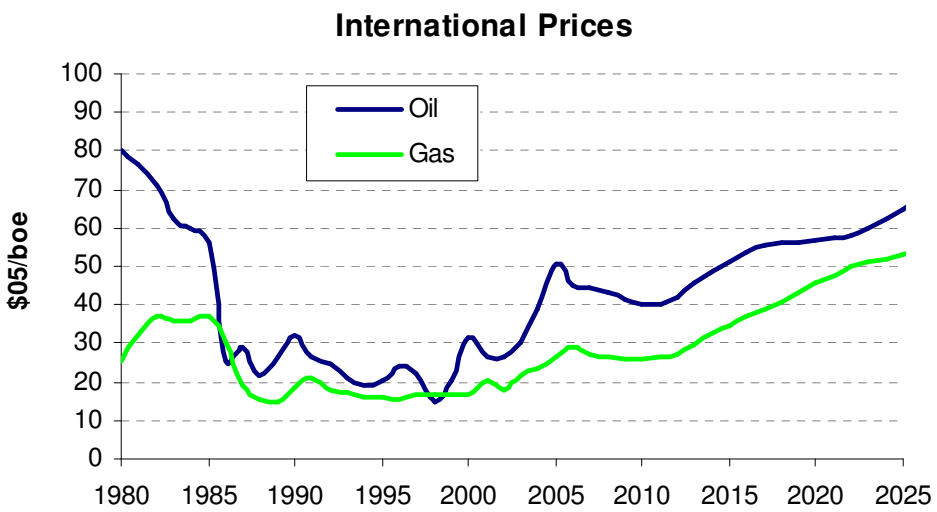
POLES 5 World Oil Production

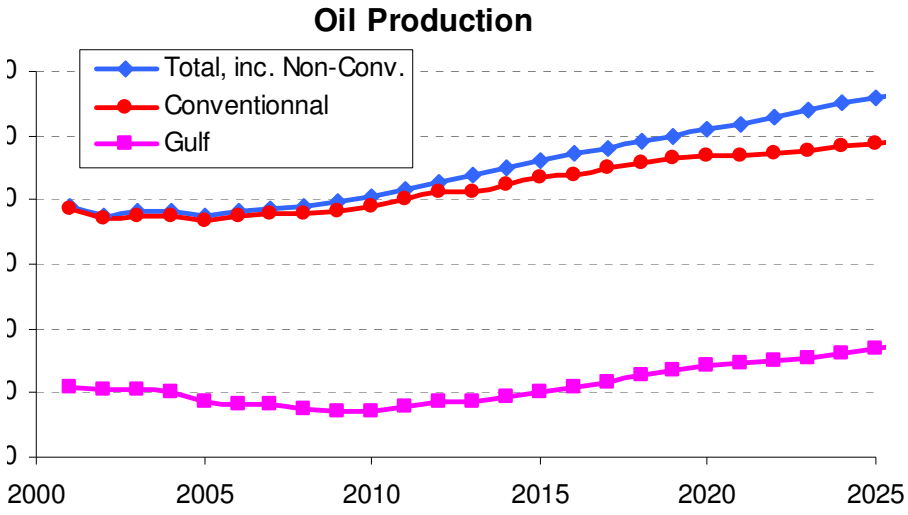
- Oil production depends :
  - for Non OPEC, on the oil price and the Reserve/Prod. ratio
  - for OPEC non-Gulf, on the residual demand for OPEC oil
  - for Gulf countries on the residual demand and on capacities



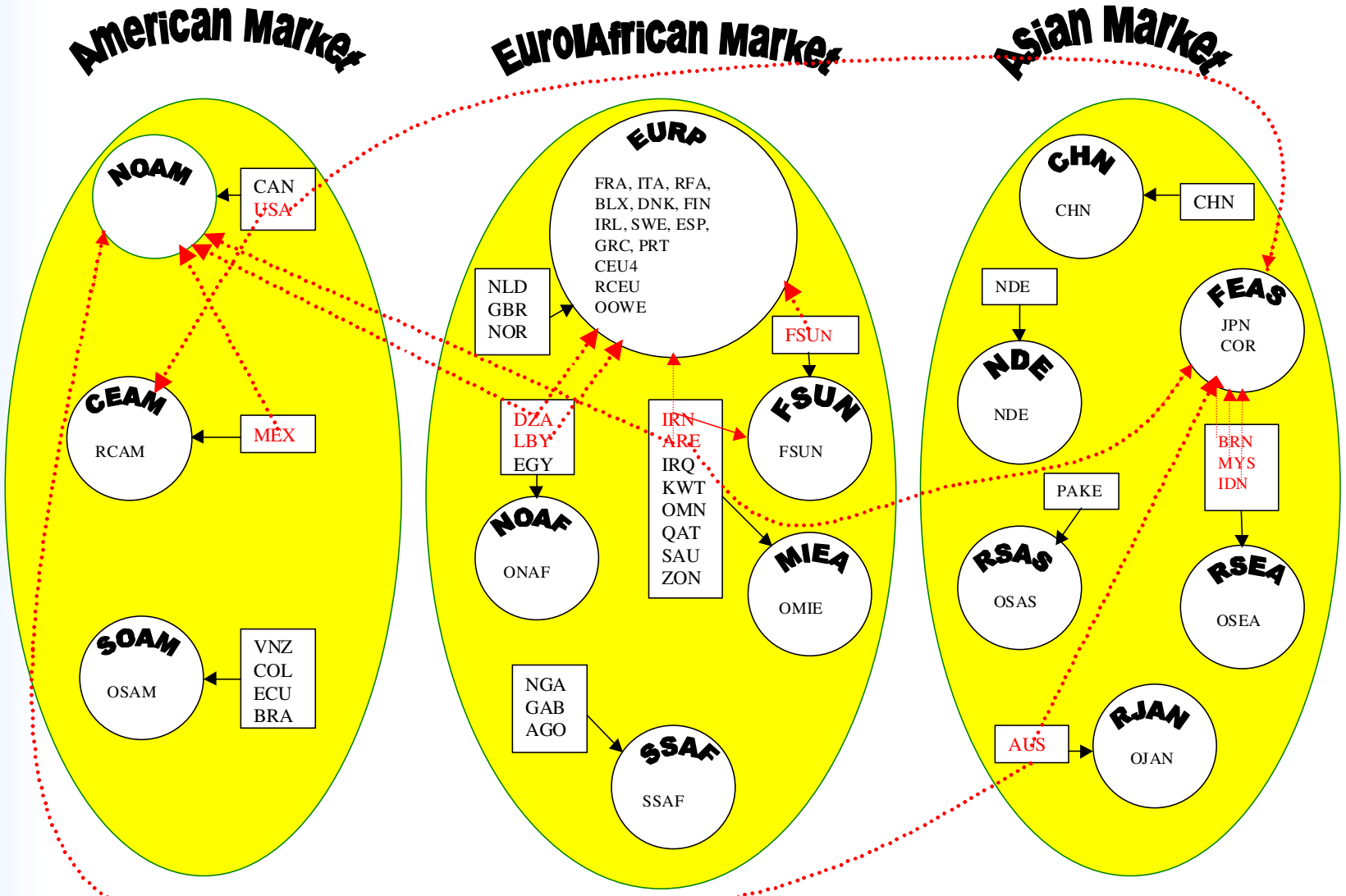
POLES 5 : International Energy Prices - OIL

- The world oil price depends in the short run on the Gulf countries capacities and in the long run on variations in the world R/P ratio





POLES 5: Natural Gas Production from three Gas Markets



Typical output

- energy balances per country/region
- development of energy prices
- trade matrices (e.g. gas, oil, coal)
- emission profiles
- technology deployment

Scenario approach

Application and Results

- Low/High resources cases
  - impact of resources (basic information from US Geological Service)
- Climate change policy
  - impact of climate change policy (Kyoto/post-Kyoto)
- Technology cases
  - accelerated technological development

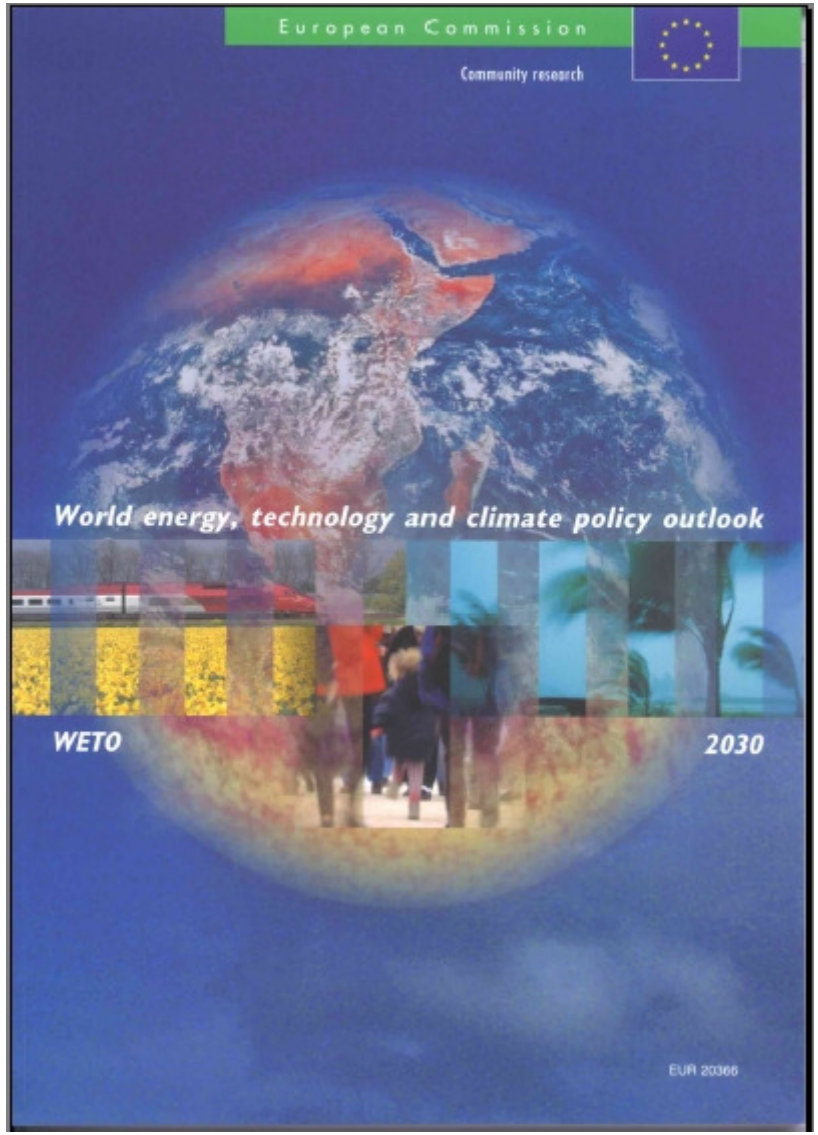
Scenario design

- Scenario design has to take into account the time horizon and the capital equipment turnover time
- Short-term disruptions cannot be properly modelled within a long-term simulation prospective (no analyses of energy crises or strategic fossil reserves, but rather security of supply indicators)
- Each scenario requires an entire definition of the main exogenous assumptions (GDP, population dynamics, reserves, technology deployment, market regulatory setup, including semi-endogenous variables, like carrying capabilities, recoverable resources and the like)

WETO

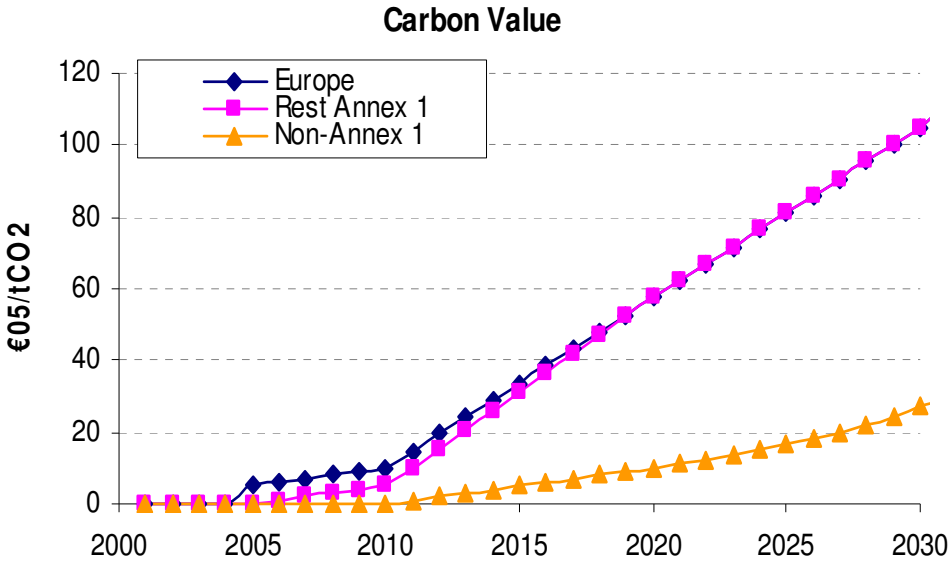
World energy, technology and climate policy outlook

http://energy.jrc.es



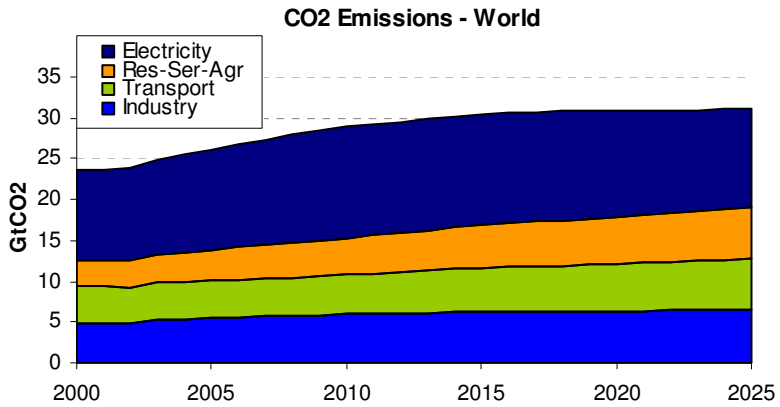
The Carbon Constraint Case (s)

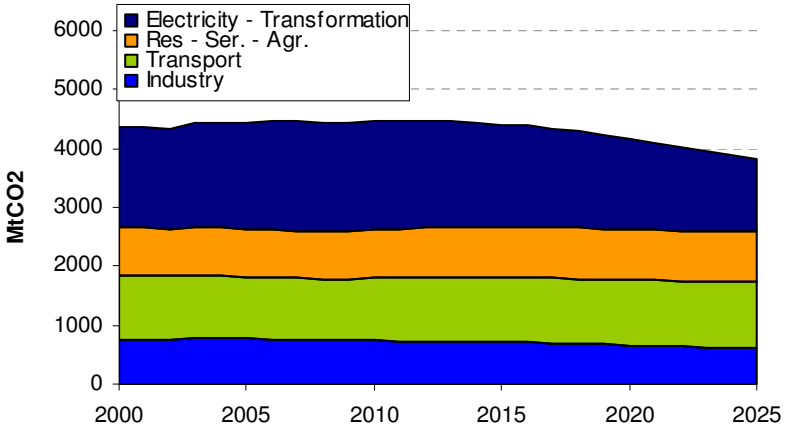
- The Carbon Constraint Case in the on-going WETO study doesn't represent an EU climate policy target.
- It simply intends to explore a future of ambitious carbon policies and their consequences on the energy systems
- The constraints that has been chosen are consistent with a long term trajectory allowing a stabilisation in CO2 concentrations in the range of 500 - 550 ppmv
- This implies an extension to the time horizon (and the embedded exogenous assumptions) to the year 2050
- A peak in emissions between 2020 and 2030, at a level that doesn't exceed + 50 % compared to 1990 emissions is expected



The resulting world CO2 emission profile

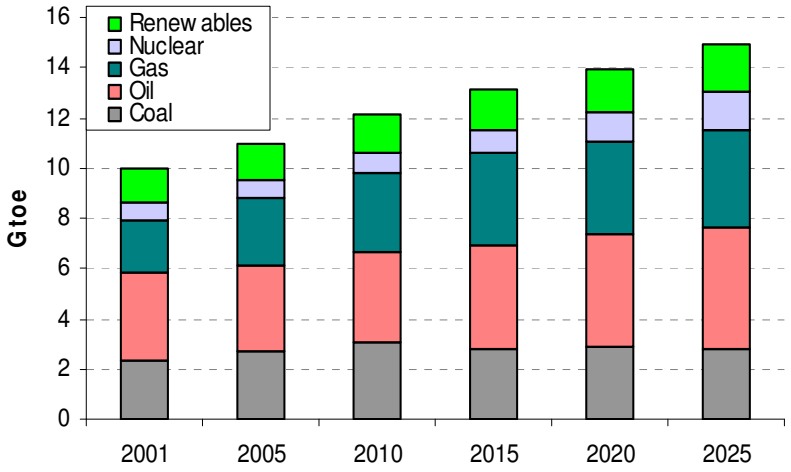
- Total emissions can stabilise between 2015 and 2025-2030 and start a decrease
- The peak in emissions seems to corresponds to the crossing of a 25-30 €/tCO2 threshold:
  - just before 2015 for Annex 1
  - and by 2025-2030 for Non-Annex 1
- The crucial sectors to achieve reductions seems to be the energy transformation ones



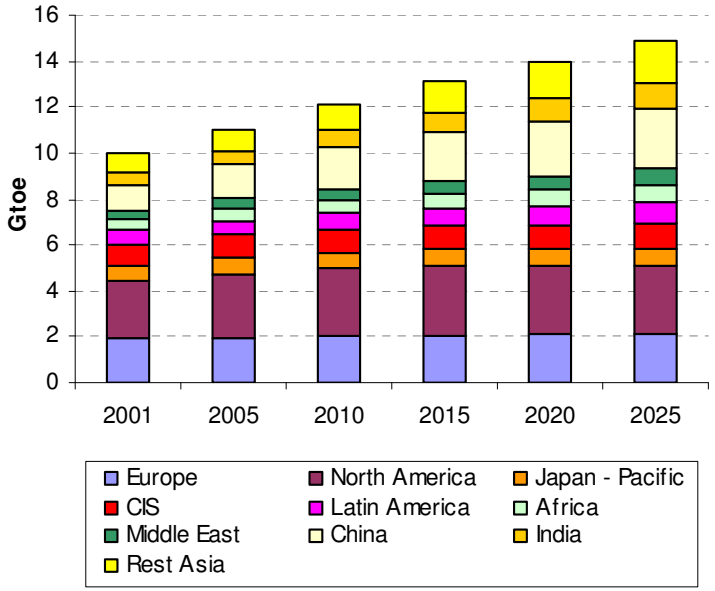


CCC: World Primary Energy

- World 2025 primary energy consumption decreases merely from 16 Gtoe in the REF to 15 Gtoe
- Part of the reduction in final energy demand is offset by the higher contribution of nuclear energy (with higher primary heat input)
- Due to early action in Annex 1, the primary fuel mix changes quite rapidly after 2010
- The structure of world primary fuel-mix is not dramatically altered already in 2025, but renewables and nuclear start gaining market share immediately after the gas peak by 2020

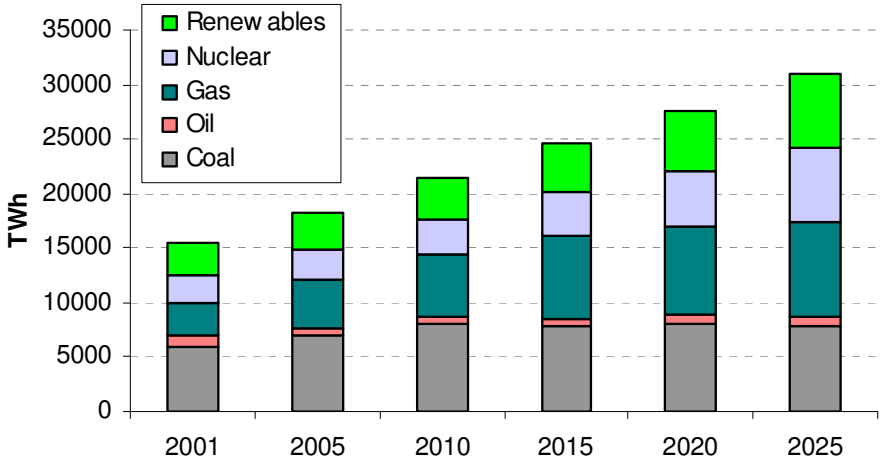


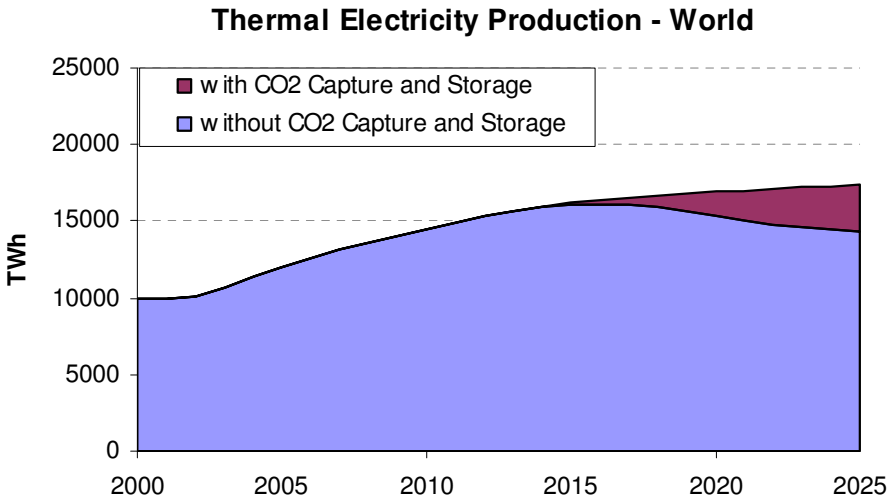
Primary Consumption by Region



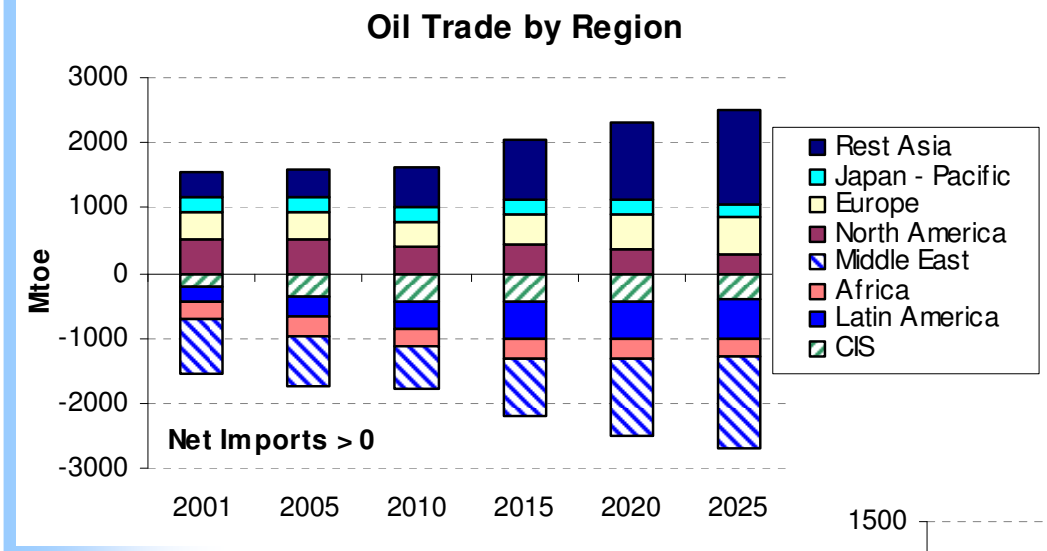
CCC: World electricity

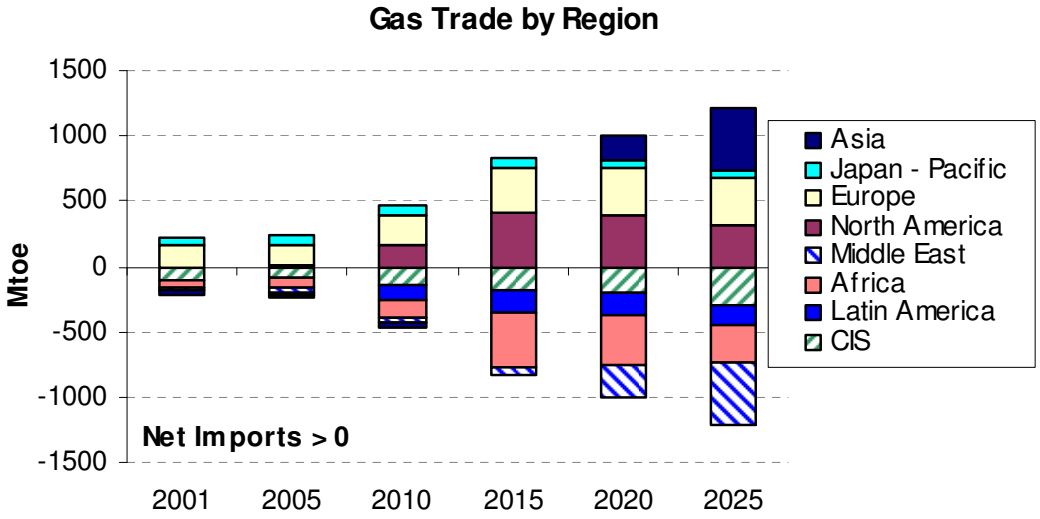
- Total electricity consumption is only 10 % down from the Reference as this increasingly low carbon energy-carrier substitutes to others
- In 2030, carbon-free electricity is projected to account for 45% of world power (renewable sources represent 23 % of total production and nuclear electricity nearly 22 %, as its “revival” is relatively quick in Annex 1 countries.





International Fossil Fuel Markets





CCC key insights

- The Carbon Constrained Case (s) is/are expected to describe a very significant reduction scenario (from factor-2 to factor-4) for Europe in a consistent world context
- It shows that ambitious climate policies :
  - increase the long-term sustainability of world oil and gas resource use, as well as Europe's energy self-sufficiency
  - require an intensified development of each one of the four key energy portfolios:

1/ efficiency 2/ renewables 3/ nuclear energy 4/ CCS