TerraWater

2050 Energy scenario

Hypothesis and bias for France to reach a reliable and low-carbon energy mix by 2050, long-lasting and sustainable by 2060 and beyond.

A scenario to guarantee, today, the promises made to the France of tomorrow

Voix du Nucléaire

Why this scenario ?
Reducing the number of bets is the objective

All scenarios, **including that of the Voices** make assumptions over : • The fact that decisions are taken early enough • Acceptance of new infrastructures • Human resources and skills required							
RTE N03	The scale of SMR development	The availability of electricity import	The deployment of a hydrogen network				
RTE N1	The scale of network flexibility	The availability of electricity import	The deployment of a hydrogen network	Feasibility of an electricity network with high VRE integration	Development of battery storage	Land availability	
ADEME S3	Profound changes in behaviours and network flexibility	The reality of biomass capacities	The deployment of a hydrogen network	Availability of rare metals and materials	Hypothesis on energy-efficiency gains (buildings…)	Land availability	Sufficient electricity production to sustain reindustrialisation
Négawatt 2022	Profound changes in behaviours and network flexibility	The reality of biomass capacities	The deployment of a hydrogen network	Availability of rare metals and materials	Hypothesis on energy-efficiency gains (buildings…)	Land availability	Sufficient electricity production to sustain reindustrialisation
Négatep	The immediate construction capacity of the nuclear industry		Energy mix not decarbonised in 2050	Still a high carbon-intensity energy mix in 2050			
CEREME	The immediate construction capacity of the nuclear industry	Consequences of maintaining fossil production	The deployment of a hydrogen network	Still a high carbon-intensity energy mix in 2050			

Framing

Borders

Metropolitan France

2050 horizons

Energy mix

+65% of electrical demand

No dependences to grid interconnectors

No hypothesis on growth

Principles

Technological and industrial **maturity**

Simplicity of the system operations

Reliability and **ruggedness** of the electric system

Social & societal realism

Economic and industrial optimization of the equipment

Objectives

Carbon neutrality from 2050 beyond

Reliable electricity access

Natural resources and spaces use reduction

Sovereignty

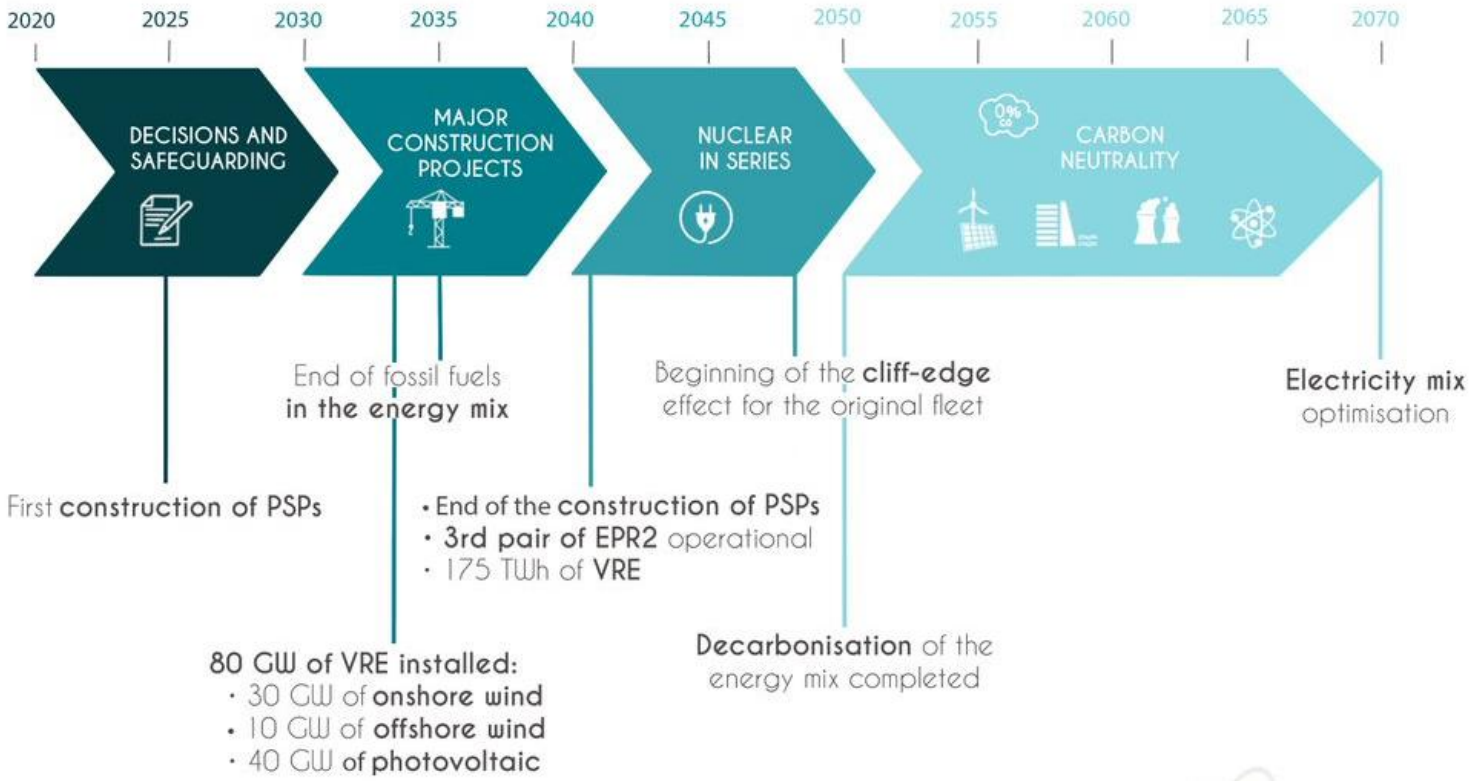
Reindustrialization

Complete and permanent fossil fuels phase-out

Energy solidarity

How ?

Grid securing / Technical optimum searching / Restart of the electronuclear industry (EPR2 then diversification) / RES optimization associated with PSH/ Energy networks rationalization by massive electrification / Industrial H_2 production located where H_2 is needed / Searching of global decarbonizing / Free and support as much as possible European neighbours' capacities.



Deep electrification: a way to limit biomass use

« We can’t electrify commercial aviation, but by electrifying everything else, we can make it more sustainable »

Commercial aviation:
~80 TWh/yr

Shipping:
~20 TWh/yr

- Lots of usages aren’t electrifiable: they require chemical fuels made from biomass
- Electrifying as much as possible the rest of the economy increases the chances of having enough biomass to cover all this usages
- Moreover, biomass resources are vulnerable to climate change and its direct usage is a big air pollution cause (mainly direct wood burning)
- By switching as much as possible the industry, buses & trucks and space heating to electricity, it’s possible to save more than 100 TWh/yr of biomass.

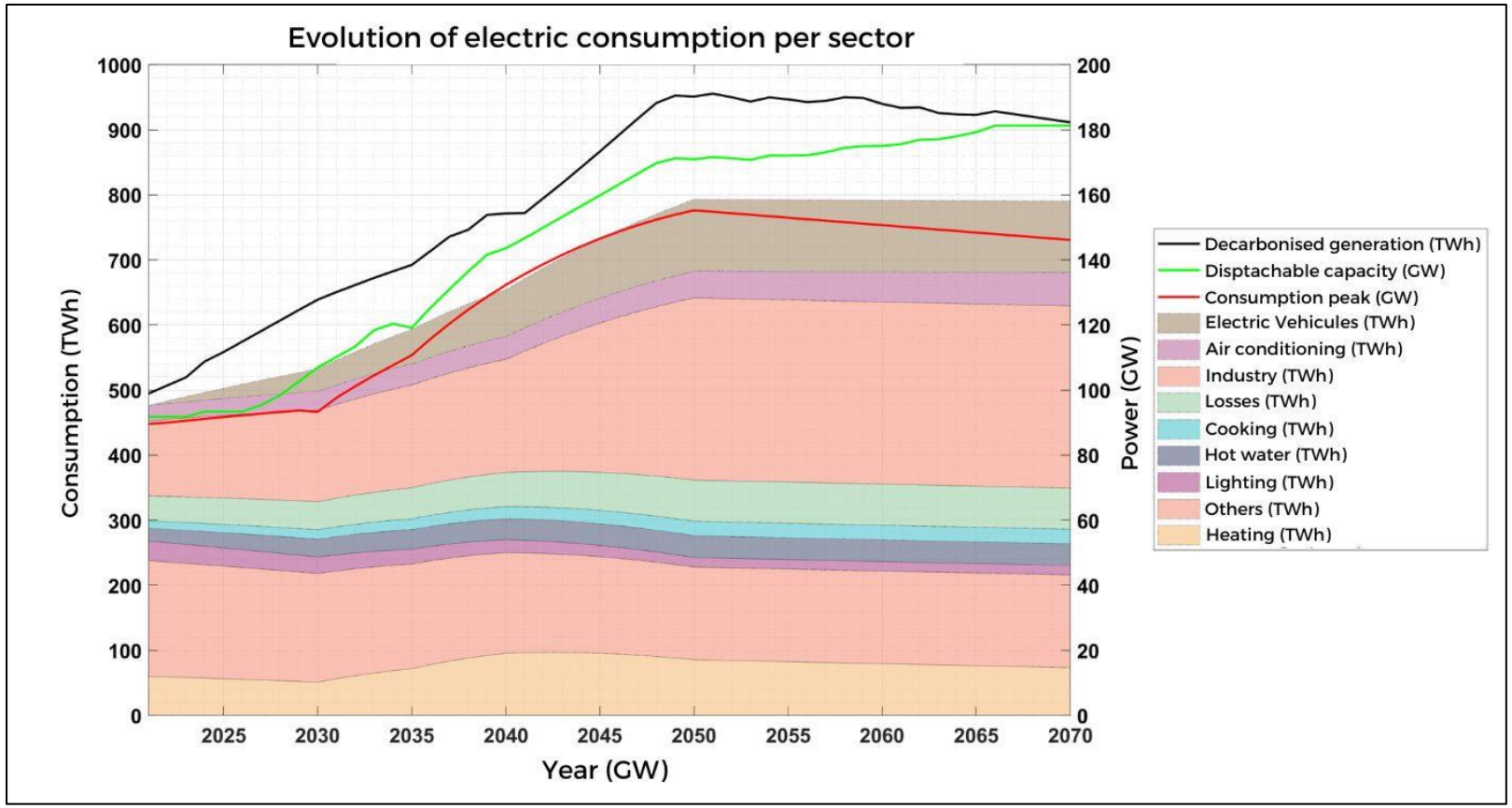
Military:
~10 TWh/yr

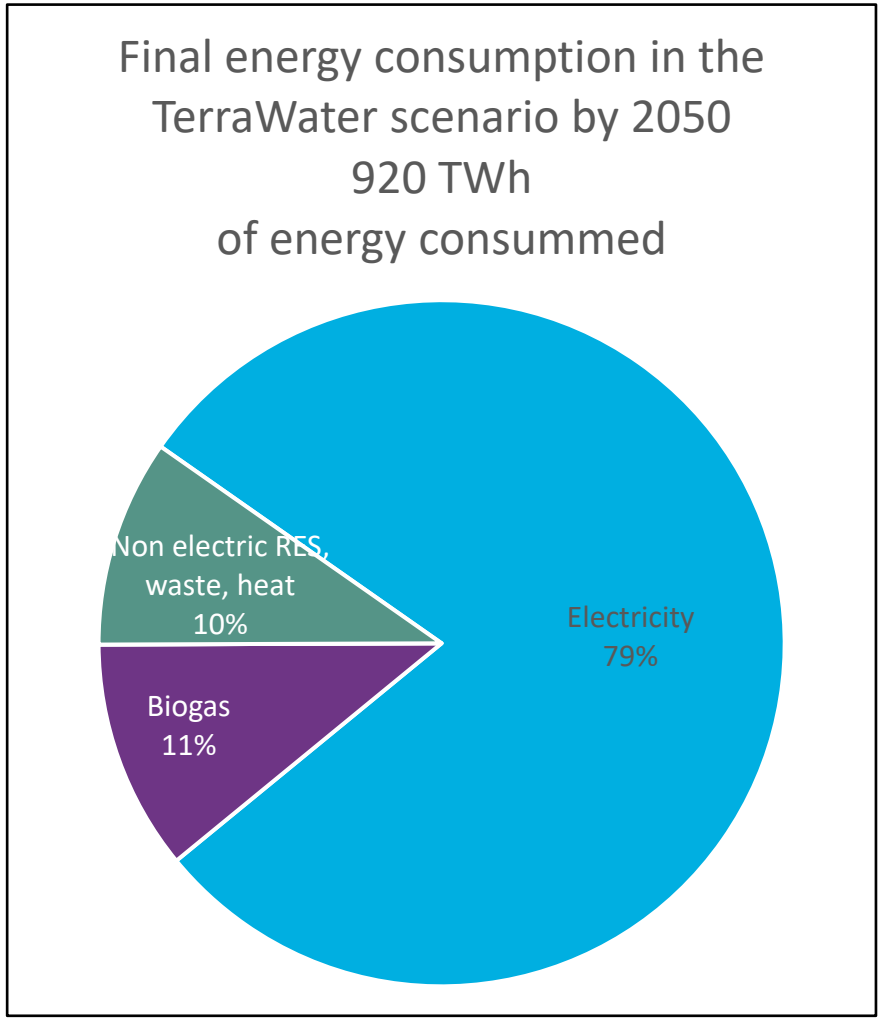
BIOMASS NEEDED FOR ENERGY USE: 190 TWh/yr

Farming and fishing:
~40 TWh/yr

Residual wood space heating:
~40 TWh/yr

Electrification pushed to 75~80%



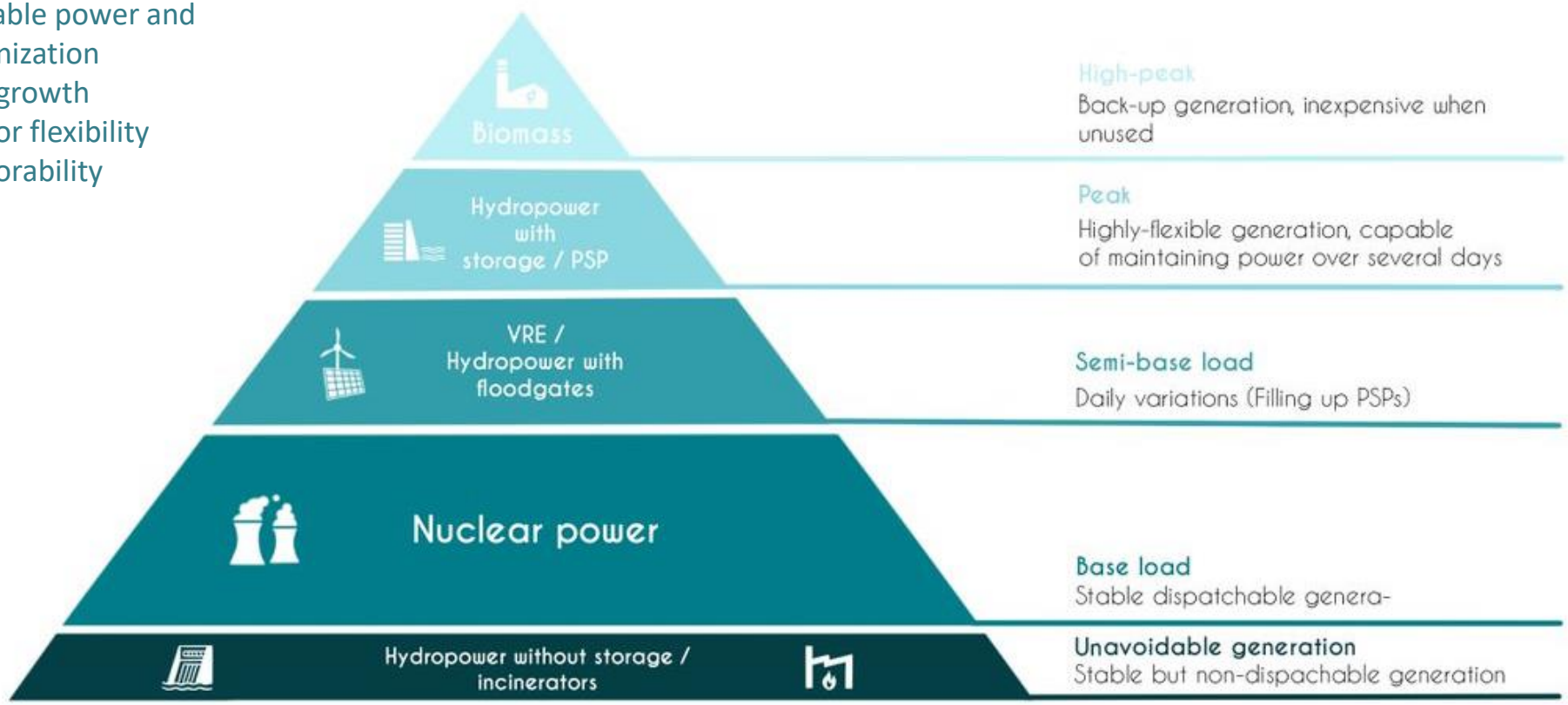


- This very high level of electrification has a paramount corollary: the question of **the robustness of the electricity system in all circumstances** is even more vital than in other scenarios → **Significant safety margins are required !**

Rationalization of the merit order

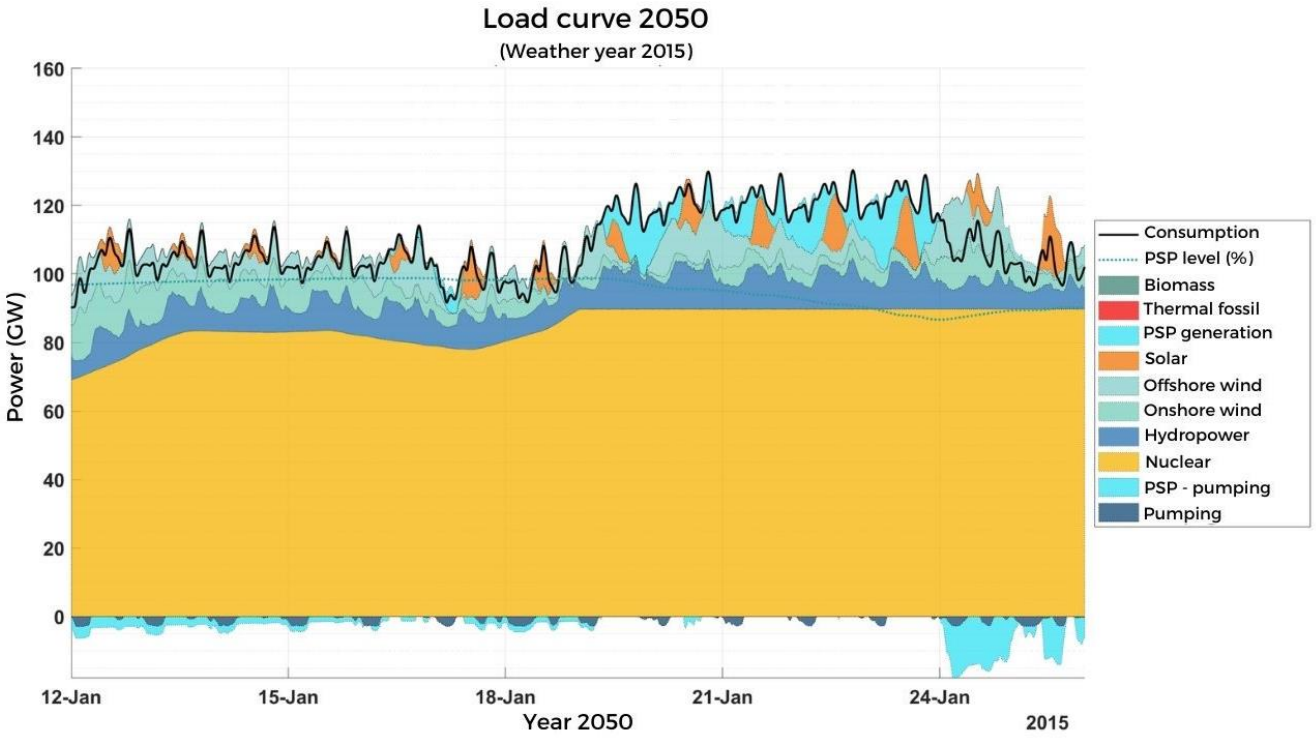
Energy sources are used at what they are best suited for:

- Nuclear for stable power and deep decarbonization
- VRE for quick growth
- Hydropower for flexibility
- Biofuels for storability



Energy sources used at what they are best suited for: illustration

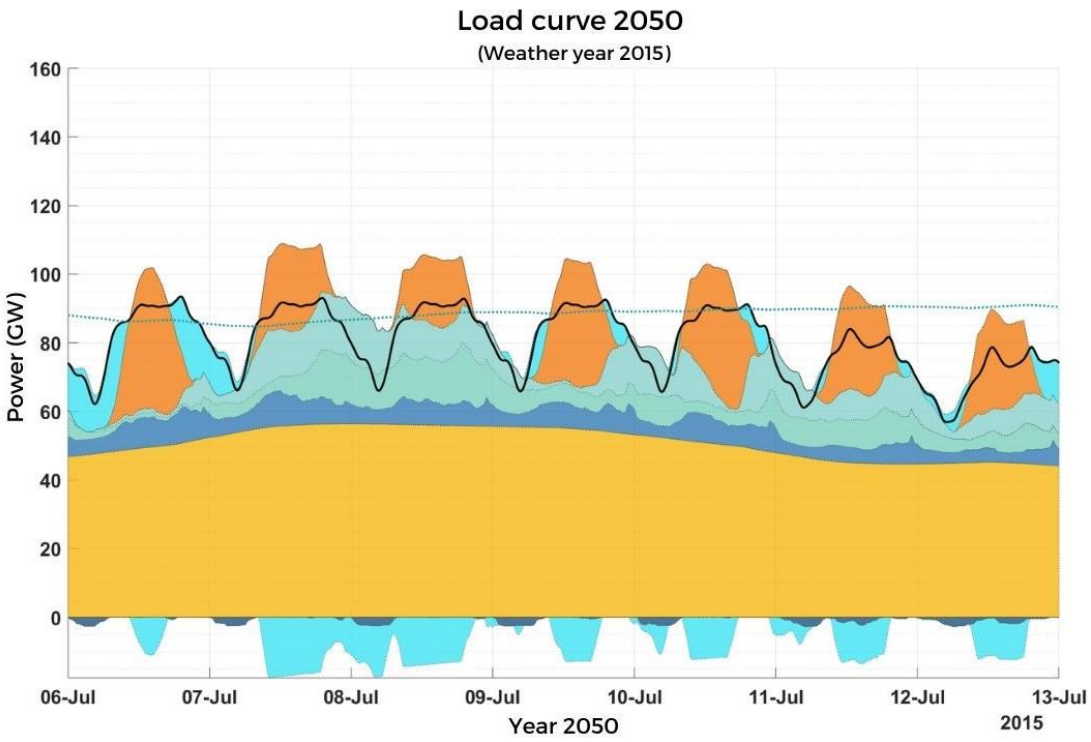
Winter



Nuclear is operating either in semi-baseload configuration (following daily electricity mean demand) if consumption isn't very high, or at full power when temperatures are lower. Pumped-hydro, reservoir dams (and marginally biofuels OCGT if demand is very high) do the fine tuning, especially in periods of low RES production.

VS

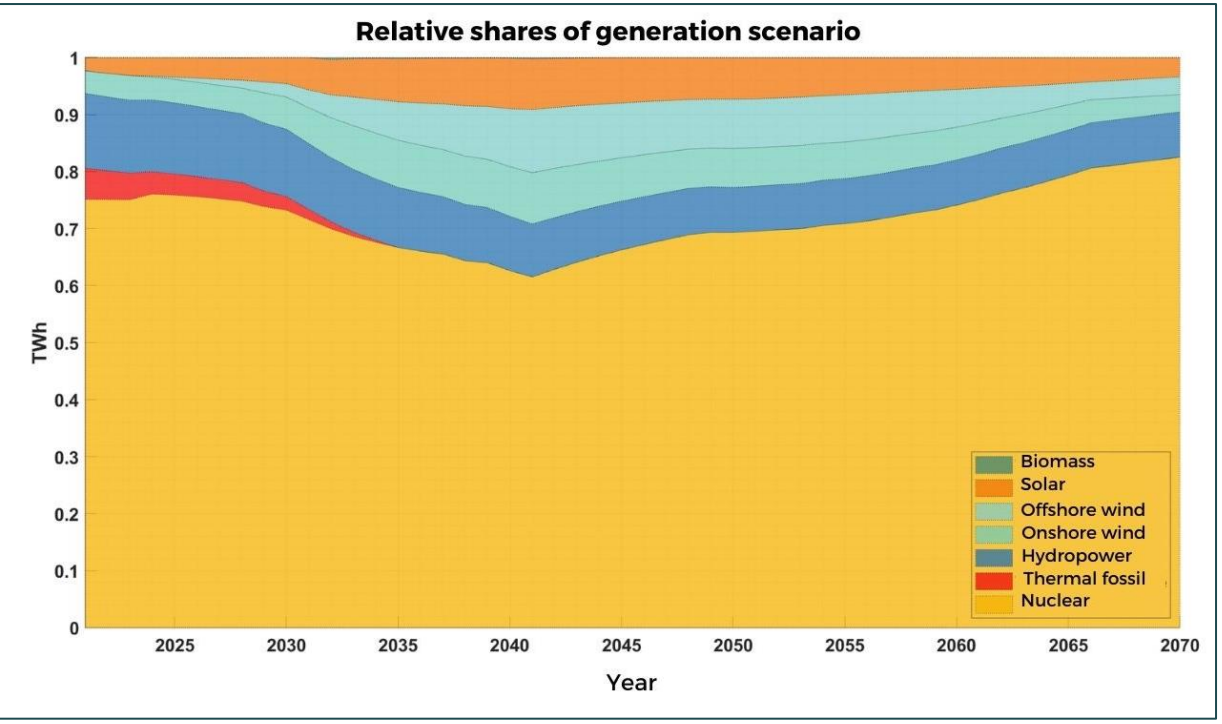
Summer

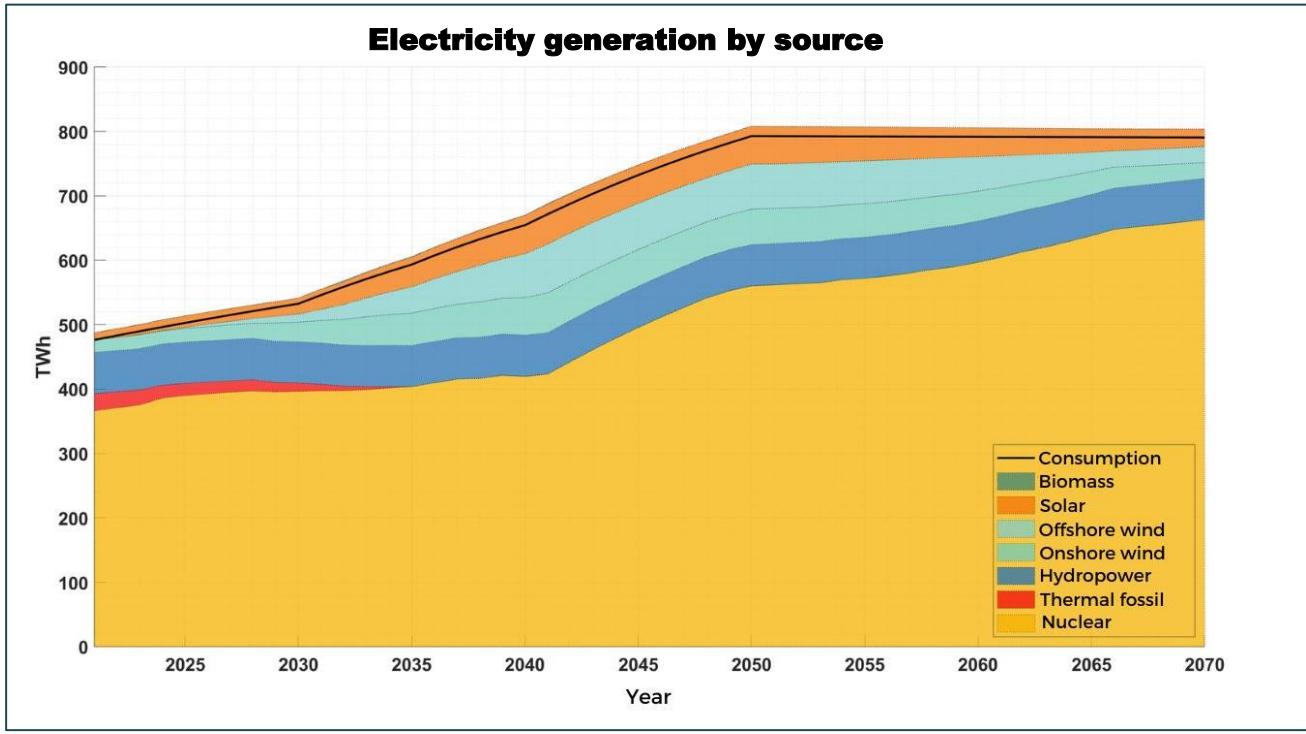


Nuclear modulation is limited to several MW/minute, and hydropower/PSH do the fine tuning. Abundant summer solar power assures the refilling of the storage during the day.

Relying on **all** low-carbon energies

Maintaining the nuclear baseload



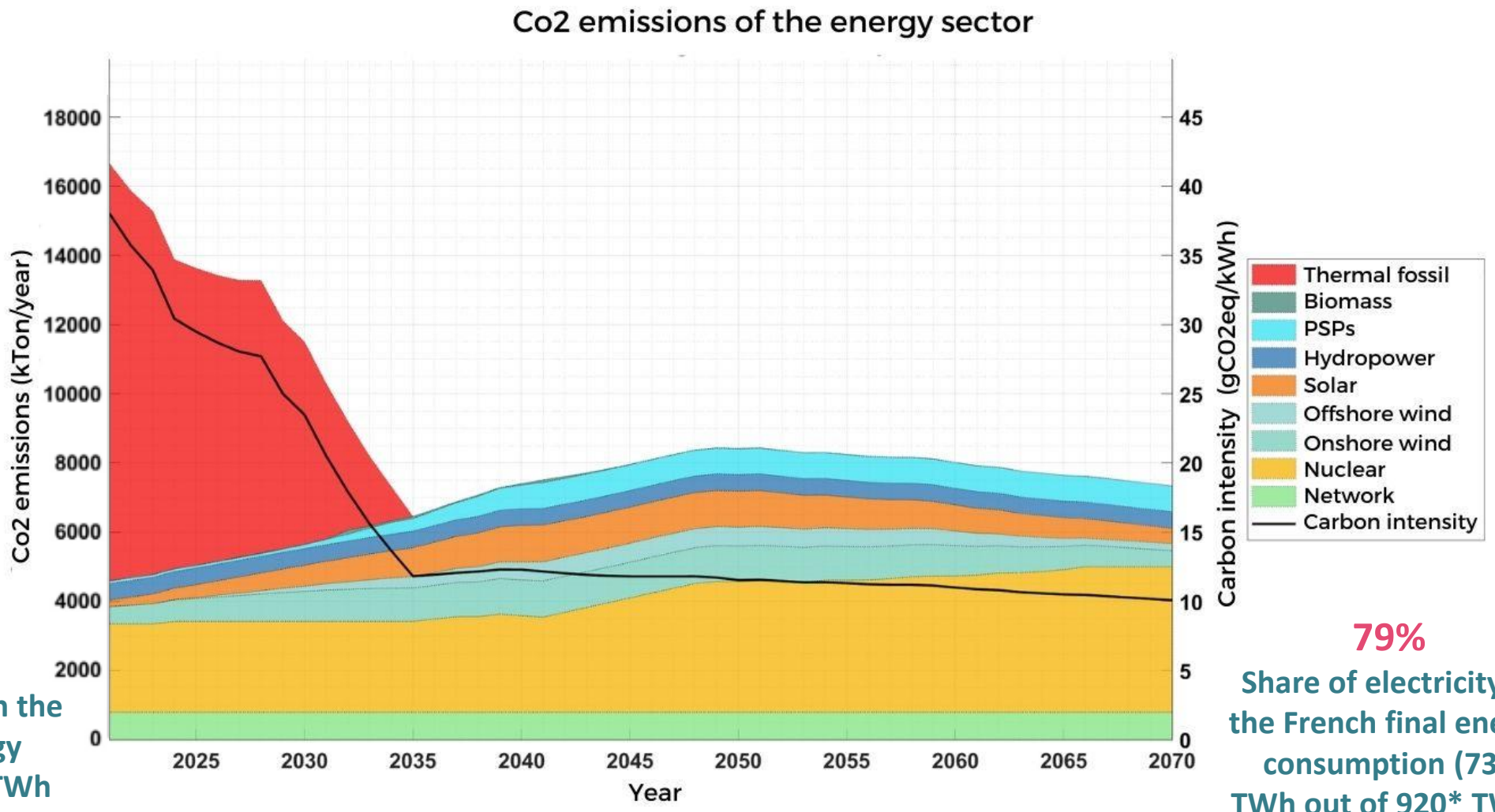


Strong growth of RES during the transition period

Other highlights and corollaries

Primary objectives	Secondary objectives	Corollaries
• Sovereignty • Equity in access to energy • Environmental impact • Reindustrialization • Foresight beyond the theoretical threshold of 2050	• No hydrogen network • Total end of gas for electricity production and its distribution network to residential and tertiary users • Limited biomass to guarantee non-electrifyable uses	• Revival of the nuclear industry • A desire to revive research in the future nuclear sector • Restarting a hydro program • Ultra-peak production provided by versatile and flexible, biofuel OCGT

The carbon intensity of the energy mix is decreasing thanks to massive electrification



24%

Share of electricity in the French final energy consumption (440 TWh out of 1680* TWh)

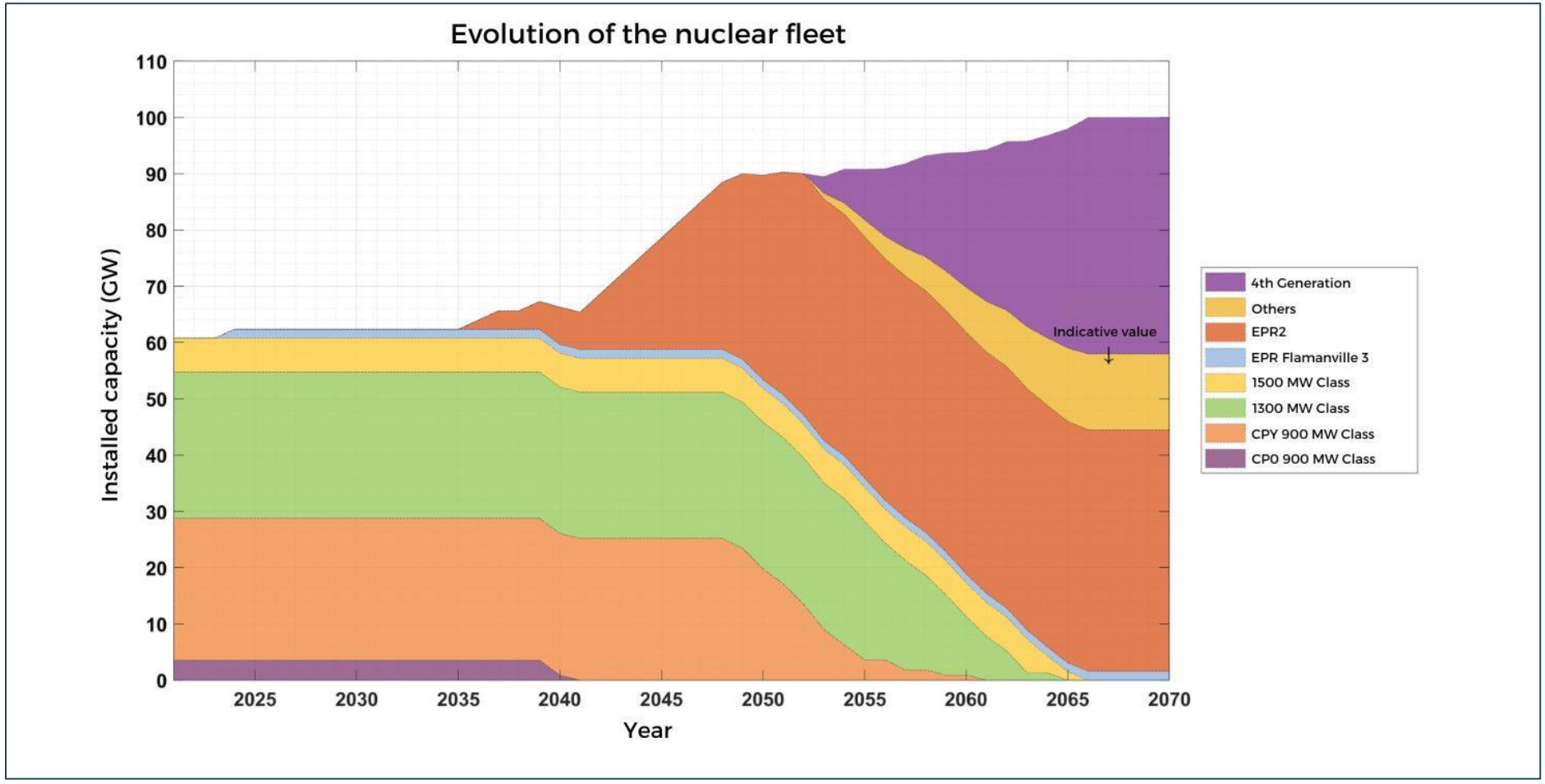
79%

Share of electricity in the French final energy consumption (730 TWh out of 920* TWh)

*These values don't account for "non energetic uses" but they include international bunker fuels for commercial aviation and international shipping

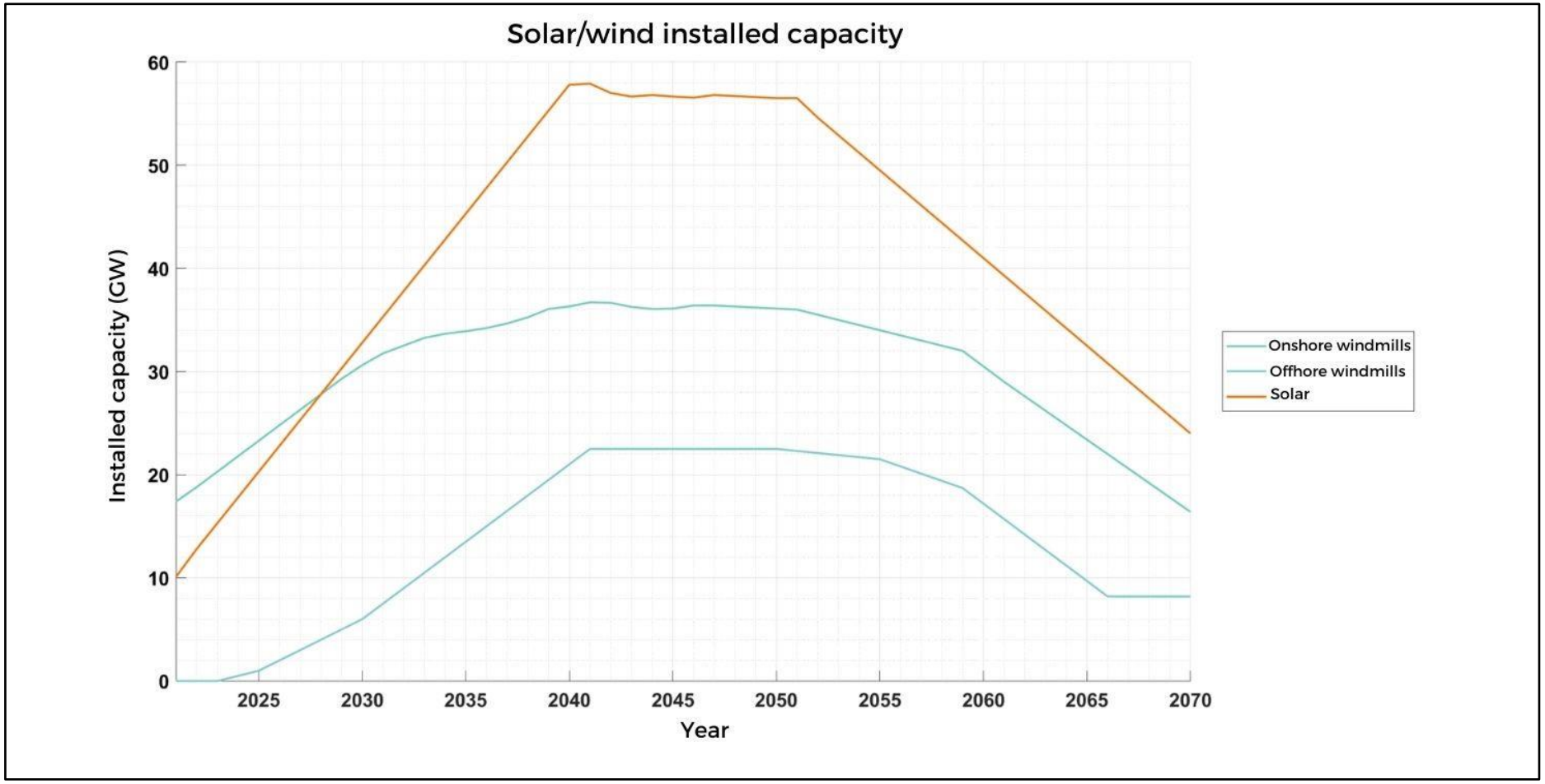
New and historic nuclear

Rational extension of existing nuclear fleet
Starting with the pace of N03 on the new but then going further



Average age of decommissioning : 69

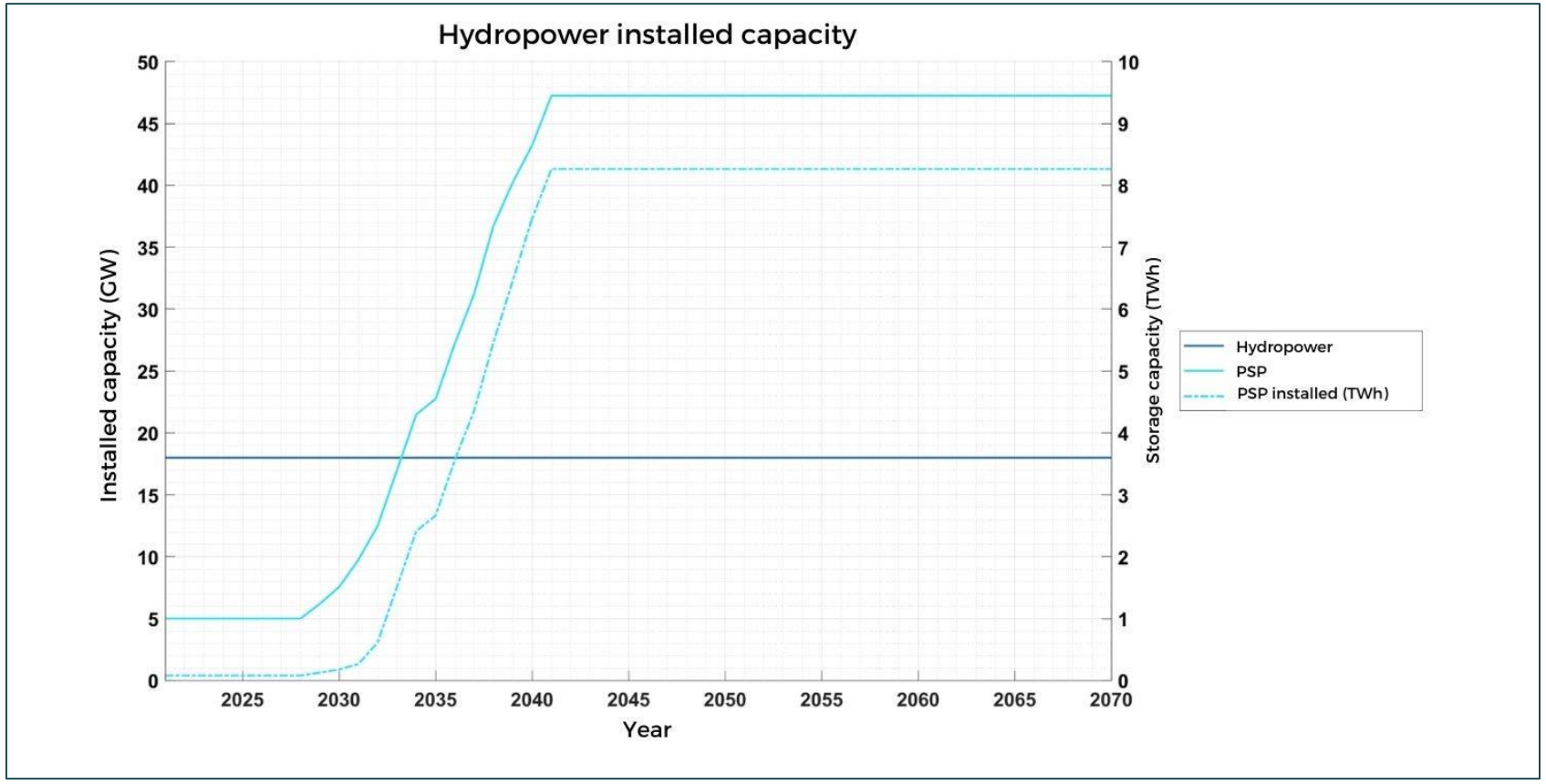
Variable RES as transition energies



- Capacities are renewed **whilst carbon neutrality isn't achieved**.
- No low-carbon production facility shall be dismantled **before the end of its service life**.
- Installation rates can be **extended if necessary**.

A real ambition on hydraulics that particularly sets us apart

PSH as the only reliable, proven and economical energy storage technology for the electricity grid



- The focus is on the **capacity of the impoundment lakes** rather than the power of the turbines.
- The need for **installed capacity** is likely to be reassessed **downwards**.

A major hydropower program

PSPs are placed as close as possible from areas with high solar and wind potential and following the topographic requirements for their installation. They may also be used for cooling nuclear reactors located downstream.

Suggested sites for PSPs
- New installations
- Using an existing hydropower installation

Nuclear sites on the banks of a river down stream of a PSP
- Existing nuclear reactor in closed circuit
- Existing nuclear reactor in open circuit

Main areas with high offshore wind potential

Main mountain ranges

High potential sites for solar
- <1200
- 1221 à 1350
- 1351 à 1490
- 1491 à 1760
- > 1760

Each site has been identified and characterized

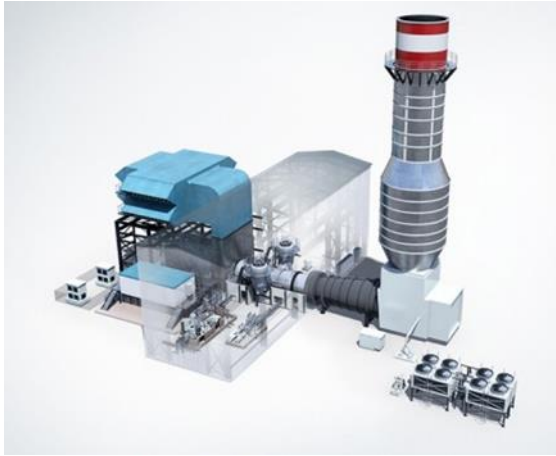
NO: French hydraulic potential is not saturated...

...and we have characterized it on a case-by-case basis.

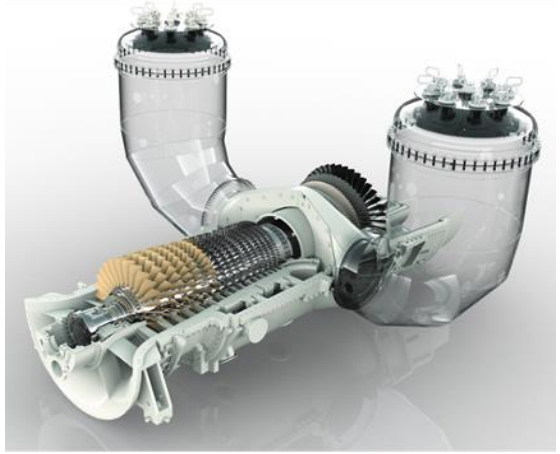
Biofuels OCGT*

Meeting extreme peak/rescue needs without betting on hydrogen

- **Last means of national production before having to rely on electricity imports -> flexible extreme peak production**
- Power plants that can use **any type of liquid, gaseous or solid fuel** to provide a backup **in case of high stress on the electricity grid** (extreme climatic event, very low windy winter, low punctual availability of the nuclear fleet)
- Fuel is to be stored on site -> reserve power plants
- **The reference fuels are bioethanol and biodiesel released by the electrification of road transport. SAF, used cooking oils, or even sawdust in the form of pellets can be added.**
- Approximately 20 GW would be commissioned between 2027 and 2034.



OCGT power plant illustration (model AE-94.2)



OCGT illustration (model AE-94.2) offering huge fuel versatility

**OCGT: open cycle gas turbine*