100% Renewable Electricity Generation in France?

Key lessons

Decarbonisation Workshop, Berlin

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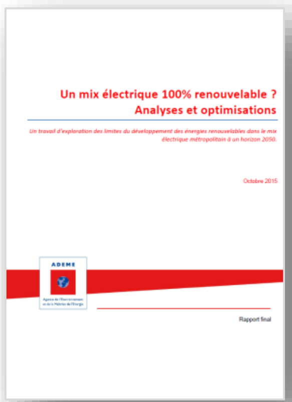
AGENDA

1. The research question
2. The French context
3. Methodology
4. Key findings
5. Conclusion

100% Renewable Electricity Generation in France?



Study available online
(English version available shortly)
http://mixenr.ademe.fr

- Could France be powered by a 100% renewable generation mix?
- How flexible should the power system become?
- What would 100% renewable generation mixes look like?
- Which spatial distribution should be favoured?
- What are the economic impacts in terms of electricity costs?

Study financed by

ADEME

Agence de l'Environnement et de la Maîtrise de l'Energie

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énergies demain

ARMINES

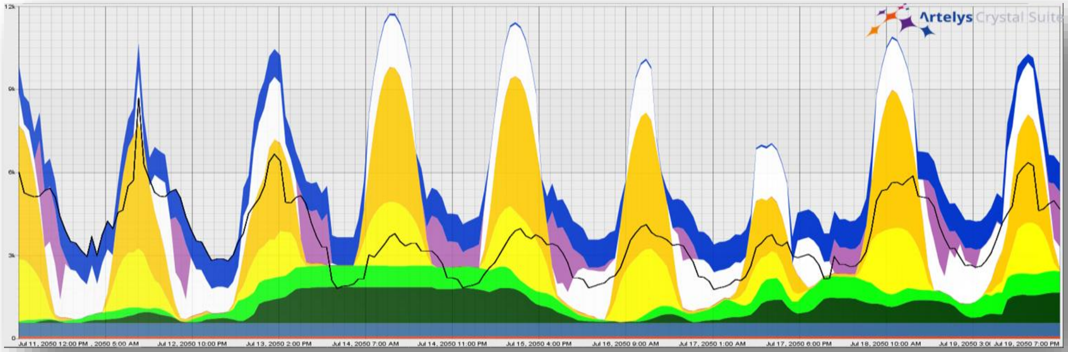
What this study is, and what it isn't

It is a snapshot of the optimal power production mix at the 2050 horizon with high shares of renewable power

> It doesn't address the design of the trajectory to reach the optimal mix

It is a feasibility study aiming at understanding the interplay between RES-e generation technologies, demand flexibility, and storage technologies

> It doesn't address sub-hourly dynamics or black-start situations



THE FRENCH CONTEXT

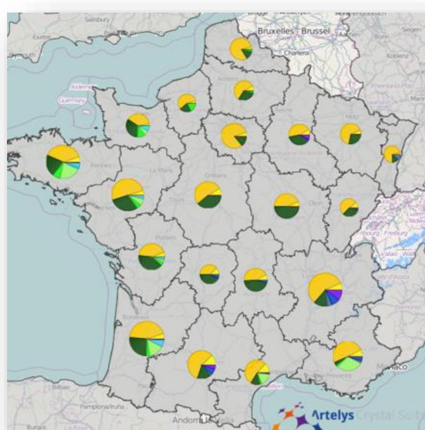
1 Demand

Characteristic	2013	ADEME 2050
Demand	466 TWh	422 TWh
Peak demand	100 GW	96 GW
Thermal sensitivity	2300 MW/°C	1500 MW/°C

2 Demand flexibility

- Heating (incl. warm water)
- White devices
- PHEVs & EVs (50% of the vehicle stock)

3 Potentials



Up to 1250 TWh

Onshore wind	172 GW
Offshore wind	66 GW
PV	411 GW
Hydro	30 GW
Biomass	3,5 GW
Geothermal	0,14 GW
Marine power	30 GW

OPTIMISATION MODEL

Inputs:

- Demand (incl. flexibility)
- Potentials (at the regional level)
- RES-e technologies
- Storage technologies
- Network technologies
- Neighbouring countries power mix (80% renewable)

→ **Optimisation model** →

Outputs:

- Installed capacities
- Operations (hourly time resolution)
- Costs

Optimisation criterion: *cost minimisation*

- Annualised investment and operations costs for RES-e producers and storage
- Annualised investment and operations costs for the high-voltage network
- Variable power generation costs (e.g. wood cost for biomass)

Constraints

- Hourly demand-supply equilibrium (8760 chronological time-steps per year, 7 years)
- Operational constraints (e.g. storage, power flow, flexibility)
- Imports and gas are compensated by exports and biogas production

HOW FLEXIBILITY IS EXPLOITED

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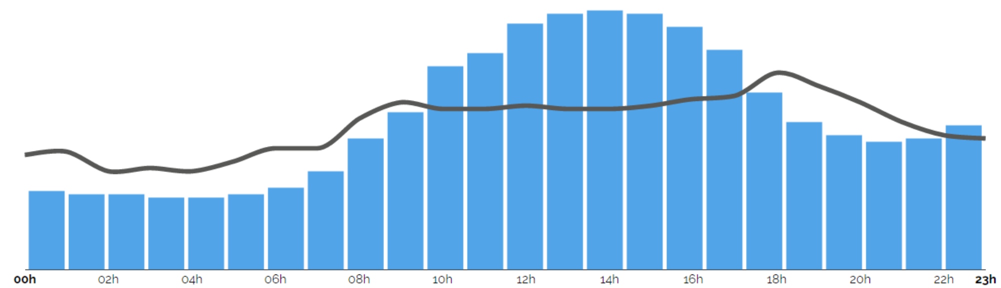
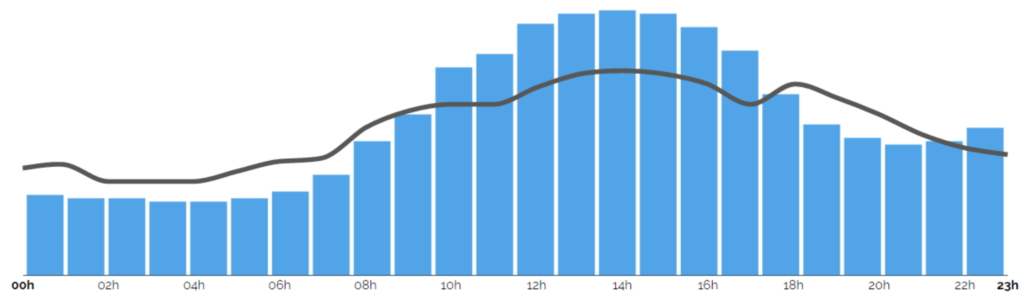
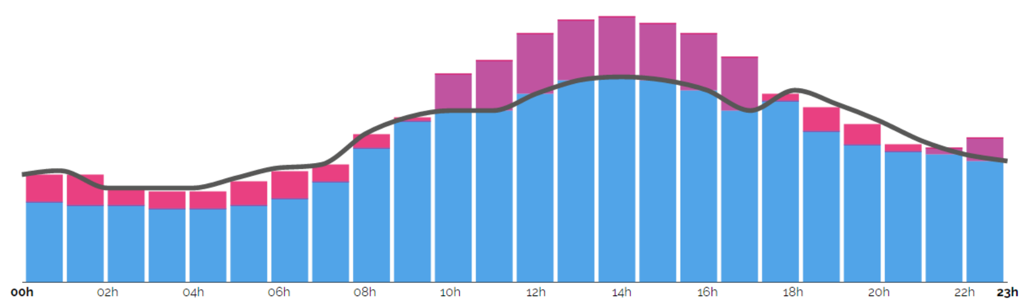
1 Original situation



2 Exploit demand flexibility



3 Exploit storage capacities and imports/exports



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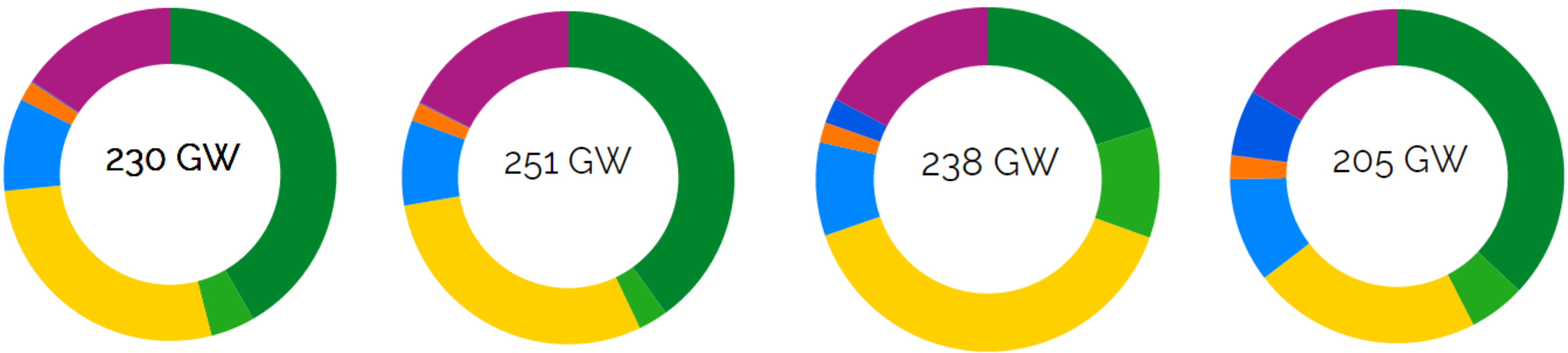
100% RENEWABLE ELECTRICITY MIXES

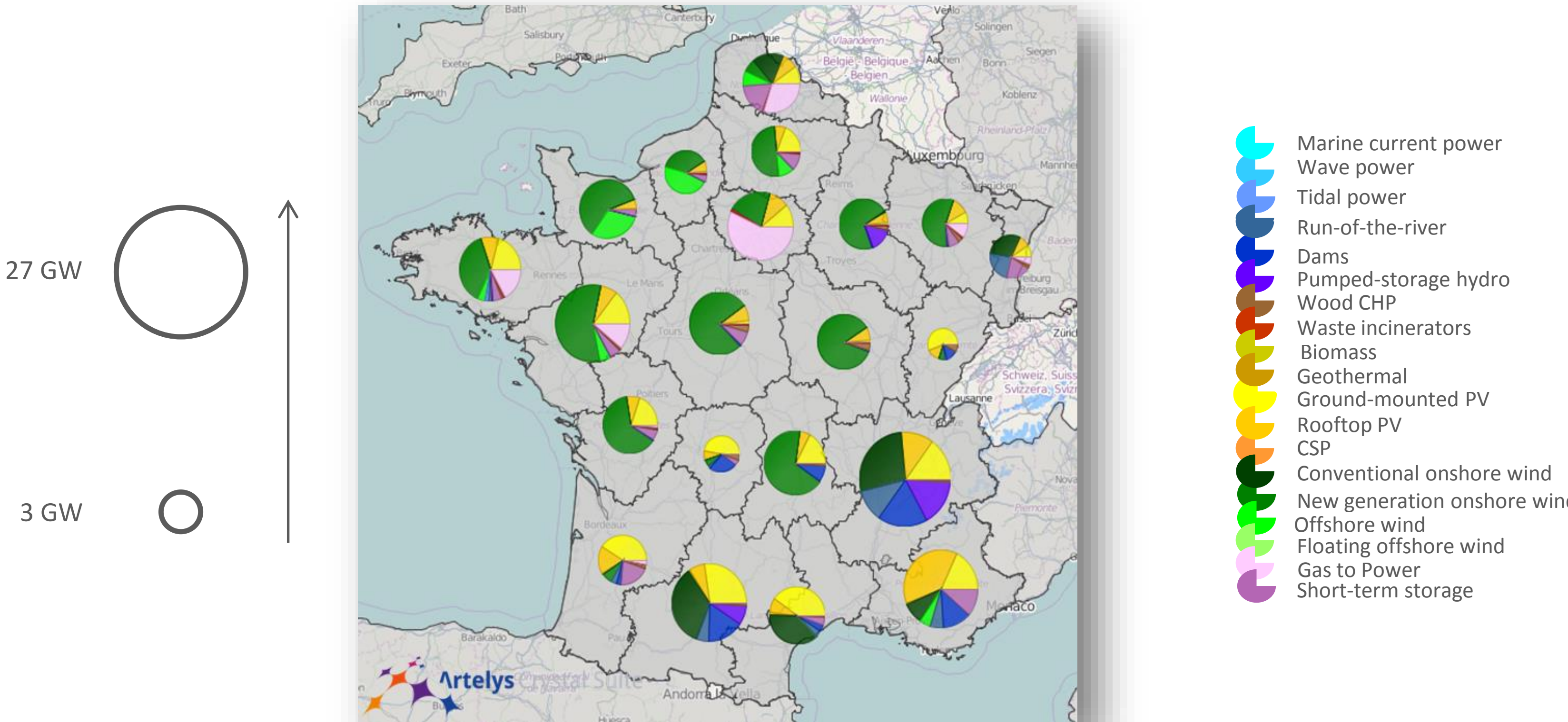
Central | **High network costs** | **Low acceptability** | **High technological progress**



Even in challenging situations, the supply-demand equilibrium can be enforced on 7 years of climatic data without loss of load

- Onshore wind
- Offshore wind
- PV
- Hydro
- Biomass
- Geothermal
- Marine power
- Storage

100% RENEWABLE ELECTRICITY MIXES

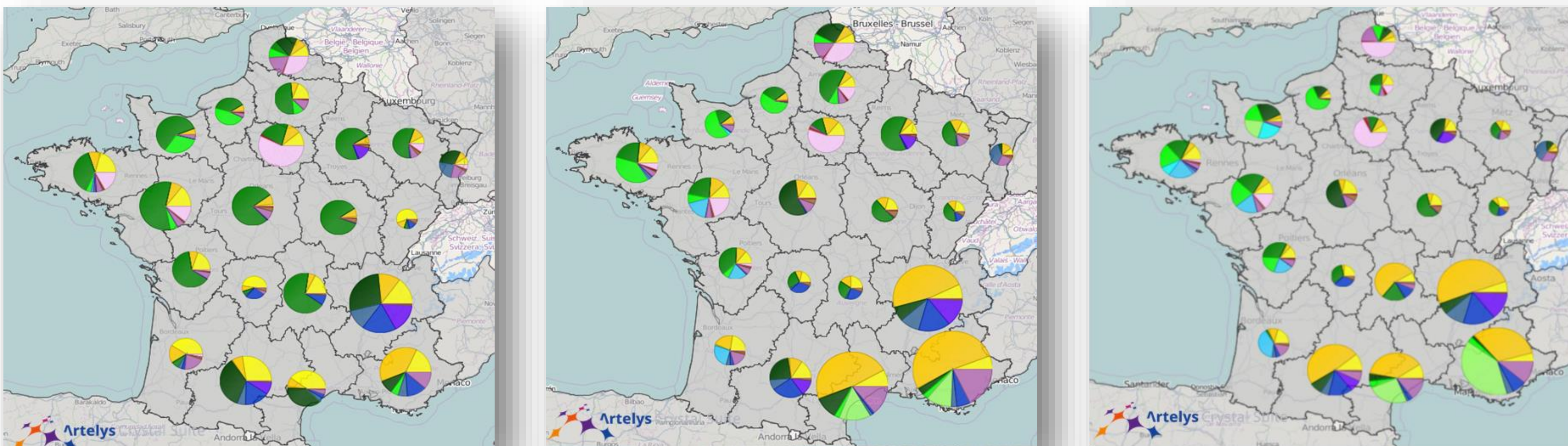


The portfolio of installed capacities is very diversified, even at the regional level

The chosen technologies are not purely determined by “merit order” considerations, but also based on the services they provide to the system

Impact of public acceptance on regional portfolios

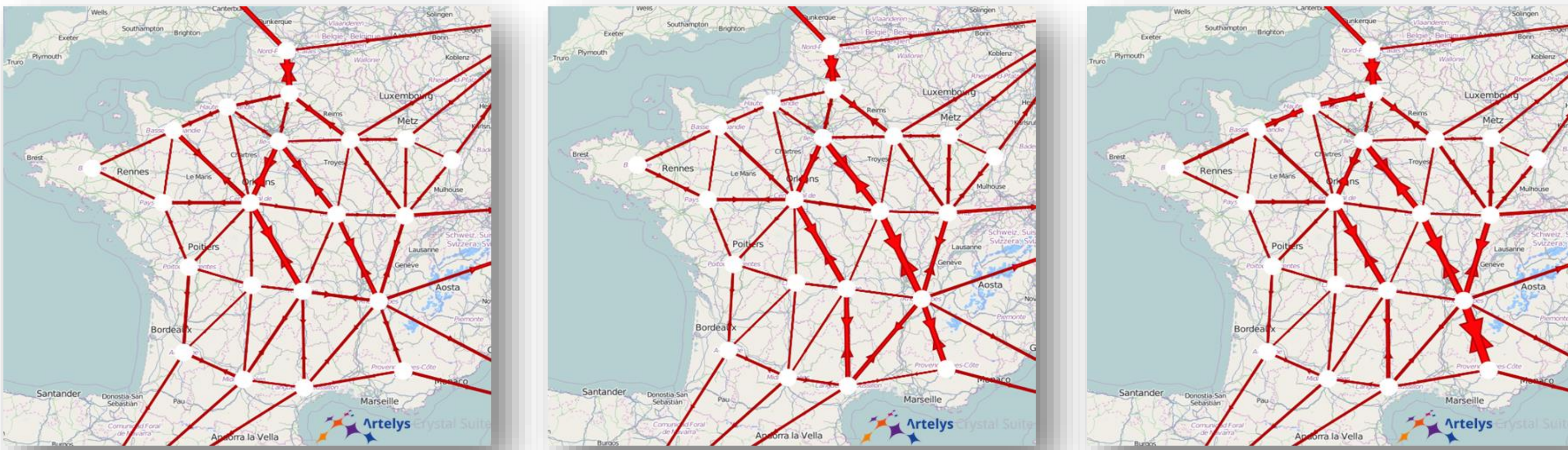
Reduced potentials for onshore wind and solar farms



High acceptance → Low acceptance

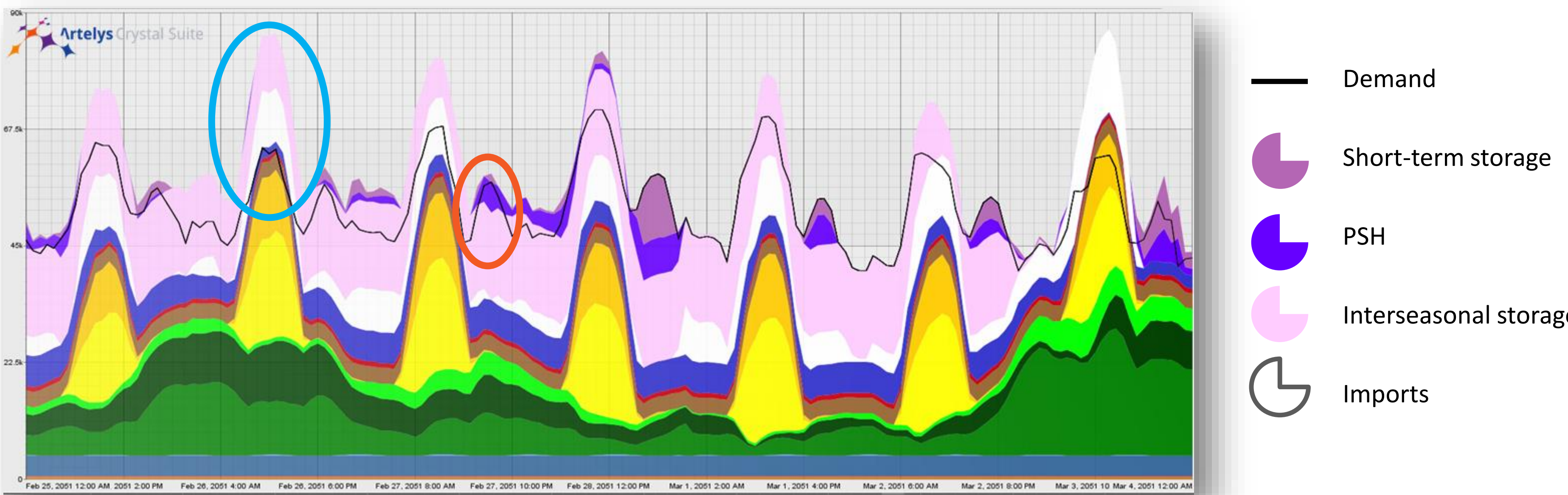
Impact of public acceptance on regional portfolios

Reduced potentials for onshore wind and solar farms



High acceptance → Low acceptance

Week with low wind production



- Long-term storage capacities feed the shorter-term ones
- All storage technologies (long- to short-term) are collectively used to ensure the evening peak demand is met

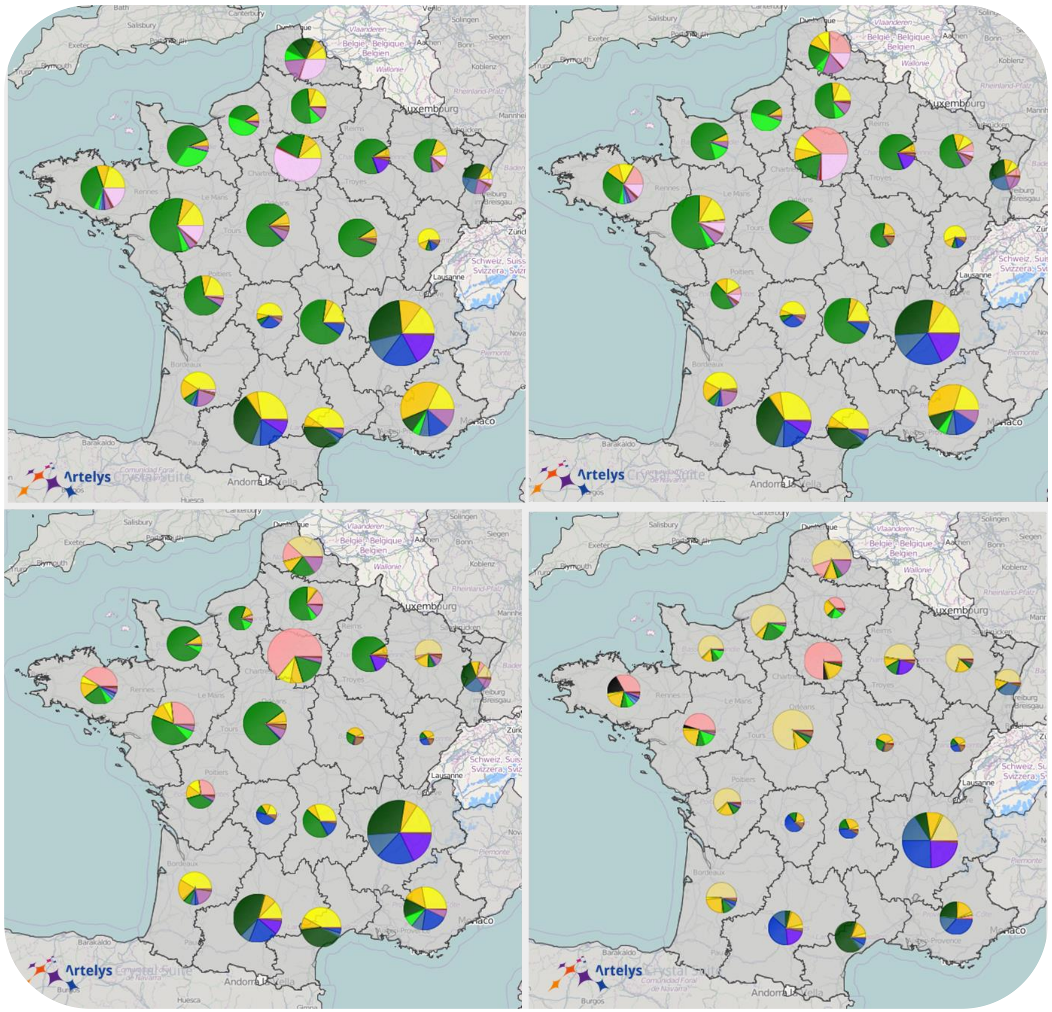
Thermal capacities progressively replace storage and renewables

100%

Tech.	Capacity
Gas	-
Nuclear	-
Renew.	196 GW
Storage	36 GW

95%

Tech.	Capacity
Gas	13 GW
Nuclear	-
Renew.	176 GW
Storage	27 GW



80%

Tech.	Capacity
Gas	23 GW
Nuclear	7 GW
Renew.	138 GW
Storage	15 GW

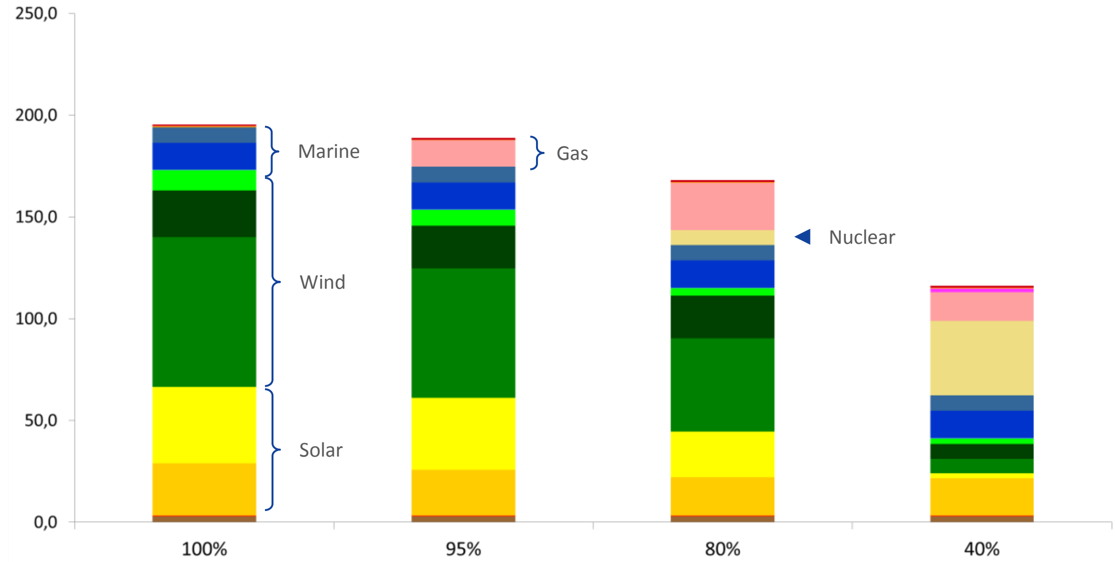
40%

Tech.	Capacity
Gas	16 GW
Nuclear	37 GW
Renew.	64 GW
Storage	9 GW

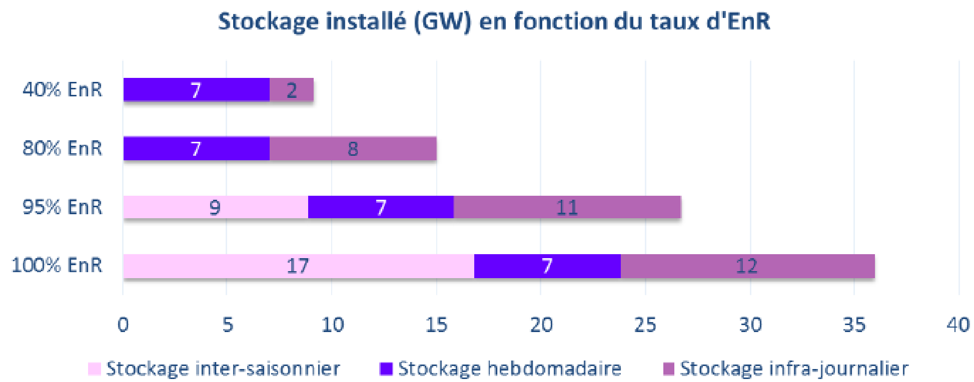
Installed capacities in GW

Nuclear reappears from 80% downwards

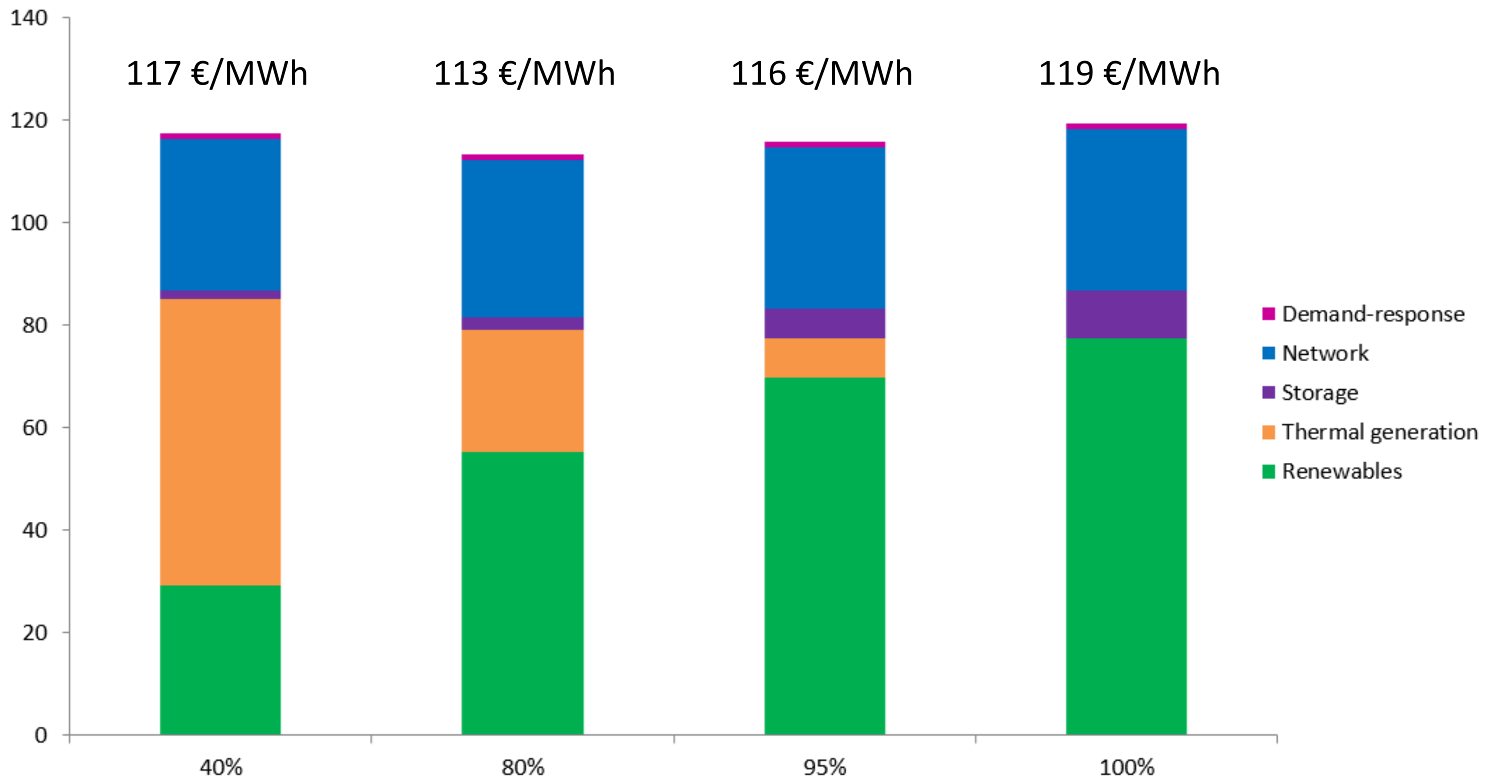
Wind turbines are the first technologies to disappear



From 80% downwards no interseasonal storage capacities are required anymore



WHAT ABOUT COSTS?



Sensitivity analysis reveals that costs vary between 103 €/MWh and 138 €/MWh
(resp. for easy access to capital, and high technological prices and low acceptability)

CONCLUSIONS

- A diversified portfolio of technologies is essential
- The network allows to pool the regional potentials
- A smart management of storage and demand-response is necessary
- Costs exhibit a low sensitivity to the RES-e share (2% add'l cost to go from 40 to 100% renewable)
- The 100% renewable generation mix is robust to climatic variations
- The hourly demand-supply equilibrium is met for seven climatic years

THANK YOU!

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