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Following the trend or changing the french paradigm?: future prospects for nuclear power in France

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UNFCCC ParisTech Side Event

Combating climate change with or without nuclear power

French paradigm

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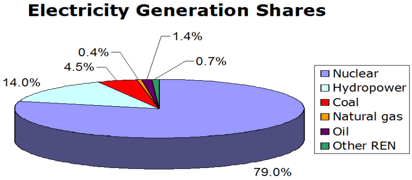
French electricity generation sector

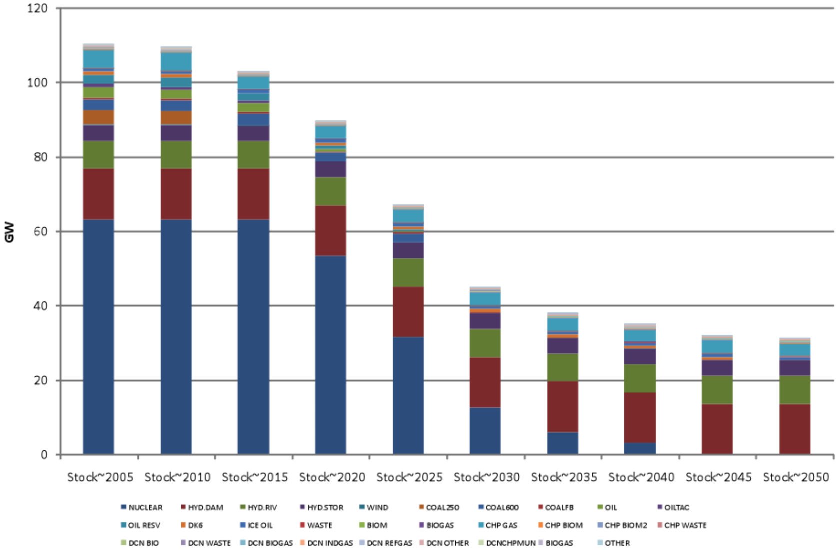
☞ dominated today by nuclear power

Installed Capacities 1/1/2011	thermal nuclear	thermal fossil	thermal Ren	Hydro power	wind power	Solar PV
(GW)	**63.1**	**27.1**	**1.2**	**25.2**	**5.8**	**0.9**



~ 500 TWh : Global production
~ 400 TWh : Nuclear thermal production (80%)
~ 30 TWh : Classical thermal production (coal and fioul)

Nuclear power replacement is the main driver for the future



Replacement of nuclear existing capacities

Fukushima triple disaster has opened the debate

- ☞ 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
  - ☞ more than 40 years submitted to ASN (french nuclear safety agency) agreement

In October 2011, The Ministry for Energy asked for a study in order to assess different options for the future nuclear power in France including **phase-out** options

France in Europe : an interconnected grid

French Net Exportation : $\sim$ 70 TWh

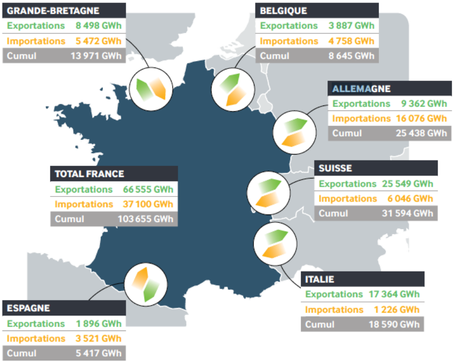


Figure : Contractual Exchanges between European borders in 2010 source RTE

Nuclear Phase out

- Germany : in 2022
- Switzerland : in 2035
- Italy : voted in 2011

Installed capacities are already reaching a critical point

Reliability issues

Missing capacities to meet the demand: foreseen in 2016

	2013	2014	2015	2016
Énergie de défaillance en espérance (GWh)	0.2	0.8	2.8	27.4
Espérance de durée de défaillance	0 h 05	0 h 22	1 h 14	8 h 50
Puissance manquante	-	-	-	2.7 GW

Figure : Reference scenario Source RTE/Bilan Prévisionnel 2011

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,. . .)

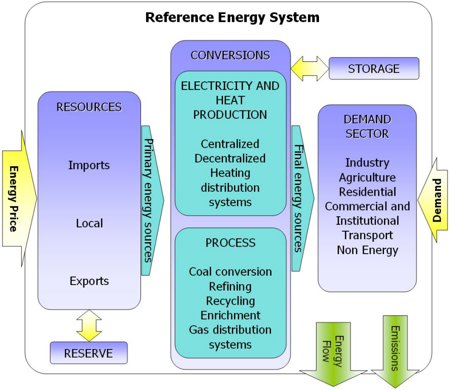

Figure : The Integrated MarkAl (market allocation)-EFOM Reference Energy System

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

Assessing the future of nuclear power for France

Three scenarios existing nuclear power plants

1. Maintain = BAU
   nuclear capacity is maintained to 65 GW (lifetime of existing capacities extended to 60 years and replaced when needed)
2. Progressive Phase-out= PROG:
   lifetime of existing capacities limited to 40 years for one plant over two; the others are extended to 60y with a cost of 600Billions€/plant
3. fast phase-out = FAST: lifetime limited to 40 years

Nuclear residual capacities according to three options

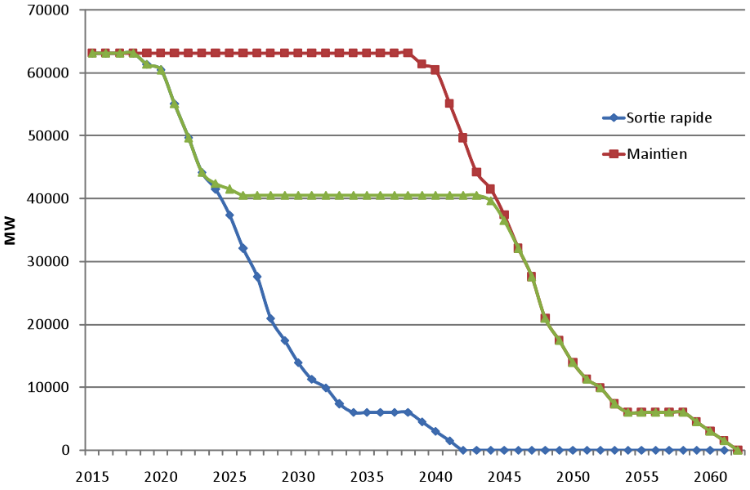

Figure : FAST (lifetime 40y) PROG (lifetime 40y to 60y) BAU (lifetime 60y)

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**
PROGv1	**ETS tax + cap BAU**	**yes**	Progressive Withdraw	reference TSO (RTE)
FASTt1	**ETS tax**	**yes**	Fast Withdraw	Variable **exports** 40 to 50 €
FASTv1	**taxe ETS + + cap BAU**	**yes**	Fast Withdraw	

Prospective analysis of the results
. . . at face value

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Nuclear lifetime sensitivity analysis

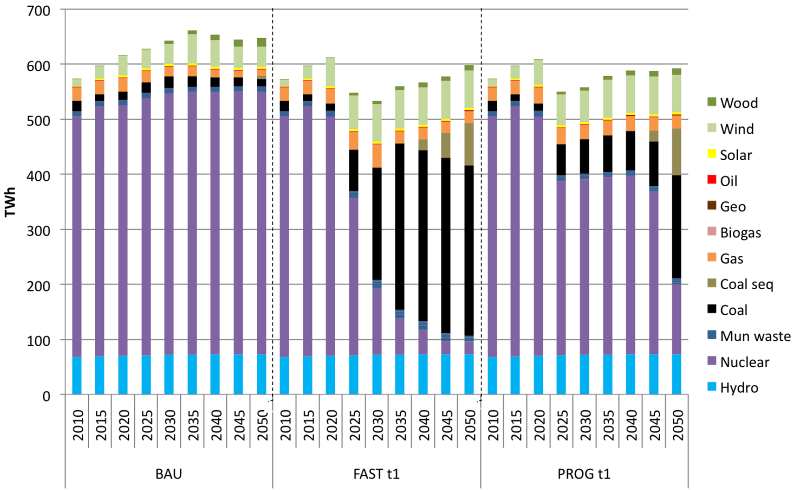

Figure : Power Mix generation (CO_2 tax)

Nuclear as a zero-emission solution

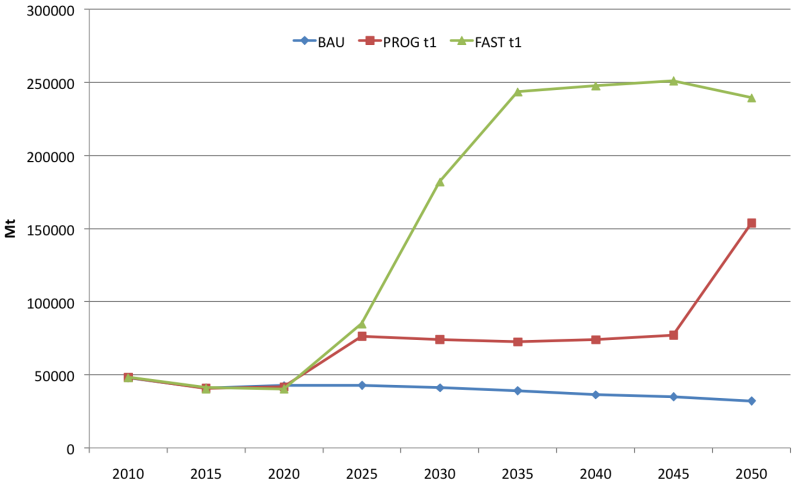

Figure : Sensitivity of the CO_2 emissions of the power sector

Nuclear lifetime sensitivity analysis : tax + cap

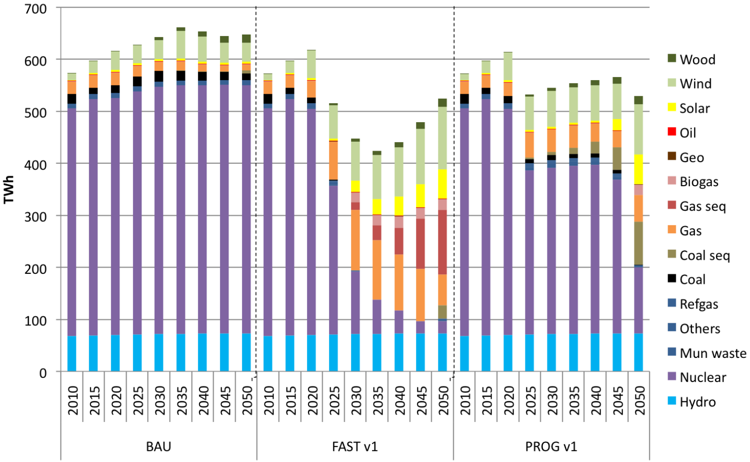

Figure : Power Mix generation (CO_2 tax + cap)

Huge investments are needed

☞ new generation capacities to secure power supply

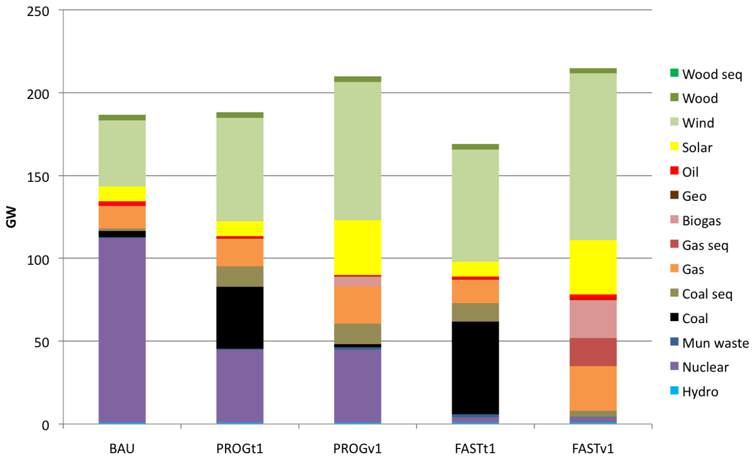

Figure : Lump sum of Power Plants Capacities (with extended nuclear plants)

New capacities Investments to maintain 65 GW

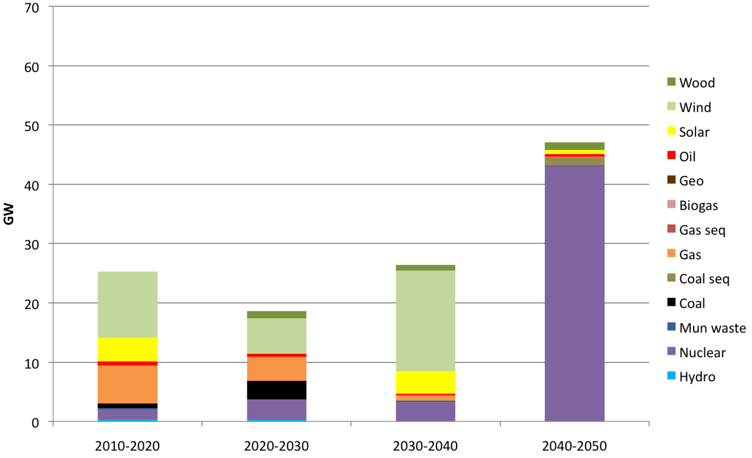

Figure : New installed capacities BAU

New capacities Investments for a fast phase-out

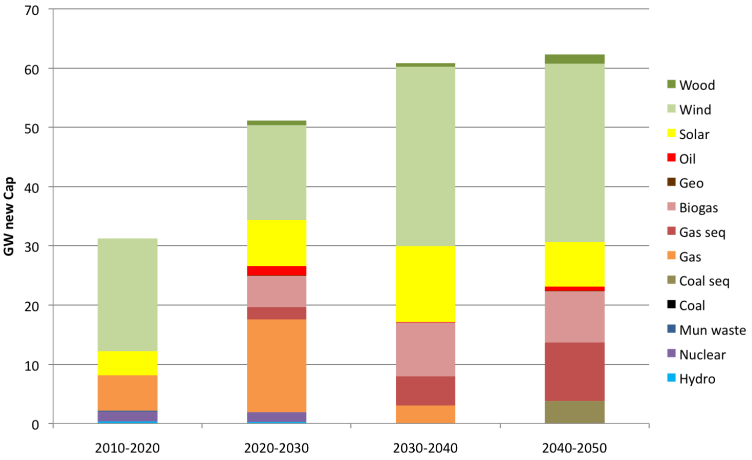

Figure : New installed capacities FASTv1 (lifetime 40y, tax + cap)

France net exportations are always decreasing

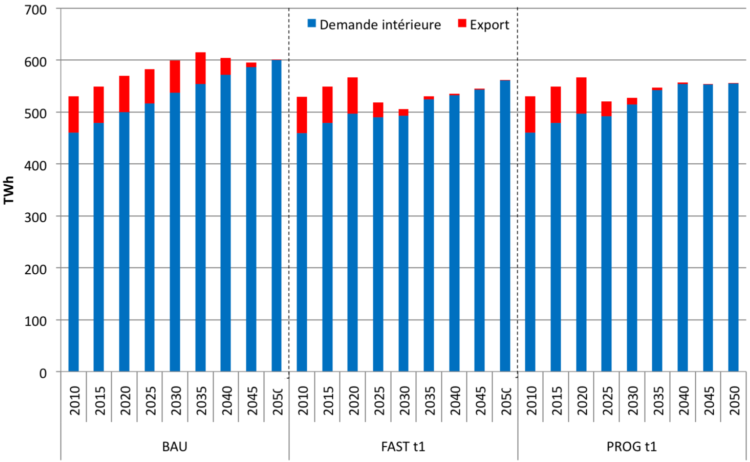

Figure : Exports/Domestic demand (CO_2 tax)

France net exportations are always decreasing

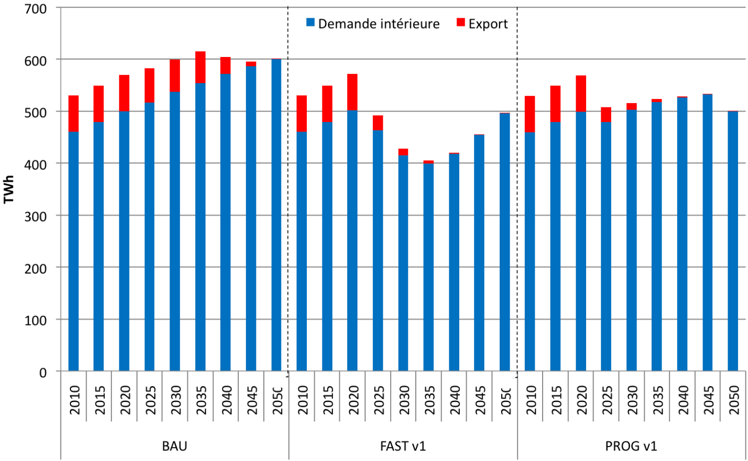

Figure : Exports/Domestic demand (CO_2 tax + cap)

Beyond the classical results: 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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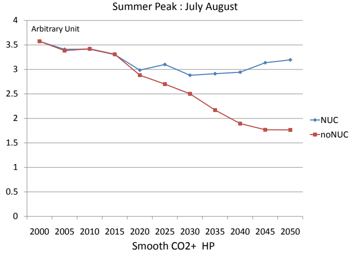
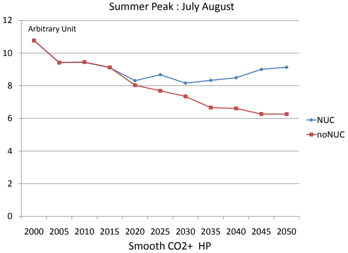
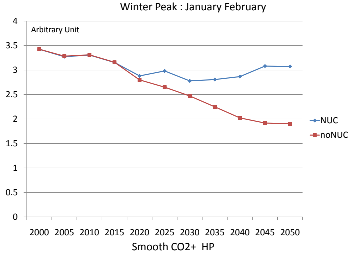
Reliability robustness of the power mix : nuclear sensitivity

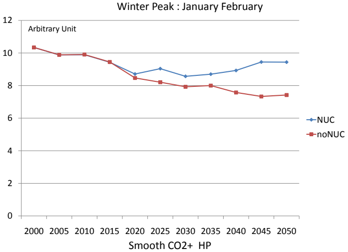




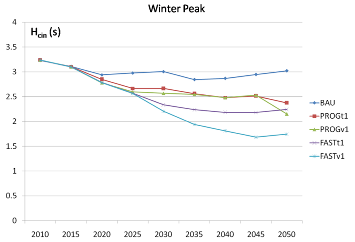
Kinetic reserves

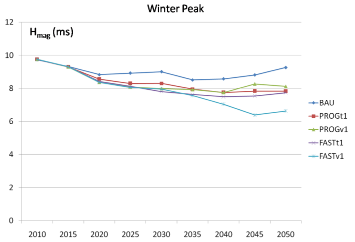
Magnetic reserves





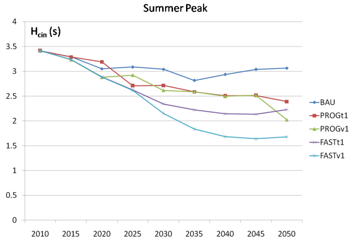
Kinetic and magnetic reserves for peak periods

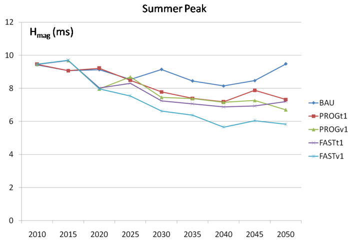




Kinetic Reserves

Magnetic Reserves





Changing the paradigm, from power mix to consumer

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Consumption, Consumers : the key issues I

1. In order to cope with climate mitigation issues, some technological options are highly recommended and the discussion opposes renewable energy and nuclear supporters;
2. the main outcome of the study delivered to the french Ministry of Energy as it was related by journalists was the recommendation to extend nuclear power plant lifetime to 60y;
3. technical issues such as reliability level might be part of the debate as they give insights about feasibility and relevance of future power mix;

Consumption, Consumers : the key issues II

Beyond technical issue, reliability also speaks about

quality of supply

the load profile

level of supply

that refer to the end of the chain : consumption usage and requirements.

A balance between reliability issue and the spread of renewable energies is required but it has to be related to consumer needs which must be at the center of the debate.

Contact

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Web Site

http://www.modelisation-prospective.org/index_en.html

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Prices and Carbon Tax Assumptions

☞ Final electricity consumption forecast 2050 = Demand scenario forecast (Source: RTE (french TSO)/BP July 2011.)
☞ Fix Carbon Tax 20 €/T according to ETS levels
☞ Fossil ressources prices : WEO 2010

unit		**2010**	**2020**	**2030**	**2040**	**2050**
\$/tep	oil	60.4	99.0	110.0	117.2	125.2
\$/MBTU	gas (EU)	7.4	11.6	12.9	13.8	14.9
\$/tonne	coal	97.3	101.7	105.6	107.7	110.0

Nuclear lifetime sensititivity : new capacities

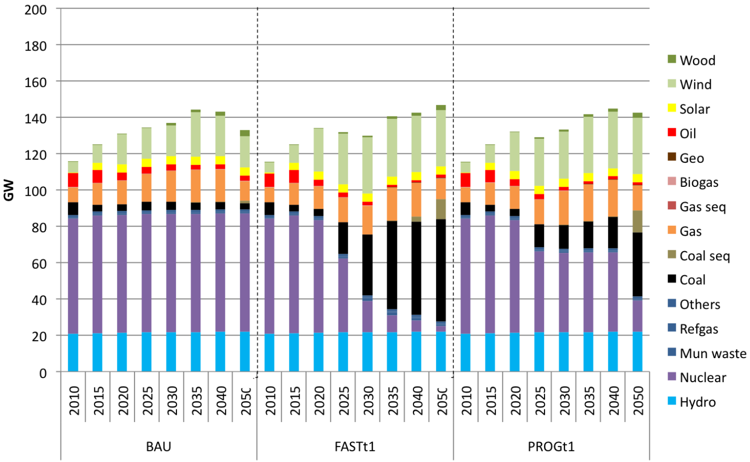


Figure : Capacities (CO_2 tax)

Nuclear lifetime sensititivity

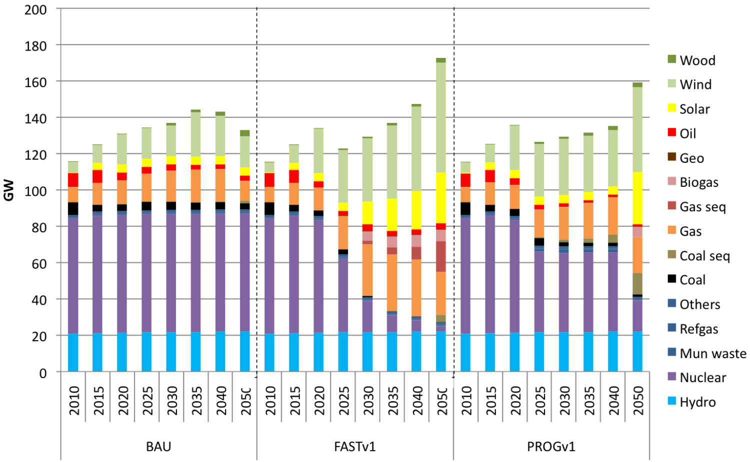


Figure : Capacités (CO_2 tax + cap)

New installed capacities (without extended nuclear plants)

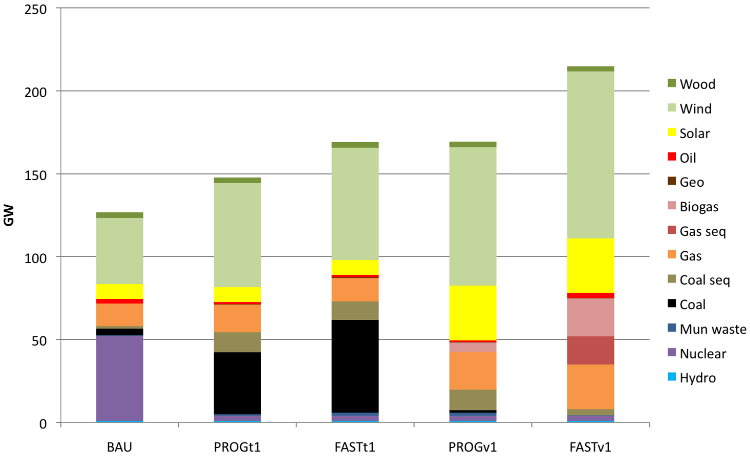


Figure : New installed capacities

Objectif function for TIMES-FR restricted to the power sector

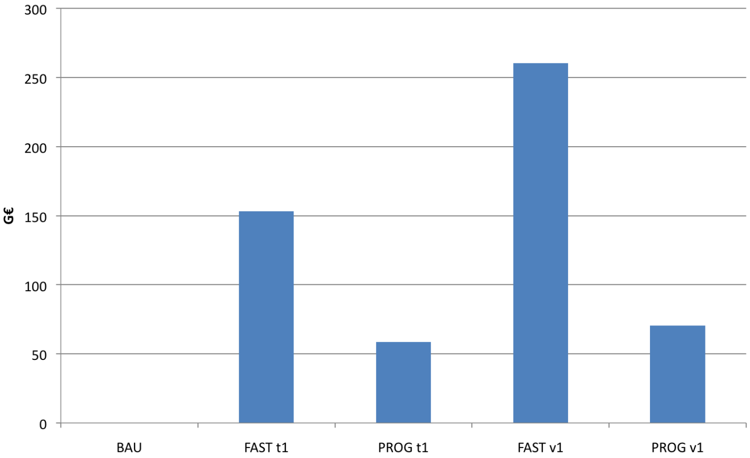
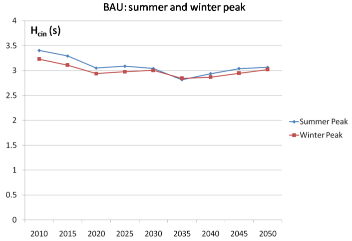
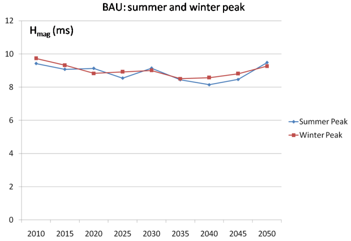


Figure : Overcost total actualised cost (in 2011) as compared to BAU

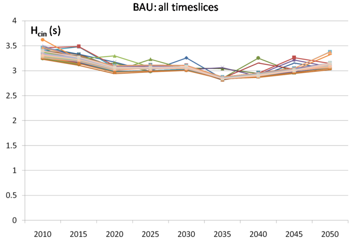
Sensitivity analysis of reliability issues

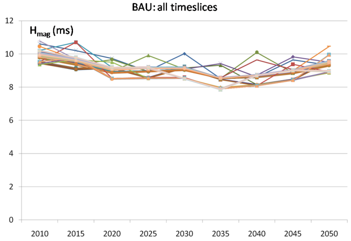




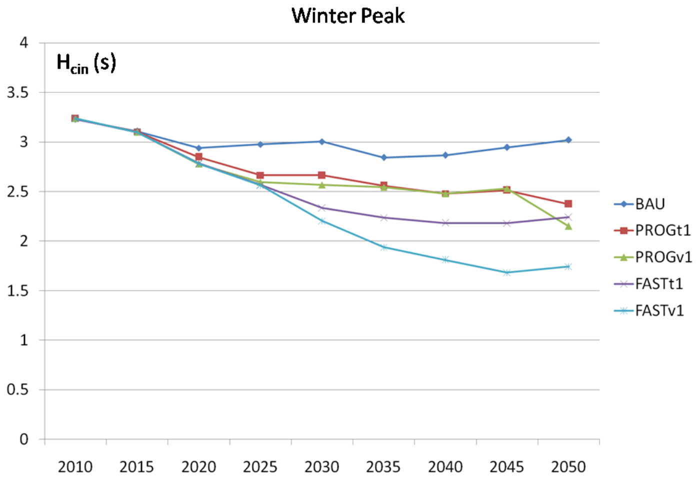
Kinetic Reserves

Magnetic Reserves





Reliability : kinetic reserve for winter peak



Reliability : magnetic reserve for winter peak