Chaire Modélisation prospective
au service du développement durable

Future challenges for the french power generation paradigm : reliability versus low carbon issues ?

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Overview of the French electricity generation sector

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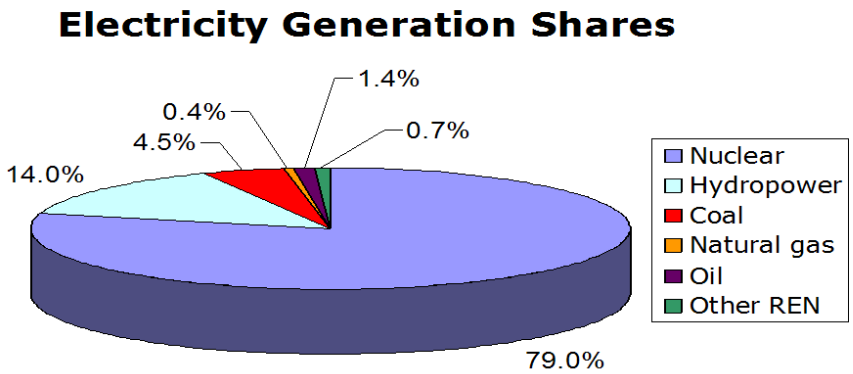
French electricity generation sector

☞ 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**

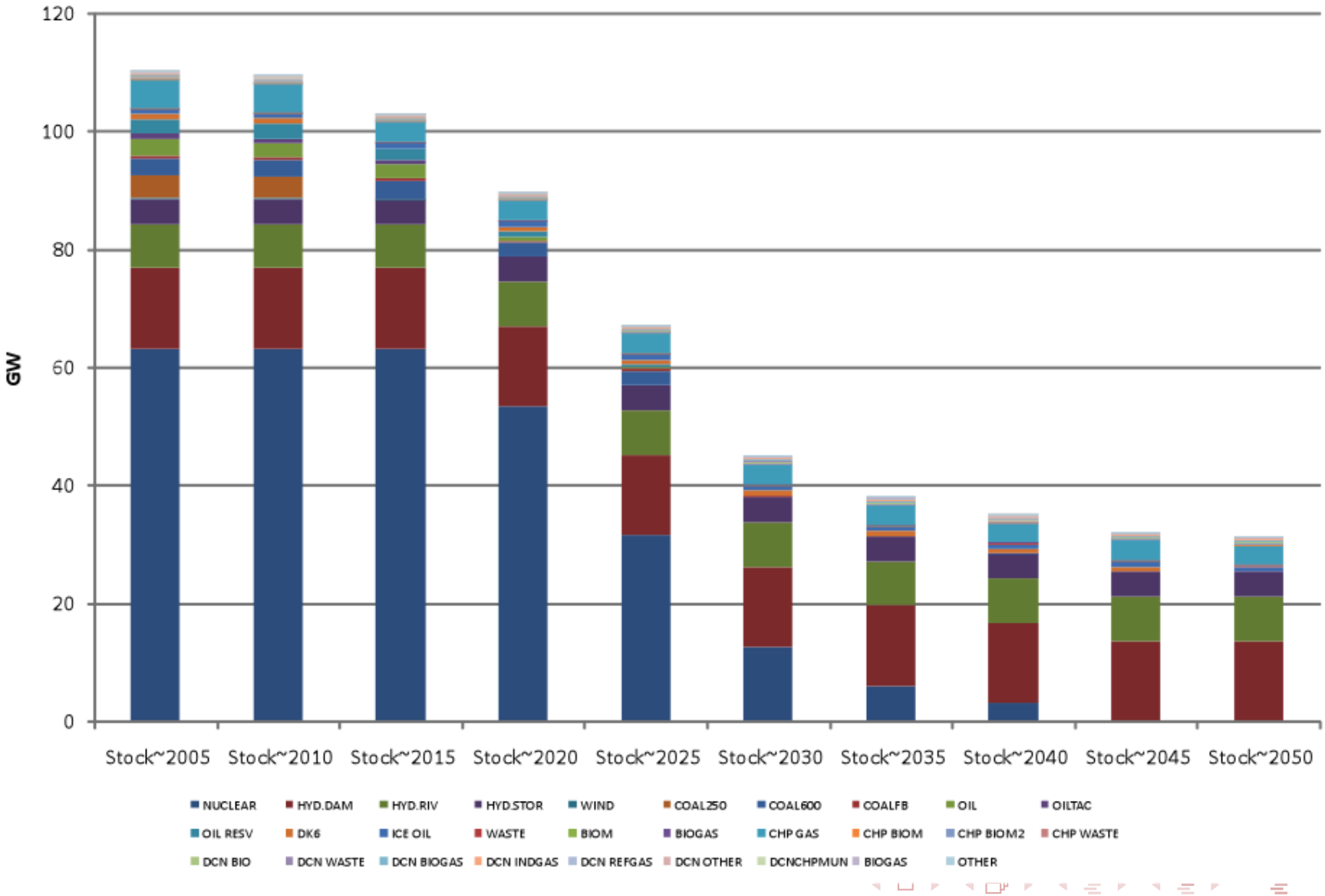


~ 500 TWh : Global production

~ 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 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

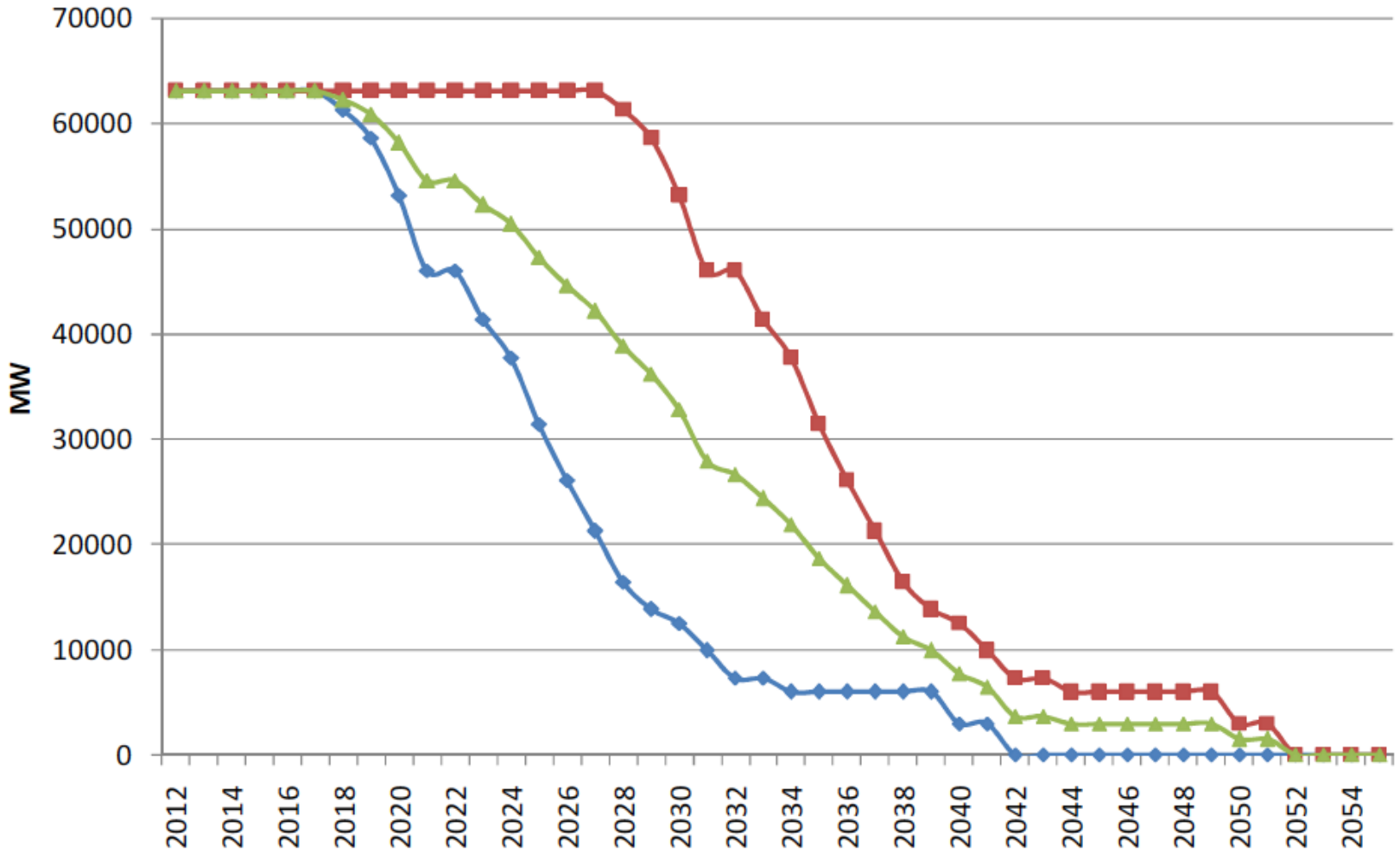
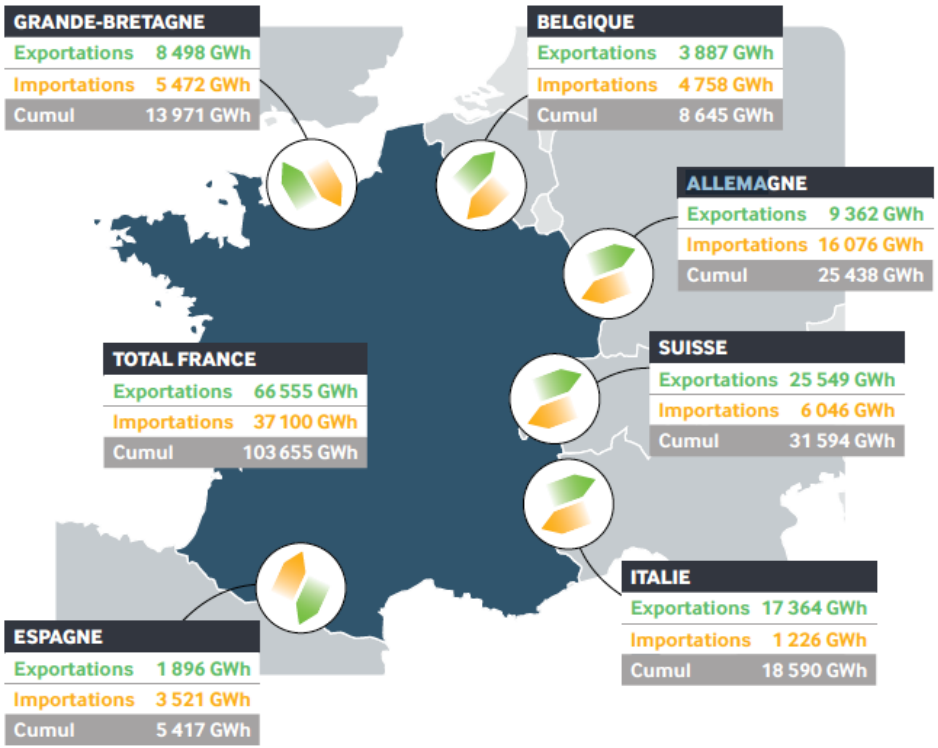


Figure: Residual installed capacities : lifetime 40 years Smooth 60 years

France in Europe : an interconnected grid

French Net Exportation : ~ 70 TWh



Nuclear Phase out

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

Figure: Echanges contractuels transfrontaliers en 2010 source RTE

Following the trend or changing the paradigm ?

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Competitions, substitutions and technical issues

The MARKAL/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)

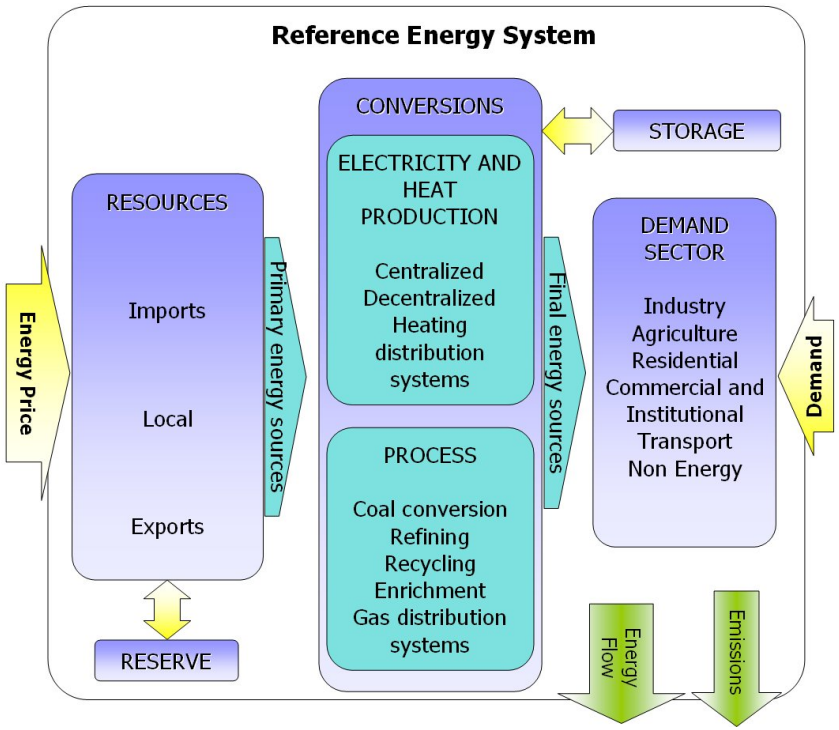


Figure: Reference Energy System

Demand Scenarios

Final electricity consumption forecast 2050

☞ **Demand scenario forecast** Source: RTE/BP July 2011.

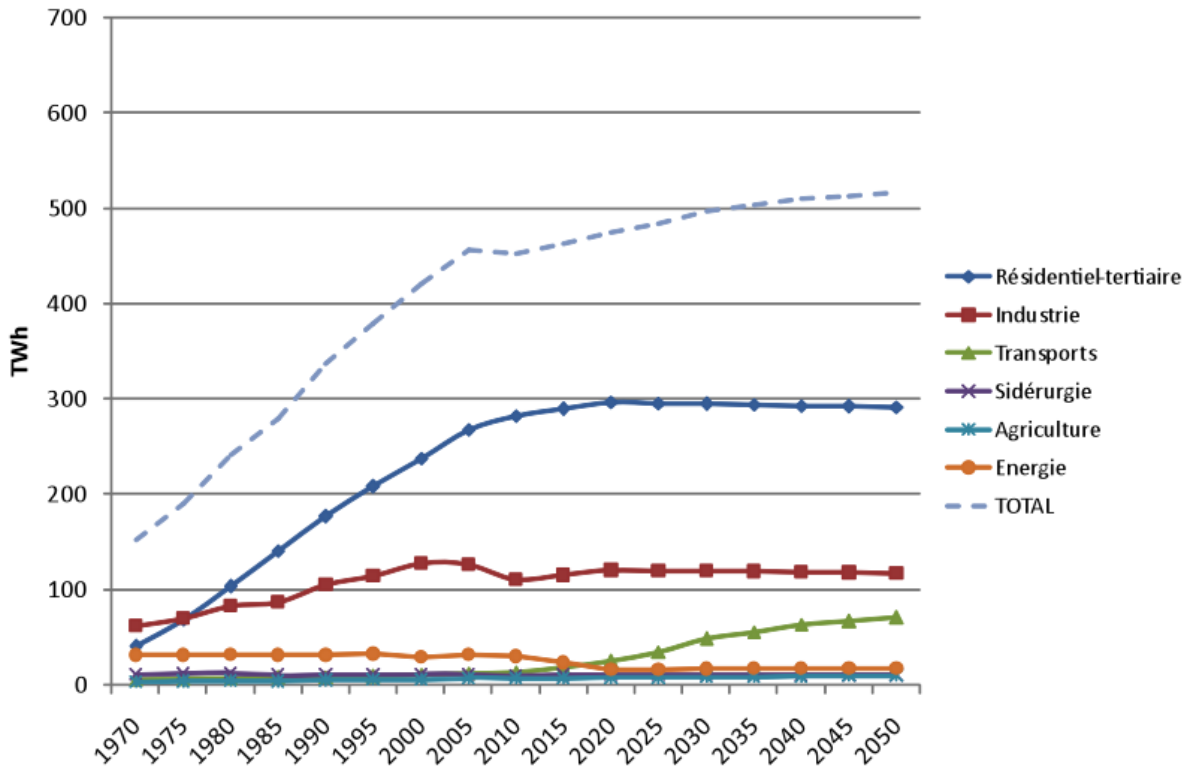
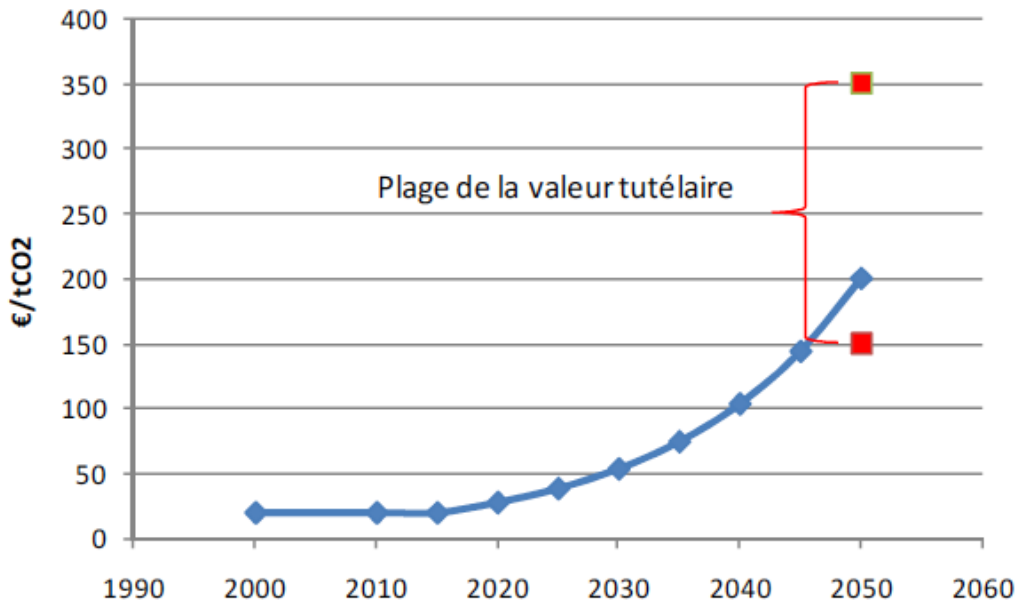


Figure: DSM enforced scenario

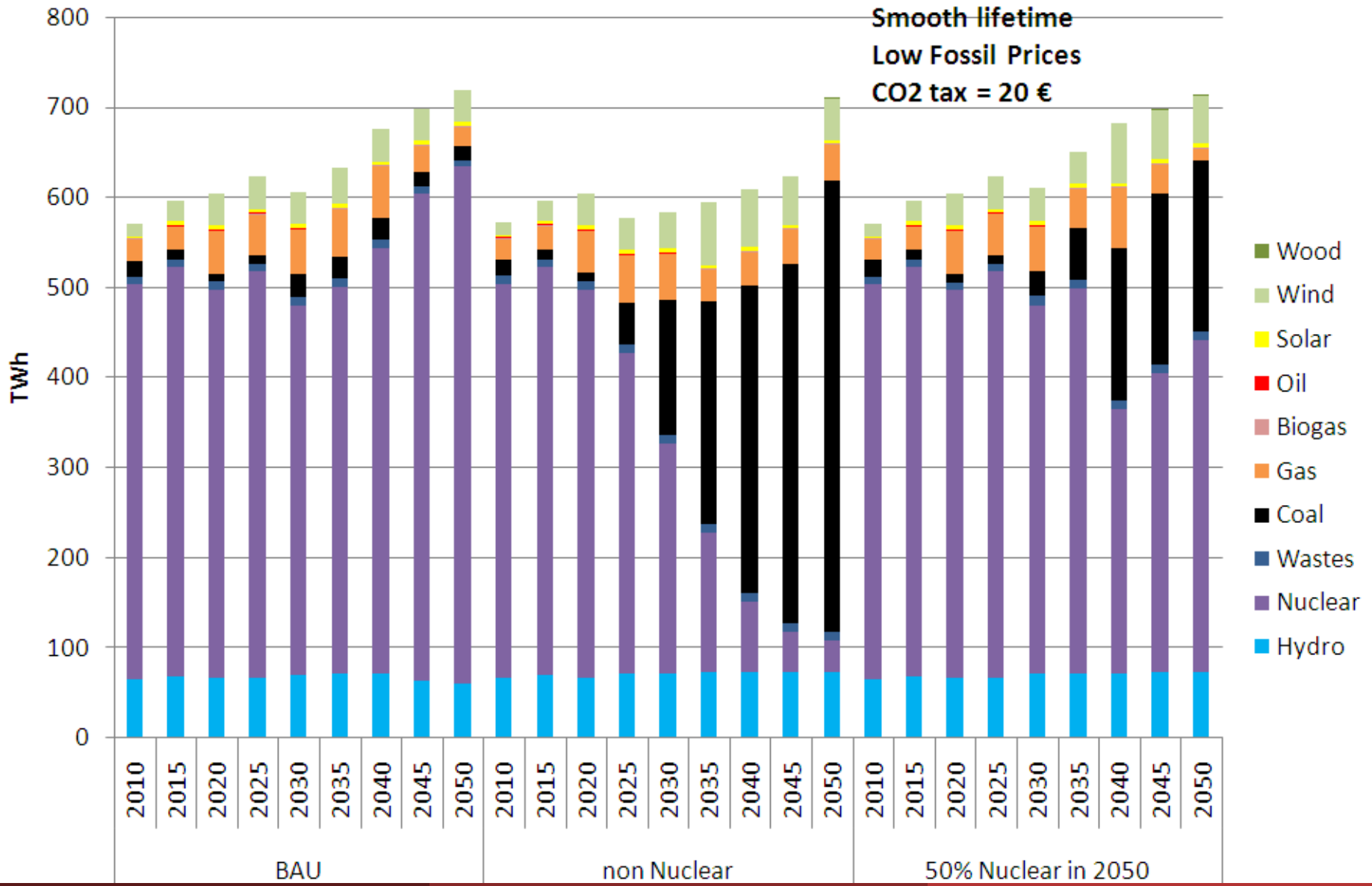
Environmental constraint : tax assumptions

CO_2 Taxes

1. Low Tax CO2 = fix tax 20 euros/T
2. High Tax CO2+ = profile varying from 20 euros/T to 200 euros/T Quinet 2008



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



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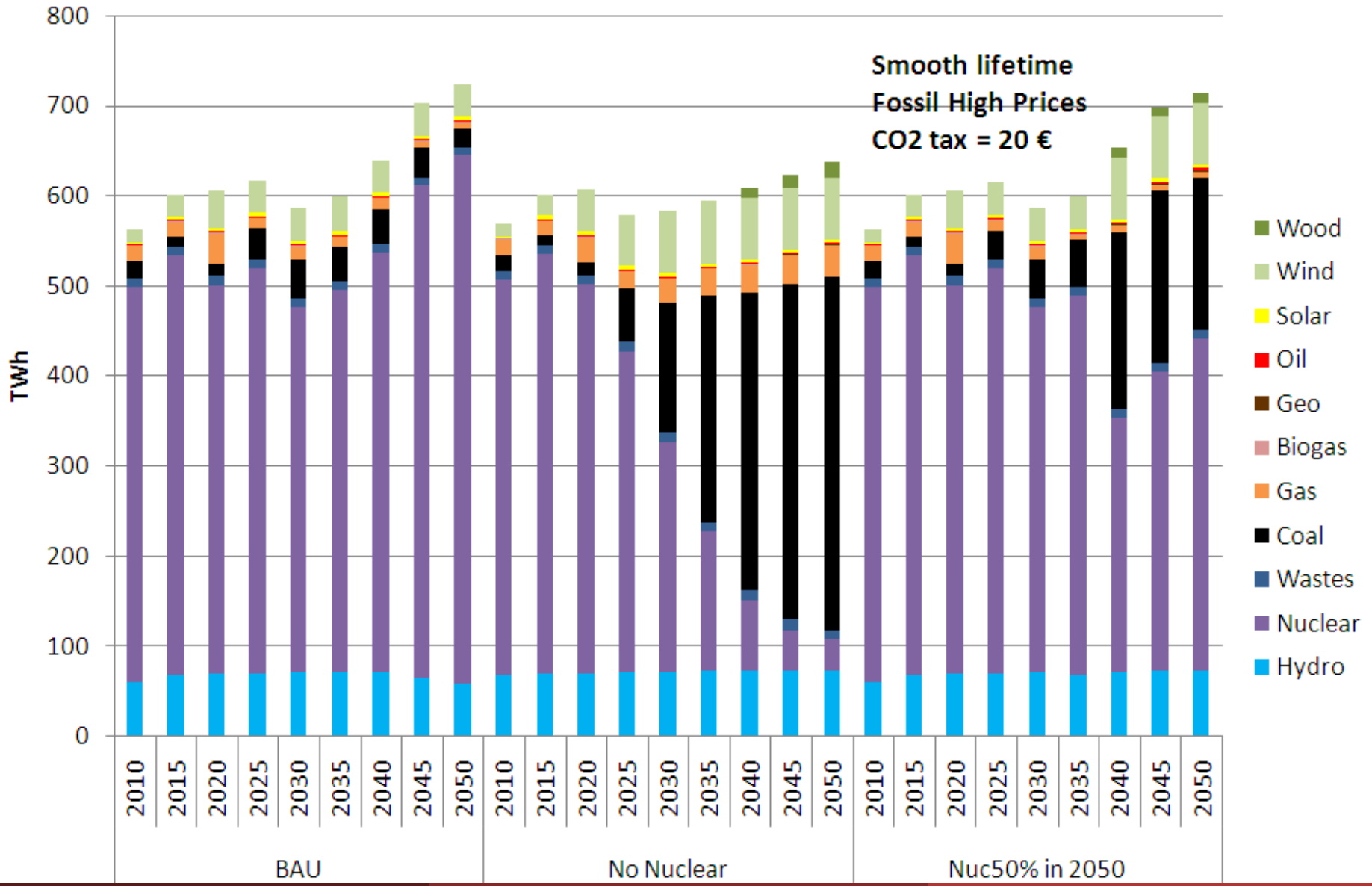

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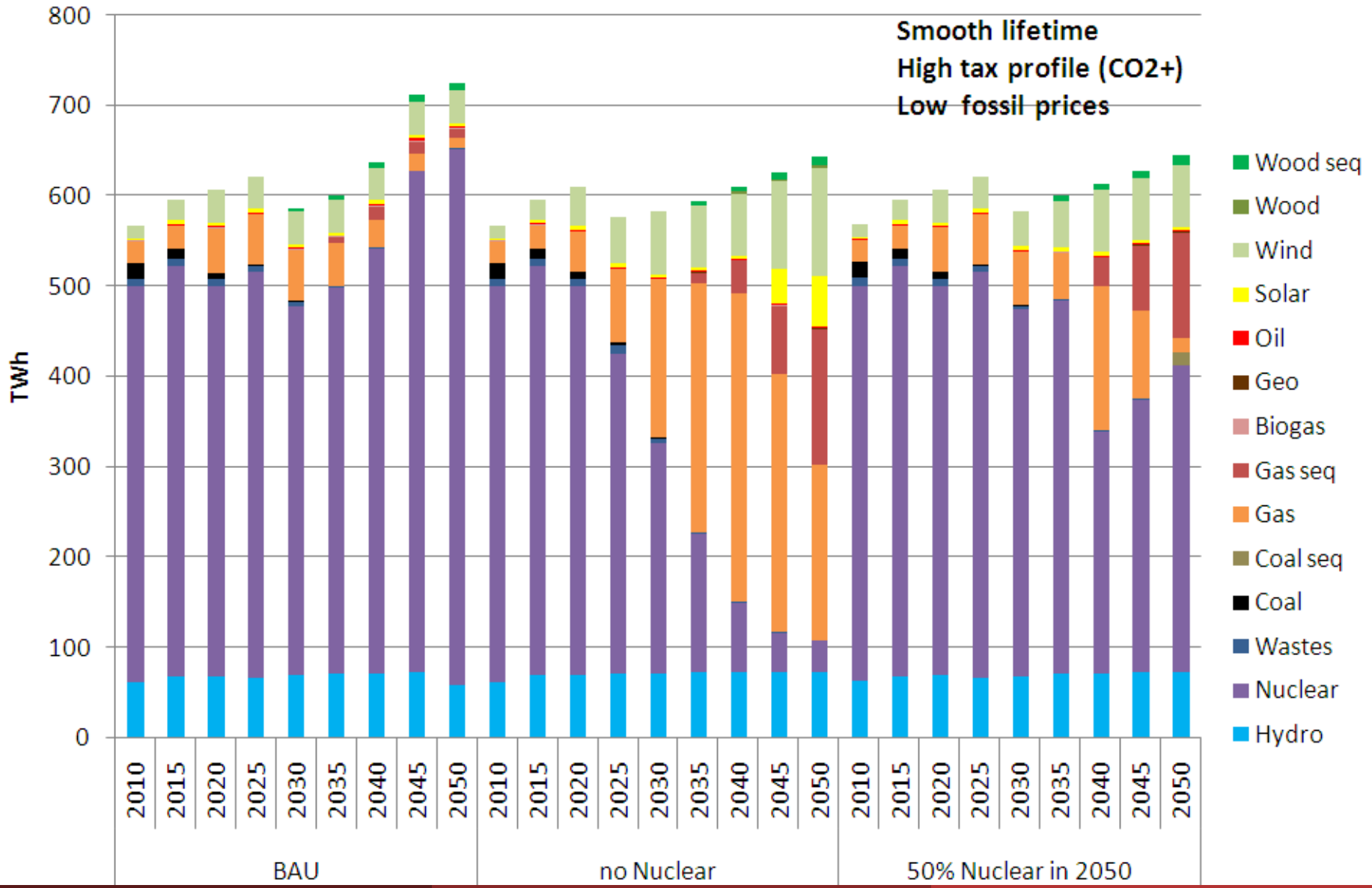

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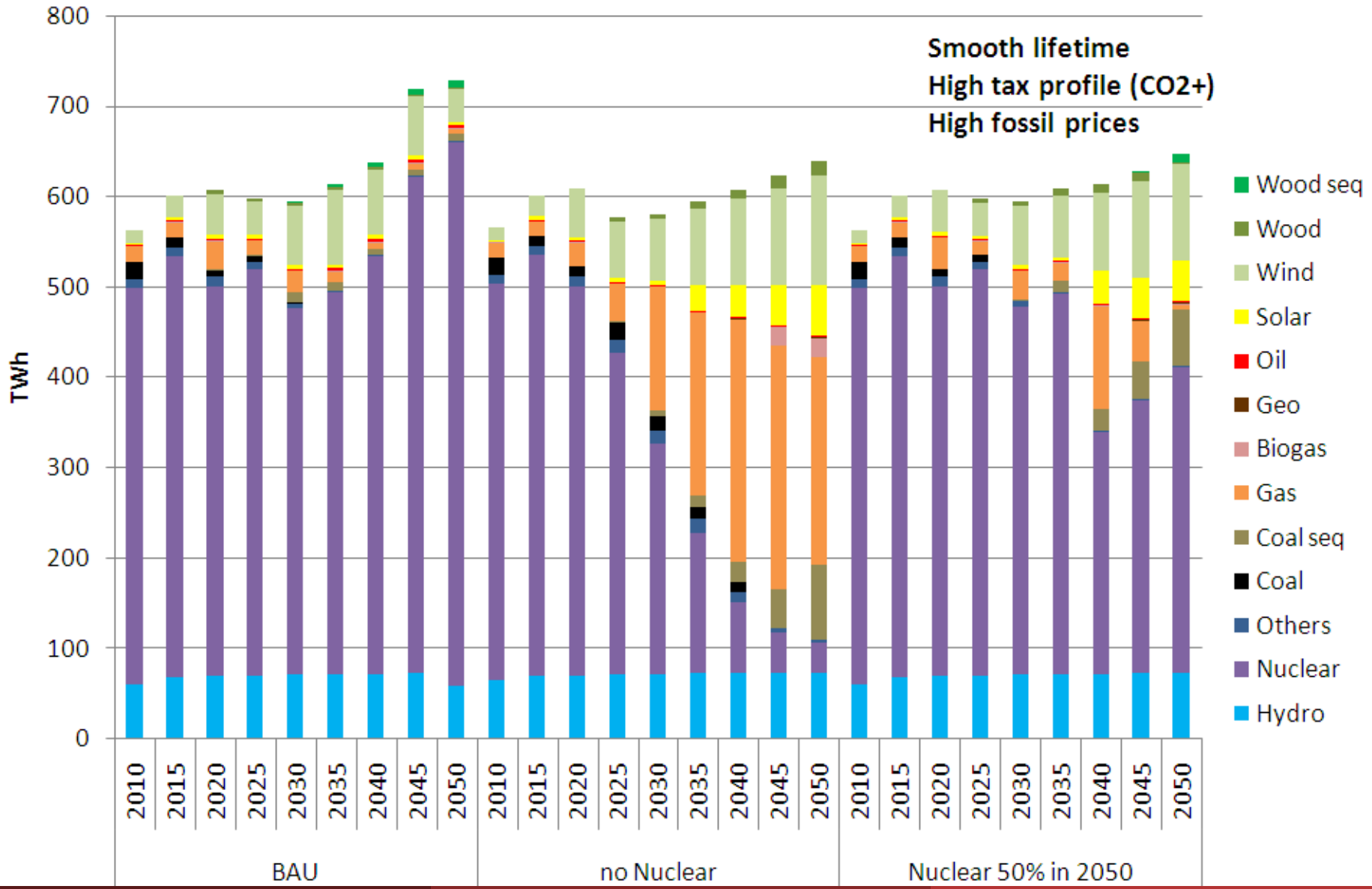
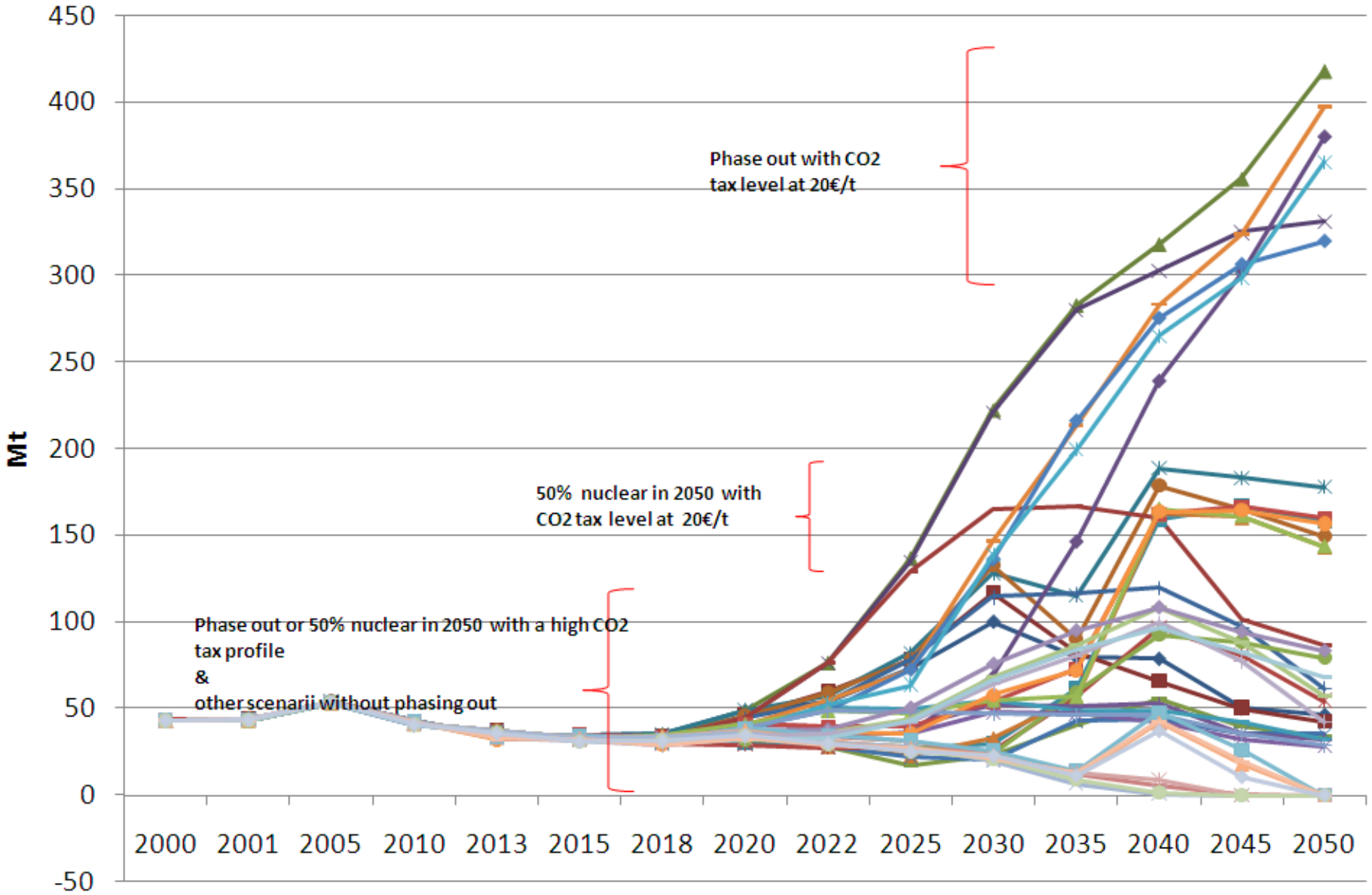


Environmental issues : low carbon scenarios



Future power mix : technically plausible and reliable ?

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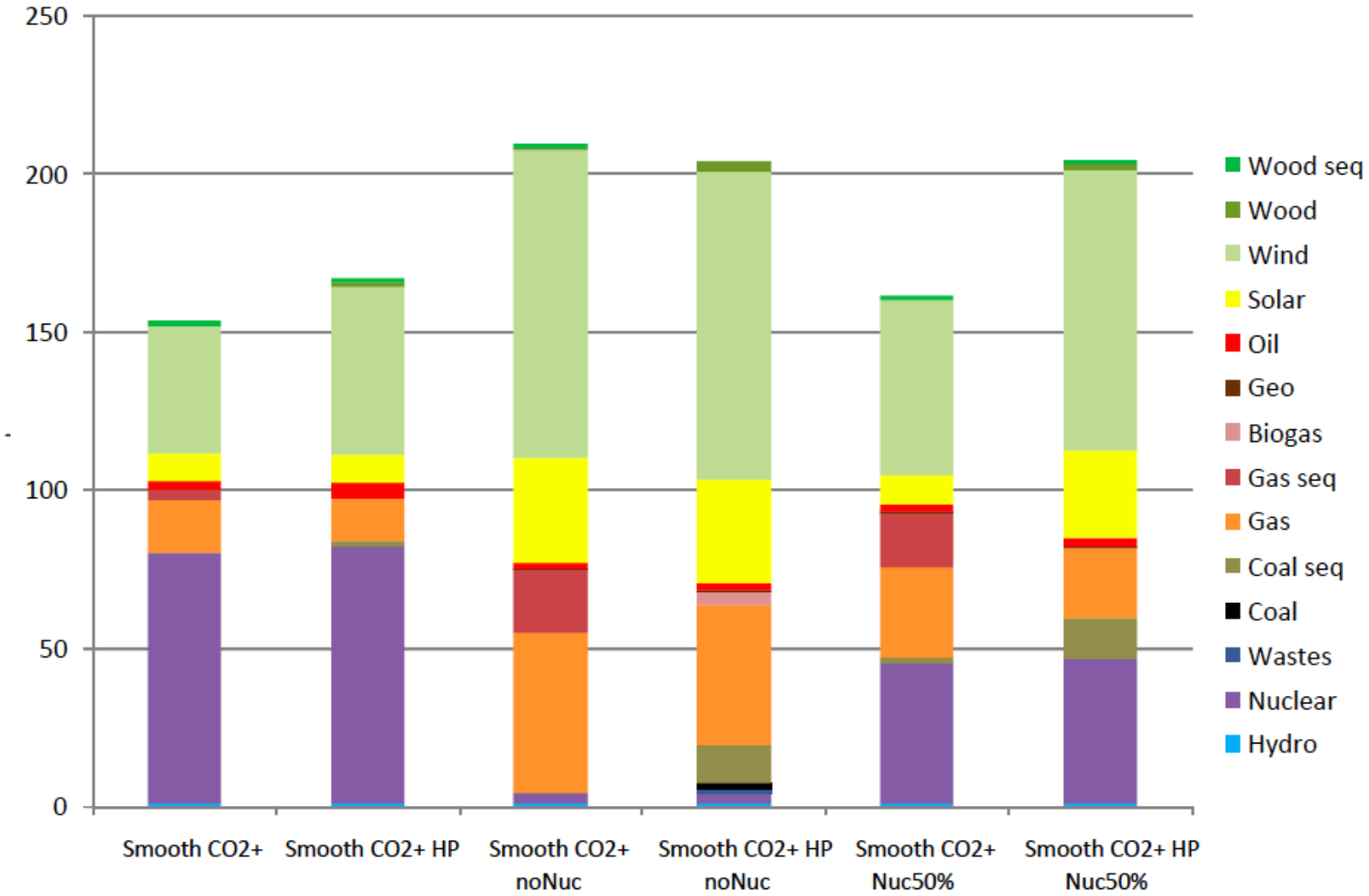
Huge investments are needed

☞ new generation capacities to secure power supply



Stakes and Opportunities for the industry

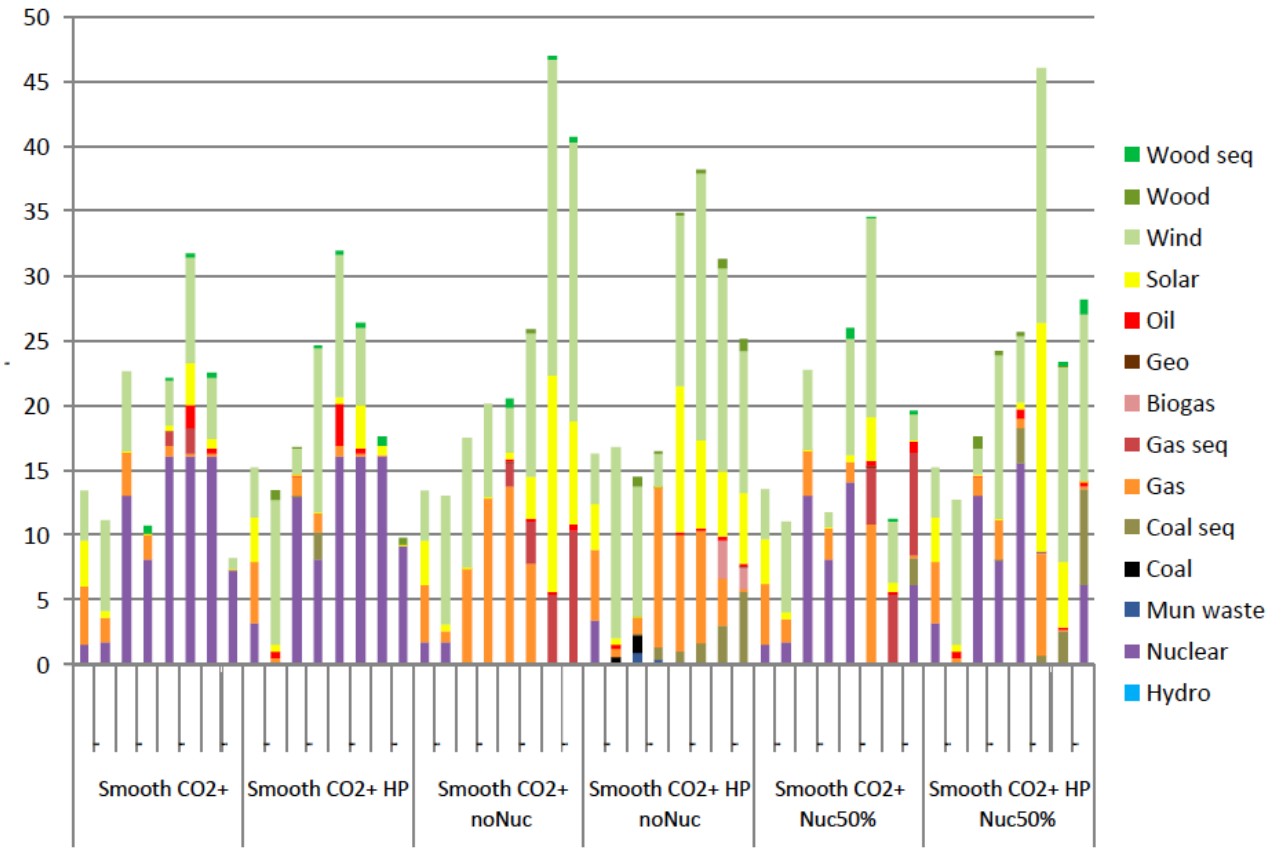
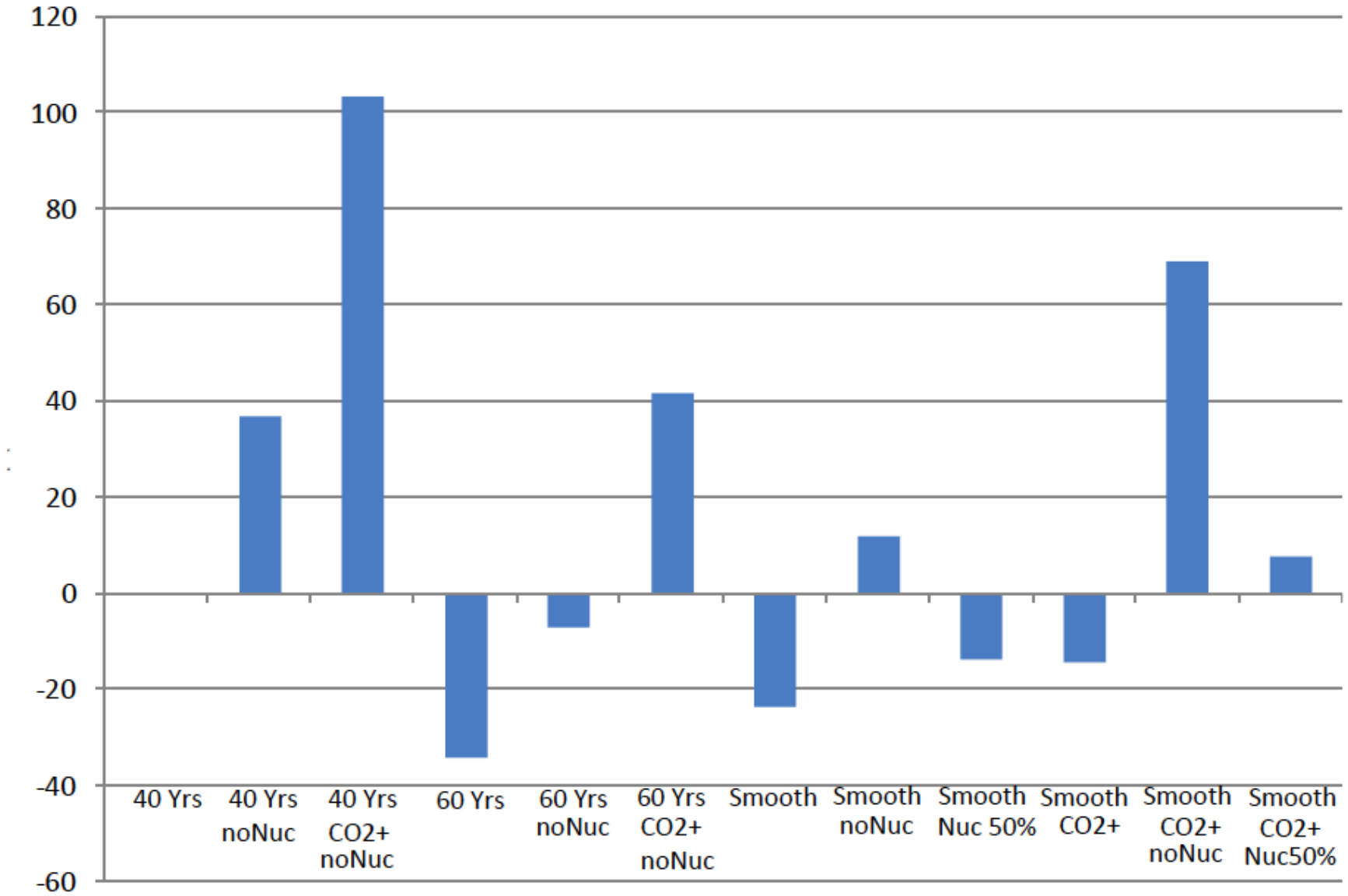


Figure: Investment rythm

rythm of replacement

- DGEMP 2004: 2/year
- today : stability 65 GW or 40 GW (scenarios RTE)
- our assumption: no more than 1 authorization per year for a new EPR (1.6 GW) before 2030 : Flamanville in 2014, Penly (Seine-Maritime) ? in 2022, then after 2030 no more than 2/year

Costs elements for the Electricity sector



Change of paradigm in the supply will impact the Demand

☞ Power mix shares will impact

Grid issues

1. remoted or interconnected options
2. the level of investments in the infrastructures

Reliability issues

	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

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

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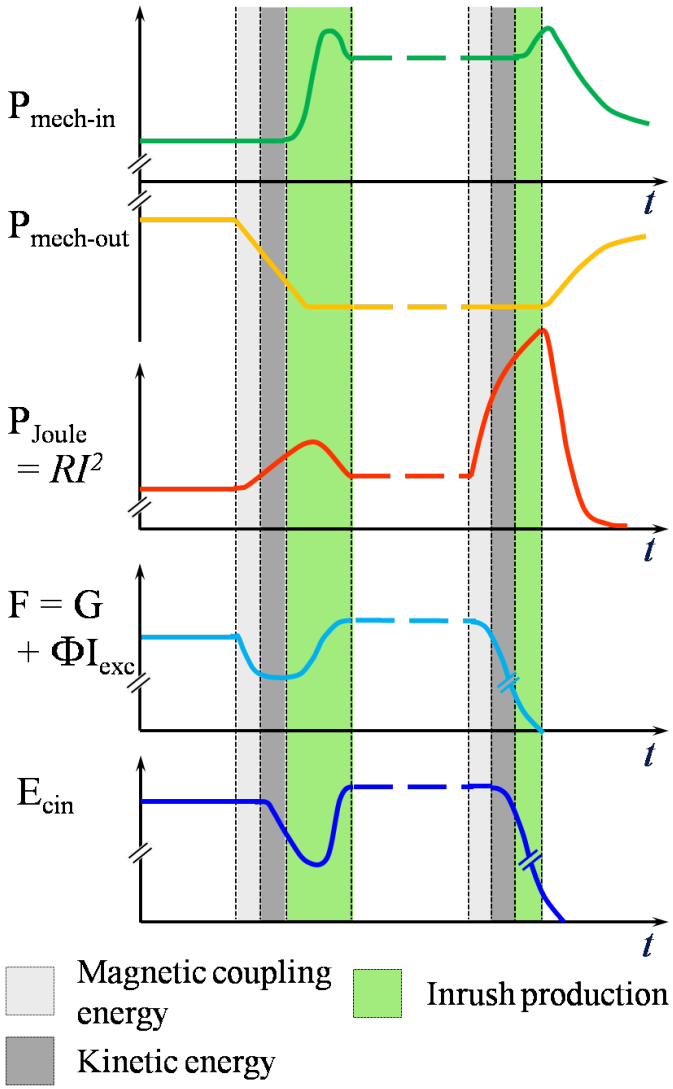
Load fluctuation and stability

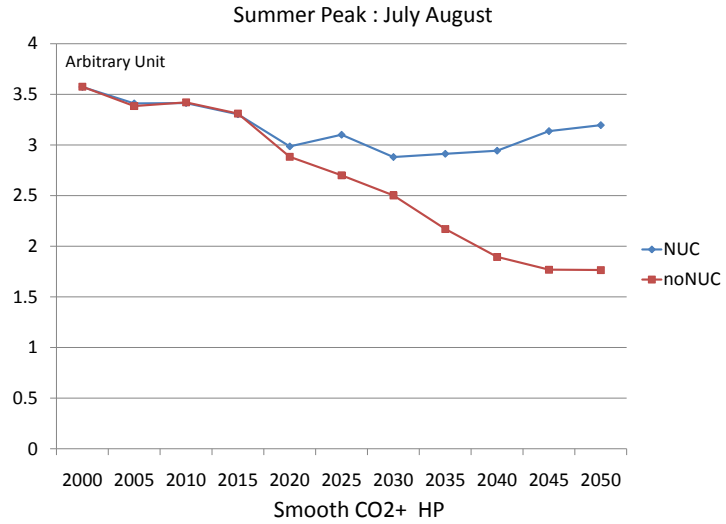
energy exchanges between the subsystems involved in the Thermodynamic Framework

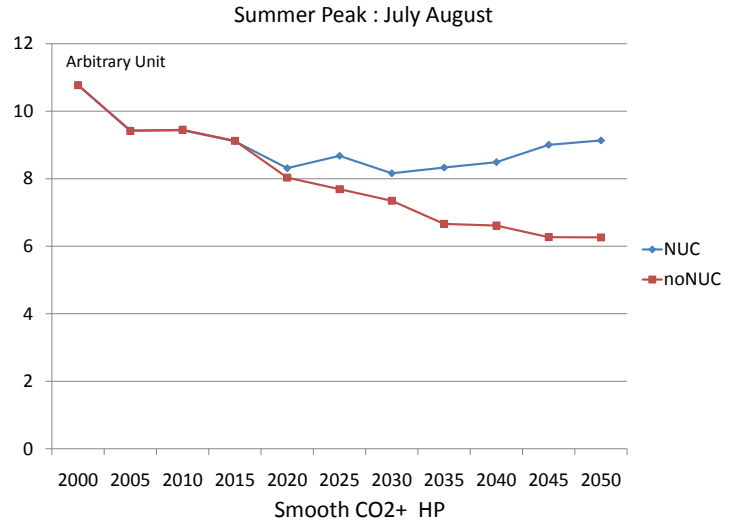
Source: V. Mazauric

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).

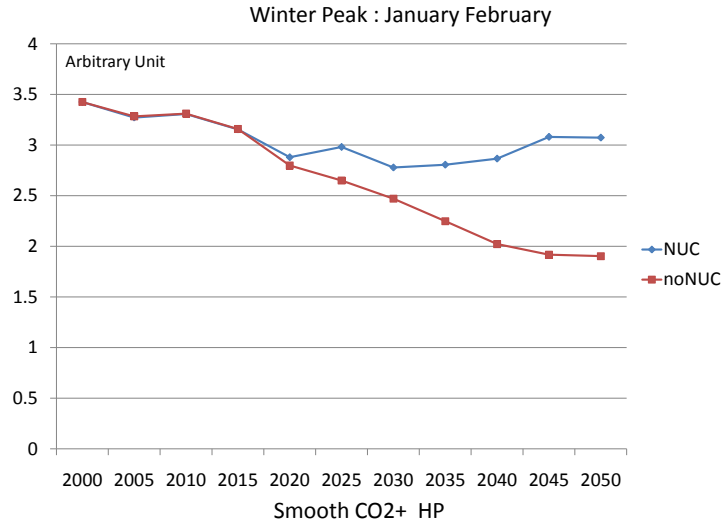


Reliability robustness of the power mix : nuclear sensitivity

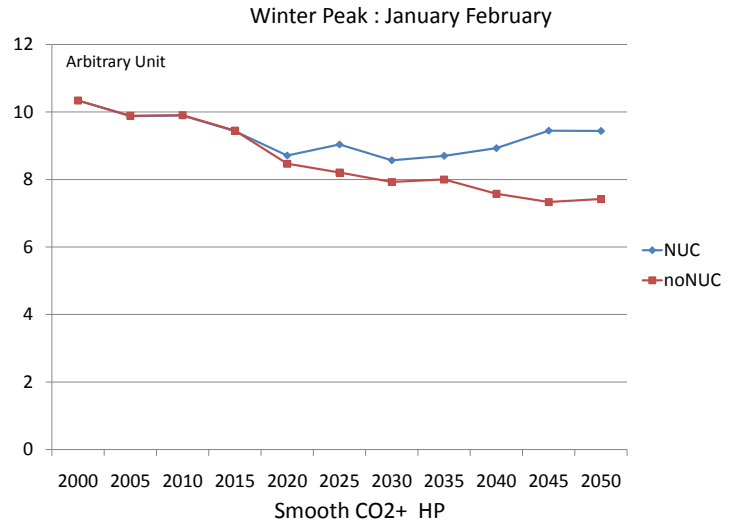




Kinetic reserves



Magnetic reserves



Questions ?

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ANNEXES

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Fossil prices

WEO 2007

	2000	2010	2020	2030	2040	2050
$/boe	34.3	59	58.7	62	65.3	68.7
$/MBTU	3.46	6.6	6.9	7.3	7.8	8.3
$/ton	41.22	56.7	57.2	61.2	64	66.9

WEO 2009

	2000	2010	2020	2030	2040	2050
$/boe	34.3	112.91	100	115	130	145
$/MBTU	3.46	12.03	12.1	14.02	15.88	17.74
$/ton	41.22	140.43	104.16	109.4	113.96	118.52