POLES

Prospective Outlook on Long-term Energy Systems

Introduction to the POLES model

Complementary documentation for the EnerFuture Forecasts

November 2012

Outline

1. **Enerdata's Forecasting Services**
2. The POLES model
3. Selection of sectoral analyses
4. References

Enerdata provides accurate forecasts relying on proven models and tools

POLES

- POLES is a world simulation model for the energy sector, 57 countries/regions, annual step throughout 2050
- Techno-economic model with endogenous projection of energy prices
- Complete accounting of energy demand and supply of numerous energy vectors, associated technologies and greenhouse gases emissions
- Developed for over 20 years, used by the European Commission in its internal exercise

MedPro/MedLoad

- Developed from the MEDEE suite (since the 1970s), with in addition a emphasis on electricity load curves and greenhouse gases
- Detailed bottom-up country-level demand model with focus on energy efficiency & technological improvement
- The MedPro dedicated software is transferred to the client with model training and maintenance
- Applied to dozens of countries over 4 decades for governments, utilities

InsularSys Power Forecast

- Provides power demand and load forecasts for islands and electrically autonomous regions, annual step throughout 2030
- Inspired from the MEDEE models, benefits from its strong experience and is adapted to client's needs and the region studied
- The finalized tool is transferred to the client with training and reference scenarios
- Used in particular by EDF in all the French island territories

Gas & power demand model

- Detailed sectoral country-level demand model, annual step throughout 2040
- Inter-fuel competition based on costs and policies, with a focus on power and gas demand
- Optional power generation module with generation allocation by technology
- Updated annually since 2008
- Used in particular by private power utilities for internal forecasts

Emissions Reduction Tool

- Identify technological options that will develop under a carbon price (or emissions cap)
- Final tool can be transferred to the client with training and scenarios
- Used by private companies to highlight market opportunities and by governments to analyse Nationally Appropriate Mitigation Actions (NAMAs)

Carbon Market Tools

- Analytical Excel tools that allow simulating future carbon markets through the equalisation of Marginal Abatement Costs in the energy sector
- The user can design its own carbon markets (regional/sectoral coverage, commitments, limitations on CDM/JI, funding mechanisms …)
- The tool produce market price, imports/exports by actor, domestic abatement cost, trading cost…

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Origins and Objectives

- The objective of POLES (**Prospective Outlook on Long-term Energy Systems**) is to analyze and forecast the supply & demand of energy commodities, energy prices, as well as the impact of climate change and energy policies on energy markets
- Initially developed in the early 1990s by the Institute of Energy Policies and Economics IEPE (now LEPII-CNRS) in Grenoble, France
- Originally financed by the JOULE II and III programmes of the EC's 3rd and 4th Framework Programmes (FP) for Research and Technological Development (1990-1998) as well as the CNRS
- Since then, POLES has been further developed by Enerdata, LEPII, and JRC-IPTS of the EC
- POLES draws on practical and theoretical developments in many fields such as mathematics, economics, engineering, energy analysis, international trade, and technological change

POLES at a glance

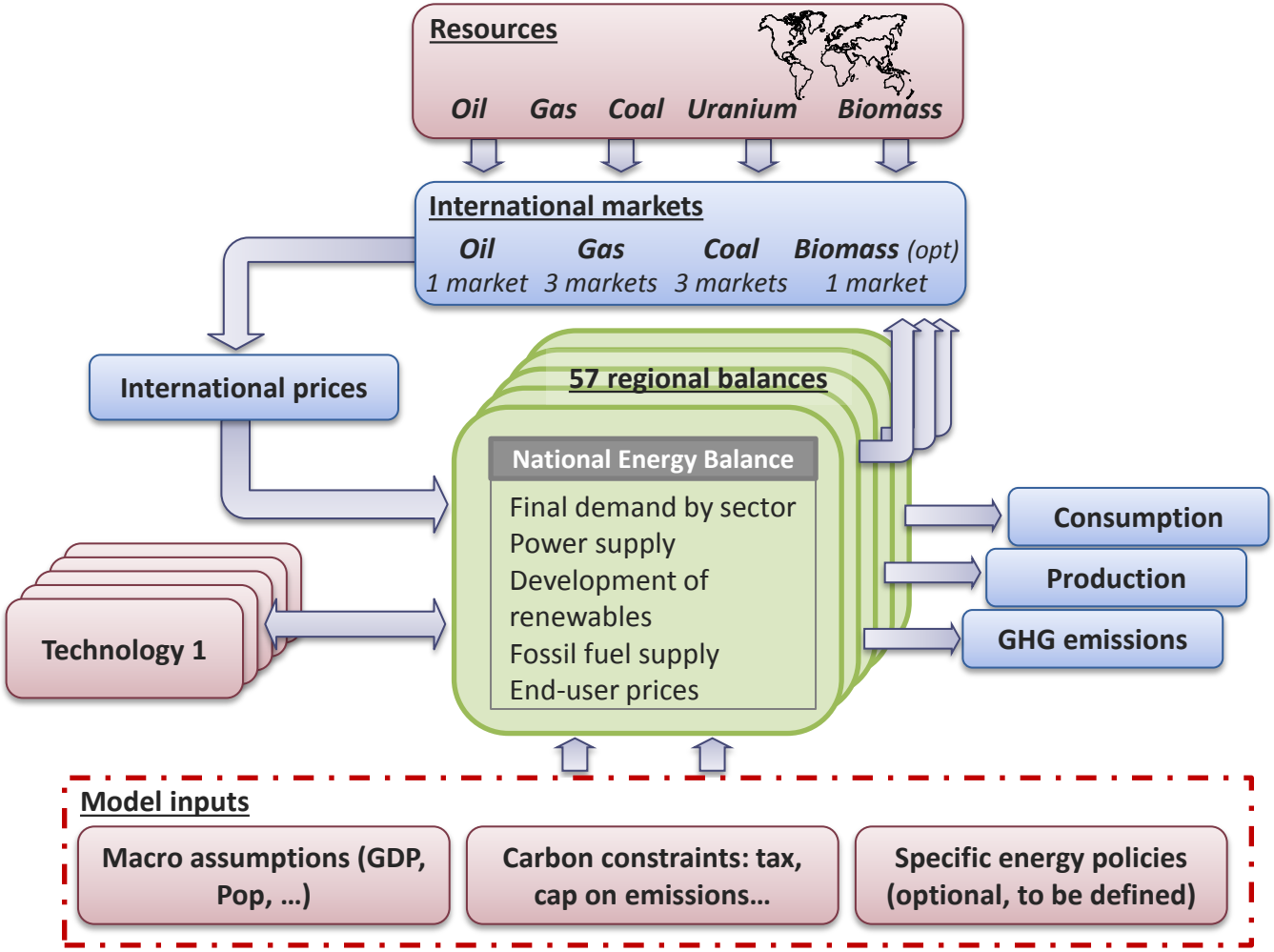
Main features

- Projections of demand & supply by country and commodity up to 2050 (-2100)
- Simulation of future technology developments in the energy sector
- Projection of international oil, gas and coal prices and end-user prices (inc. power)
- Simulation of GHG emissions (all Kyoto gases), analysis of GHG abatement strategies, impacts on energy markets
- Continuous development efforts

Structure & functions

- Yearly dynamic recursive, includes anticipation behaviors
- Simulation of energy balances for 57 countries/regions
- Disaggregation into 15 energy demand sectors, 50 technologies (power generation, buildings, transport) & technological learning
- Simulation of oil and gas supply (80 countries)
- Full power generation system (and feedback effect on other energies)
- Uranium & renewables resources, associated land-use
- International energy prices and markets (oil, gas, coal)

POLES: A multi-issue energy model



POLES geographical coverage: 57 countries and regions (*new countries on request*)

Regions	Sub-regions	Countries	Country aggregates
North America		USA, Canada	
Europe	EU15	France, United Kingdom, Italy, Germany, Austria, Belgium, Luxembourg, Denmark, Finland, Ireland, Netherlands, Sweden,	
	EU25	Spain, Greece, Portugal Hungary, Poland, Czech Republic, Slovak Republic, Estonia, Latvia, Lithuania, Slovenia, Malta,	
	EU27	Cyprus Bulgaria, Romania	
		Iceland, Norway, Switzerland, Turkey, Croatia	Rest of Europe
Japan – South Pacific		Japan	Rest of South Pacific
CIS		Russia, Ukraine	Rest of CIS
Latin America	Central America	Mexico	Rest of Central America
	South America	Brazil	Rest of South America
Asia	South Asia	India	Rest of South Asia
	South East Asia	China, South Korea , Indonesia	Rest South East Asia
Africa / Middle East	North Africa	Egypt,	Rest of North Africa
	Sub-Saharan Africa	South Africa,	Rest of Sub-Saharan Africa
	Middle-East	Gulf countries	Rest of Middle East

Issues and topics covered by POLES

Energy Demand

- 57 countries, 20 detailed sectors: industry, buildings & transportation
- Detailed description of large Energy Intensive Industries : Steel, Aluminium, Glass, Cement…
- All key energies: oil products, gas, coal, power, biomass, solar, wind
- End consumer energy prices
- Electricity load forecasting
- Detailed demand technology description (buildings, transport)
- Demand function based on activity levels, prices effects, autonomous technological change

Energy supply

- Oil, gas, coal, and renewables
- Resources, discoveries and reserves for 80 producing countries
- Production strategies (countries)
- Unconventional oil and gas
- International and regional prices: oil, gas, coal
- Development potential for renewables (e.g. biomass)
- Rare materials related to energy technologies: Pt, Li…
- Oil, gas, coal, and biofuels, imports & exports

Power Generation

- Detailed description of generation technologies (26 technologies)
- Simulation of future power generation mix by country
- Capacity planning
- Power price analysis
- Technology availability scenarios: Nuclear revival or phase-out, CCS, wind & intermittency…
- Impact of support schemes for renewables (feed-in tariffs…)

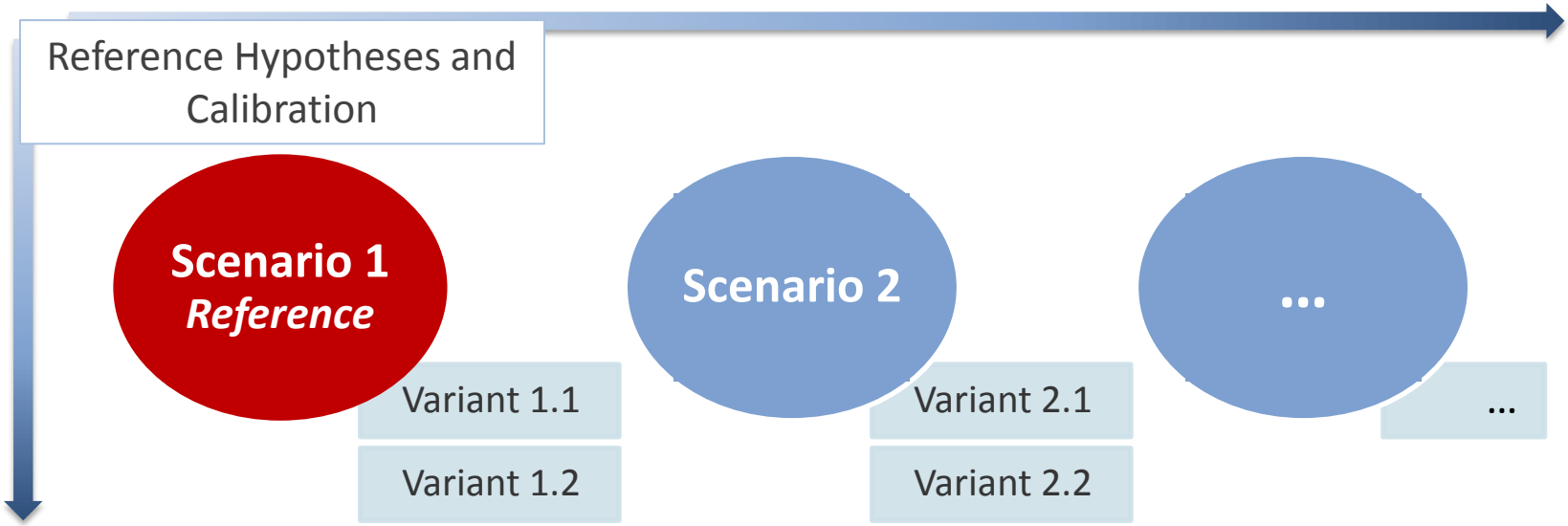
Resources and markets covered

	RESOURCES *(by country/region)*	SUPPLY & DEMAND *(by country/region)*	INTERNATIONAL PRICES *(prices & volumes)*
ENERGY	▪ Oil (inc. non-conv) ▪ Gas ▪ Coal ▪ Biomass ▪ Wind ▪ Solar ▪ Uranium (world)	▪ Oil (inc. non-conv) ▪ Gas ▪ Coal ▪ Biomass ▪ Wind ▪ Solar	▪ Oil ▪ Gas (pipe vs. LNG) ▪ Coal ▪ Biomass ▪ CO2 ▪ Uranium (price)
MATERIALS *(development)*	Rare materials related to energy technologies: Pt, Li,…	"Raw" materials: steel, cement, aluminium	"Raw" materials: steel, cement, aluminium

Sectors covered

	BUILDINGS *(residential, services)*	**TRANSPORT** *(road, rail, air, other)*	**INDUSTRY** *(steel, cement, chemistry, others)*
ENERGY	▪ Oil ▪ Gas ▪ Coal ▪ Biomass ▪ Electricity (subs) ▪ Electricity (captive) ▪ Heat ▪ Hydrogen	▪ Oil ▪ Biofuels ▪ Electricity ▪ Hydrogen ▪ (Gas) ▪ (Coal)	▪ Oil ▪ Gas ▪ Coal ▪ Biomass ▪ Electricity ▪ Heat
MATERIALS *(development)*	*Consumption:* ▪ Steel ▪ Cement ▪ Aluminium ▪ Glass	*Consumption:* ▪ Steel ▪ Cement ▪ Aluminium ▪ Glass	*Production:* ▪ Steel ▪ Cement ▪ Aluminium

Process design for global energy scenarios

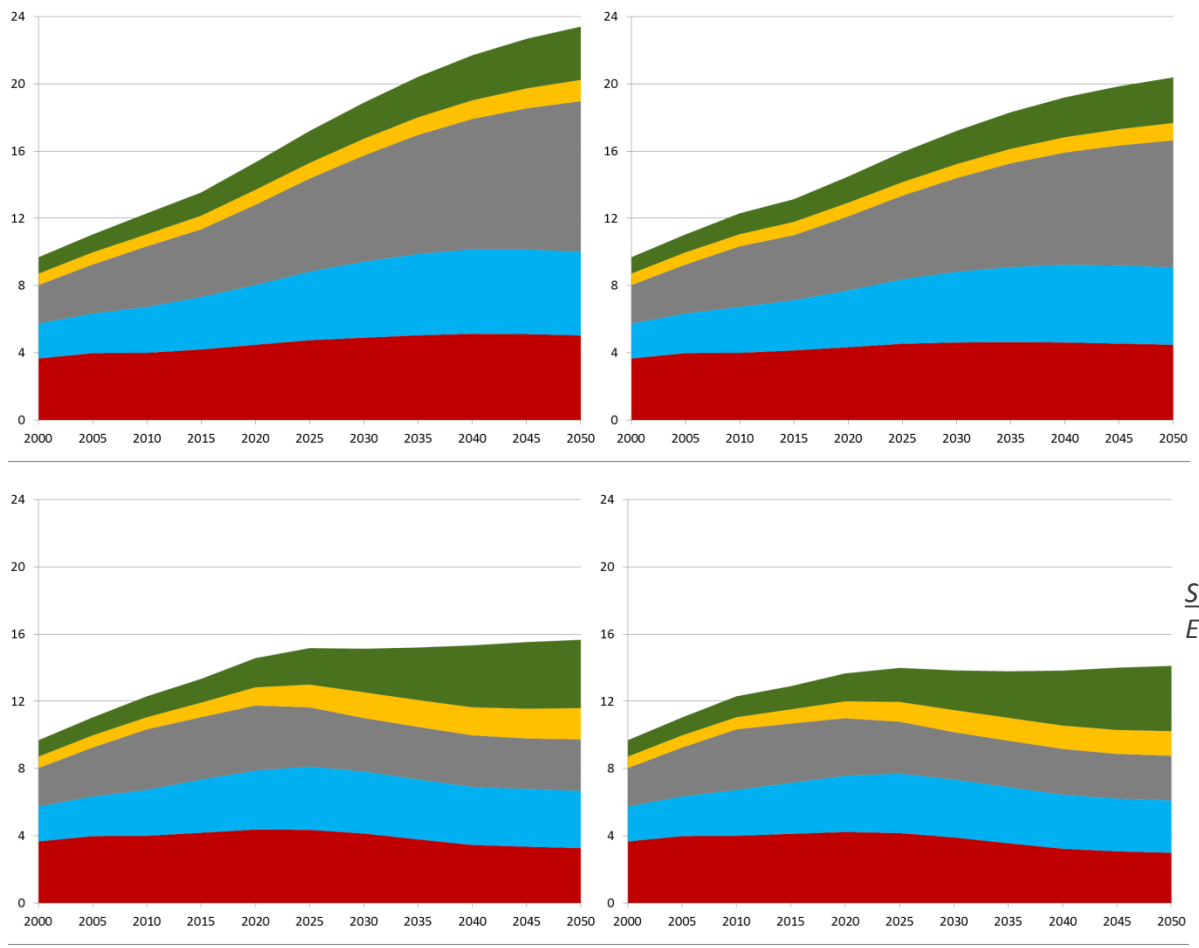


- We agree on a set of hypotheses to **define and calibrate a Reference case**: macro-economy, demography, climate regimes, available technological options…
- We **produce alternative scenarios** (different assumptions, full calibration of the model) and/or estimate the possible range of parameters to **perform sensitivity analyses**: cost of technologies, carbon values, ultimate resources…

Sample: Impact of GDP growth & carbon taxation on primary energy demand

Impact of a slower economic recovery

Impact of a strong carbon taxation



Source: POLES model, EnerFuture scenarios

- Biomass
- Nuclear
- Coal
- Gas
- Oil

POLES sample output: Country or Commodity Energy Balances

Enerdata	1990	2000	2010	2020	2030	2040
Primary Production (Mtoe)	**98**	**153**	**230**	**271**	**291**	**243**
Coal, lignite	2	3	3	3	3	3
Oil	**33**	**64**	**103**	**132**	**143**	**76**
Natural gas	3	5	13	21	29	40
Nuclear	**1**	**2**	**4**	**3**	**6**	**13**
Hydro, geothermal	18	26	35	41	48	53
Biomass and wastes	**41**	**53,2**	**73,4**	**68,3**	**58,5**	**49,9**
Wind, solar	0	0	1	2	4	8
Gross Inland Consumption (Mtoe)	**134**	**204**	**261**	**317**	**366**	**391**
Coal, lignite	10	14	18	26	36	43
Oil	**59**	**99**	**112**	**145**	**174**	**180**
Natural gas	3	7	16	28	36	41
Biomass and wastes	**41**	**53**	**73**	**68**	**59**	**50**
Others	21	32	42	49	61	77
Final Consumption (Mtoe)	**116**	**158**	**197**	**244**	**279**	**289**
by source						
Coal, lignite	6	9	10	13	13	12
Oil	**54**	**81**	**92**	**122**	**147**	**152**
Natural gas	2	5	9	12	15	15
Electricity	**18**	**27**	**35**	**45**	**58**	**71**
Biomass and wastes	35	36	51	51	45	37
Heat	**0**	**0**	**0**	**0**	**0**	**0**
Hydrogen	0	0	0	0	1	2
by sector						
Industry	53	73	89	94	82	62
Transport	**34**	**49**	**65**	**94**	**125**	**143**
Household, Service, Agriculture	29	36	43	56	72	84

Incomplete, illustrative only

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Disaggregation of final energy demand

In each sector, energy consumption is calculated separately for substitutable fuels and for electricity, with specific energy consumptions:

- Electrical processes and coke for other processes in steel-making
- Oil and gas as raw material for chemical industry
- Electricity for specific uses in the residential and service sectors

INDUSTRY	Steel Industry Chemical industry (+chemical feedstock) Non metallic mineral industry Other industries (+non energy use)	
TRANSPORT	Road transport Rail transport Air transport Other transports	
OTHER	Residential sector Service sector Agriculture	**BUILDINGS**
BUNKERS	International air International marine	

Energy demand – General principles

Demand function

- **Price effects**: short term elasticity ($\alpha 1$, 1-2 years) & long-term elasticity ($\alpha 2$, 3+ years)
- **Activity effect**: activity elasticity (β)
- **"Autonomous technological change"**: exogenous trend (Tr)

$$E = f\left(P_{(-1,-2)}^{\alpha 1} * P_{(-2,-t)}^{\alpha 2} * A^{\beta} * Tr \right)$$

Competition process

- Consuming equipment with lifetime / scrapping rate
- Competition occurs on new equipment only (new consumption and replacement of scrapped capital),

$$\text{Market share} = \alpha * Ci^{\beta} / \Sigma(\alpha * Ci^{\beta})$$

-with :
- C cost for the user (inc. taxes)
- α: calibrated on historical data
- β: sensitivity to price / cost (negative)

Energy demand: demand gap, new demand

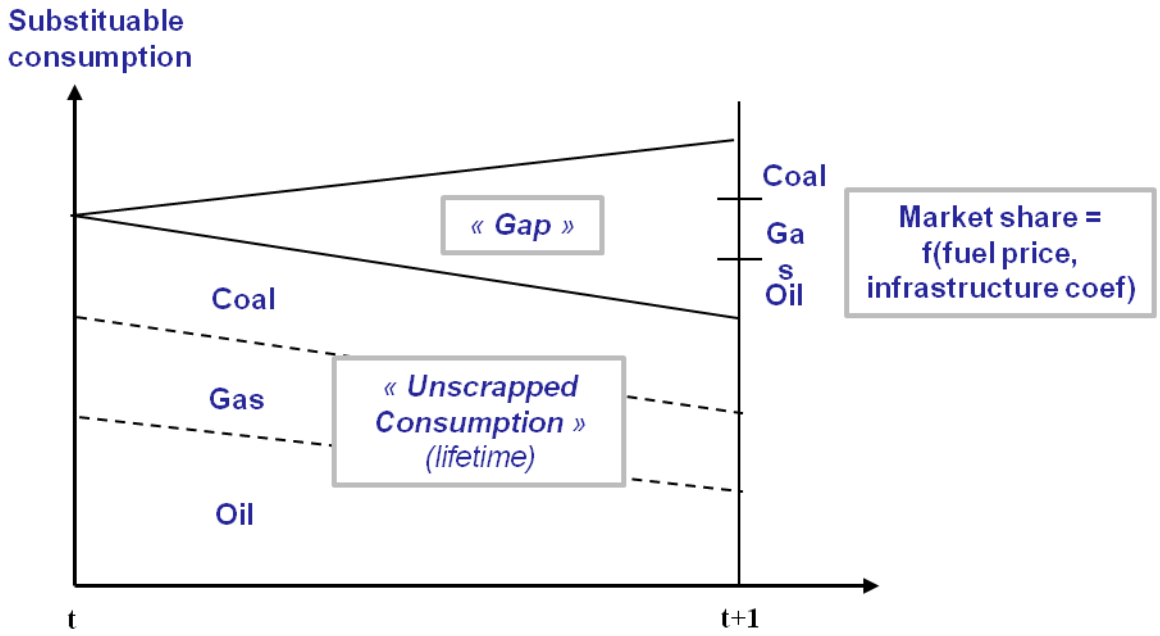
Principle

POLES uses a « putty-clay » approach to determine the interfuel substitution process:

Industry: oil, gas, coal, biomass

Buildings: oil, gas, coal, biomass, substitutable elec.

Transport: competition takes place between vehicles



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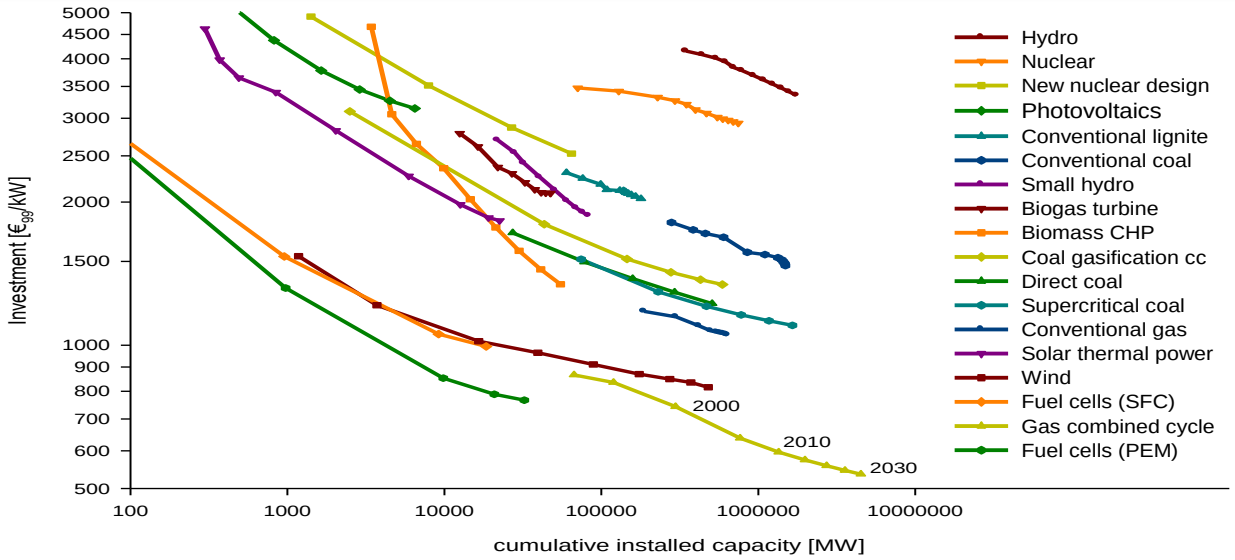
Power sector – Main features

- Describes **30 plant types**, including new technologies:
  - Renewables (PV, CSP, onshore wind, offshore wind, thermal biomass, biomass gasification, small and large hydro are differentiated)
  - CCS (coal, gas and biomass)
  - Generation IV nuclear reactors (fast breeders…)
- Simulates **future capacities development** by technology on a cost-based competition, including endogenous technology learning (“learning by searching”, “learning by doing”)
- Simulates **power generation** by technology on a merit-order based approach
- **Databases** on total capacities (no explicit plants), updated every year
- Fuel efficiencies & merit order calibrated on historical data

Technology representation in POLES: 45 technologies grouped in 5 categories

Learning curves for power generation technologies



The 5 POLES technology groups

- **Large scale power generation (15)**: nuclear (2), coal (6), gas (4), hydro, oil (2)
- **New and renewable energy systems (15)**: wind (2), solar (4), biomass (3), small hydro, CHP, fuel cells (2), geothermal, wave & tidal
- **Hydrogen production (10)**: nuclear (2), coal (2), gas (2), wind, solar, biomass, grid electrolysis
- **Vehicles (6)**: conventional (gasoline/biofuels), plug-in hybrid, electric, fuel cell (gas/hydrogen), hydrogen (internal combustion)
- **Low energy buildings (2)**

Endogenous technological learning – Investment costs

- POLES uses **"two factor learning curves"**, defined by the cumulative effects of:
  - "**Learning by Searching**" (R&D effort) - *early learning*,
  - "**Learning by Doing**" (installed capacities),

$$Inv = f(RD^{\alpha} * Cap^{\beta})$$ with $\alpha, \beta = f(Inv - Floor\ cost)$

- The module uses:
  - Existing technologies: historical data (IEA, Literature, TECHPOL, ..),
  - Other technologies: Literature, extrapolation
- Significant uncertainties: sensitivities (Floor cost, elasticities, ..)
- Such issues have been studied in various projects : SAPIENT, SAPIENTIA, MENGTECH (DG RTD) and PROTEC-H2 (French National Research Agency ANR)

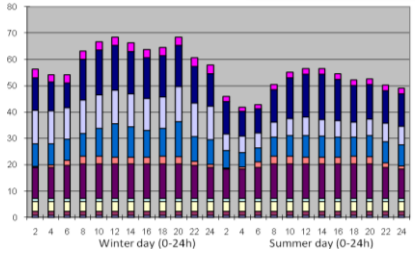
Power sector – Structure and functions

- **Demand load curve:**
  - 15 demand sectors, 24 points (2 seasons, 12 time arrays per season)
  - Considers T&D losses, net exports
- **Capacity planning:**
  - Based on total production cost over life-time of the plants (levelized cost, including discounted yearly investment and variable cost)
  - Considers past evolution of power demand
  - Consider technical & resource limitations
  - Considers placement on load curve
- **Power generation by installed capacity:**
  - Considers placement in load curve, back-up needs and additional costs for variable energy sources
  - Production depends on load factor for “must run” plants and merit order
- **Calculation of base load and peak load prices:**
  - Possibility to study the impact of a larger integration of European electricity markets
  - Dynamically affects demand forecasts

General structure of electricity module in POLES

Sectoral consumption

Total Electricity Consumption



Imp/Exports + Losses + Autoconsumption

Distributed electricity (CHP, BIPV, …)

Load curve

Total Electricity production from large-scale plants (incl. large renewables)

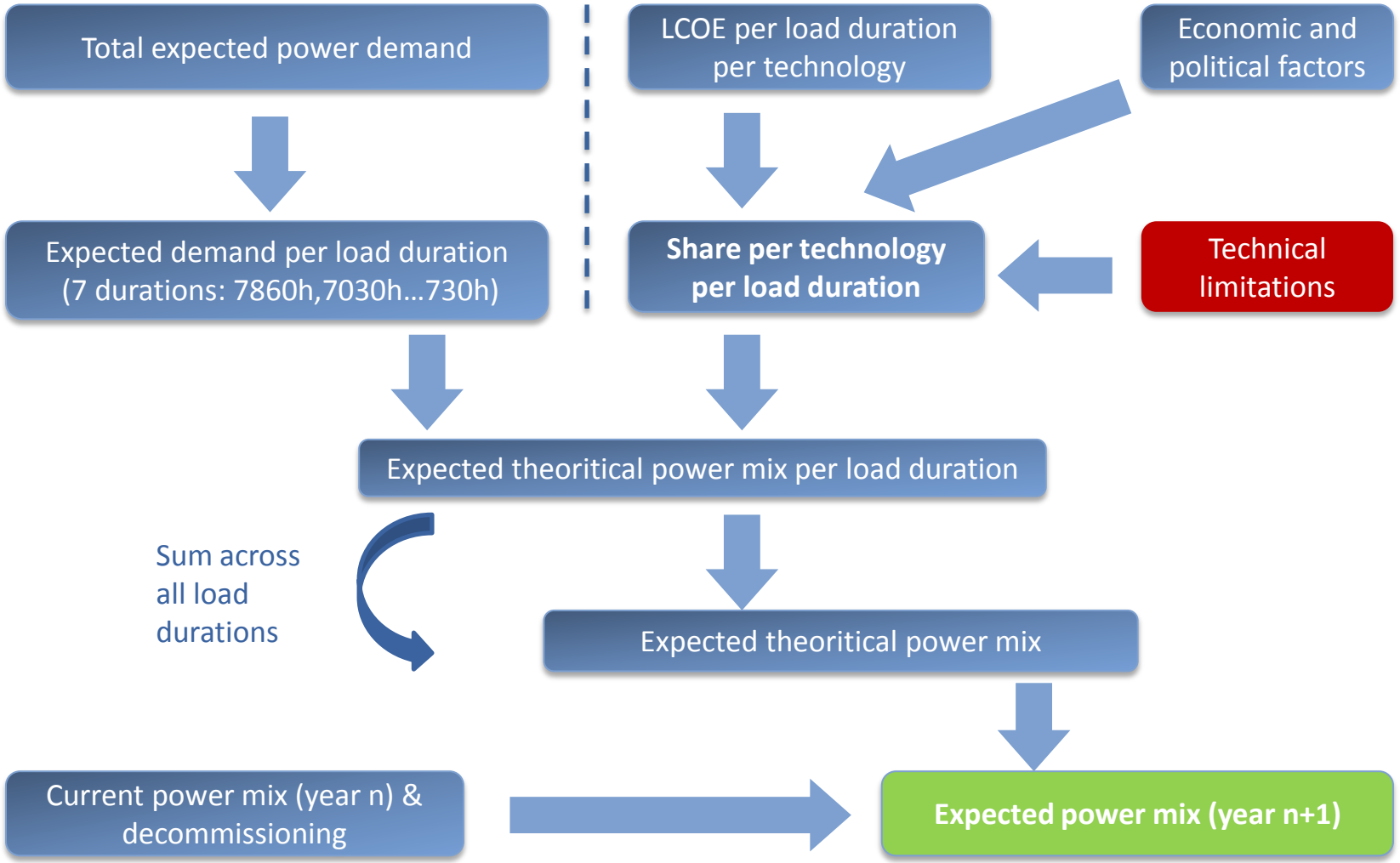
24 time arrays across 2 typical days

Production =
f(installed capacity, distribution over time arrays)
f(existing capacity, short term marginal cost)

New capacity planning

1. for "must run" technologies
2. for merit order plants

New capacity planning



Electricity prices : price construction

Calculated through the variation of complete production cost of merit order and must run technologies (incl. wind technologies) :

Variable cost *(w/o Subsidy)* **+ Fixed cost**

Base load electricity price:

- Electricity price to Industry (ie. base load technologies)

Peak load electricity price:

- Electricity price to Residential and Service sectors (ie. peak load technologies)

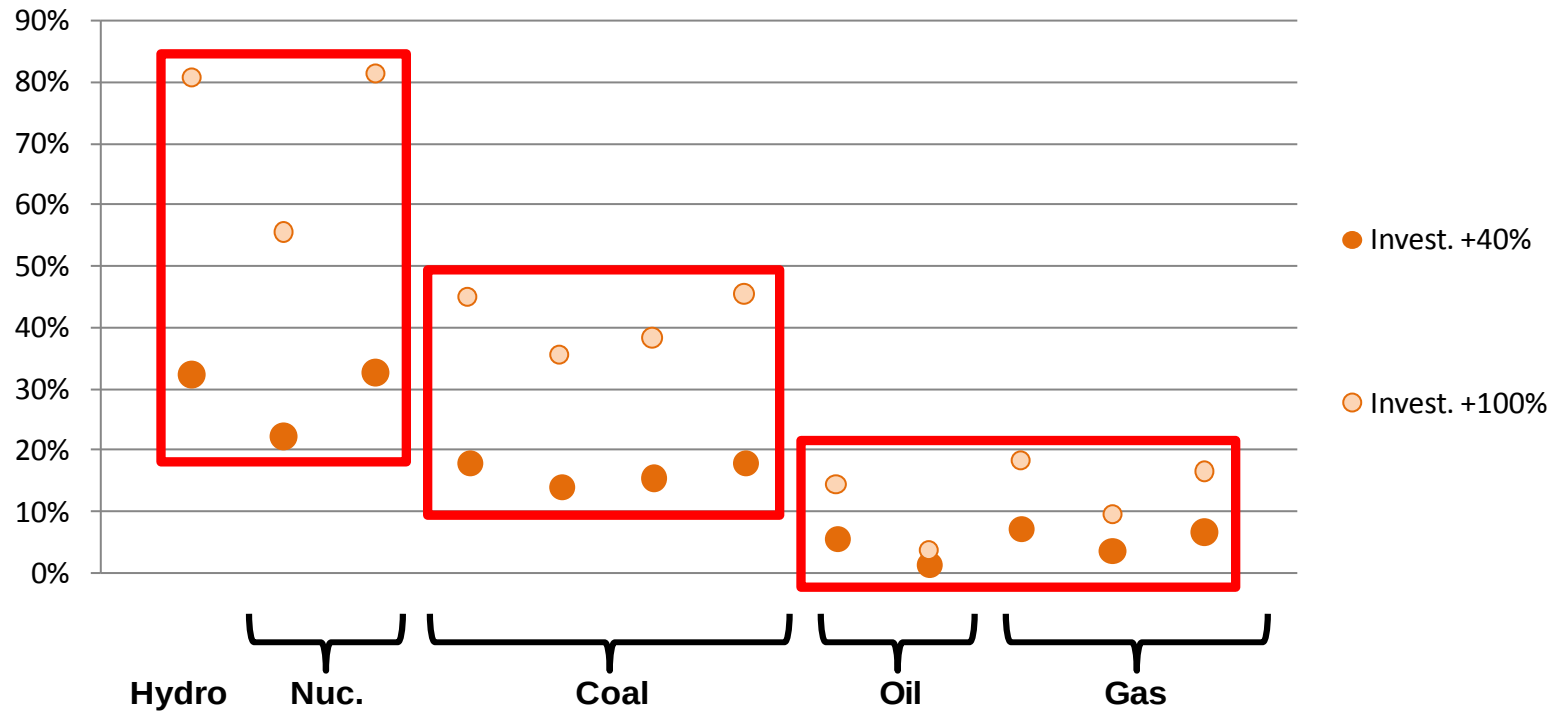
Possible integration of European electricity markets (i.e. convergence of national prices at the European scale)

Power production – Renewable energies

Different sources of limitations for the development of renewables are considered in the POLES model:

- **Geographical constraints**:
  - Wind potential
  - Solar irradiation
  - Surface available (buildings, grasslands, forest, deserts …)
- **Technical limitations**:
  - Availability of “back-up” technologies related to intermittency
  - Placement on the load curve of intermittent technologies
  - Limitations depending on storage capacity (CSP)
- **Economic aspects**:
  - Impact of subsidies, feed-in tariffs
  - Additional costs for storage in CSP (molten salts)
  - Additional costs for intermittency (wind)

Production costs sensitivity to investment costs



Source: TECHPOL

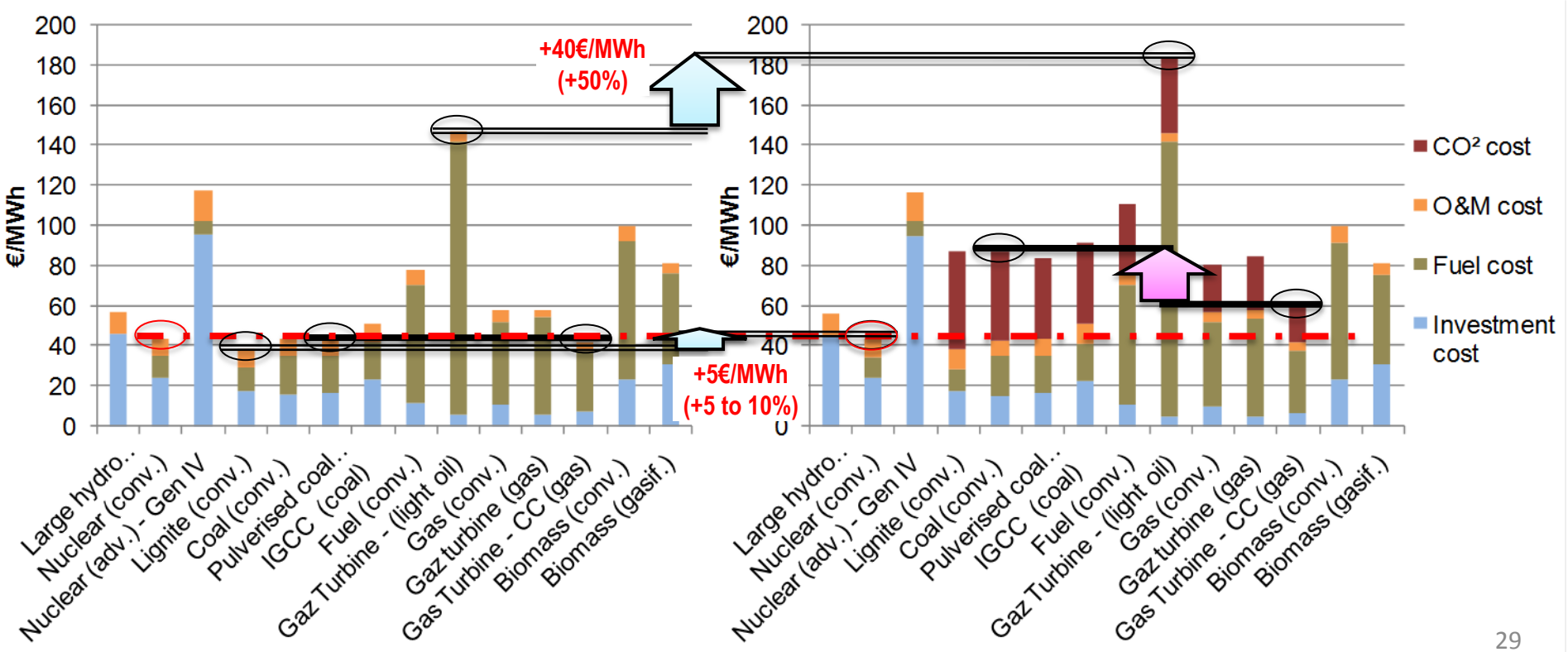
Production costs: impact of a $50/tCO2 tax

- **Shifts in the merit order (base load)**

  Coal plants become uncompetitive

- **Base load prices vs peak load prices**

  No real not emitting alternative for peak production



Possible calibration/sensitivity study on power sector

Enerdata has its own parameters sets based on in-depth data research and experts estimations, and aims to be transparent on them.

Exchanges with analysts to understand the underlying model behavior and to provide and test alternatives datasets can be organized.

Examples of possible subjects of study:

- Alternative data on technology costs (investment costs, variable costs, O&M costs, discount rate…)
- Calibration of non-cost related drivers
- FIT and subsidies for renewables technologies
- Availabilty of CCS
- Phasing-out of nuclear
- Tax policies on end-user prices
- Convergence of European electricity prices
- Impact of a boosted development of electric cars in the transportation sector (strong reduction of their costs, infrastructure development, …)
- Alternative land-use assumptions
- Limits on renewables integration
- Effects of storage/smart grids: smoothing of the load curve
- ….

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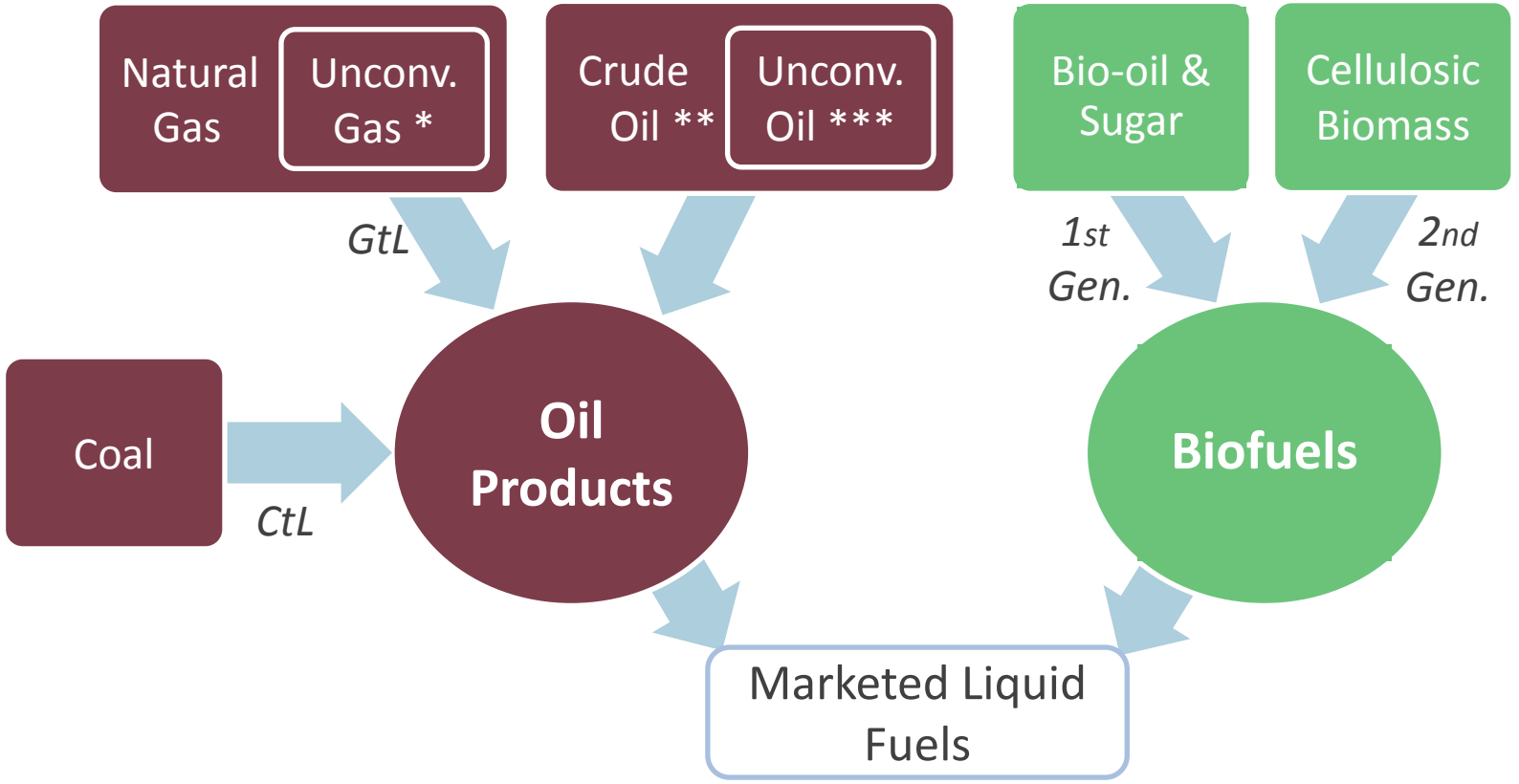
   Liquid fuels, gas and coal markets
4. References

The liquid fuels supply module



** : Unconventional gas covers: shale gas in 34 countries/regions*

*** : Conventional oil can include environmentally sensitive oil (Arctic, deepwater)*

**** : Unconventional oil covers: extra-heavy oil, tar sands, oil shales*

Simulation of the oil market

- **Crude oil** is simulated through a process of evolution of discoveries and reserves and interactions with demand via international prices:
  - **80 oil producing countries/regions** (all OPEC modelled individually)
    - Non-OPEC producers: “fatal producers” based on R/P ratio
    - OPEC non-Gulf producers: based on residual demand and total OPEC reserves
    - OPEC Gulf countries: “swing producers” with explicit capacity utilization rate
  - **1 global “pool” market** where producers export, with **one international price**
  - **57 oil consuming countries/regions**
  - there is no “bilateral” oil trade between producers and consumers, meaning that trade routes cannot be specifically tracked or blocked

- Production of **other liquid fuels** based on their production costs and an equilibrium of crude oil supply and liquids demand:
  - Unconventional oil in 43 countries/regions
  - Environmentally sensitive oil (Arctic in 5 countries, deepwater in 14)
  - Coal-to-Liquids (9 countries), Gas-to-Liquids (9 different countries)
  - Biofuels in 57 countries/regions

International oil price: determinants

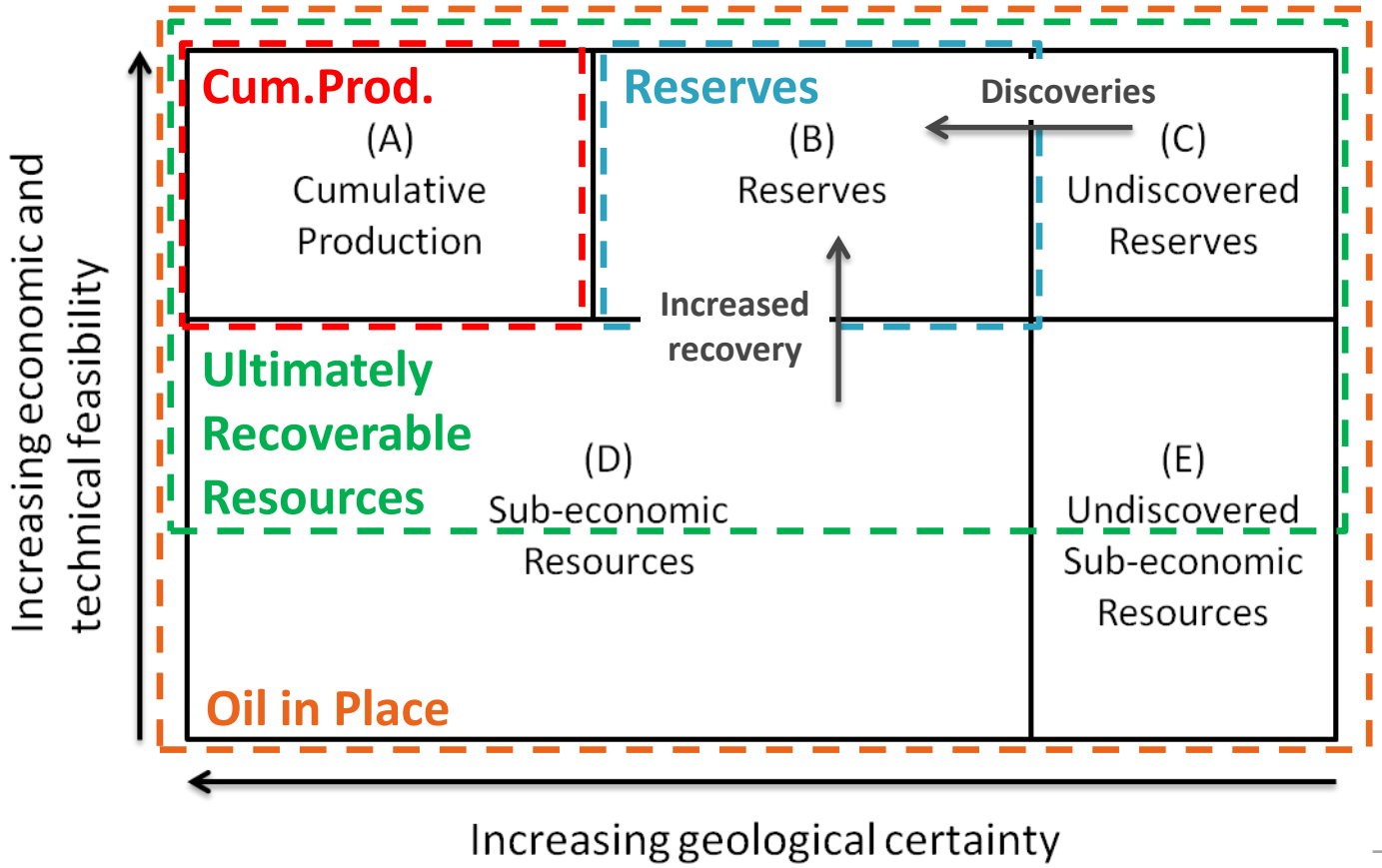
The oil price can be either fixed exogenously or calculated at the world level; it depends, in the short run on the variations in the **capacity utilisation rate of the Gulf countries,** and in the medium and long run on the world average **Reserve on Production ratio.**

$$\frac{dCPOIL}{CPOIL} = E_{CAPgulf} \cdot \frac{dCAPgulf}{CAPgulf} + E_{ORvP} \cdot \frac{dORvP}{ORvP}$$

- $\frac{dCPOIL}{CPOIL}$: **Oil price**
- $E_{CAPgulf}$: **Elasticity to Gulf capacity utilization**
- $\frac{dCAPgulf}{CAPgulf}$: **Gulf production capacity utilization**
- E_{ORvP}: **Elasticity to world R/P ratio**
- $\frac{dORvP}{ORvP}$: **World Reserves / Production ratio**

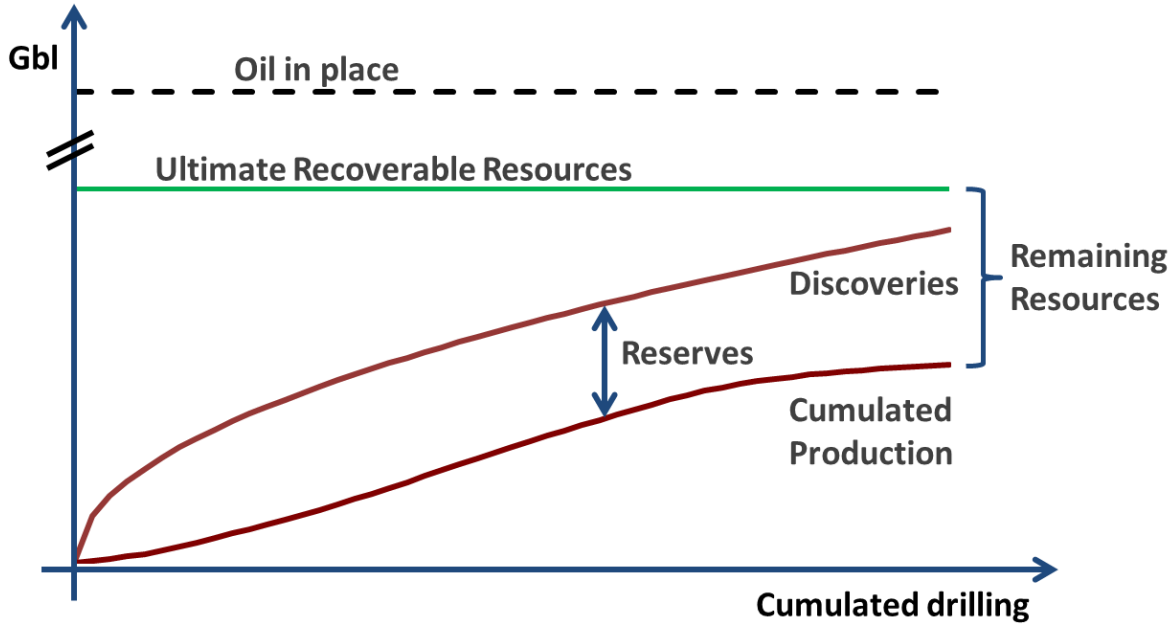
From oil resources to oil price (1/3)

- POLES follows an explicit representation of the oil discovery and production process
- Reserves grow as a result of recovery improvements and new exploration effort



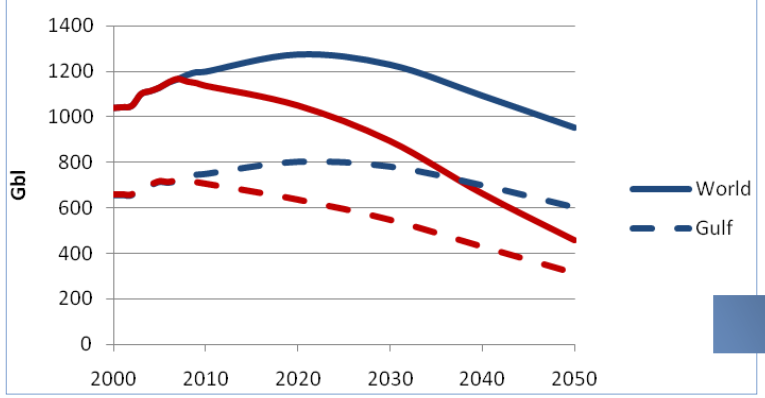
From oil resources to oil price (2/3)

- Oil in Place = Ultimate Recoverable Resources / Recovery Rate
- **Ultimate Recoverable Resources** considered fixed
- **Recovery Rate** = f(Oil Price)
- "**Discoveries**" increase with cumulated drilling (diminishing returns) and increase of recovery rate of existing fields
- **Reserves** = Discoveries – Cumulated Production
- Oil Price = f(Capacities Utilisation Rate of Gulf countries, World R/P)

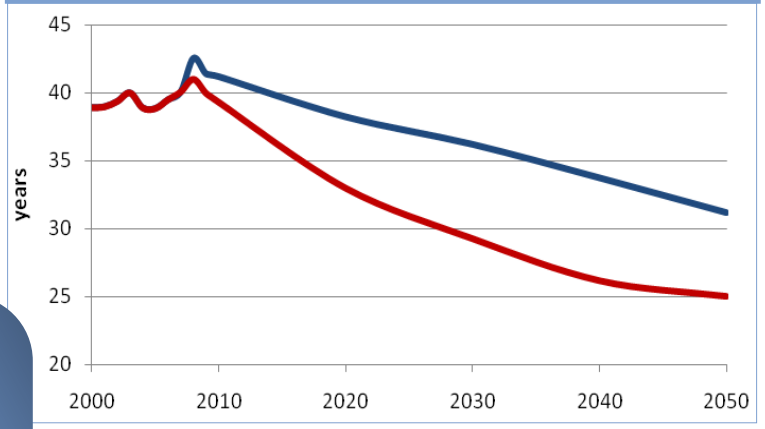


From oil resources to oil price (3/3)

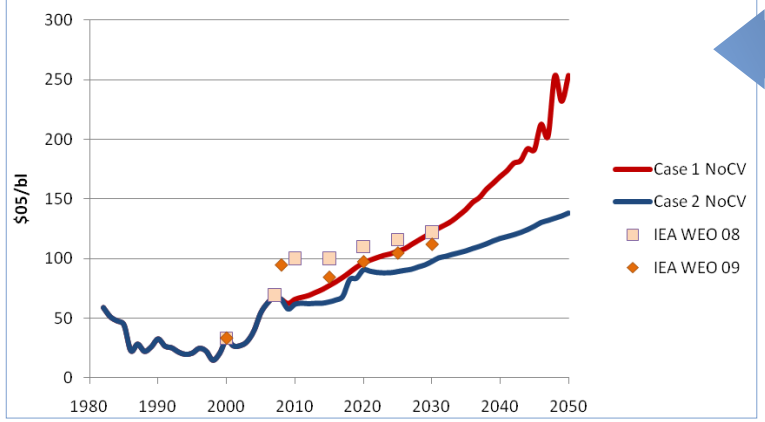
Oil Reserves



Oil R/P ratio (world)

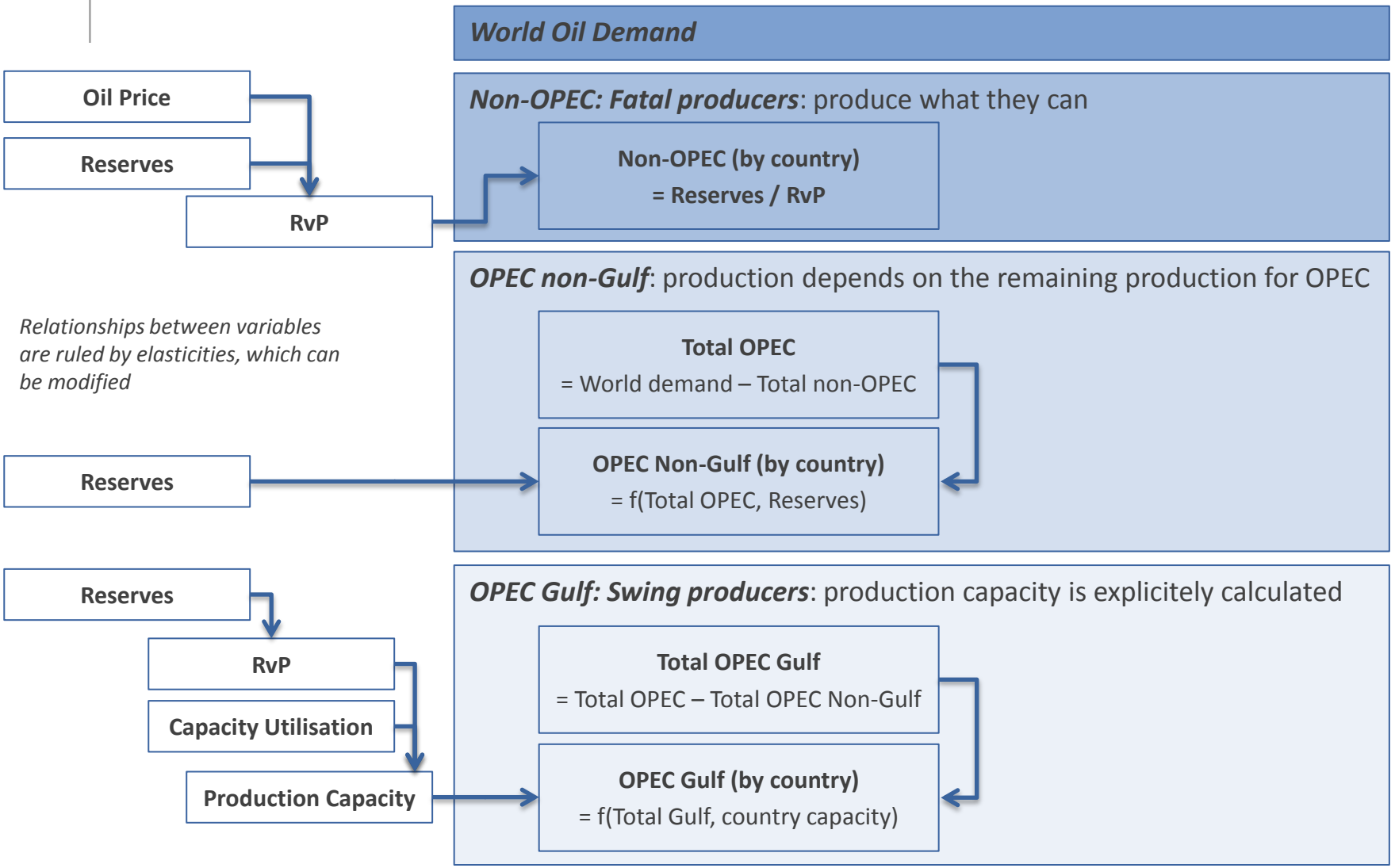


International Oil Prices

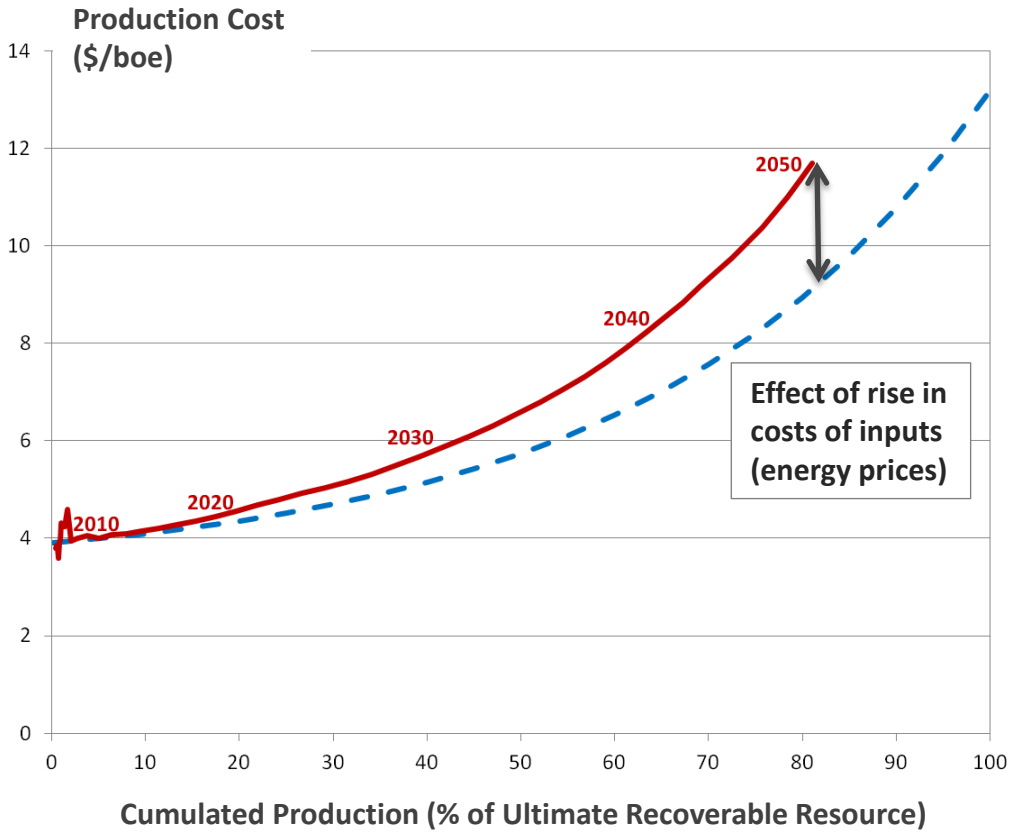


Different assumptions on oil resources and technology costs lead to different results in terms of discoveries, reserves and oil price

Conventional oil production: regional allocation



Oil and gas: the production cost curve approach



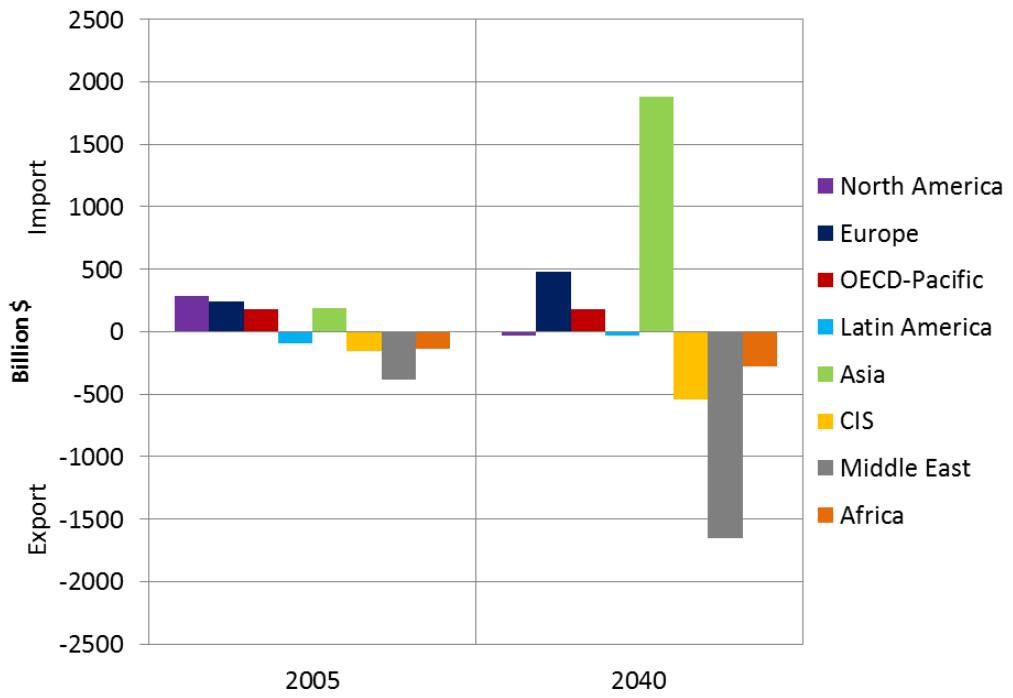
Possible supply changes include:

- Evaluate available resources at a given price threshold
- Range of resources given high/low assumptions on URR

- For each non-conventional resource type and each producing region, a production cost curve is associated, defining production based on past cumulated production and the distance to the international oil price
- Cost curves are calibrated on production history (where there has been one) or on exogenous calibration
- For countries without history, use the cost from the highest calibrated country
- Production cost used in production function (compared to world prices) and recovery rates (helps set growth rate in recovery)
- Depends on an *energy return on investment*, which takes into account the energy inputs for extraction (both direct and indirect); optional additional environmental costs can be taken into account

Forecasts: Oil Energy Bill

Oil Energy Bill



	2005	2010	2040
Oil demand (Mbl/d)	80	78	89
Internat. traded oil (Mbl/d)	45	42	61
Oil price ($/boe)	55	69	132

- Study of oil export incomes, as volumes and as a share of GDP
- Sensitivity analysis: income change with different non-OPEC climate policies, OPEC internal market subsidies change, …

Scenario illustrated here:

- Financial « transfers » from oil trade keep increasing
- Europe and Asia become the largest purchasers, with Asia expenses representing ME revenues
- North America becomes energy independant

Source : POLINARES, 2011

Simulation of gas markets

- The simulation of gas discoveries and reserves is similar to the case of oil , however there are significant differences:
  - **80 gas producing countries/regions**
    - 37 “key producers” based on regional market supply/demand
    - 43 “fatal producers” based on R/P ratio
  - **3 regional gas prices** are identified: Asia, Europe, America
  - there are **14 explicit consuming gas markets**
  - there is « bilateral » **gas trade** between producers and each of these 14 markets, either through gas pipeline or LNG

- **Main drivers of the regional gas prices**:
  - Gas R/P of regional main gas producers
  - Connection to oil price
  - Interconnection of regional gas prices
    through the development of LNG
  - Transport Cost

The elasticities to all these drivers can be defined with your internal experts and/or be the subjects of in-depth analysis through sensitivities studies.

Gas prices modelling

Gas price on the regional market

$$CP_{gaz} = CP_{trans} + CP_{NB}$$

- CP_{NB} : « Net-Back » value
- CP_{trans} : Average transport cost (pipe et LNG)

« Net-Back » value

$$\frac{CP_{NB}}{CP_{NB\,-1}} = \left(\frac{RvP_{mkt}}{RvP_{mkt\,-1}}\right)^{E_{rvp}} \times \left(\frac{CP_{oil}}{CP_{oil\,-1}}\right)^{E_{oil}} \times \left(\frac{CP_{gasWrd}}{CP_{gasWrd\,-1}}\right)^{E_{gasWrd}}$$

- $\left(\frac{RvP_{mkt}}{RvP_{mkt\,-1}}\right)^{E_{rvp}}$: impact of the market RvP ratio
- $\left(\frac{CP_{oil}}{CP_{oil\,-1}}\right)^{E_{oil}}$: oil price correlation
- $\left(\frac{CP_{gasWrd}}{CP_{gasWrd\,-1}}\right)^{E_{gasWrd}}$: distance with the average international price

Coal prices modelling

- Coal “fatal producers” and 13 large producers
- 3 regional coal prices

Coal price on the regional market

$$CP_{coal} = CP_{lp} \times \left(\frac{CP_{oil}}{CP_{oil_{-1}}}\right)^{E_{oil}}$$

- CP_{lp} : Coal price for a large producer in the market
- E_{oil} : Oil price correlation

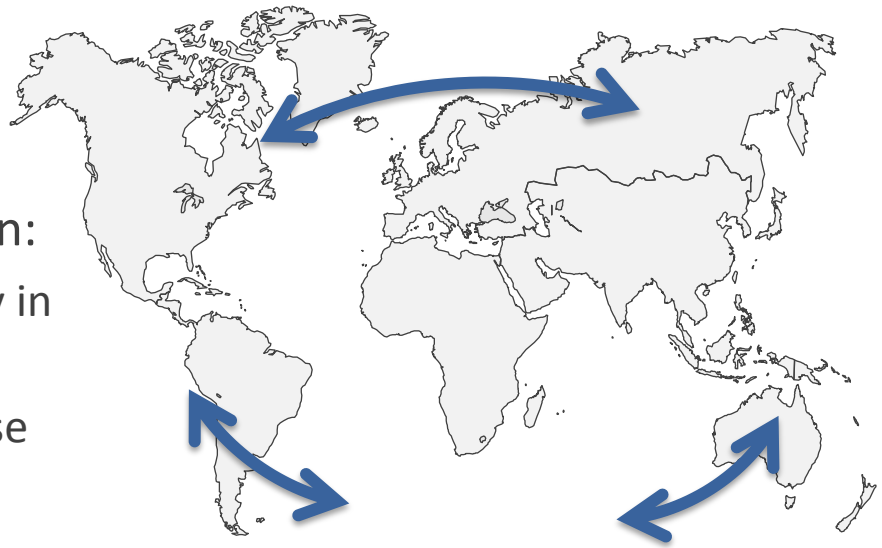
Coal price for Large producer

$$CP_{lp} = CP_{OP} + CP_{KTL}$$

- CP_{OP} : mining and operation costs
- CP_{KTL} : capital, transport and loading costs

Interactions of prices and production levels

- POLES simulates energy supply and demand based on an equilibrium via international prices
- Example: coal and oil interaction:
  - Direct effect: oil price elasticity in coal price equation
  - Indirect effect: oil price increase results in a loss of competitiveness of oil in the power or energy mix of a consuming country, making coal more competitive; the increased use of coal results in higher demand and higher price



Some drivers of the oil, gas & coal supply
Calibration / sensitivity studies possible

Enerdata has its own parameter sets based on in-depth data research and expert estimations, and aims to be transparent on them.

Exchanges with the client to understand the underlying model behavior and to provide and test alternatives datasets can be organized.

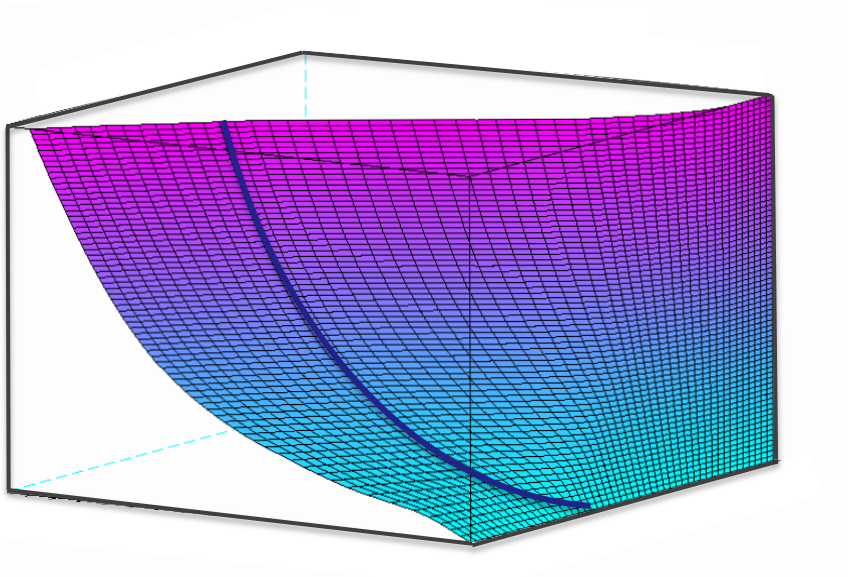
Examples of possible study topics:

- Remaining oil and/or gas resources (OPEC, non-OPEC)
- Calibration of oil discoveries (elasticity to oil price…)
- Reactivity to Gulf spare capacities (elasticity to oil price, imperfect perception of capacities utilization rate)
- Elasticity of oil production capacities to RvP (“resource nationalism”)
- Impact of alternative assumptions on unconventional resources and/or production costs (inclusion or exclusion of certain resources, extra costs, …)
- Correlation between gas price and oil price, between coal price and oil price
- Convergence between regional gas prices
- Subsidies to domestic prices in producing countries
- ….

Outline

1. Enerdata's Forecasting Services
2. The POLES model
3. **Selection of sectoral analyses: *Carbon Markets***
4. References

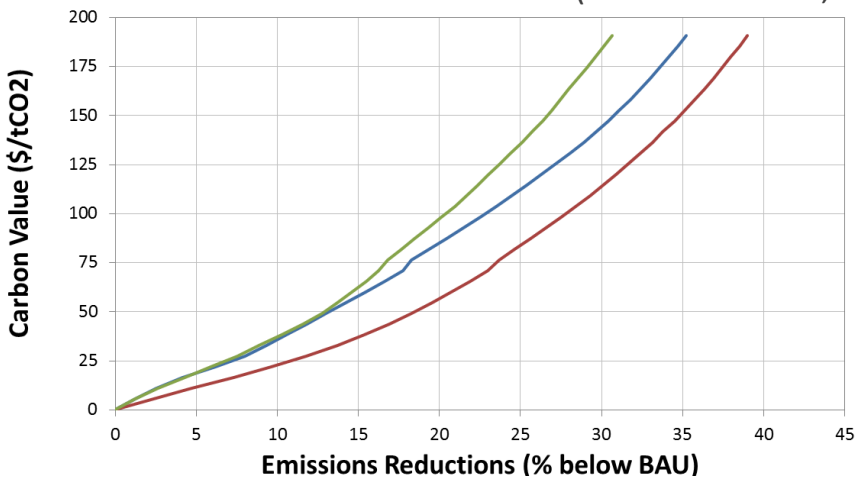
Marginal Abatement Cost Curves are produced with the POLES model



- Studies on carbon markets are driven using Marginal Abatement Cost Curves
- Curves are produced by POLES for:
  - 57 countries/regions
  - 20 emitting sectors
  - 6 GHGs (from energy and industrial activities)
  - All years from 2010 to 2050
- The MACCs from POLES are based on:
  - Power sector: full technological description and load curve simulation
  - Final demand sectors: finely tuned econometric demand functions (including short price and long-term price elasticities), incorporating explicit description of technologies in road transport and buildings
  - All sectors: capital vintage modeling

Carbon Market Tool

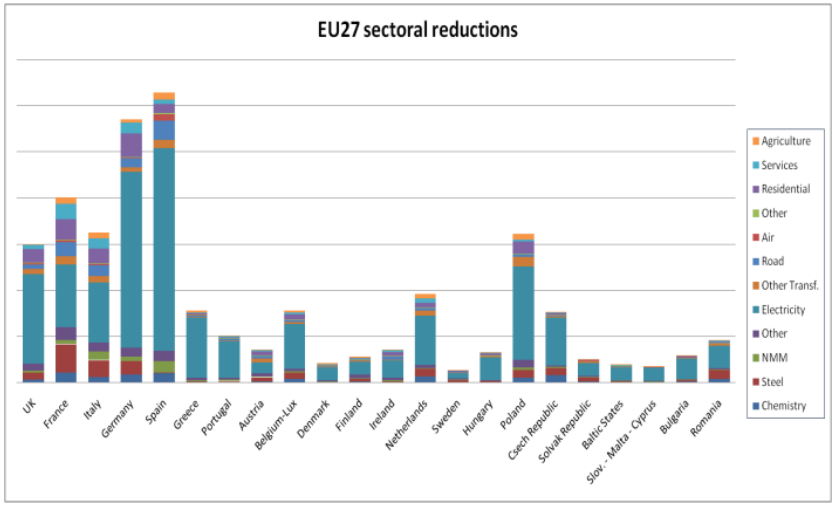
- Enerdata also operates a dedicated tool (CMT) for the **detailed analysis of carbon markets**:
  - Main inputs are **MACCs produced by the POLES** model
  - The structure allows integrating **multiple features** affecting carbon markets:
    - **CDM credits**, **hot air** management, limitations on **credits trading**, ceilings on credit purchases, **taxation** of credits traded, inclusion of sectors (e.g. international aviation), etc.
    - Possibility to include exogenous datasets (land-use/forestry)
    - CO_2-only or multi-GHG configuration
    - **Various time horizons** (standard : 2020, 2030, 2050)

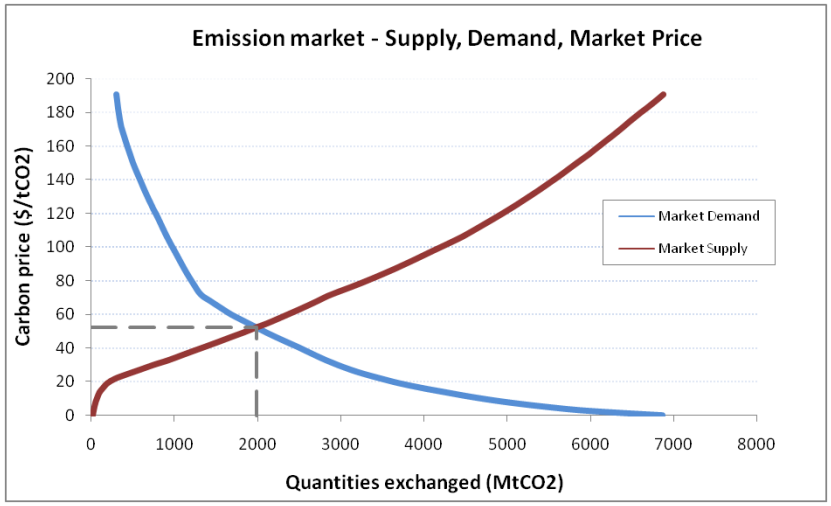


The Carbon Market Tool can either be run by Enerdata's experts to produce detailed analyses or transferred with support to the client

Carbon Market Tool

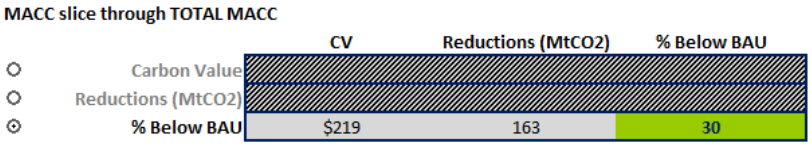
- CMT provides useful forecasts on emissions reductions by sector, market prices, carbon trades, and financing flows
- Valuable to the following audiences:
  - Governments involved in international negotiations for climate and carbon regulation
  - Private companies exposed to carbon markets
  - Large private companies considering the economic environment of their international assets
  - Investors, originators looking for new market opportunities

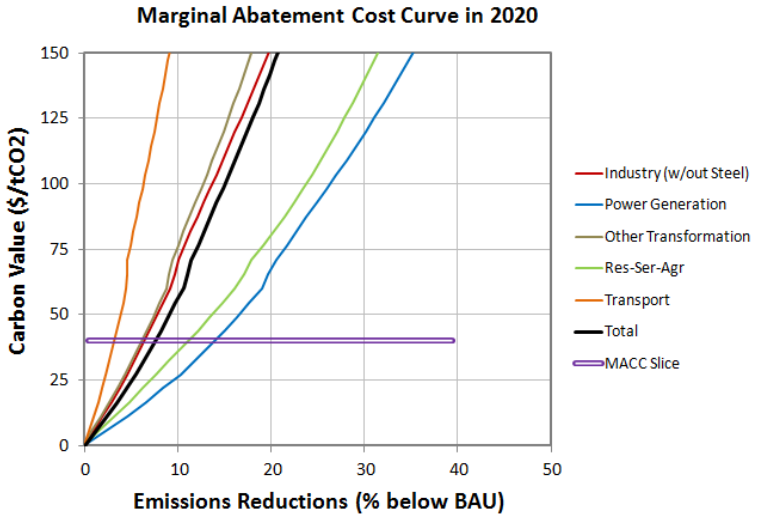


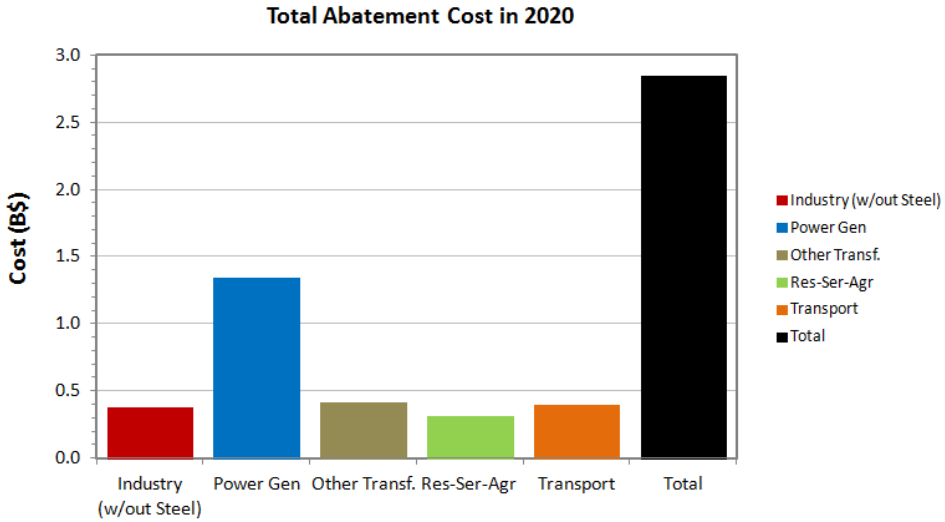


Emission Reductions Assessment Tool

- In response to the rise of carbon policies and low emitting investments in developing countries (CDMs, NAMAs), Enerdata has developed the ERA tool
- This tool provides the emission reduction options and the associated costs, which develop in a country under different energy and climate policies



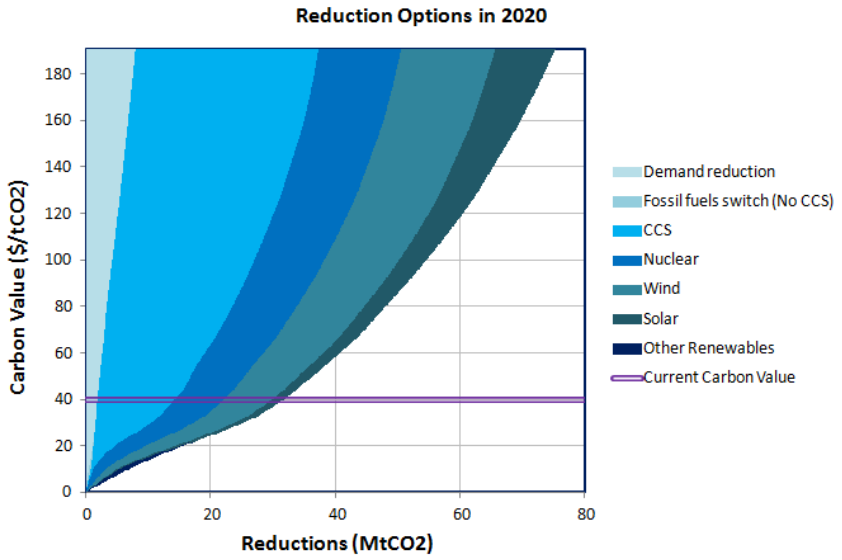


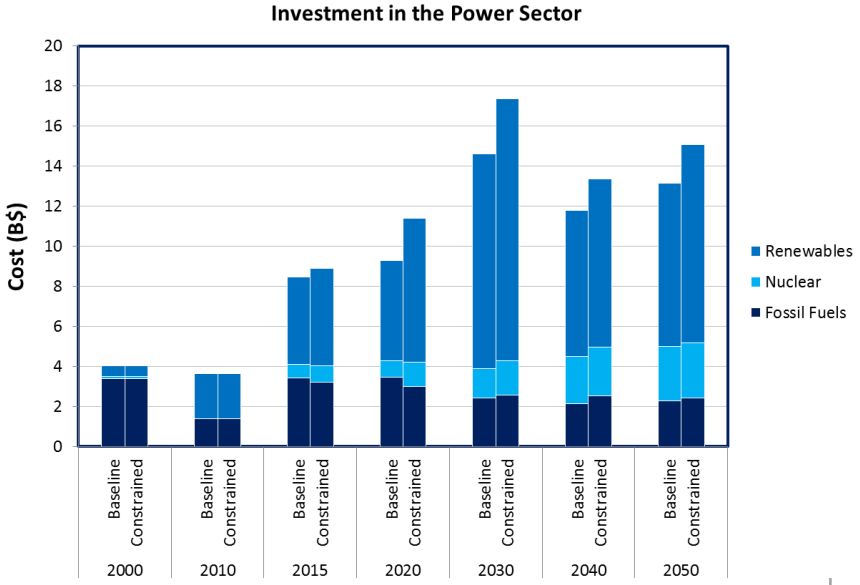


ERA tool

- The ERA model calculates the reduction options developed under a range of carbon prices in the industrial, power, transportation, residential, services, and energy transformations sectors

- The tool is valuable for:
  - Assessing cost-efficient policies at national level: policies to promote, technologies to develop
  - Quantifying the sensitivity of future investments to carbon taxation
  - Identifying new market opportunities and their sensitivity to carbon regulation





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3. Selection of sectoral analyses
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Selected projects with POLES: private firms

- Leading European Oil & Gas company (top 5)
  - 2030 Global World energy scenarios with a focus on international oil, gas, coal and carbon markets and prices
  - Objective of the project was to benchmark and stress test our client's long term oil & gas resources and demand scenarios

- Leading European Power and Gas Utility #1 (top 5)
  - For the Strategy Department, definition of power supply and demand scenarios based on various carbon constraints assumptions
  - Results used by client to define their own reference scenarios to 2050

- Leading European Power and Gas Utility #2 (top 5)
  - For the Corporate Strategy Department, development of a forecasting model for energy demand in all EU 27 countries

Selected projects with POLES: governments

- French Ministry of Energy
  - Production of the French official prospective scenarios to 2030
  - Assessment of Nationally Appropriate Mitigation Actions (NAMAs) portfolios for two developing countries (India and Brazil); Collection and information organization on energy and climate policies in these two countries; benchmark of the efficiency of the policies and measures planned with reference long-term energy scenarios
  - Development of scenarios including alternative trajectories for nuclear power
- Department of Energy and Climate Change (DECC, British Government)
  - Development of a set of Marginal Abatement Cost Curves (MACCs) for the UK Department of Energy and Climate Change

Selected references: energy outlooks and forecasting projects

- 2035 world and European energy scenarios with a focus on power generation– Leading European Utility (2009-2014)
- Realization of the French official prospective energy scenarios and analysis of the impact of a nuclear phasing-out policy – French Ministries of Energy and Environment (2010-2011)
- 2030 Global energy scenarios with a focus on international O&G markets – Leading European O&G company (2009-2010)
- 2020-2030 World & European energy scenarios with a focus on power generation – Leading European Utility (2009-2012)
- Development of a forecasting model for electricity demand and load curves for 5 insular energy systems – Leading European utility (2010)
- Analysis of energy and climate policies of key emerging countries – Danish Energy Agency (2012)
- Development of a carbon markets simulation tool to support real-time assessment of burden sharing proposals in COP; production of marginal abatement cost curves by country and sector up to 2050 - Danish Energy Agency (2009-2012)
- Development of Marginal Abatement Cost Curves (MACCs) for the study of the EU ETS – UK Department of Energy and Climate Change (2012)
- World energy forecasts scenarios by world region – World Energy Council (WEC) (2007)
- WETO-H2 2050 report: World Energy, Technology and Climate Change Outlook - European Commission (2007)
- Development of a forecasting model on energy demand, for 10 countries in Western and Central Europe – leading European utility (2006)
- Evaluation of GHG policies in Europe - French Energy Institute (IFE) (2002, 2004)
- For a leading LNG exporter, detailed review of the French market energy demand per sector, with a focus on natural gas; calculation of gas market replacement value indicators per sector (2004)

Thank you for your attention !

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