The role of nuclear in the Scenarios of the French Long-term Adequacy Report

Conference on the role nuclear power in Low Carbon Electricity Systems

Organised by the Chaire European Electriciyt Markets (CEEM)

at Université Paris-Dauphine 18th December 2018

Outline

The role of nuclear in the scenarios of the 2017 adequacy report

The role of nuclear beyond 2035 ?

Conclusion

1

The role of nuclear in the scenarios of the 2017 adequacy report

Framework of the Long-term Adequacy Report

- RTE **legal mission** (article L. 141-8 of the French Energy Code)
- **Broad public consultation** on assumptions (supply and demand)
- Establishment of five scenarios with strengthened **economic coherence**
- **Variants** established for all scenarios to assess their robustness and be able to compare them

A document to link the short-term decisions and the long-term changes of the power system

New scenarios based on the diversification of the electrical mix

OHM — A scenario based on reaching an objective of 50% nuclear power generation in 2025

AMPERE — Diversification backed by strong development of renewable energies (2035: 50% renewables)

HERTZ — Diversification backed by the development of the thermal power sector and renewables (2035: 45% renewables)

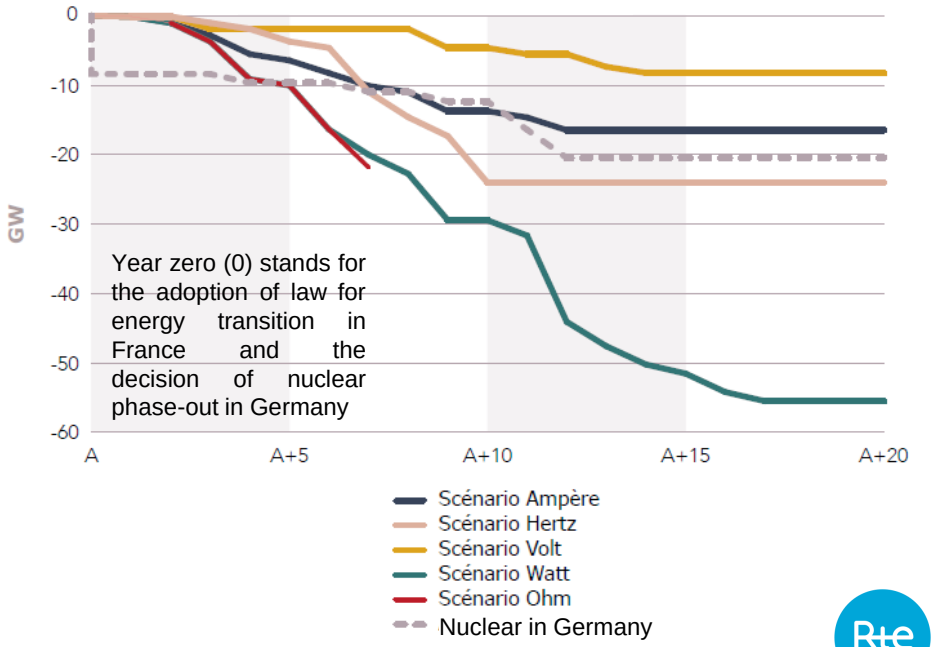
VOLT — Economic management of nuclear facilities with sustained development of renewables (2035: 40% renewables)

WATT — Automatic decommissioning of nuclear facilities after 40 years of operation (2035: 70% renewables)

Very different options for the French nuclear fleet and associated possible trajectories

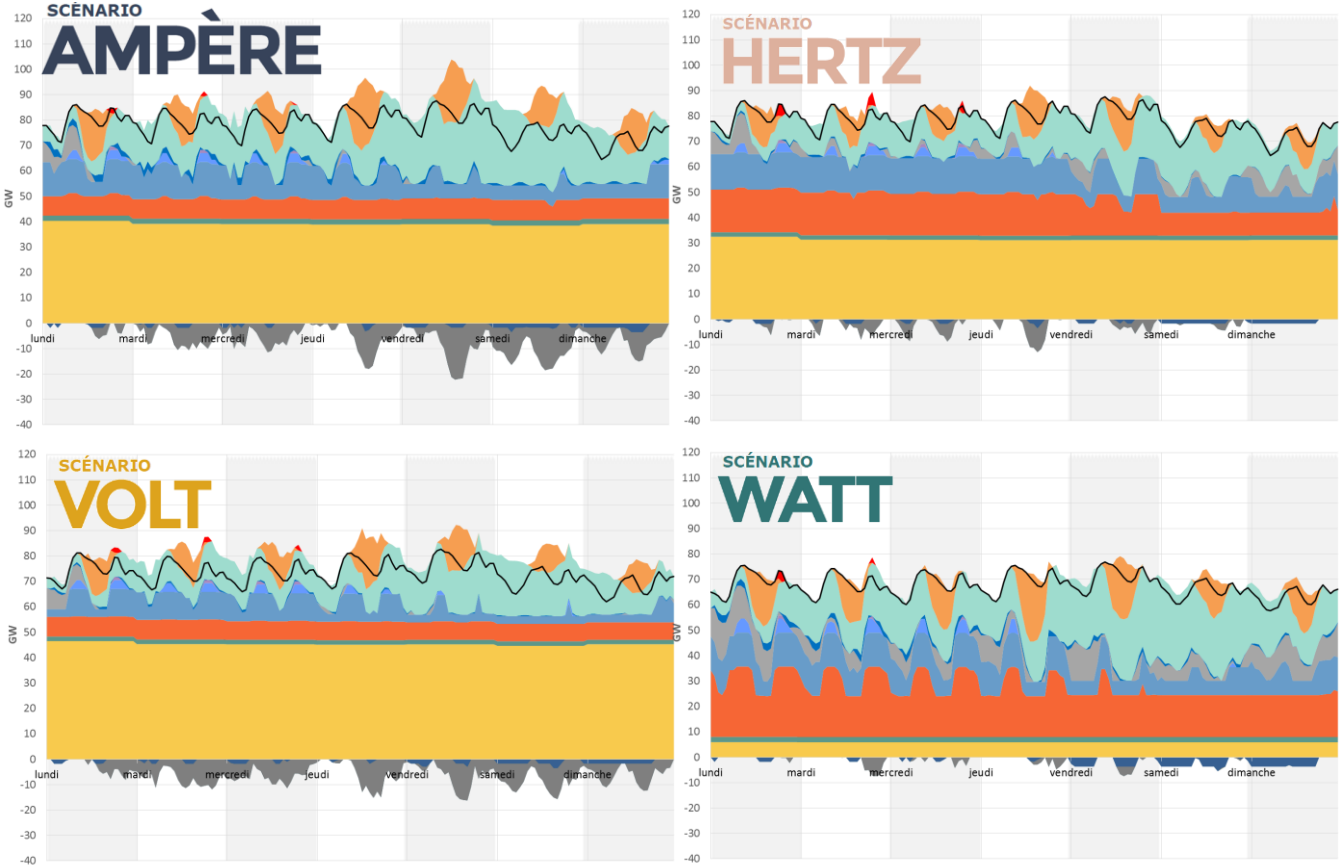
- The various scenarios based on a rapid decommissioning of nuclear reactors (to varying degrees) lead to unprecedented changes in the French electricity mix (since the construction of the nuclear fleet).
- **The trajectories must be based on specific management to support the closure of nuclear reactors** and on the development of other power technologies to maintain the level of security of supply for France.

Reduction path of the installed French nuclear capacity in the different scenarios and in Germany for comparison



Nuclear production, a major contributor to security of supply

Power technology mix in a winter week in 2035

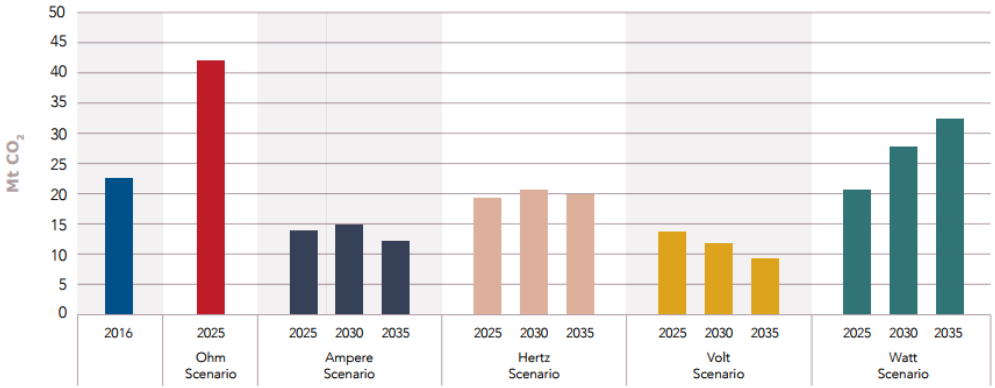


- **Nuclear capacity remains a major contributor to security of supply** of the French power system during peak period depending on remaining capacity
- And **other technologies contributing to power security of supply** depend on the scenario (wind, thermal, demand response, interconnection)

Loss of load	Hydro
Dmd response	Gas
Photovoltataic	Bioenergy
Wind	Coal
Marine	Nuclear
Import	Storage PHS
Oil	Export
Prod. PHS	RES curtailment

Nuclear capacity is one of the main levers to keep on reducing CO_2 emissions in the French power system

Annual CO_2 emissions in the French power system

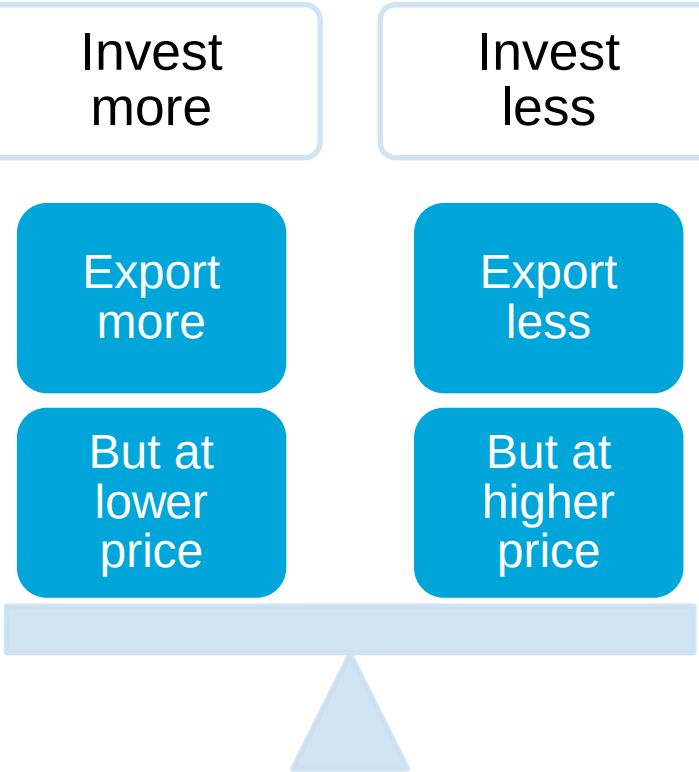


- Closure of coal stations for all scenarios (except ***Ohm***)
- **<u>No need for new thermal facilities in the *Ampere* and *Volt* scenarios (strong renewables and nuclear)</u>**
- Peak load power plants needed mainly in the *Hertz* scenario
- In the ***Ohm*** *and* ***Watt*** scenarios (strong renewables and significant decrease of nuclear power), the semi-base load power plants are supplemented by peak load power plants and increased control of consumption.
  - A growing share of biogas injected in the gas network could reduce these emissions even further

Focus on the Volt scenario

OHM	A scenario based on reaching an objective of 50% nuclear power generation in 2025
AMPERE	**Diversification backed by strong development of renewable energies (2035: 50% renewables)**
HERTZ	Diversification backed by the development of the thermal power sector and renewables (2035: 45% renewables)
VOLT	**Economic management of nuclear facilities with sustained development of renewables (2035: 40% renewables)**
WATT	Automatic decommissioning of nuclear facilities after 40 years of operation (2035: 70% renewables)

A nuclear capacity resulting from an economic arbitrage integrating the revenues and costs from cross-border exchanges



To determine a robust nuclear capacity with uncertainties about market opportunities, many variants from the base case were considered

Unfavourable variants

- A more sustained development of RES in France at the **high level of the multi-year energy programming** (PPE) (+11 TWh/year)
- **Lower** interconnection capacities (27 GW in export)
- A much **lower** CO2 price (5 €/t)
- **Higher capacity** of foreign production fleets with renewable, thermal or nuclear capacity, e.g.

  + 10 GW of brown coal in Germany

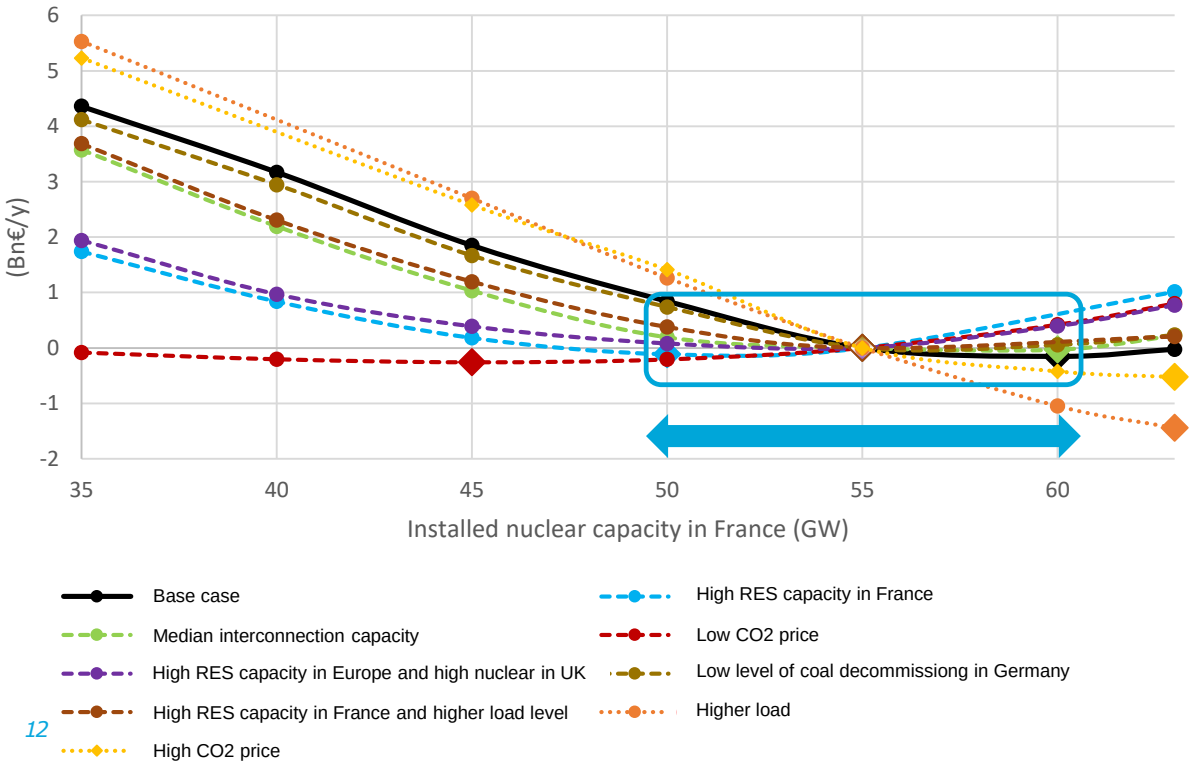
  + 14 GW of nuclear power in Great Britain

Favourables variants

- A **higher** French load level (483 TWh)
- A **higher** CO2 price (108 €/t)

55 GW of nuclear capacity in 2035: a capacity level more robust to uncertainties

Overcost of the French power system (not including network costs) integrating the revenues from interconnections - Horizon 2035

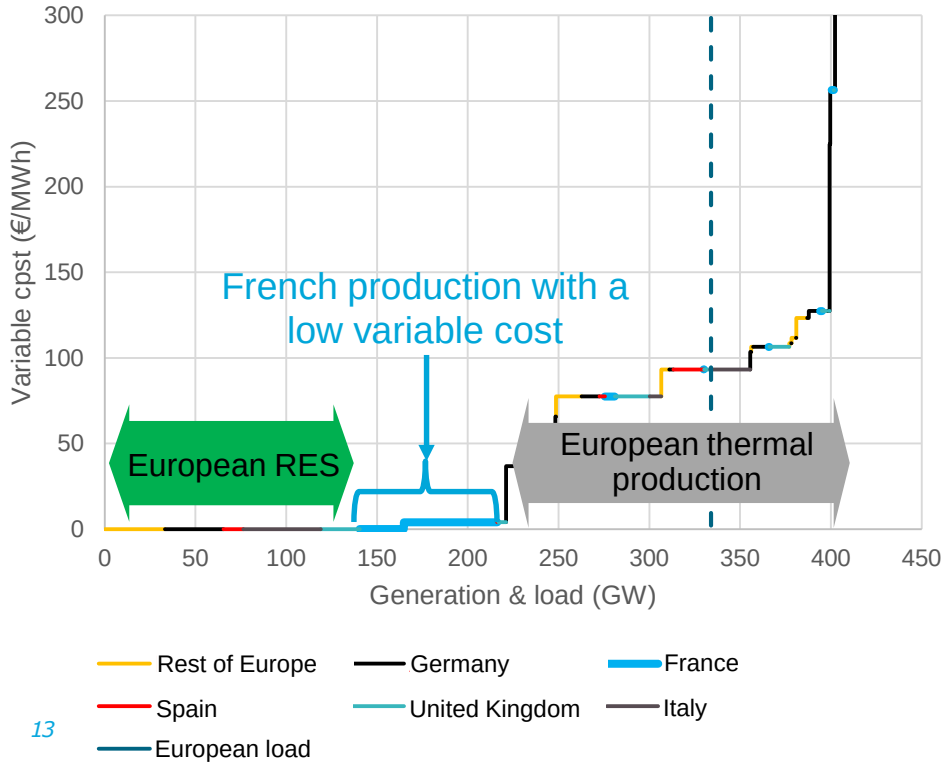


- **The equilibrium points vary according to the simulations**
  - favourable variants
  - unfavourable variants
- **Between 50 and 60 GW, many balances are close by**
- **55 GW a good representative (w/o claiming to be the optimum)**
- **Could be sensitive to French (load, RES, nuclear costs) & external factors (CO_2 price, RES)**
- **55 GW: 9 reactors to be decommissioned**

Source – cost assumptions:
Cour des comptes / French Court of Auditors

French production with a low variable cost is competitive in the European mix in 2035

Illustration: generation & load, 29th November 2035, 3 p.m.



In order to deliver energy to the European consumers through national productions and interconnections, the cost of the French generation mix is between the cost:

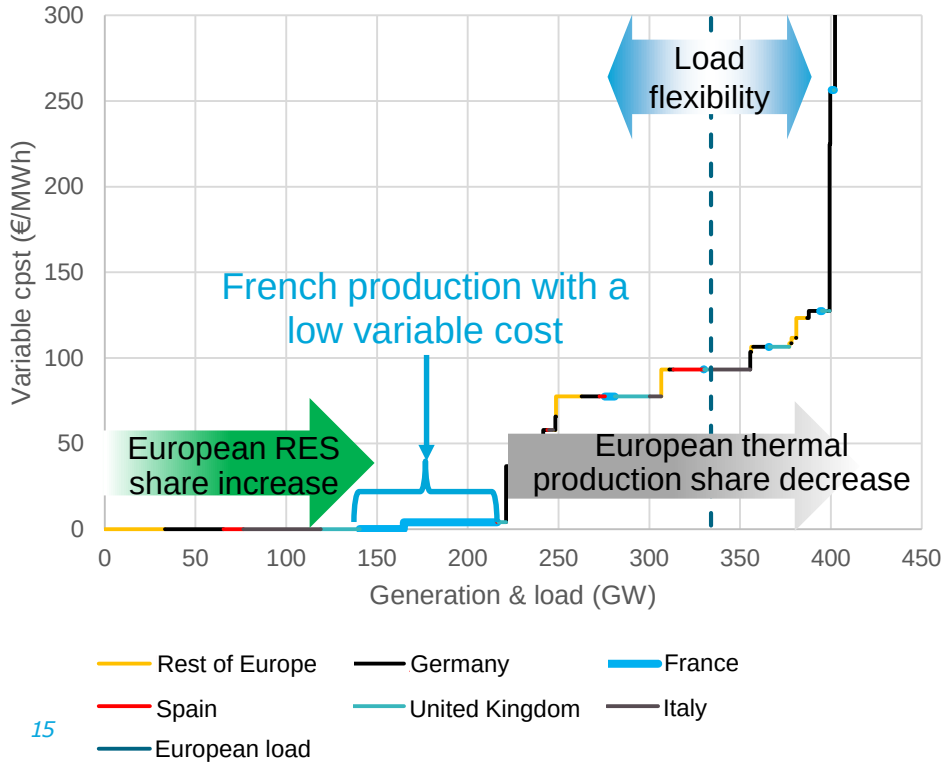
- The RES production from other European countries
- And their thermal production

2

And beyond 2035?

Are previous conclusions still true in 2050 ?

Illustration: generation & load, 29th November 2035, 3 p.m.



RES capacity of Europe should significantly increase and fossil thermal capacity of Europe should significantly decrease

Load flexibility could increase

Role of nuclear then?

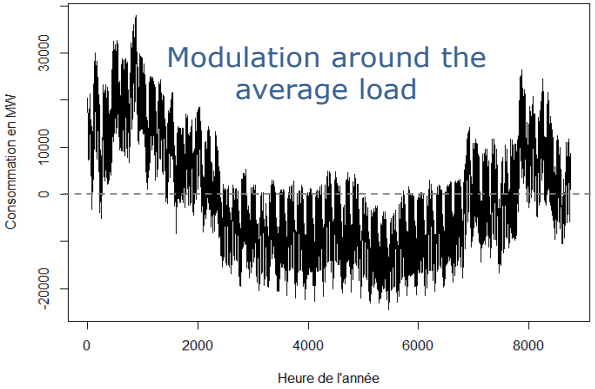
➔ **need to look beyond 2035** to question the development of new nuclear reactors and consider the whole bunch of generation and load technologies

Technical need for nuclear capacity?

- Seasonal need
- Inertia

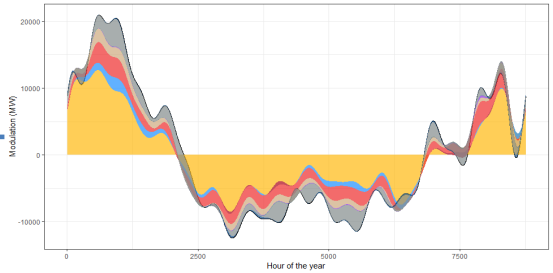
Technical need of nuclear? Example of annual flexibility

Fourrier decomposition of contributions of technologies on 2015 residual load curve in France = flexibility need on annual, weekly & daily time horizons

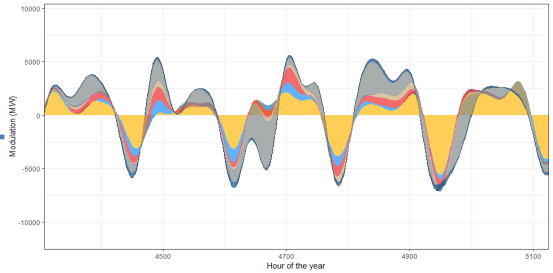


Source: « *Le stockage un levier de flexibilité parmi d'autres* », Heggarty et al, RTE R&D, Revue de l'Energie n°640, sept – oct 2018

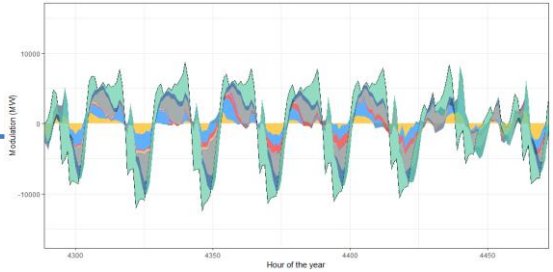
Annual modulation



Weekly modulation



Daily modulation



Nuclear capacity is today a **significant contributor to the annual and weekly flexibility need**

With other generation technologies and load profile and flexibillities, should we expect **similar contribution in a 2050 power system**?

- Oil
- Coal
- Gas
- Hydro
- Nuclear
- Interconnectors
- PHS
- DSM

Technical need of nuclear? Example of inertia

Inertia ~ enough running synchronous generators to make the power system frequency resilient enough to disturbances

BUT PV & wind are not synchronous generators

Possible solutions?

- Inertia by RES synchronous generators (hydro & bioenergy)
- Synthetic inertia provided by RES generators
- New control framework adapted high share of power electronics connection from PV and wind
- Keep synchronous generators online such as nuclear

6

Conclusions

Work opportunities and more detailed analyses

- The five scenarios are published in the reference document. http://www.rte-france.com/sites/default/files/bp2017_synthese_va.pdf
- Different nuclear trajectories were considered. When **optimised from an economic point of view**, it was found relevant to **maintain a significant nuclear capacity**, even if smaller than today and sensitive to several factors
- French production with a low variable cost is competitive in the European mix in 2035

➔ need to look beyond 2035 to question the development of new nuclear reactors

- considering the whole bunch of generation and load technologies
- as well as the whole bunch of services to provide (reserves, inertia, flexibility on every time horizons…)

Future works investigating future technology mixes for power generation, load and flexibility

Programmation PLURIANNUELLE DE L'ÉNERGIE

2016

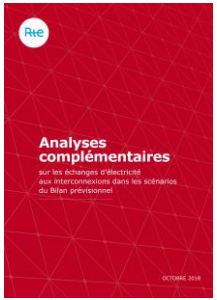
Programmation PLURIANNUELLE DE L'ÉNERGIE

2018

Adequacy report

Next long-term adequacy report

Some extensions or other studies



E-mobility w/ AVERE FRANCE

Liberté • Égalité • Fraternité RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

Rte

iea

Power heating study w/ ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

H_2 & P2G

MIGRATE

OSMOSE

OPTIMAL SYSTEM MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY

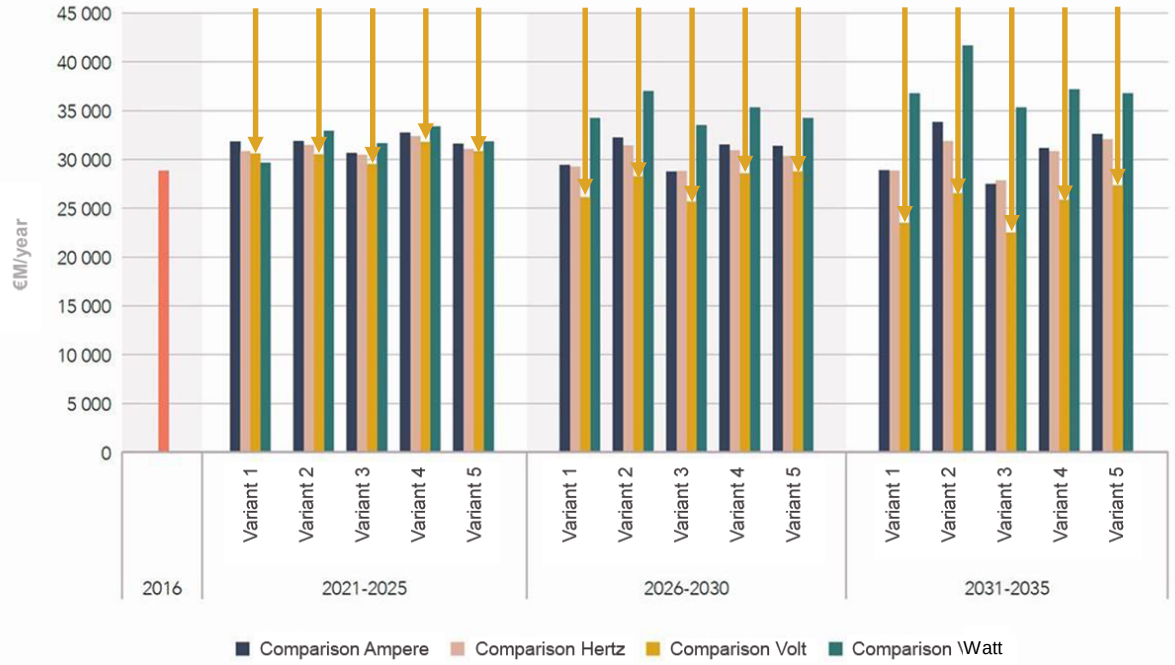
Thank you for your attention

Questions ?

The analyses confirm the economic interest of the lifespan extension of some nuclear reactors

- Analyses based on **concerted assumptions** on the costs of extending the lifespan of nuclear reactors beyond 40 years of operation, from the **Court of auditors and financial communication by EDF**
- **Robustness of the analyses** confirmed by variants 4 and 5 considering higher costs of the lifespan extension of nuclear reactors
- Extending the lifespan of some nuclear reactors results in **lower annualised net costs**

Figure 11.45 Annualised net costs of the balance of trade for electricity exchanges



"Comparison" scenarios: stable consumption, median interconnection, CO2@€30/t