# Costes de mitigación de $CO_2$ y escenarios energéticos

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*Fronteras de la Energía*

*6 Julio 2009,, Benasque*

# Contenido

# 2. POLES
## Policy Outlook on Long-term Energy Systems

# Energy Models: A Brief History

- 1970s
  Energy models became popular after the oil shocks
- 1980s, 1990s
  Environmental concerns (acid rain, climate change) and "globalisation"
  - Energy-Environment-Economy (E3) approach
  - Simulation (versus optimisation) approach
  - more emphasis on technology development
  - inter-national models (Europe, World)
  - scenarios and projections for energy demand, supply (partial) equilibrium models, time horizon 30 years ahead

# 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 $CO_2$ emission reduction options in an international perspective
  - impacts of technological change and R&D strategies

# Model Development

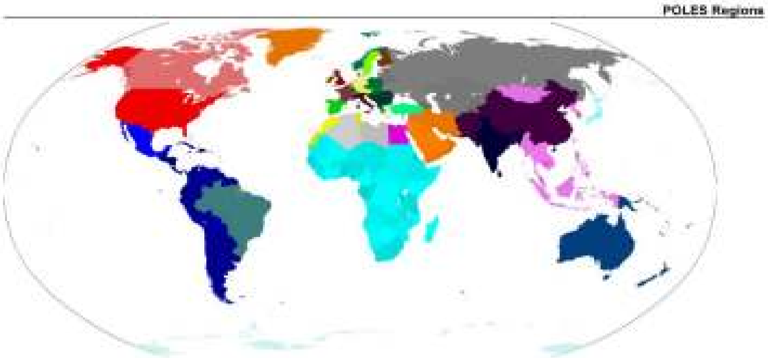
- Initially funded under the JOULE II programme of EU-DG Research
- Main contribution from the CNRS-IEPE, ECOSIM, JRC-IPTS and the support of Enerdata, CEPII, ETSU, FhG-ISI and other partners.
- Complementarity with other E3 models: PRIMES and GEM-E3
- 1993-1995, a first version
- Related research projects (e.g. TEEM, Technology Endogenisation in Energy Models)
- Related *application* projects: WETO 2030 (World Energy, Technology, and climate policy Outlook), ACROPOLIS
- Several *energy-intensive modules* (Steel, Cement, Pulp & Paper, Refineries) currently being developed at IPTS

# POLES Characteristics

- 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 approx. 10,000 exogenous variables and 15,000 endogenous)
- Main exogenous variables are GDP and population. Energy prices are 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

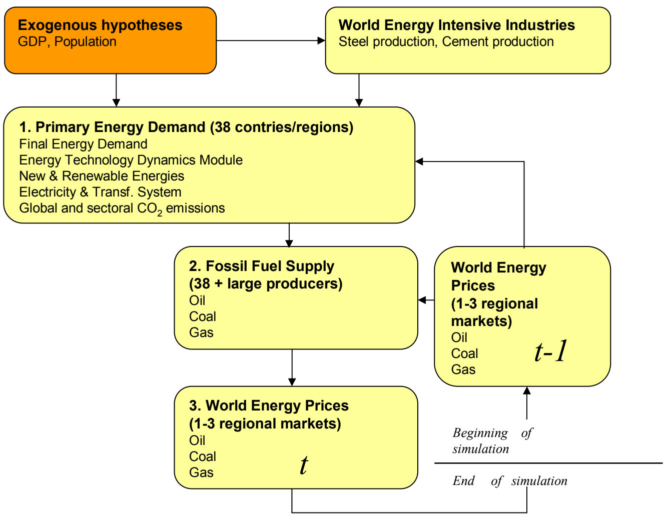
- Interconnected modules: international energy markets, national energy demand, new technologies, electricity production, primary energy production and $CO_2$ emissions, energy-intensive sectors
- Outcomes
  - Regularly updated Reference Case
  - World long-term energy scenarios or projections (*WETO*)
  - 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: Modules and simulation process



# POLES 5: Energy demand disaggregation

| | | |
|---|---|---|
| INDUSTRY | Steel Industry<br>Chemical industry (+feedstock)<br>Non metallic mineral industry<br>Other industries (+non energy use) | STI<br>CHI (CHF)<br>NMM<br>OIN (ONE) |
| TRANSPORT | Road transport<br>Rail transport<br>Air transport<br>Other transports | ROT<br>RAT<br>ART<br>OTT |
| RAS | Residential sector<br>Service sector<br>Agriculture | RES<br>SER<br>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*(DP**2-1))*(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

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# 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 (stationary and cogeneration) | FCV, MFC, SFC |

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# 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 |

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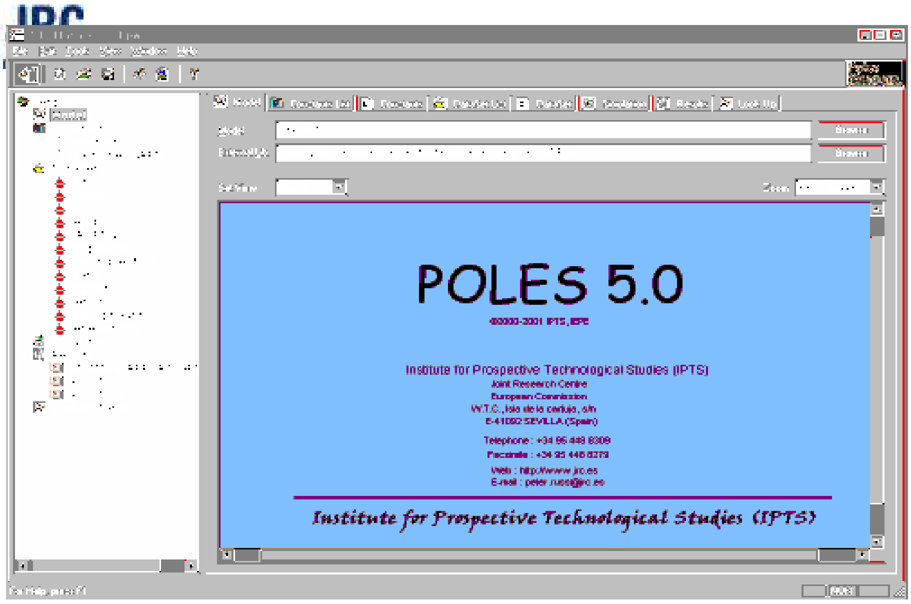
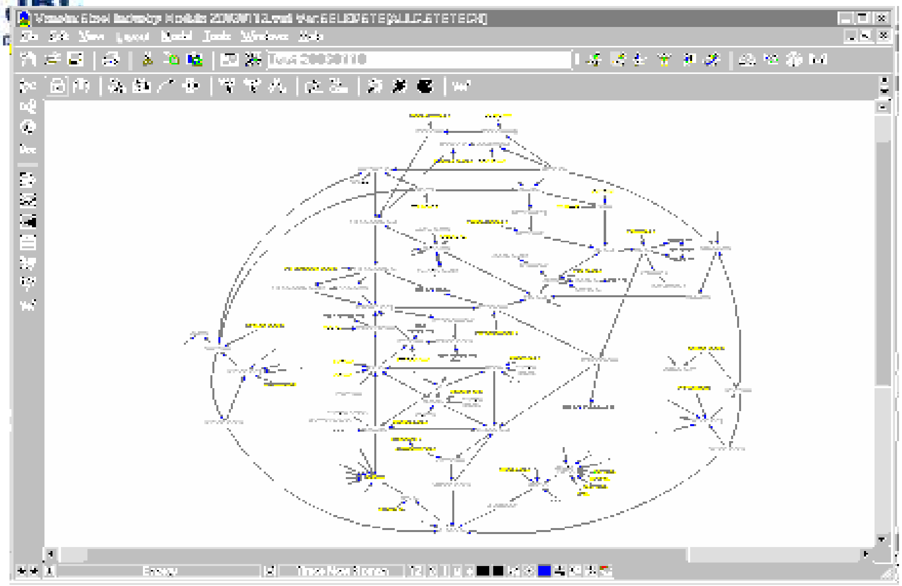
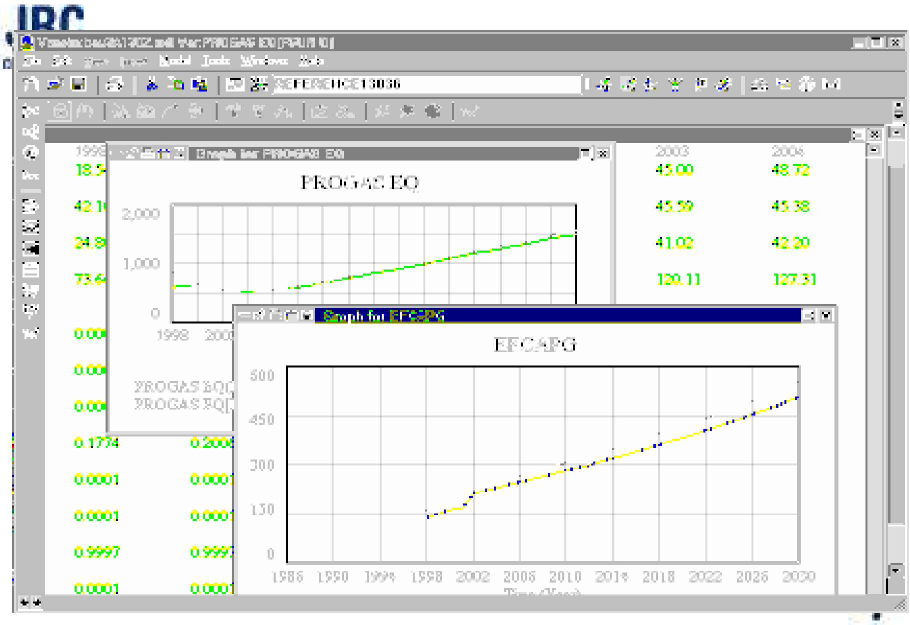
# Techno-economic Characterisation of Technologies

For each technology and country, and time period:

- Costs (fixed –investment-, variable)
- Installed capacity
- Efficiency
- Emission factors
- Life time of plants
- Construction time






PROGAS EQ
2,000
1,000
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EFCAPG
600
450
300
150
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1986
1990
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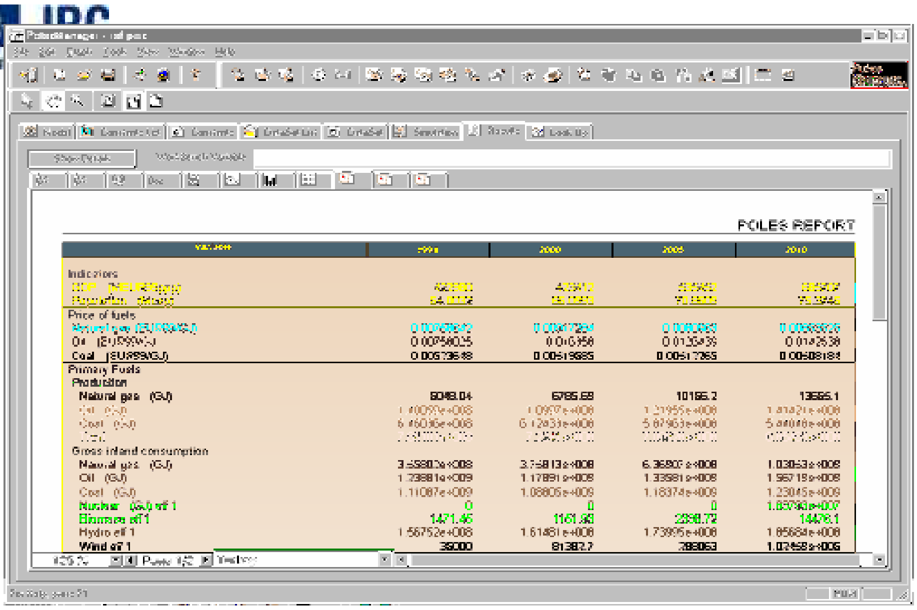
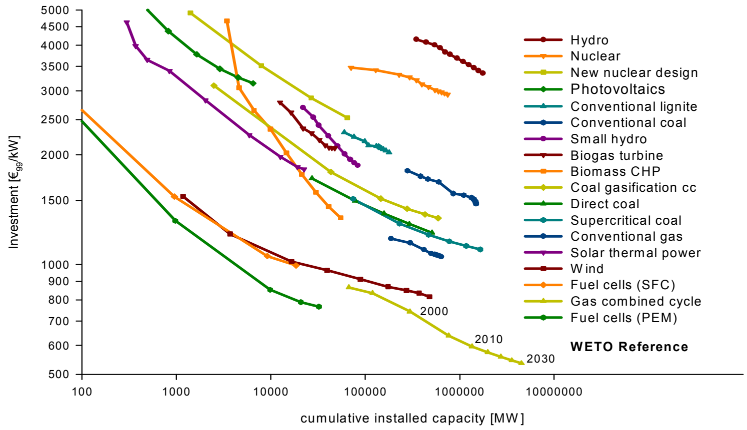



# Technology development / Learning



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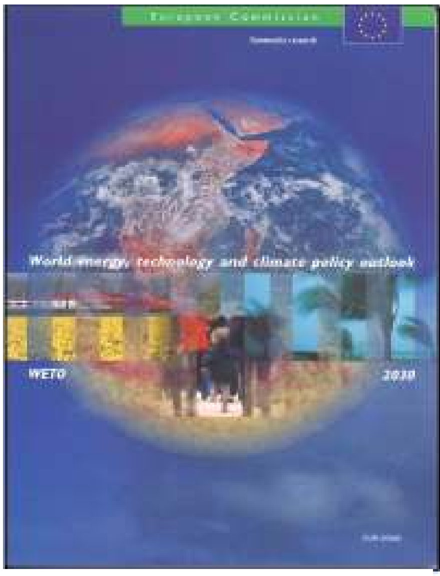
# WETO

World energy, technology and climate policy outlook

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## 2. Aplicación del modelo POLES

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The scenarios are described in the report:

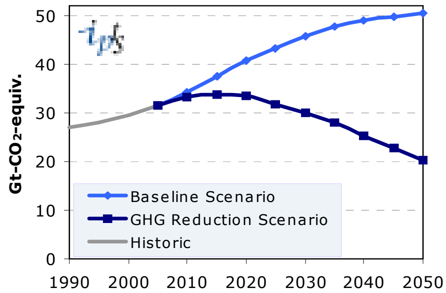

http://ftp.jrc.es/eur23032en.pdf

## Assessing the mitigation potential: objectives

- Technically feasible vision on how to reach an ambitious emission development, for the EU and rest of the world (2 degrees target)
- Global cost/technology estimates for mitigation scenarios until 2030
- Options for viable long-term technology paths identified beyond 2030 up to 2050
- Realistic role of the carbon market and the use of flexible mechanisms defined.
- Identify options for policy instruments that engage all key players on the basis of their responsibilities and capabilities

# POLES Model: Scenario assumptions

- Global GHG emissions peak before 2020 and reduce to 10% above 1990 levels by 2030. Economic assessment up to 2030
- Global GHG emissions continue to decrease up to 2050 to allow for a technology assessment up to 2050
- Multi-gas and introduction of Carbon Capture and Storage
- Global Emission trading market develops gradually in power and energy intensive sectors.
- Non Trading sectors experience policies that lead to emission reductions.




# POLES MODEL: Assumptions on how to broaden participation

- All countries, also DCs, implement Energy Efficiency policies, specifically in transport and residential sectors. Includes:
  - Better foresight and information.
  - Increased Technology Development
  - Additional Energy Efficiency Standards
- In order to achieve the 2° target, developed countries take the lead but targets but gradually more and more participation from developing countries.
- Answer the question to what extent the guidance from the 2005 EU Spring Council can translate into a 2° emission scenario:

*the EU looks forward to exploring with other parties strategies for achieving necessary emission reductions and believes that, in this context, reduction pathways for the group of developed countries in the order of 15-30% by 2020, should be considered*

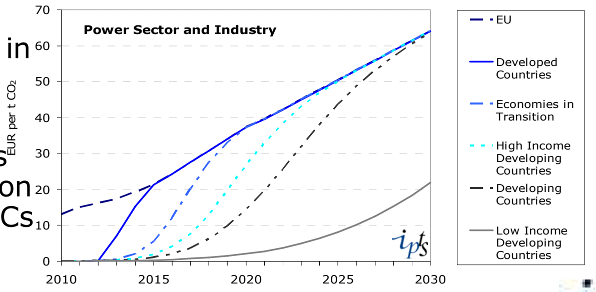
## POLES model: assumptions on the evolving global carbon market

- Markets develop at different speed and companies experience different carbon prices in different countries.

- E.g. a carbon prices in the EU of 25 € does not translate automatically into a global price of 25 €.

- Carbon price developing countries catches up with those in the EU and other developed countries

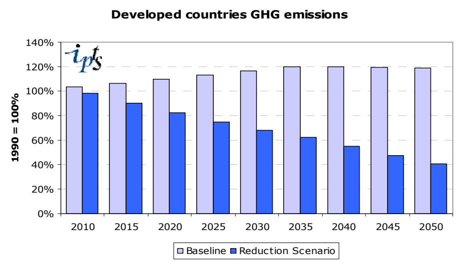
-By 2030 all industries experience same carbon price except in poor DCs

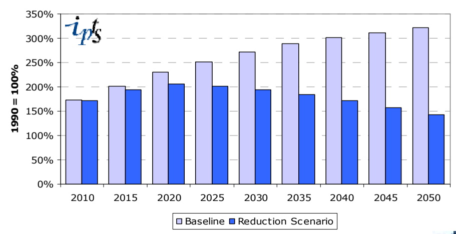



## Results: Global Participation

- Emissions in developed countries on a continues descending path.
- Internal emissions should be at -20% by 2020 and –60% by 2050 compared to 1990

- Developing countries emissions may grow but at lower rate than baseline.
- Need to peak also between 2020 and 2025

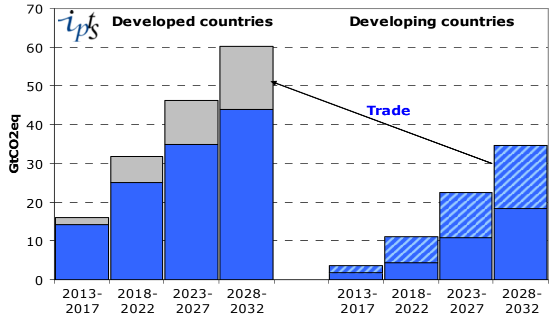


# Cost of action: role of the global carbon market (1)

• Developed countries targets need to be at 30% by 2020 to see sufficient global reductions (± 2/3 domestic, ± 1/3 trade)

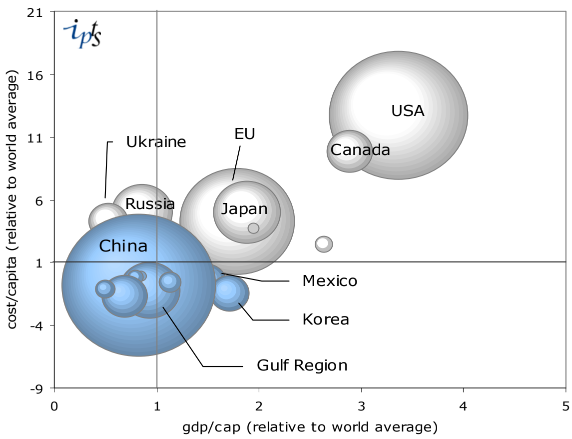
• But developing countries need to reduce substantially more than what is bought by developed countries !




# Cost of action: How to bring in developing countries?

• The economic impact of internal effort and trade seem to be equitable

• Size of bubble corresponds to the amount traded

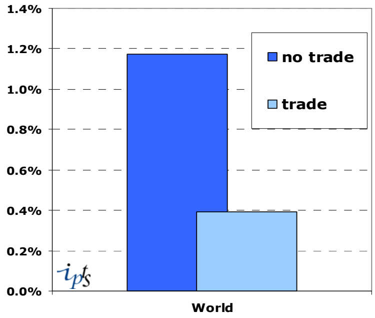


# Cost of action: role of the global carbon market (2)

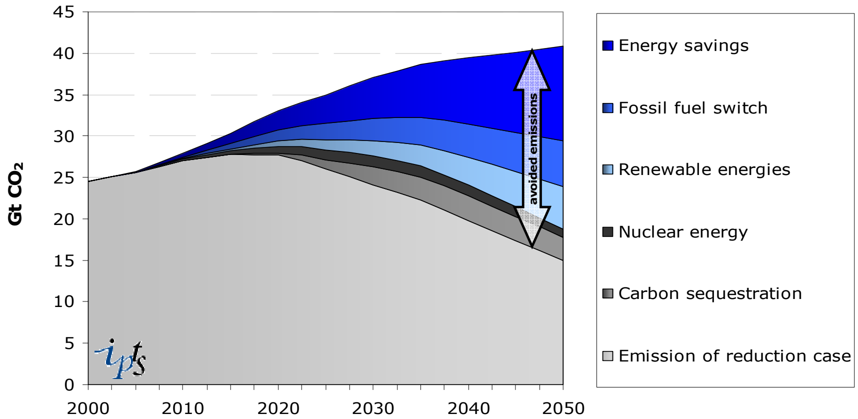
- Carbon market decreases investment costs by a factor of 3.

- Carbon price is substantial but evolves gradual

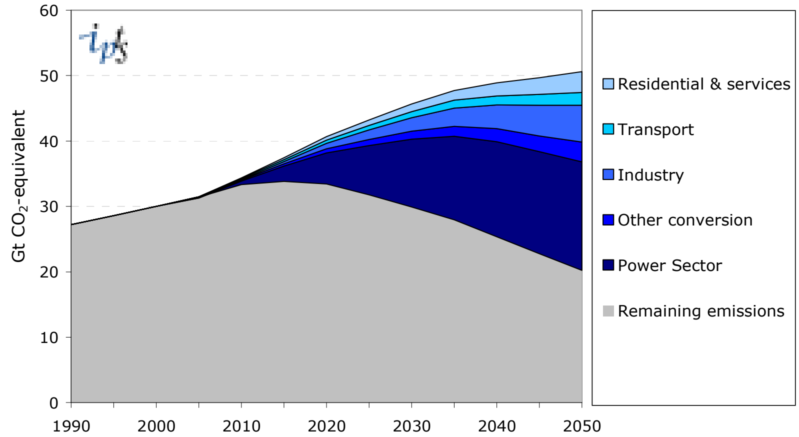
| Carbon Price Trading Sectors €/t $CO_{2eq.}$ | |
|---|---|
| 2010 | 14 |
| 2015 | 21 |
| 2020 | 37 |



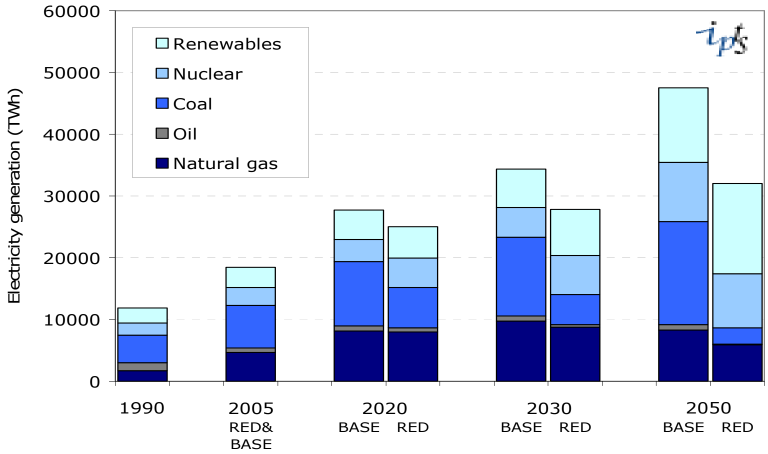

# Technologies: there is no silver bullet



# A post-2030 glimpse: contributions of sectors




# A post-2030 glimpse: technology deployment on a 2°C trajectory



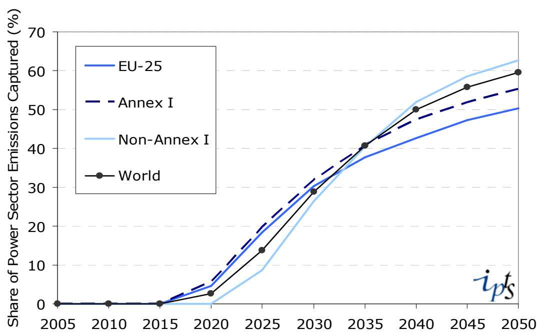
# The role of energy efficiency by 2020

- EE reduces emissions most in transport, residential and commercial sectors.
- EE achieves 1/3 of the necessary global reductions by 2020.
- Energy standards key to deliver real reductions
- Trickle through effect developing countries product markets
- Difficult to steer through the UNFCCC, look for role of the Gleneagles Dialogue and a G20 energy efficiency pact

| | 2020 Share of emission reductions due to EE scenario |
|---|---|
| Developed countries | 35% |
| China | 31% |
| Developing countries | 27% |

# Carbon Capture and Storage

- CCS needs to be first deployed in developed countries
- By 2020 full deployment of technology in EU power sector
- Crucial to prove technology and build capacity in developing countries

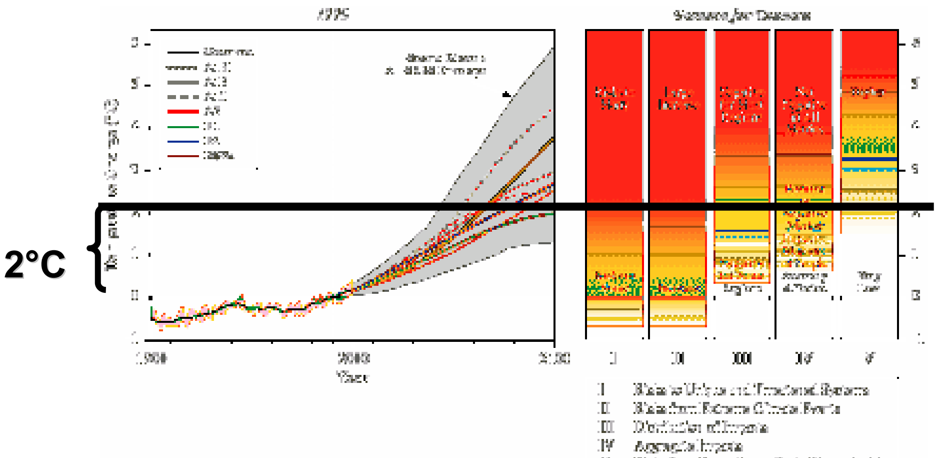


## 3. Las políticas climáticas

## Multilateral negotiations

- 1992: United Nations Framework Convention on Climate Change (UNFCCC)
- 1997: Kyoto Protocol targets for industrialised countries (EU15: minus 8% in 2008-2012 compared to 1990)
- 2001: US withdraws from Kyoto Protocol & Gothenburg summit
- 2002: all Member States & Community ratified the Kyoto Protocol
- 2005: Kyoto Protocol into force

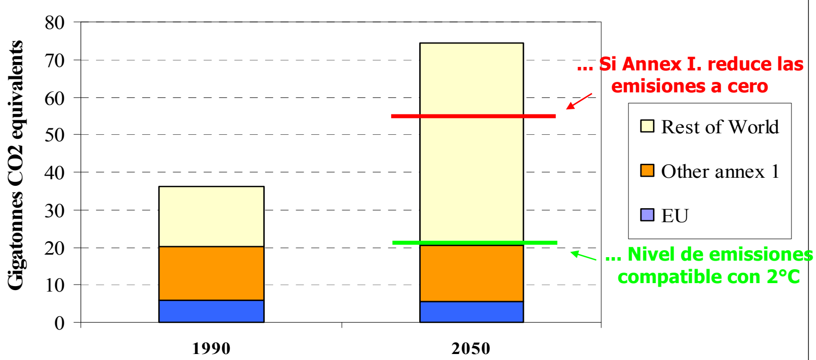
# 2º C: objetivo de la UE




Source: IPCC 2001

# UE por sí sola no puede resolver el problema del cambio climático

**Figure 1: Projected development of greenhouse gas emissions in different regions of the world**

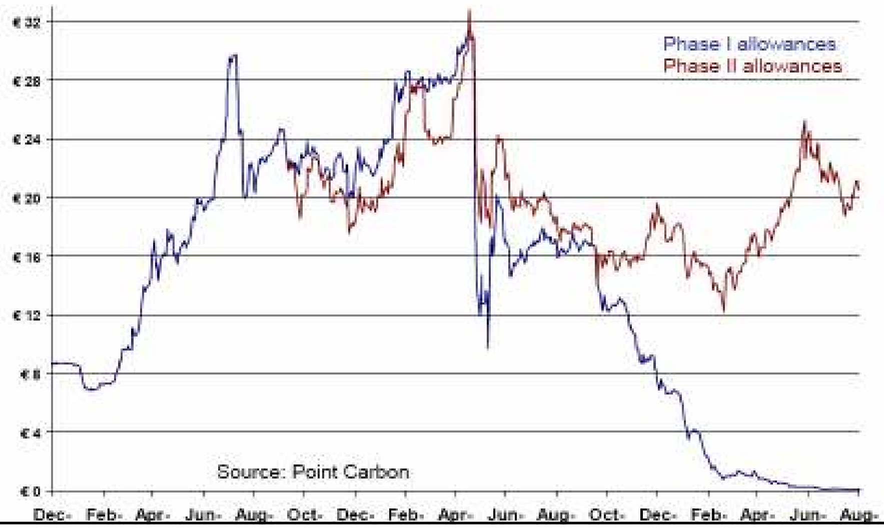



Source: Greenhouse gas reduction pathways in the UNFCCC process up to 2025, CNRS/LEPII-EPE, RIVM/MNP, ICCS-NTUA, CES-KUL (2003).

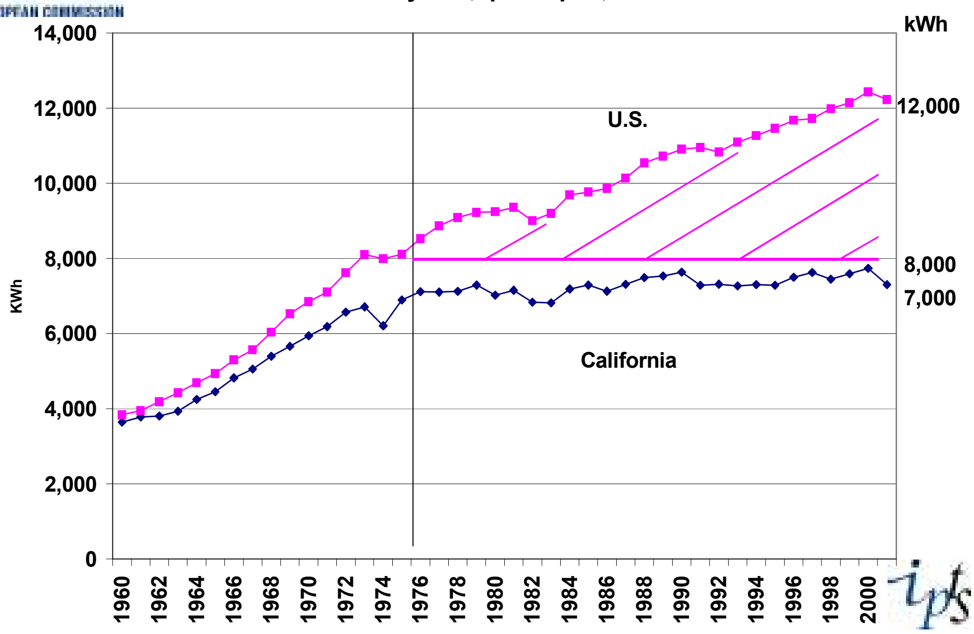
# *Nuevos Objetivos para el 2020*

- 20 % reducción GEI comparado con 1990
  compromiso independiente de acuerdo internacional
- 30 % GEI reducción
  sólo si hay acuerdo internacional
- 20 % Cuota de energías renovables en el consumo final de energía
- 10% biocarburantes en el transporte

## EU ETS Price Development



**Total Electricity Use, per capita, 1960 - 2001**




# Links adicionales

- - Economic Assessment of Post-2012 Global Climate Policies - Analysis of Gas Greenhouse Gas Emission Reduction Scenarios with the POLES and GEM-E3 models. Peter Russ, Juan-Carlos Ciscar, Bert Saveyn, Antonio Soria, Laszló Szábó, Tom Van Ierland, Denise Van Regemorter, Rosella Virdis
- http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1980

- - Global Climate Policy Scenarios for 2030 and beyond – Analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with the POLES and GEM-E3 models

Peter Russ, Tobias Wiesenthal, Denise van Regemorter, Juan Carlos Ciscar http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1510