MINES ParisTech

ParisTech's Chair Modeling for sustainable development

Smart, Sustainable and Low-Carbon growth of electricity systems

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ParisTech Chair Modeling for Sustainable Development

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Future power mix issues

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Future power mix : a major issue for the next decades

- Huge investments are forecasted in the power sector ▸ Jump to IEA prediction.

- Electricity environmental impact are consequent: power generation stands for more than 45% of Carbon Dioxide emissions.

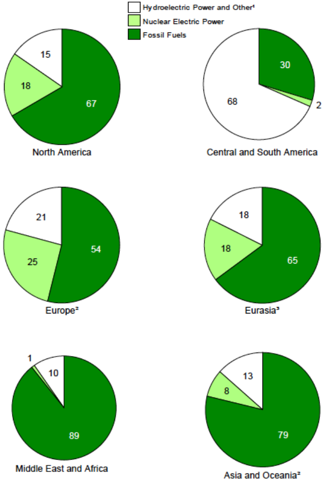

Figure: Power generation by region Source: AER 2009.

Trend towards low carbon future power system

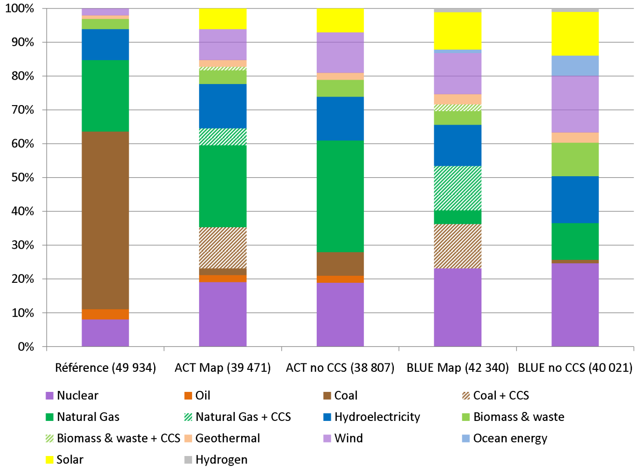

Figure: Power Generation Mix Scenarios ETP 2008

Multiple recommendations for a low carbon electricity system

Generation Solutions

☞ *Renewable and distributed energy sources* are attractive alternatives for power generation
☞ *Nuclear* is stated as a zero-emission technology
☞ Claim that *new capture and storage technologies* may provide major opportunities in several areas

Policies and Tools

- *Markets* (carbon, power,. . .): taxes, prices, incentives,. . .
- *National commitments*: POPE law 13/07/2005 and Grenelle (in France) , dividing by 4, RT,. . .
- International commitments: 3x20, post Cancùn, . . .
- Nuclear policy options: phasing out or continuation . . .

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New paradigms present major technical challenges

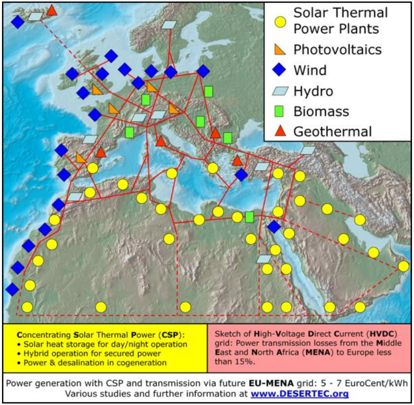

Figure: All-Renewable Electricity Generation in 2050.Source: DESERTEC.

Technical Solutions

- embedded solutions
  - *Energy Efficiency*
  - *Smart* solutions : grids, water, sustainable cities ...
- *integration of intermittency at large scale*;
- *mobility* : electric, biofuels,..
- *centralized / decentralized grid*.

In order to elaborate a Smart transition for the power sector

Smart

Desirable, Plausible, Sustainable

it is mandatory to sort out the **imbroglio of technical recommendations and policies** throughout a long term approach, always revisited and that allows to:

- reconcile time and space scales
- assess the global impact of the proposed solutions
- consider the externalities
- propose a trade-off to taking into account competitions and substitutions

TIMES as a Prospective tool

"What we have the right to ask a conceptual model is that is seize on the strategic relationships that control the phenomenon it describes and that it thereby permit us to manipulate, i.e., **think about the situation**"

Source: R. Dorfman, P. A. Samuelson,R. M. Solow

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Competitions, substitutions and coherence

TIMES

A technical linear optimization model, **open-source** developed in the framework of **ETSAP**: Energy Technology Systems Analysis Program initiated by the IEA (in 1980)

- demand driven
- on a long term horizon: (50/100 years)
- in order to achieve **a technico-economic optimum** minimizing the overall actualized cost of the reference energy system

1. whose flows are balanced
2. satisfying a set of relevant technical constraints (peak reerve for the power system,. . .)

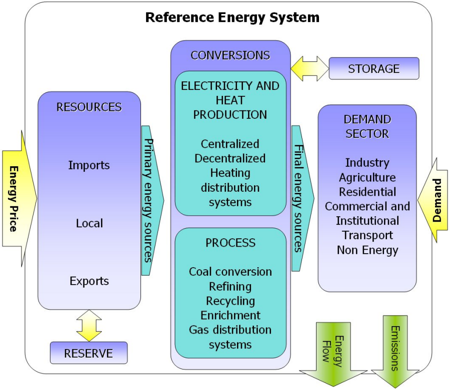


Figure: The Integrated MarkAl (market allocation)-EFOM Reference Energy System

The use of scenarios: prospective versus prediction

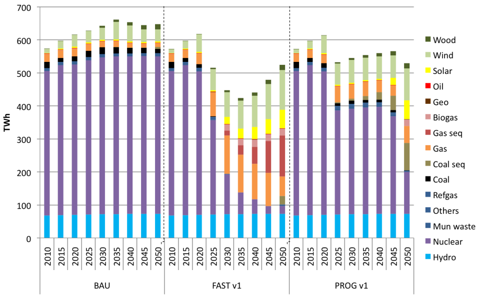
Energy planning modelling through TIMES enables to:

- **envision** all the possible futures
- in order to **lighten** tomorrow's consequences of today's choices and decisions

- Instead of using **scenarios kept in a stock**
- each question requires **a flow of dedicated scenarios**, to assess a future power system

Desirable, Plausible, Sustainable

Reliability of power systems



Power production carbon tax and carbon cap

☞ Assessing the production mix **relevance** and **plausibility** : reliability issue.

Figure: Europe from orbit during the Italian blackout (Sept. 28th, 2003). Source: RTE.

French electricity paradigm

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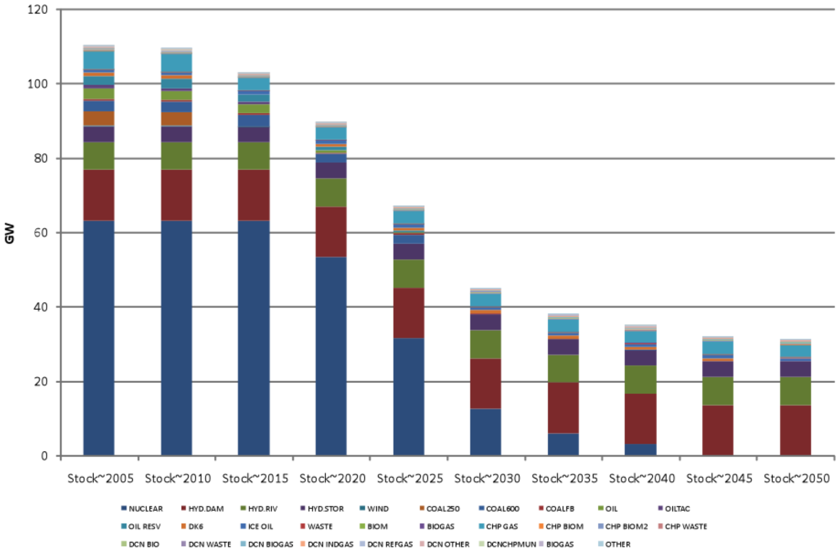
Nuclear power replacement is the main driver for the future



Replacement of existing capacities

Major uncertainties remain

☞ lifetime : discussion has moved from 30 to 60 years

- debate in 1999 : between 30 and 40 years [Bataille, Galey 1999] (nominal 30)
- today discussions : between 40 and 60 years
- PPI 2009 recommands : more than 40 years submitted to ASN agreement
- our assumption: Smooth profile

Nuclear residual installed capacities profiles

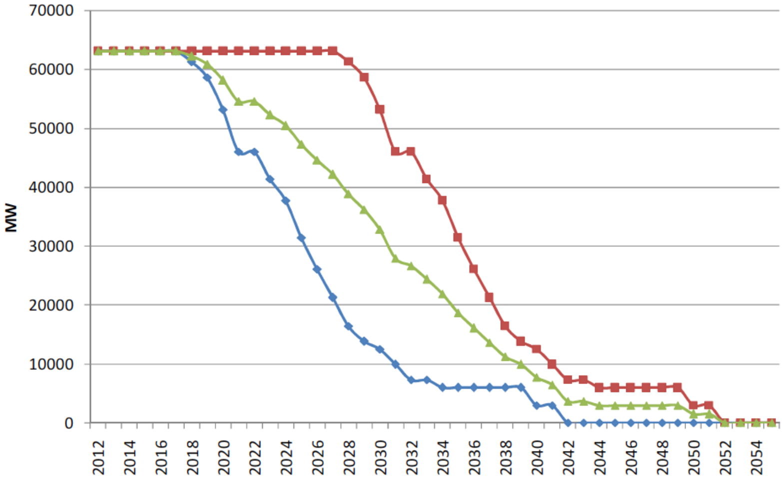
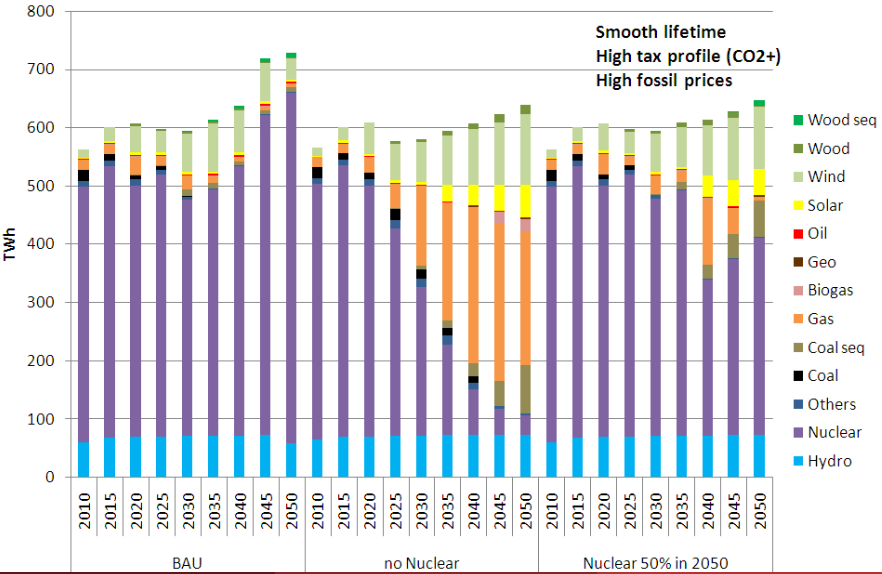


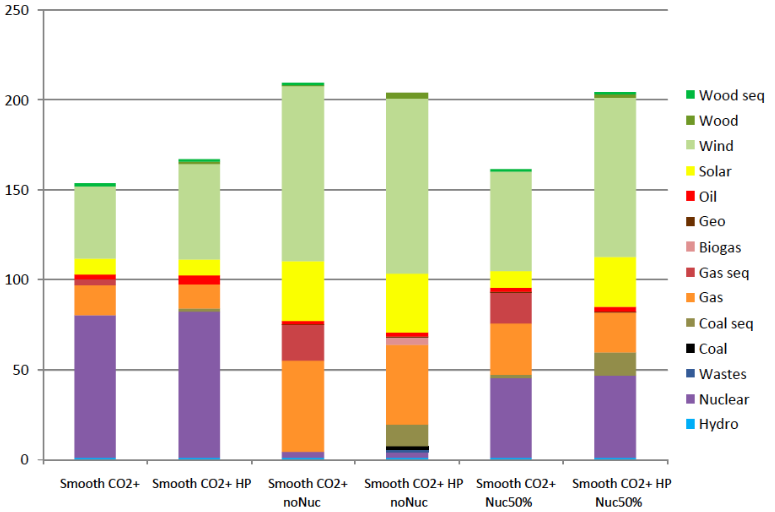
Figure: Residual installed capacities : lifetime 40 years Smooth 60 years

Fossil price and CO_2 tax sensitivity : High Prices, High Tax



Huge investments are needed

☞ new generation capacities to secure power supply



Reliability issues

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Future Power System : Reliability of electricity supply

Figure: Europe from orbit during the Italian blackout (Sept. 28th, 2003). Source: French TSO.

Technical constraints binding the operation of the future power system are related to:

- the given level and spatial distribution of loads and capacities;
- the expected level of reliability to prevent from power outages.

☞ Where **reliability** is the capability of the power system to withstand sudden disturbances due to load fluctuations.

Assesing future power systems : dynamics issues

Stability studies

involve time scales ranging from a few milliseconds to a few hours

Long-term planning models

deal with several years or decades

The level of reliability of the power system can be derived from

- the **dynamic properties** of the installed capacities
- the associated inertia of the system (kinetic and magnetic)
- the load profile.

characterized by H :

the time you have to recover the stability of the system after a load fluctuation by monitoring its reserves.

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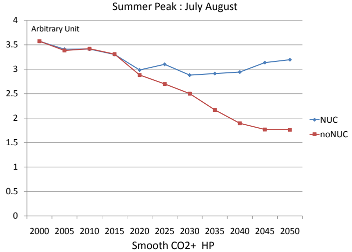
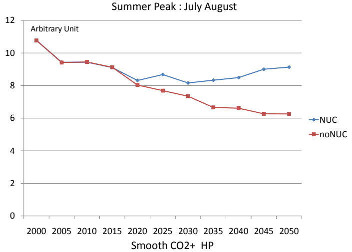
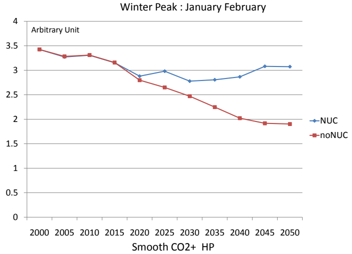
Reliability robustness of the power mix : nuclear sensitivity

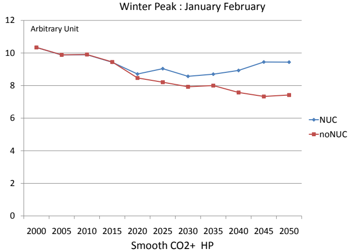




Kinetic reserves

Magnetic reserves

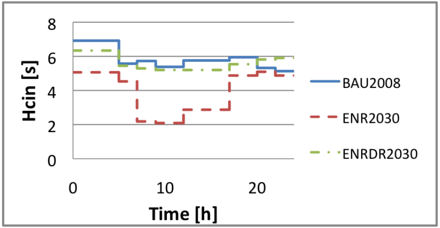




Smart Grid Impact on reliability level PhD S. Bouckaert

☞ Demand response

- aiming to peak rebate and load shedding
- enables the enhancement of reliability



Reliability level for the kinetic reserve

The Réunion Island:

- BAU 2008
- 100 % renewable in 2030
- 100 % renewable in 2030 + Demand response

Water impacts of power generation

S. Selosse and E. Assoumou

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Policies dealt separetely but... interdependecy

Growing issues for water and energy

- Energy sector: depletion of fossil resources, environmental impacts
- Water supply: availability and sustainability of water resources

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