ParisTech's Chair Modeling for sustainable development

Les outils de la prospective long terme pour le business et l'efficacité énergétique

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et Chaire ParisTech Modélisation Prospective

Journée Schneider electric

Smart cities et prospective : une contribution à RIO+20

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

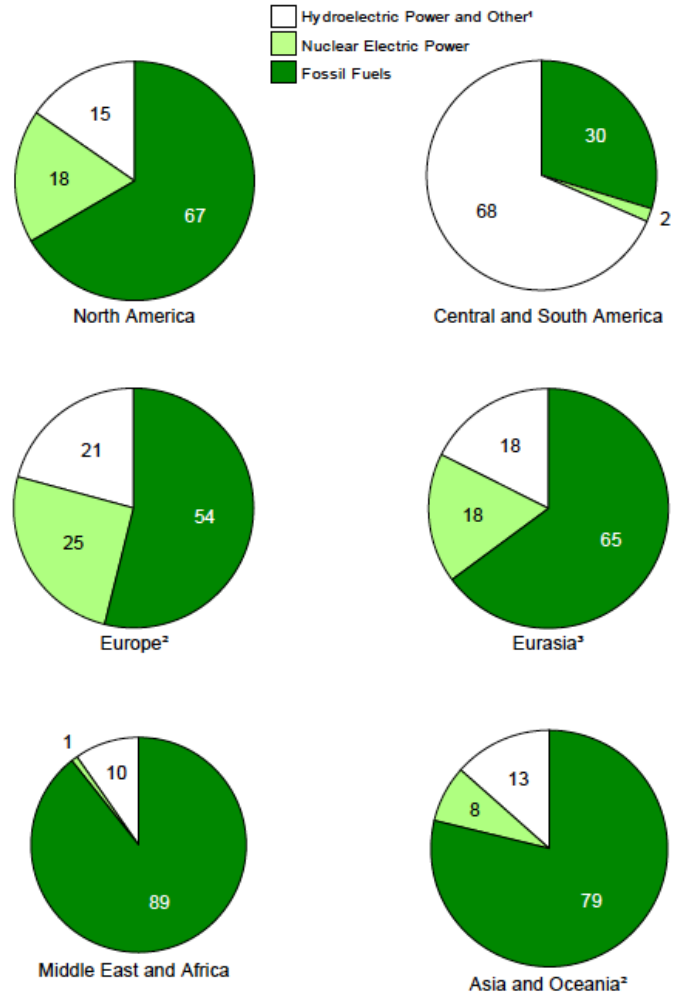

Figure: Power generation by region Source: AER 2009.

Future Power System : generation mix

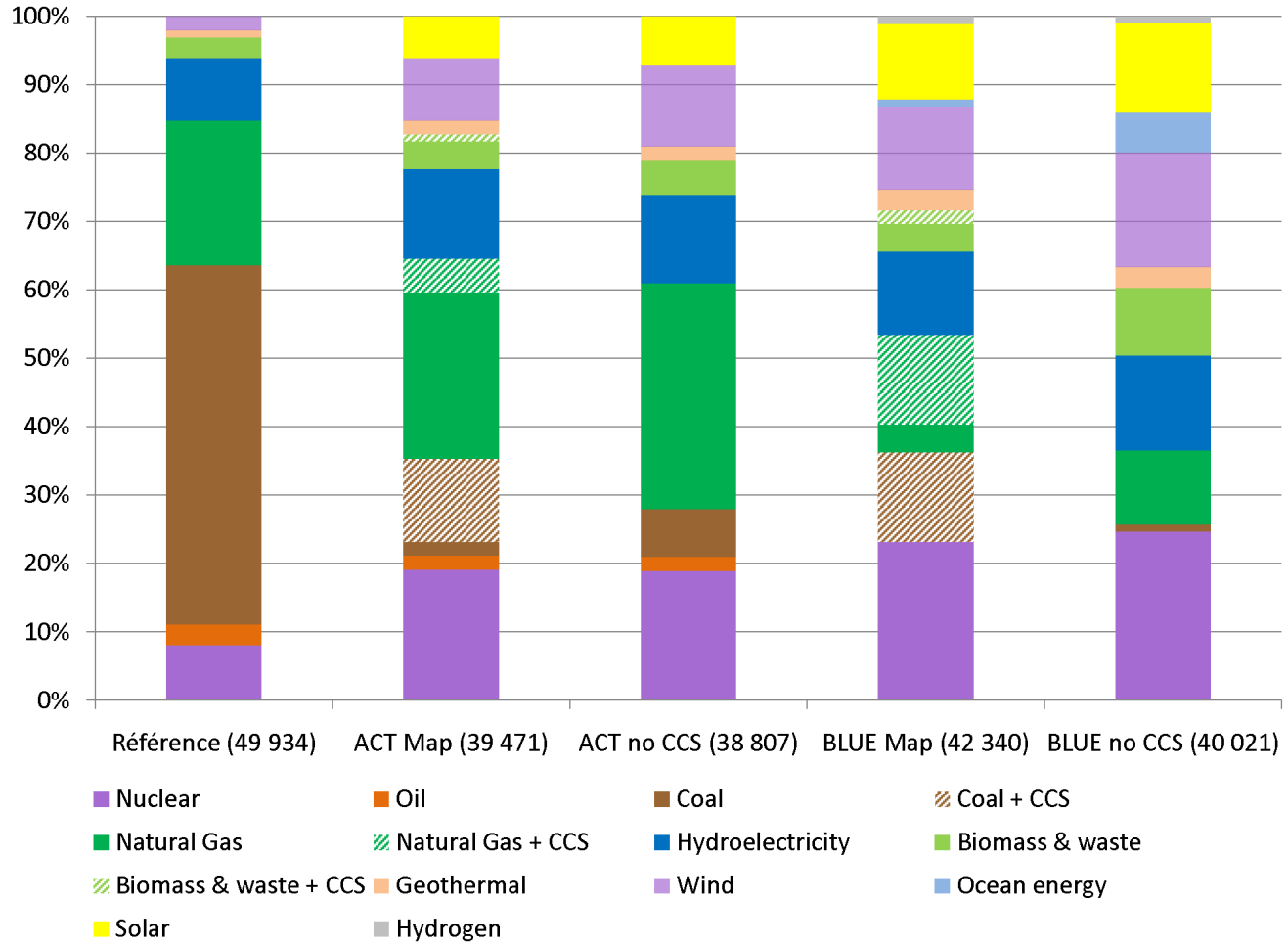

Figure: World generation by share ETP 2008

Future low-carbon Power Systems

Moving to a low-carbon society

☞ *Renewable and distributed energy sources* are attractive alternatives for power generation

☞ *Nuclear power* is stated as a zero-emission technology

Beyond the debate between pros and cons the different options induce major technical challenges to shift the paradigm towards new power systems

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Future Power System : network issues

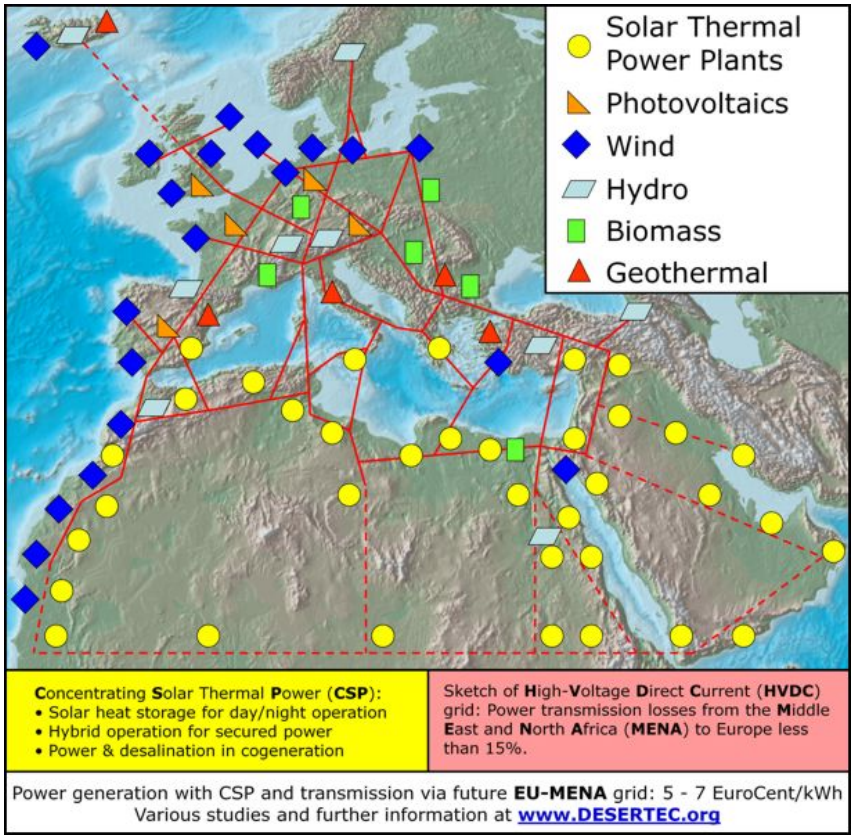

Figure: All-Renewable Electricity Generation in 2050.Source: DESERTEC.

New paradigms induce Technical issues related to

1. Decentralized options.
2. Intermittency.
3. Water.

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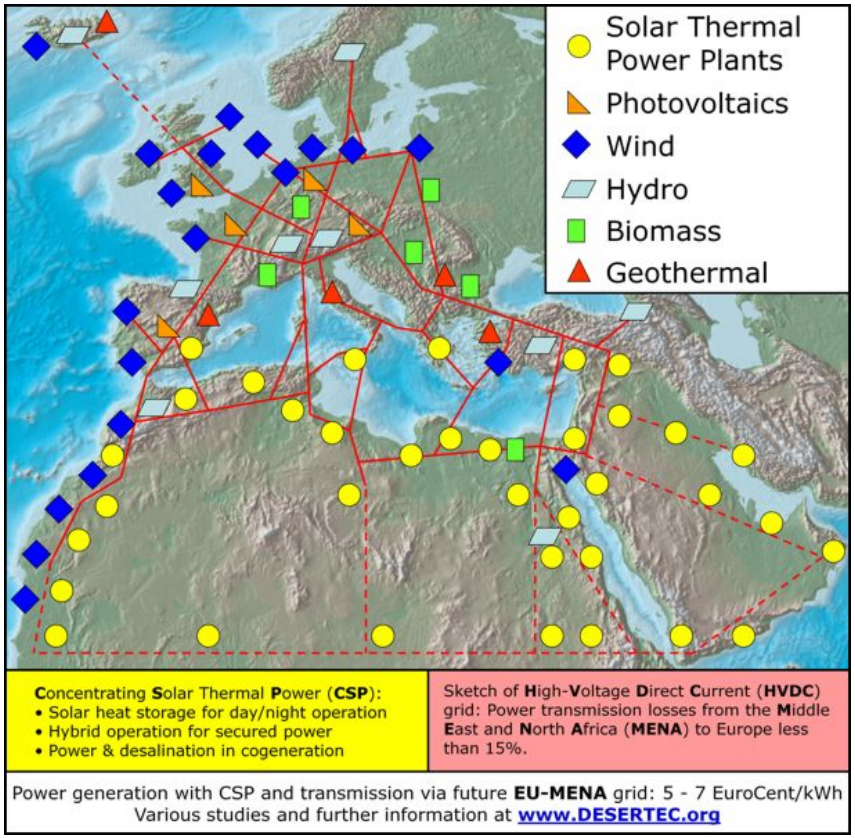

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3. **Water.**

Future Power Systems : business opportunities

Companies which to develop specific solutions compatible with low-carbon society

1. *Energy efficiency* solutions
2. *Smart* solutions : grid, cities, water, ...
3. *Markets* : carbon, power, ...
4. *Transportation* : electric vehicle, biofuels, ...

TIMES and IMACLIM as Prospective tools

"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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Prospective versus Prediction

Whilst Prediction **imposes** the future.

Prospective

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

In other words Prospective exercises enable to :

- **be prepared** to unexpected trends or events thanks to the assessment of a **diversity of imagined futures**
- i.e. **to build a prosthesis** for the stake-holders or decision-makers who desire a **calculated adventure**

☞ Tools are needed to think, debate, and to evaluate decisions and measures

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Competitions, substitutions and technical issues

A technological energy-sector model:

TIMES based on a MARKet ALlocation

- **a highly detailed technological representation** for existing and future technologies enabling:
  - a complete description of consumption trends,
  - a precise analysis of substitutions between types of energy,
  - an interpretation of the notion of energy needs in terms of services and equipments,
  - a better evaluation of renewable energy sources.
- an **open-source** model developed in the framework of **ETSAP**: Energy Technology Systems Analysis Program initiated by the IEA (in 1980)

An optimization approach to assess future power systems

The TIMES model

A technical linear optimization model driven by demand achieving **a technico-economic optimum**

1. for the **reference energy system** (RES)
2. submit to a set of relevant technical and environmental constraints
3. over a **definite horizon** : long-term (50 years)

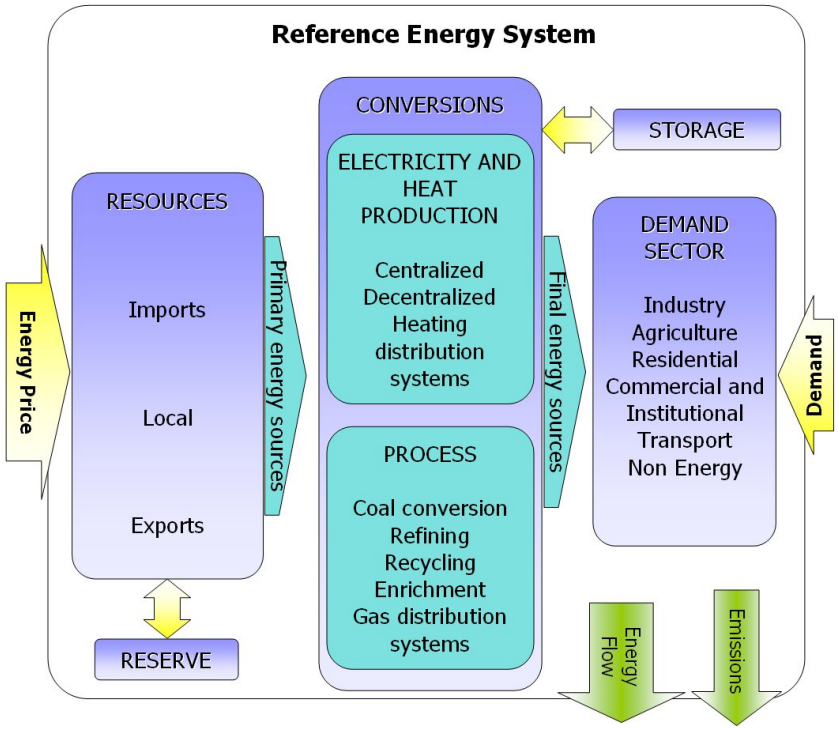

Figure: Reference Energy System

Water impacts of power generation

S. Bouckaert

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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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Water for energy

- Cooling systems
- Hydropower
- Extraction and mining
- Fuel production
- Emission controls

Energy for water

- Pumping
- Transport
- Treatment
- Desalination

Water impact of the assessed Power mix

In order to analyze the influence on water of the assessed power mix

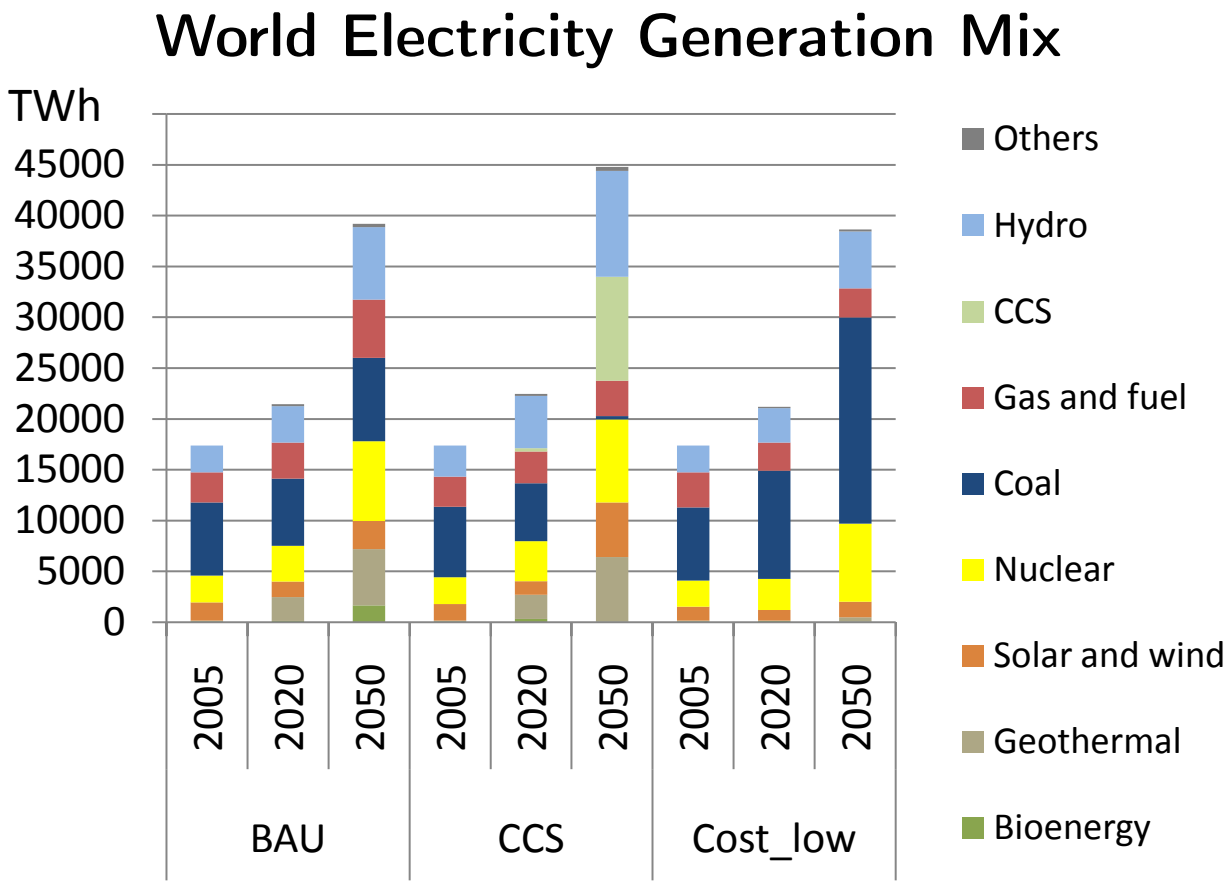
we consider scenarios reflecting

1. Environmental policies and extraction costs
2. Water as a constraint

where Water factor for each technology mainly depends on :

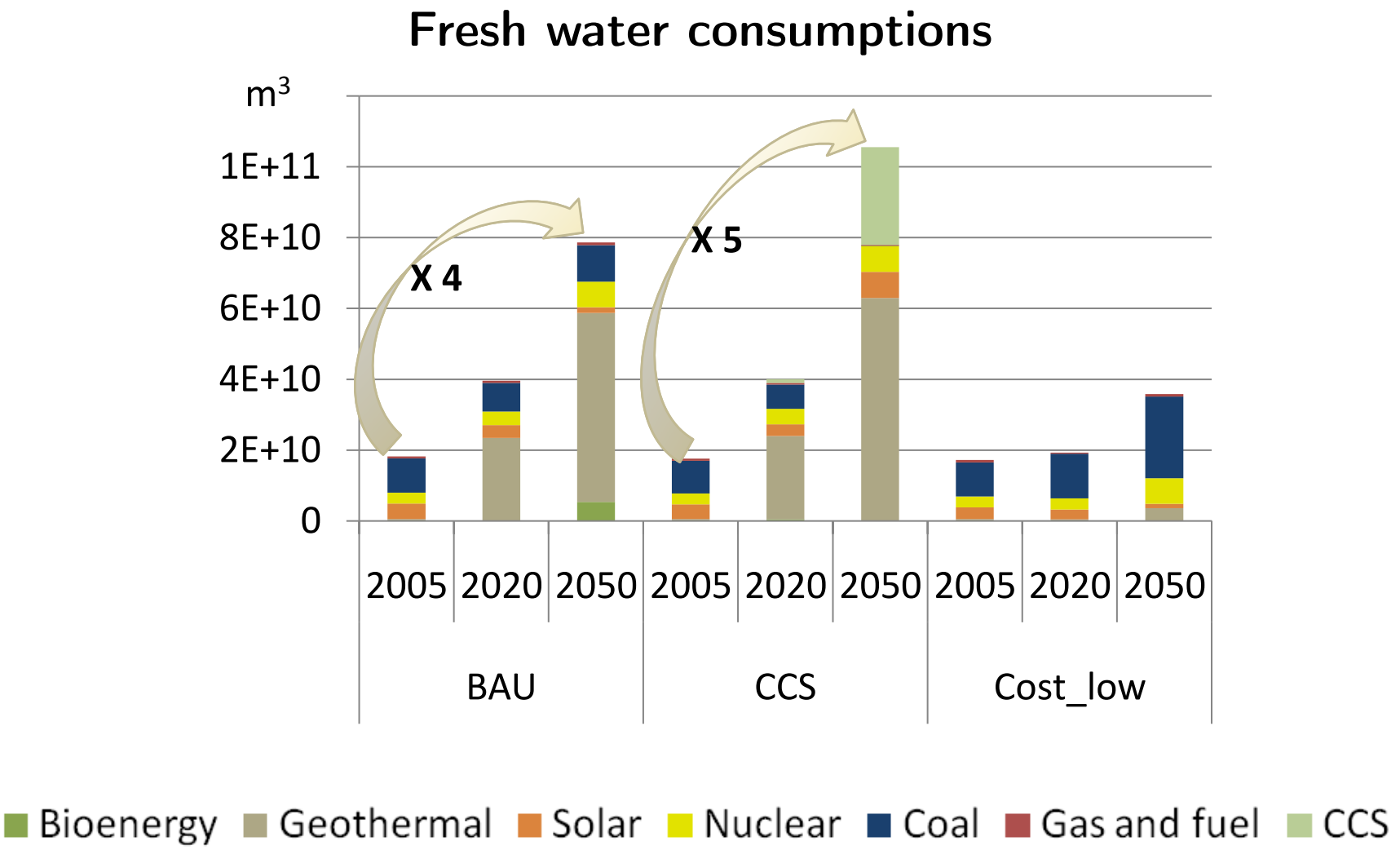
- *Upstream*: type of coal mine, ratio onshore/offshore etc.
- *Electricity*: cooling systems, efficiency, FGD etc.

Environmental policies and decrease of extraction costs

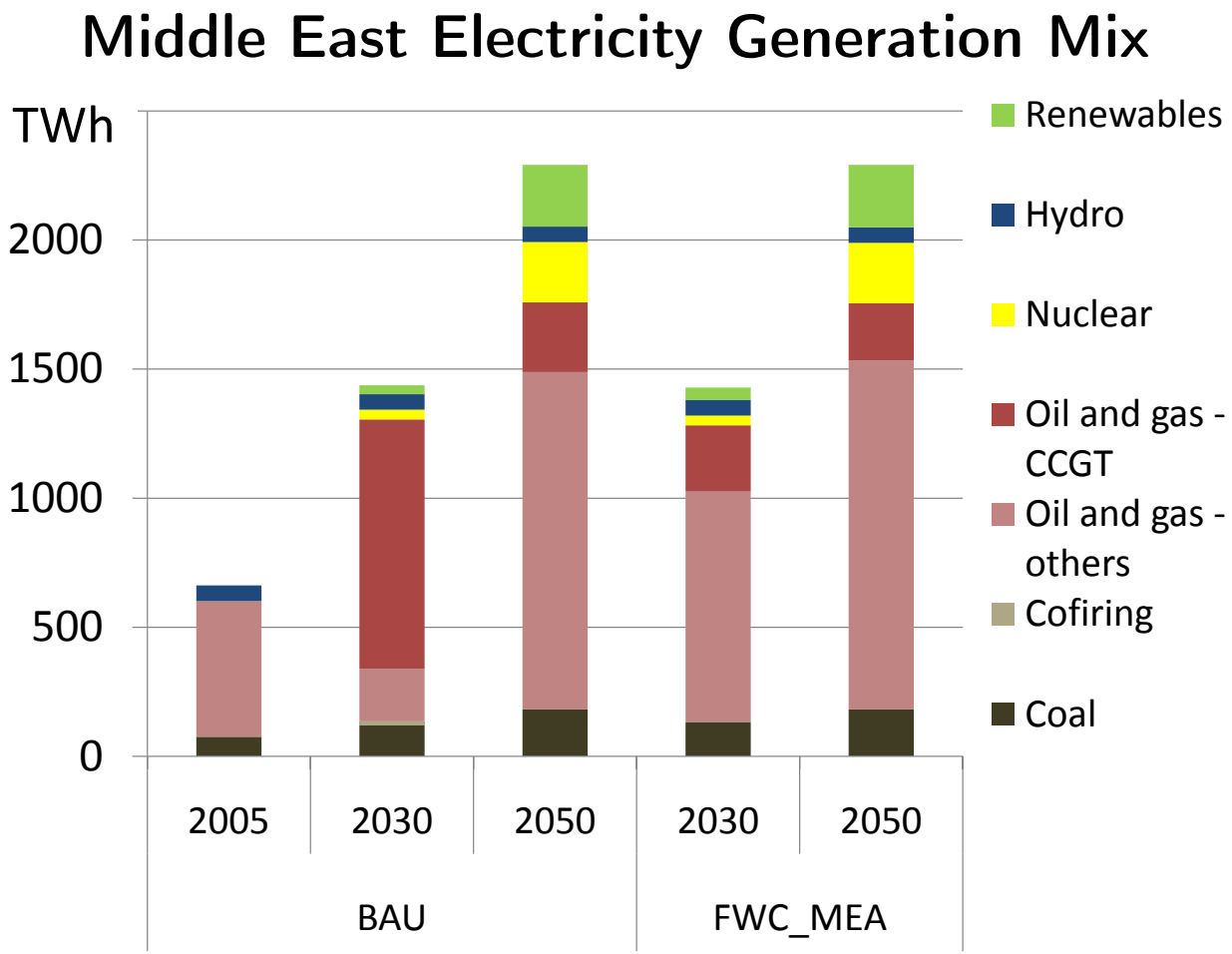


- CCS : constraint the energy system to a maximum increase of temperature of 2°C in 2100
- Cost_low : decrease of extraction cost of fossil energy

Environmental policies and decrease of extraction costs



Water as a constraint



- FWC_MEA: fresh water consumptions in Middle East until 2100 $\leqslant$ consumptions in 2005

Reliability issues

V. Mazauric, E. Asssoumou, M. Drouineau

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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.

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Adressing dynamics issues of future power systems

☞ we might question the implementation **relevance** and **plausibility** of the future energy mix through Prospective exercises

Long-term planning models

deal with several years or decades

Stability studies

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

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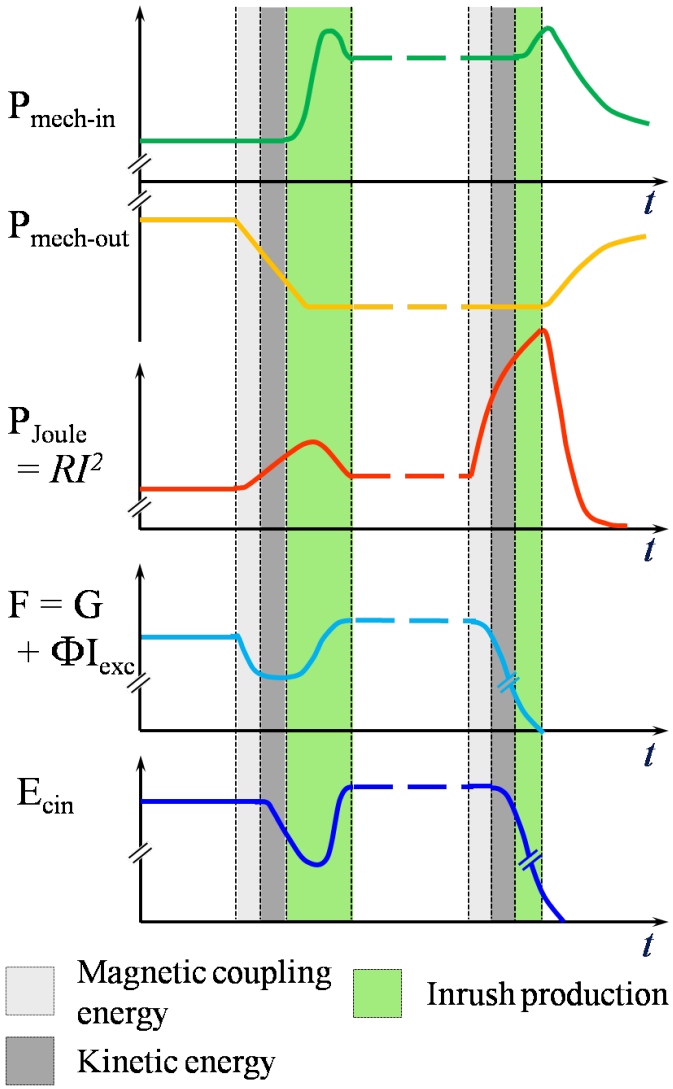
Load fluctuation and stability



energy exchanges between the subsystems involved in the Thermodynamic Framework

Two events experienced by a power system: an admissible load fluctuation is lifted by the electromagnetic coupling energy (ΦI_{exc}), the kinetic reserve (E_{cin}) and the generation realignement during a load fluctuation (left) ; conversely, a short circuit lowers the coupling energy and the kinetic reserve leading to a collapse of power transmission (right).

Deriving reliability indicators (Patent FR 11 61087) ARMINES/Schneider electric

Reliability criteria

- The reserves are associated to two indicators H_{cin} H_{mag} ensuring system reliability
  - magnetic reserve : transmission maintenance ;
  - kinetic reserve : frequency maintenance.
- They refer to **dynamic properties** of the installed capacities, each contributing to the reserves level in a specific way

☞ **The higher the reserves, the more reliable the system is.**

The values of H_{cin} H_{mag} characterize the level of reliability as :

the time you have to recover the stability of the system after a load fluctuation (equivalent to the whole system capacity) by monitoring its reserves.

Assessed Scenarios for the French Power System

Scenarios	CO_2 Constraints	Elastic Demand	Nuclear Status	Common assumptions
BAU	**ETS tax**	**Reference**	Maintained	**Prices** WEO 2010
PROGt1	**taxe ETS**	**yes**	Progressive Withdraw	**Demand** reference TSO (RTE)
PROGv1	**ETS tax + cap BAU**	**yes**	Progressive Withdraw	
FASTt1	**ETS tax**	**yes**	Fast Withdraw	Variable **exports** 40 to 50 €
FASTv1	**taxe ETS + + cap BAU**	**yes**	Fast Withdraw	

Nuclear as a zero-emission solution

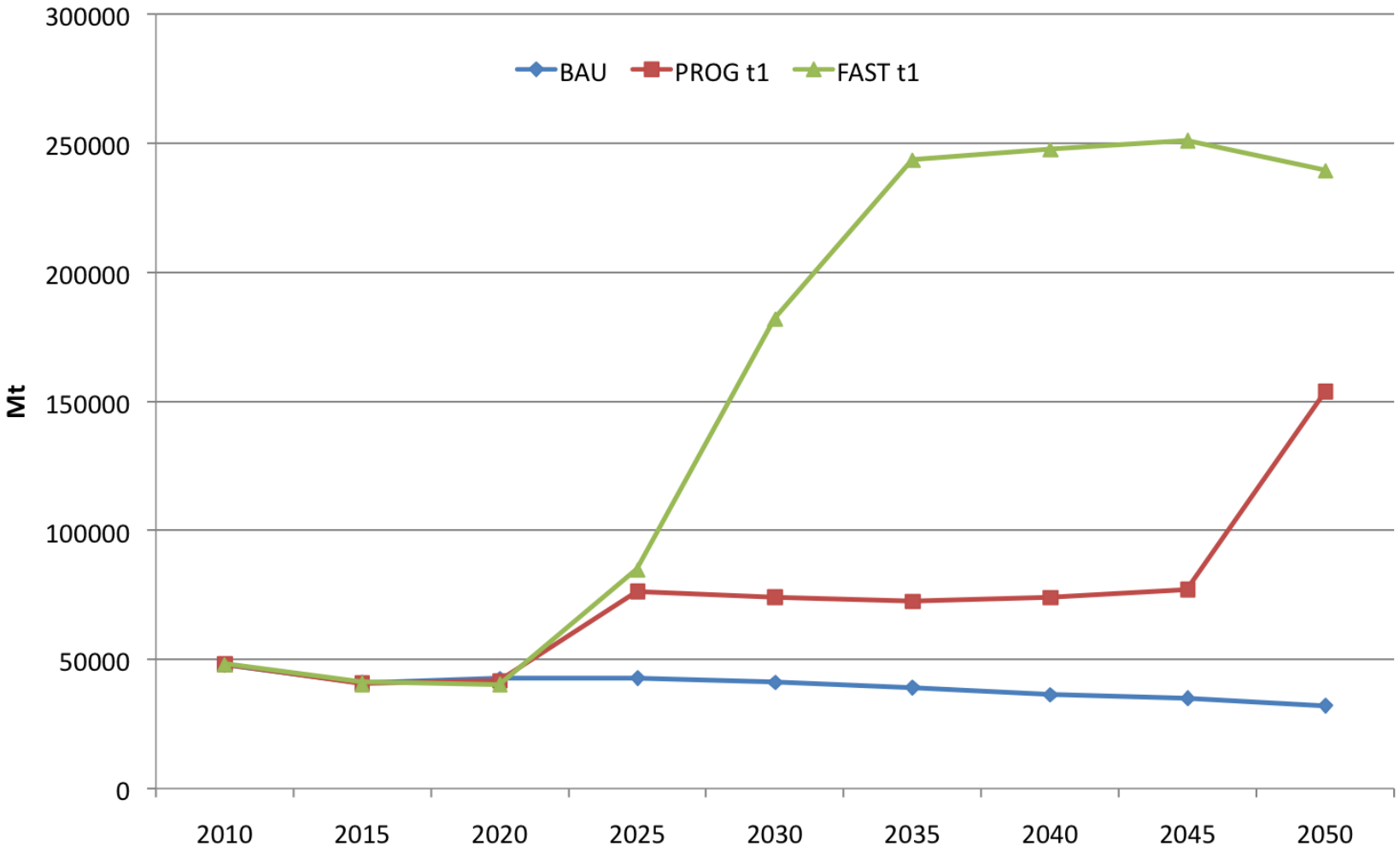


Figure: Sensitivity of the CO_2 emissions of the power sector

Nuclear lifetime sensitivity analysis : tax + cap

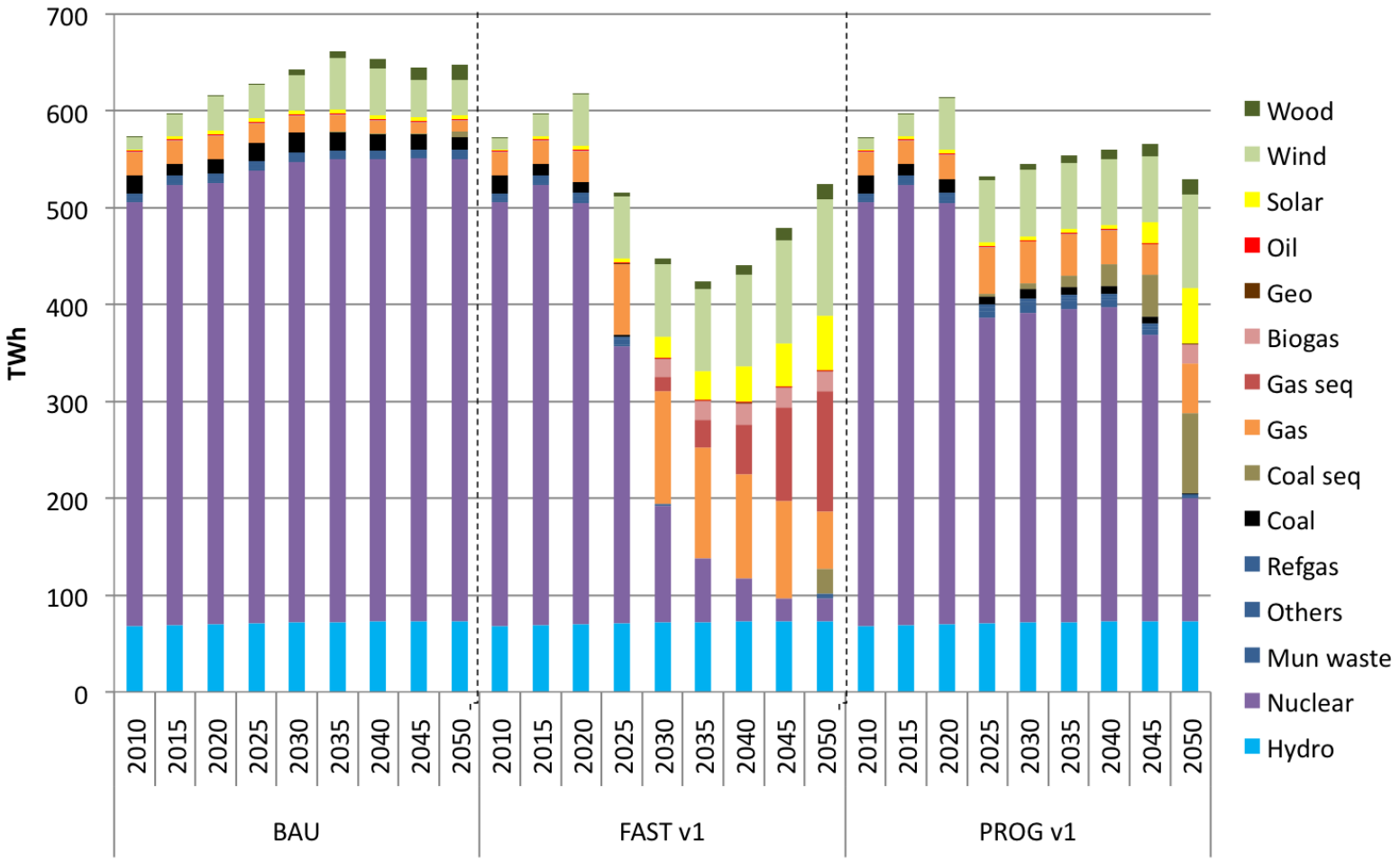


Figure: Power Mix generation (CO_2 tax + cap)

Huge investments are needed

☞ new generation capacities to secure power supply

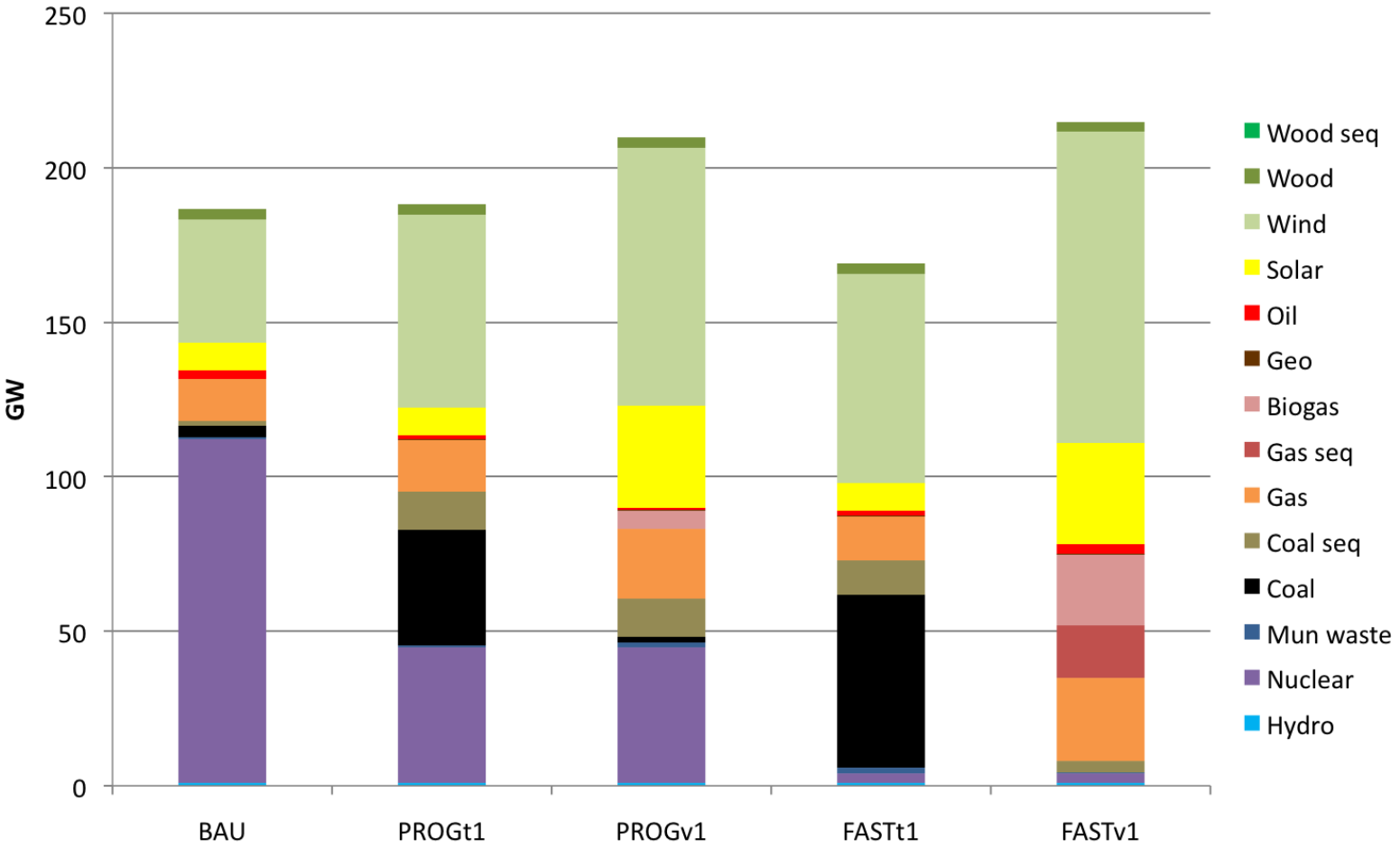
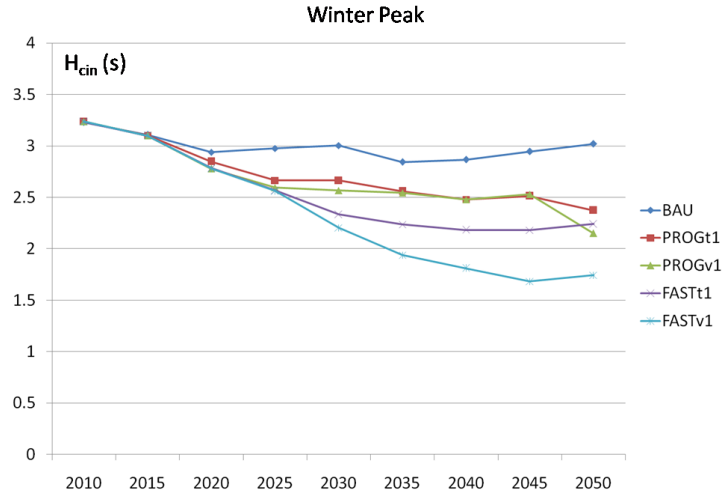
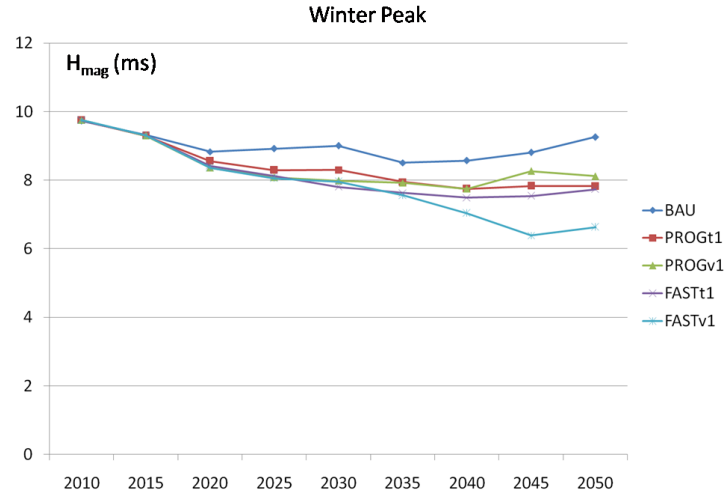


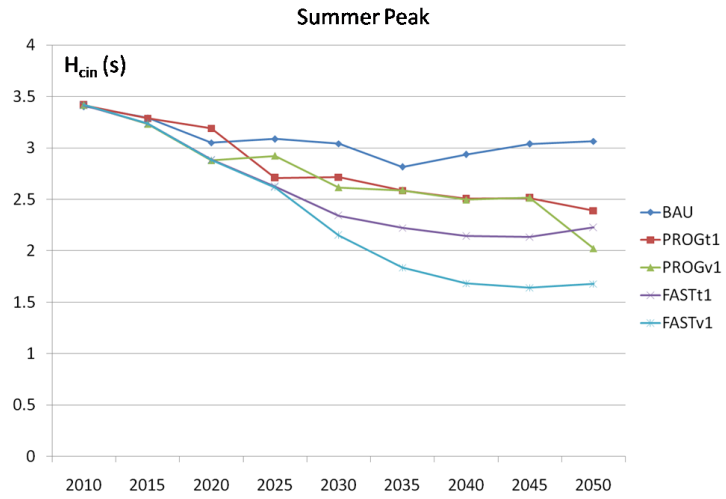
Figure: Lump sum of Power Plants Capacities (with extended nuclear plants)

Reliability of the assessed scenariis

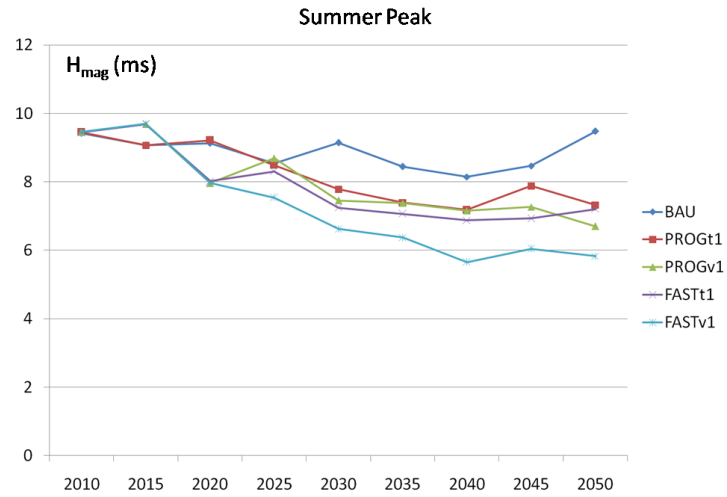




Kinetic Reserves



Magnetic Reserves



Carbon Issue and Energy Efficiency

M. Thiboust, V. Mazauric, S. Selosse

By 2030, energy efficiency and behaviour change will offset more CO2 than all the new wind, solar, and other alternative energy generation methods combined

Source: IEA : World Energy Outlook 2009

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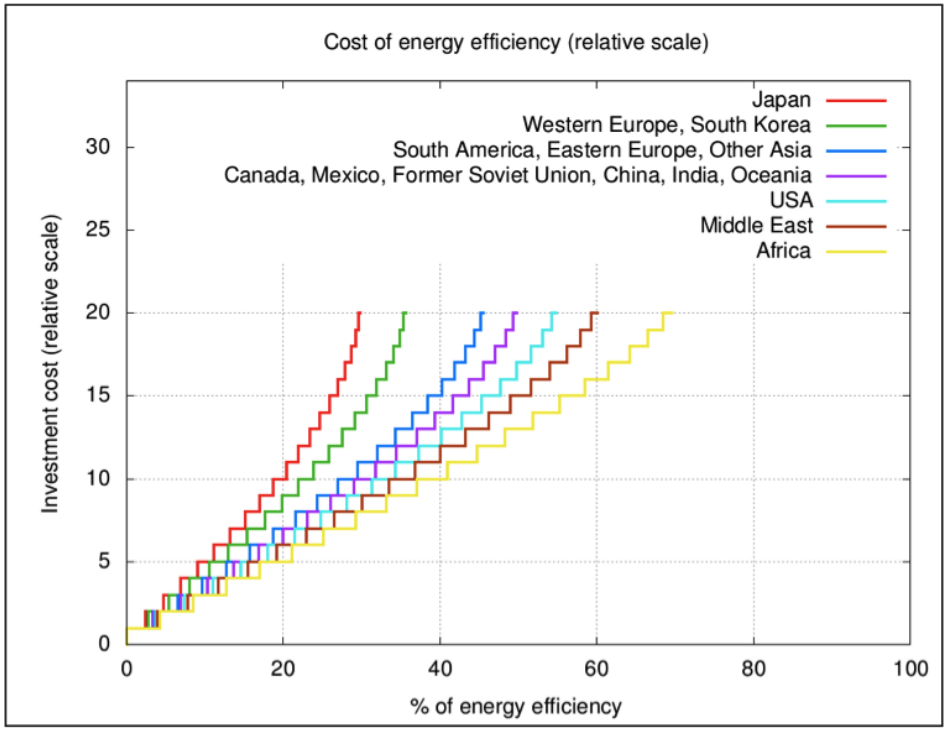
Assesing the impact of Energy efficiency

Energy efficiency with respect to TIMES model

- endogenous efficiency : embedded in new technology features
- exogenous efficiency : through system solutions and EE technologies enhancing existing technologies



Energy efficiency solutions : business opportunities

☞ Do Low-carbon policies foster Energy Efficiency solutions ?

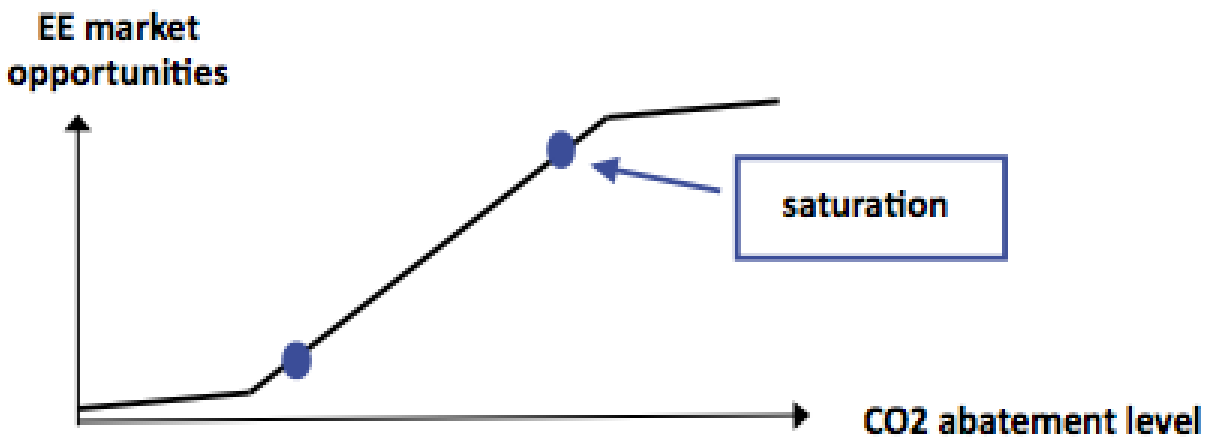


Figure: Carbon and EE trends

Impact of climate policy on EE needs

☞ Low sensitivity in China, High sensitivity in US and Europe

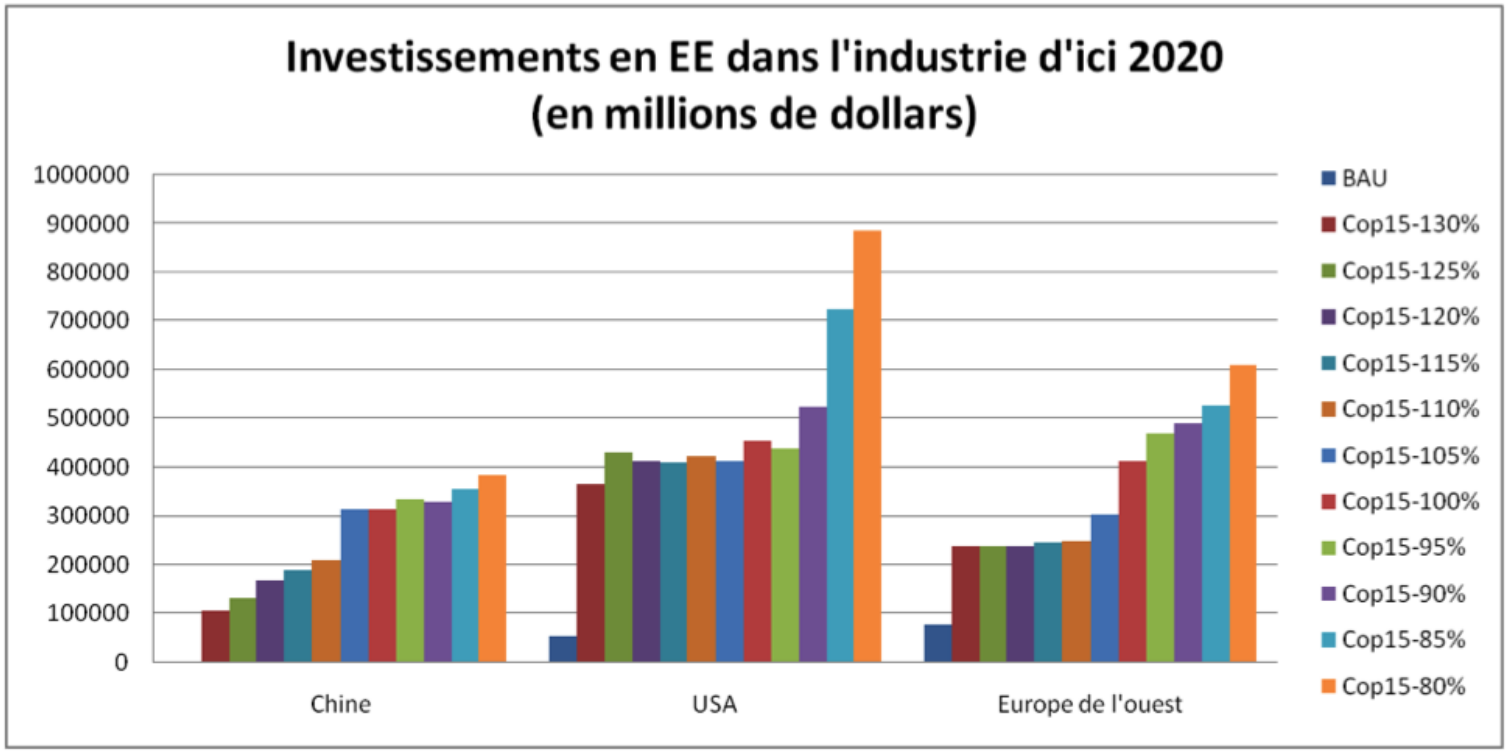


Figure: Exogenous Energy efficiency market opportunities for the industrial sector

Seeking for Plausibility and Relevance

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Long term scenariis and technical plausibility

In order to cope with environmental issues, some technological options are highly recommended :

Strategic factors impact technical feasibility and relevance of future low-carbon power mix

1. **Water** as an output commodity and as a constraint
2. **Level of reliability** of an assessed power mix system
3. **Impact of climate constraints** on Exogenous energy efficiency needs

☞ **Following this approach**

Smart grid options and Smart cities issues are discussed

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Web Site

http://www.modelisation-prospective.org/index

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