Main results:

A 100% RENEWABLE ELECTRICITY MIX ?

ANALYSES AND OPTIMIZATIONS

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

David MARCHAL, Deputy Director, Sustainable Productions and Energies

ENTSOE, Febryary 2017

ADEME at a glance

- **Public establishment under the joint authority of the Ministries in charge of :**
  - *Ecology, sustainable development and Energy*
  - *Research*
- **Areas of activity:**
  - *Waste mangement*
  - *Transport & mobility*
  - *Sustainable city*
  - *Energy & Climate*
  - *Energy efficiency*
- ***Budget:***
  - *590 M€ , in 2016*
  - *3 300 M€, for the « Inves for the future »*

- **ADEME's objectives**
  - ***Forerunner** for the energy & environmental transition*
  - ***Generalizer** of good practices*
  - ***Expert** of the energy & environmental transition*
- **How many, where?**
  - *Around 900 employees*
  - *Head offices (Angers, Paris, Sophia Antipolis)*
  - *17 regional Directorates*

Agenda

« Testing the boundaries of renewable energy development in the French continental electricity mix by 2050 »

1. **Context and objectives**
2. **Methodology and main assumptions**
3. **Results**
4. **Conclusions**

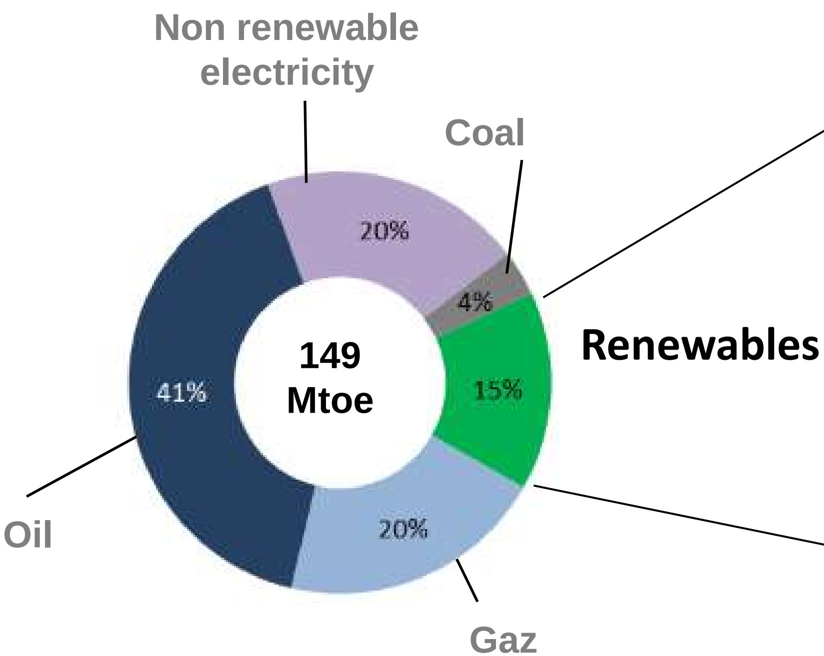
- **Based on a snapshot of an optimal electricity mix in the remote future (2050)**, rather than an energy transition scenario. Exclusion of investment temporality.
- **Supply and demand are balanced all year long on an hourly basis**: stability and network dynamics are not assessed at shorter time steps.

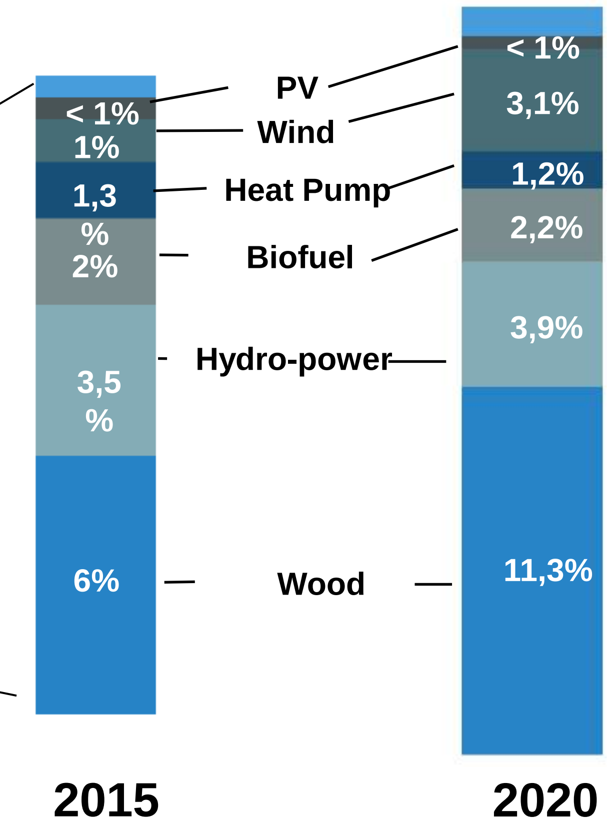
Agenda

« Testing the boundaries of renewable energy development in the French continental electricity mix by 2050 »

1. **Context and objectives**
2. **Methodology and main assumptions**
3. **Results**
4. **Conclusions**

1. In 2015, in France, RE represents 15% of final energy consumption

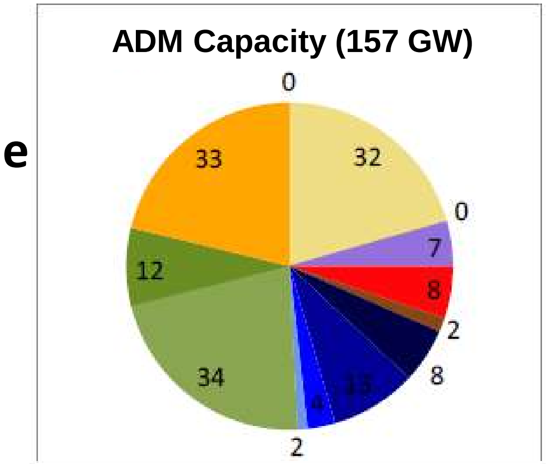


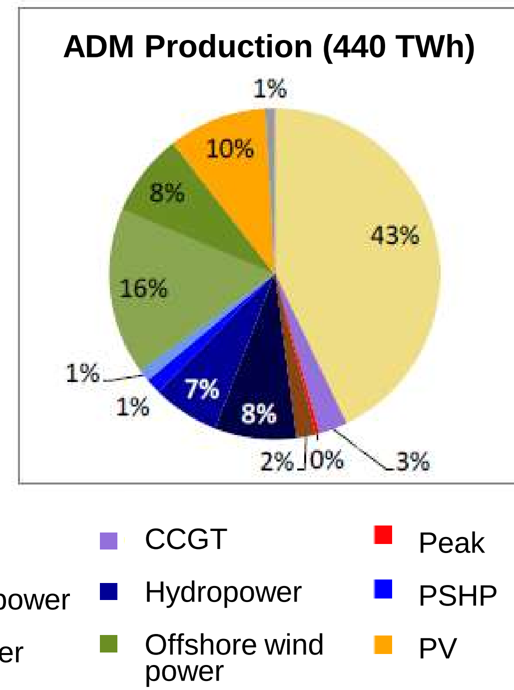


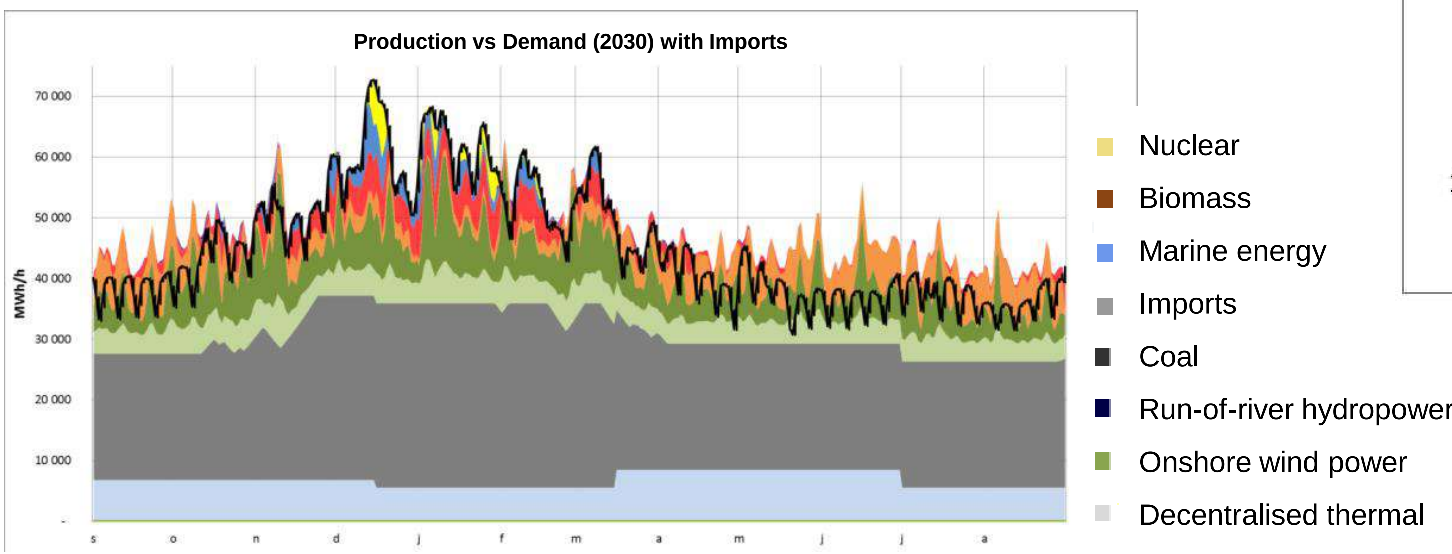
2. Today's 2 main ressources: biomass & hydro
3. For electricity: RE share is around 20% of consumption in 2016

- **ADEME Energy Transition Scenarios to 2030:**
  - **An electricity mix with 50% of renewables is possible**
  - **Demand and supply are balanced**

- **PEPS 2030 Study:**
  - **The French electrical system is already very flexible**
  - **Economically-profitable extra storage potential is rather small (<2 GW)**







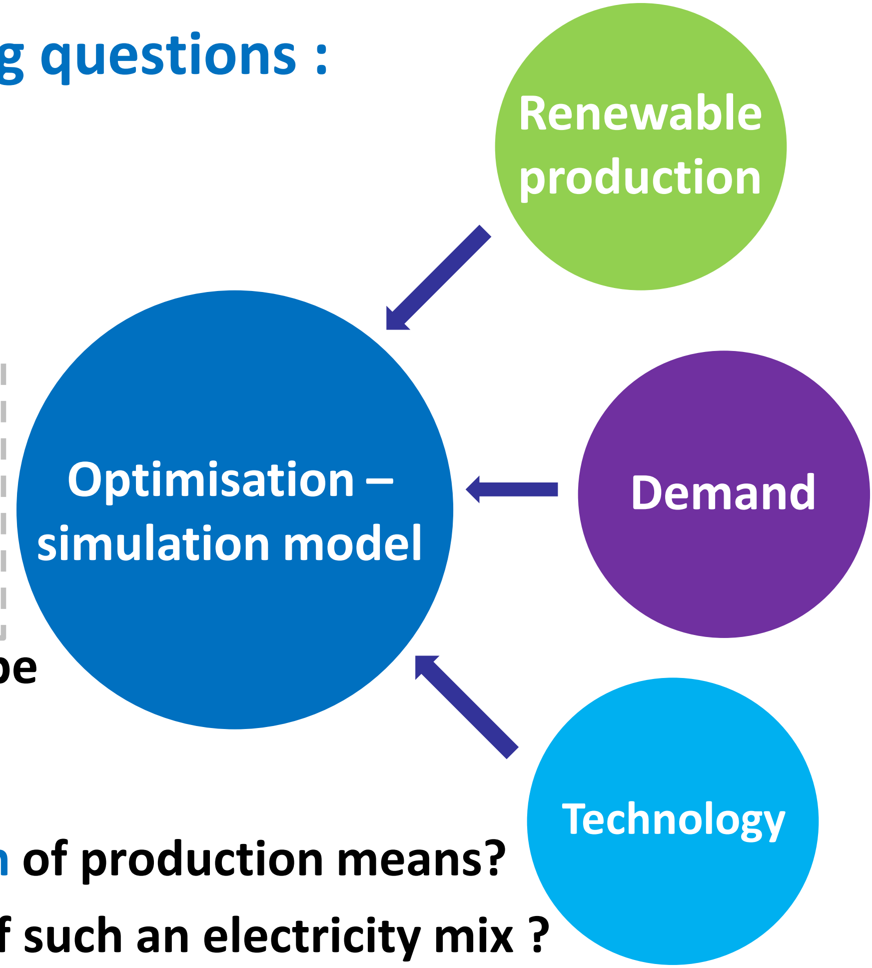
The purpose is to answer the following questions :

- **What is required to increase significantly renewables' share in the electricity mix of continental France?**

  => Situation :

  - Case scenario: 100% of renewables in the electricity mix
  - With a long-term time horizon (without looking at the path required to achieve this)

- **Based on these assumptions, what would be the optimum electricity mix?**



- **What would be the geographic distribution of production means?**
- **What are the possible economic impacts of such an electricity mix ?**

« Testing the boundaries of renewable energy development in the French continental electricity mix by 2050 »

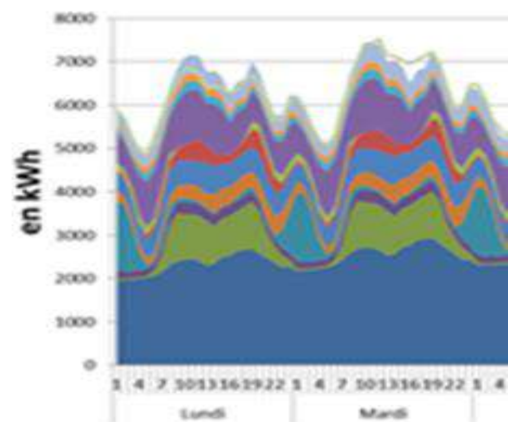
1. **Context and objectives**
2. **Methodology and main assumptions**
3. **Results**
4. **Conclusions**

Main assumptions

- **Demand** [420 TWh; peak of 96 GW]

De ma nd

  - **A drop in electricity demand level, but new uses to be covered, and a strong evolution in electrical structure**
  - **Strong assumptions about demand flexibility**
  - **A reconstruction of hourly demand by usage**



- **Renewable electricity resources** [1250 TWh]

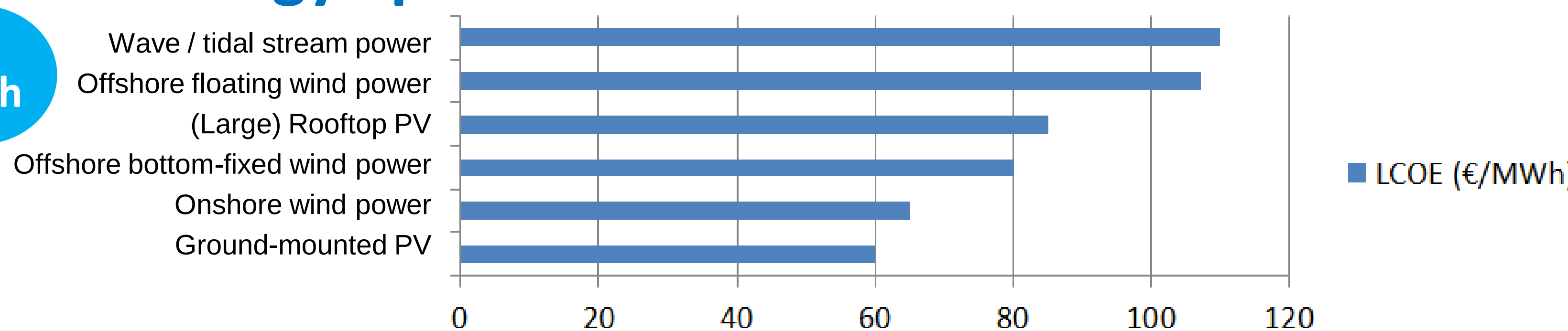
RES

  - **Resources assessed using a mapping approach**
  - **Large amounts of renewable resources available**
  - **Fifteen renewable technologies modelled**

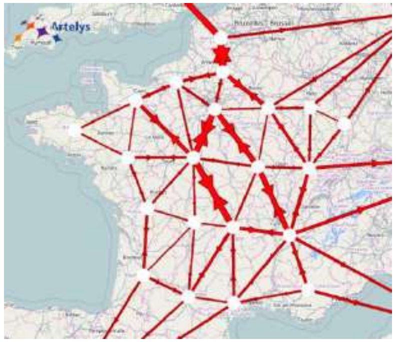
PV	Ground-mounted: 47 GW Rooftop: 364 GW
Wind	Onshore: 172 GW Offshore: 66 GW

- **Technology-specific costs**

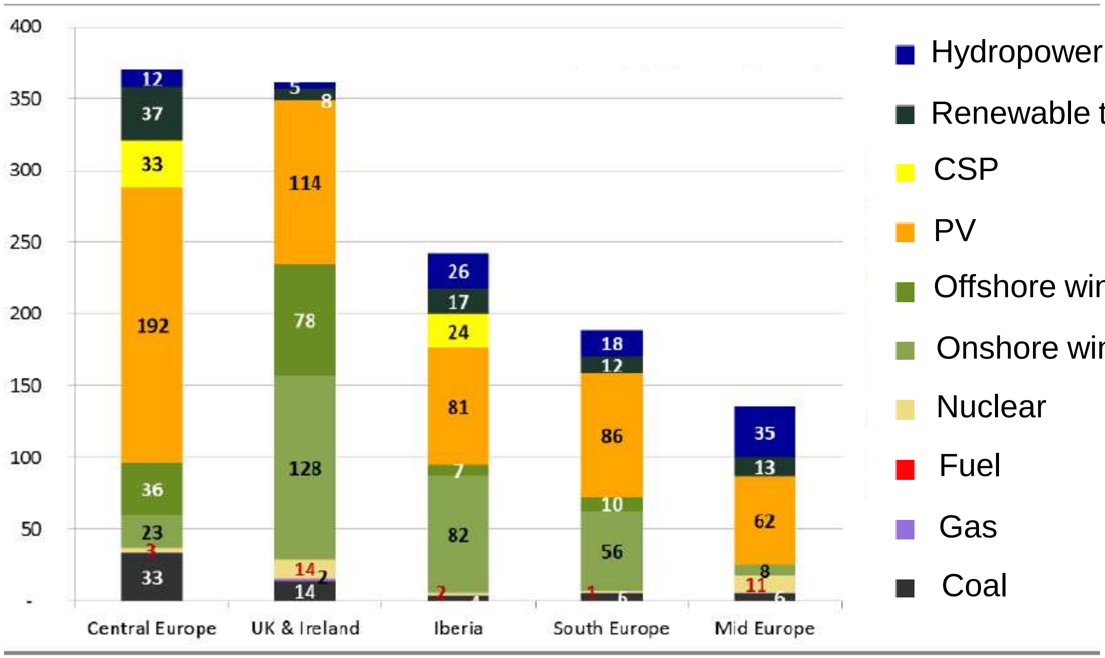
Tech



- **France interconnections**
  - **23 GW interconnection capacities for export**
  - **16 GW interconnection capacities for import**



- **European electricity mix**
  - **Based on the scenario elaborated by the European Climate Foundation (ECF), from the Roadmap 2050 project : 80% renewable electricity**



One central case and several alternate scenarios

	Pénétration EnR	40%	80%	95%	100%
	Baseline scénario	✓	✓	✓	✓
Variantes « acceptabilité / comportement »	Complex grid reinforcement				✓
	High level of demand				✓
	Moderate acceptance og Wind & PV		✓		✓
	Very limited acceptance				✓
	Unfavorable scenario		✓		
Variantes « économie »	High costs				✓
	Lower costs for non mature RE				✓
	Lower capital cost				✓
Variantes « Contrastes »	Drought				✓
	Without PV				✓
	Without New generation wind turbine				✓
	Without dynamix flex				✓
	Repartition grid	✓			✓

Agenda

« Testing the boundaries of renewable energy development in the French continental electricity mix by 2050 »

1. **Context and objectives**
2. **Methodology and main assumptions**
3. **Results**
4. **Conclusions**

1. Several 100% renewable electricity mixes are possible, under multiple constraints

- Always largely based on PV and wind power
- Supply and demand are balanced hourly, for 7 historical meteorological years, at European level

2. The total cost of electricity only slightly varies between 40% and 100% renewable

- But mainly depends on energy efficiency, social acceptance and technological progress

3. Storage and flexibility are essential

- Demand flexibility complements daily variability of renewables
- Different distributions of storage means according to the constraints

4. Complementarity between renewable technologies is essential

- Economic optimum is based on balance between LCOE and system services

5. Inter-regional network growth is necessary to pool potentials

- + 36% of inter-regional network capacity

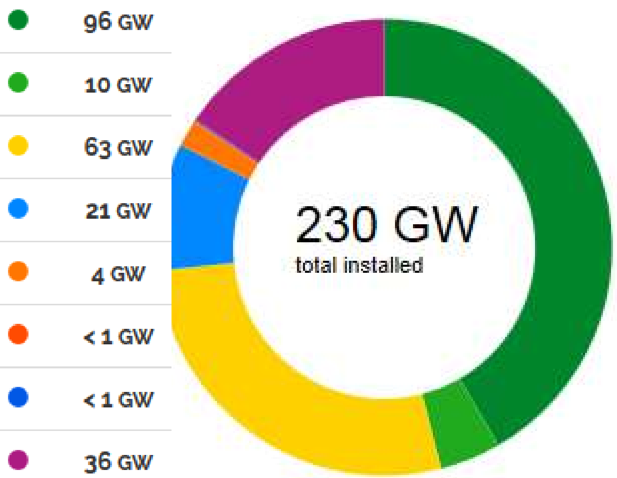
Result 1

Several electricity mixes with 100% of renewables

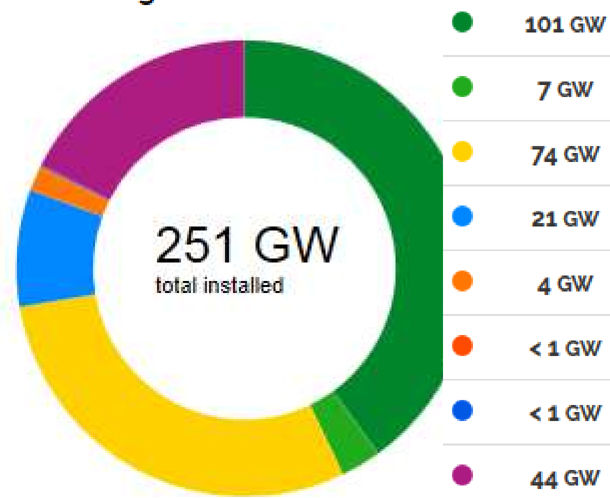
According to the assumptions, several optimum mixes are identified.

PV and wind power are the two key pillars in each case

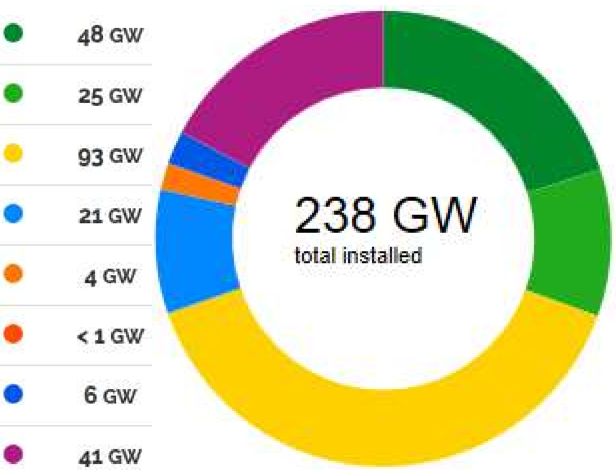
Central scenario



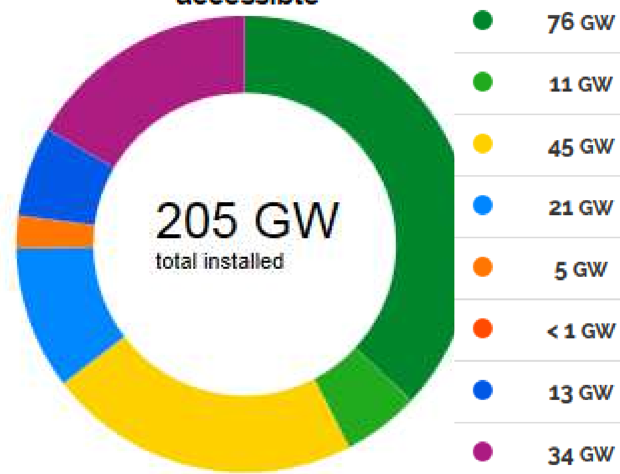
High cost of network



Moderate acceptability



Emerging technologies accessible



- Onshore wind
- Offshore wind
- Solar
- Hydraulic
- Biomass
- Geothermal
- Marine renewable energy
- Storage

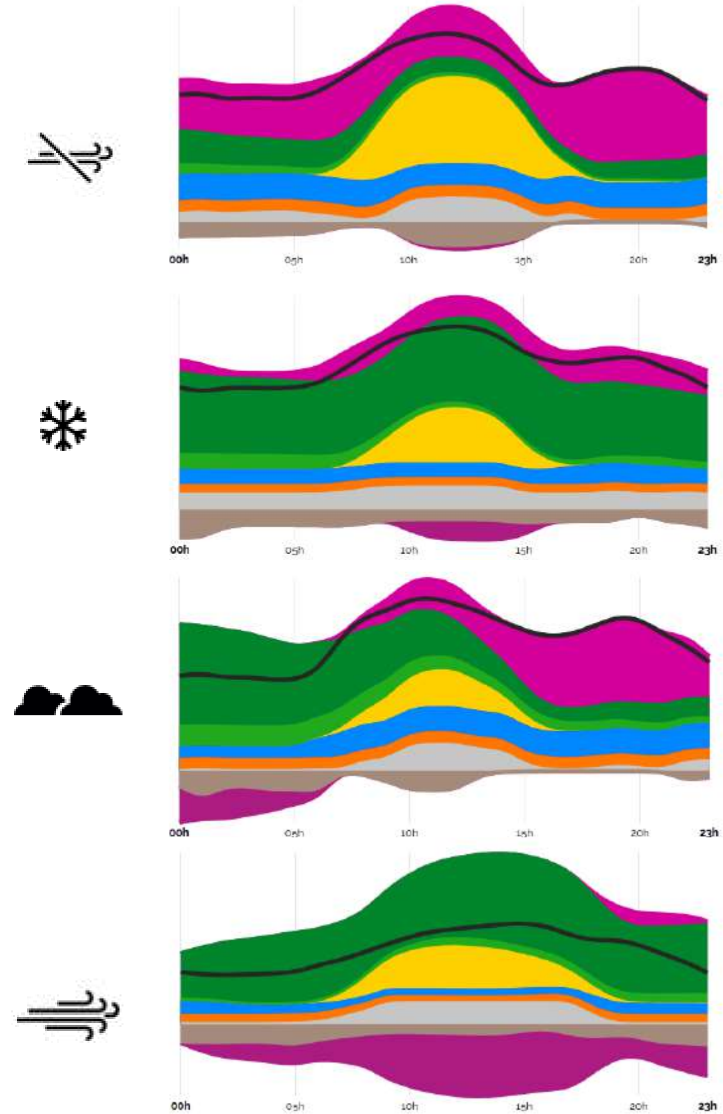
ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

Result 1

Several electricity mixes with 100% of renewables

100% renewable electricity mixes are robust to meteorological hazards:

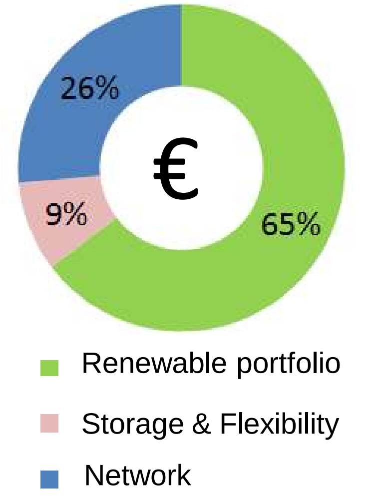
- **Methodology:**
  - Wind and PV productions coordinated at French and European levels
  - Foreign mix 80% of renewables
  - French demand is correlated with temperature
- **Failure-free for 7 historical meteorological years: from June 2006 to May 2013**
- **A « drought year » variation is also tested**

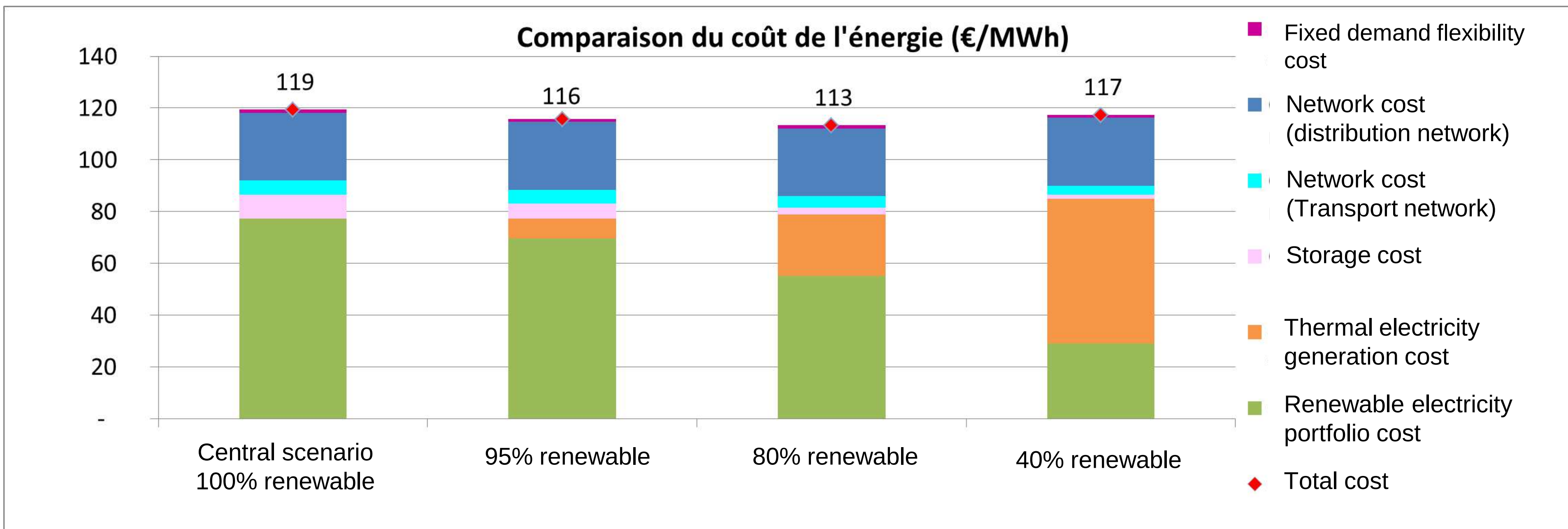


Result 2

Deciding factors in costs

- **Total cost of electricity around €120 /MWh**
- **Main costs come from renewable capacity investment**
- **Costs depend little on renewables share (with the central set of assumptions):**
  - 2% cost difference between the 100% and the 40% renewable electricity mixes
  - 80% renewable mix appear slightly cheaper

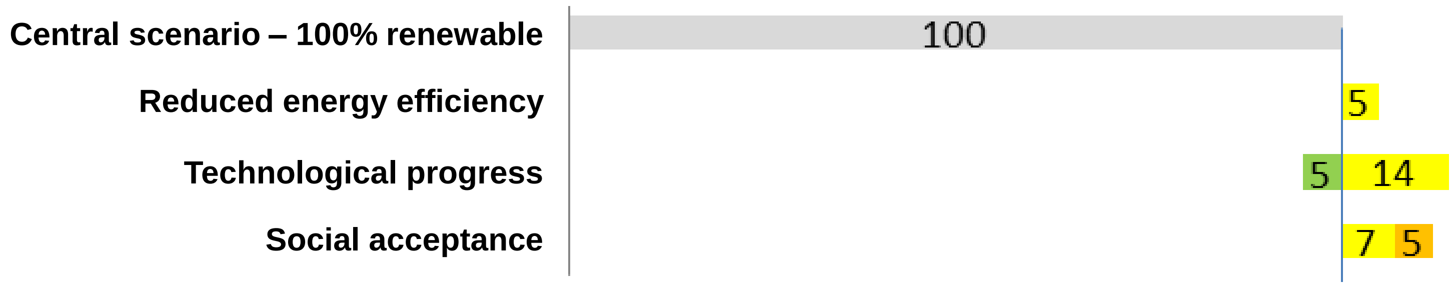




Cost efficiency mainly depends on:

- **Energy efficiency**: if electricity demand is 20% higher and peak demand 40% higher:
  - Last kWhs cost 30% more to produce
  - Electricity cost (per kWh) 5% higher, total cost 26% higher
- **Technological progress**: *[small / incremental / breaking]*
  - A range of variation from -5% to +14% of electricity cost
  - Technological progress assumptions have different effects depending on renewable technologies
- **Social acceptance**: *[good / moderate / very limited]*
  - +7% of electricity cost in case of moderate acceptance
  -

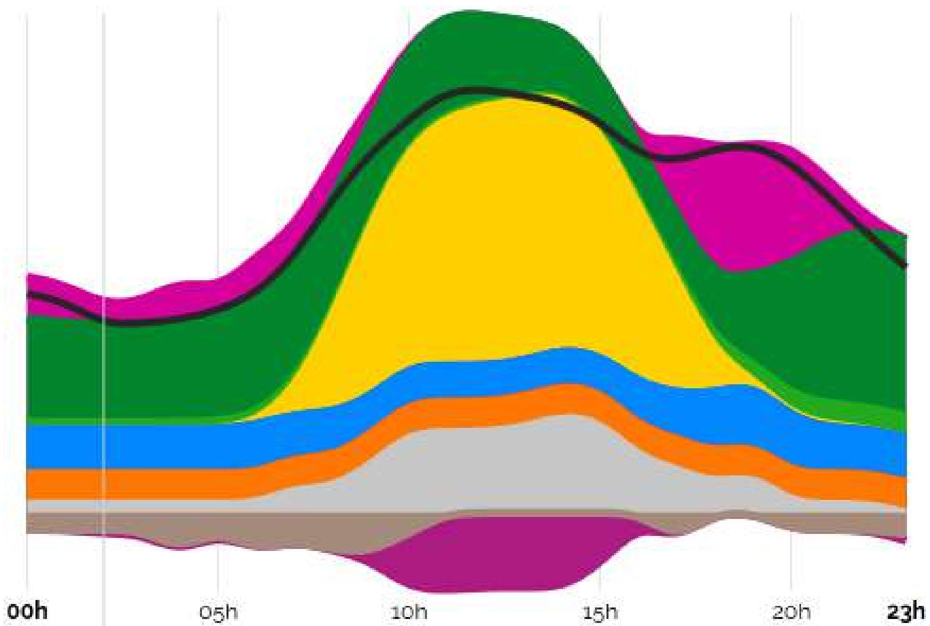
Cost sensibility of electricity (%)

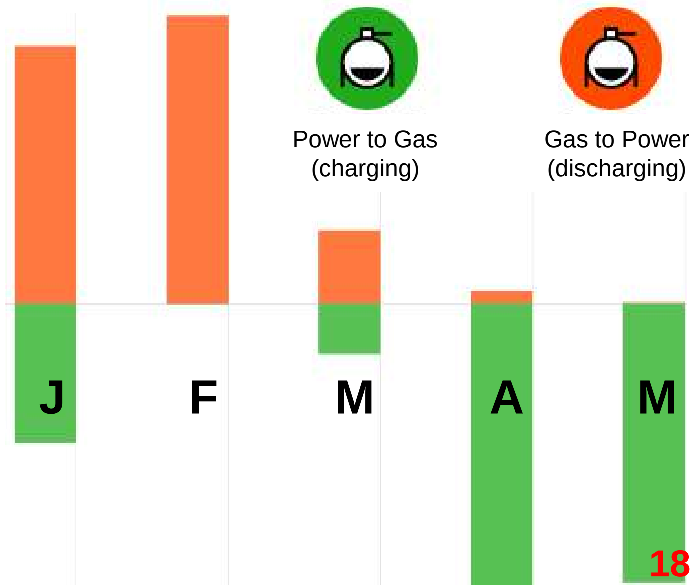


Result 3

Different types of flexibility on different time scales

- **Demand curve is adjusted to match solar production peaks**
- **In summer, solar surplus is valued through the use storage, from short-time to inter-seasonal storage**

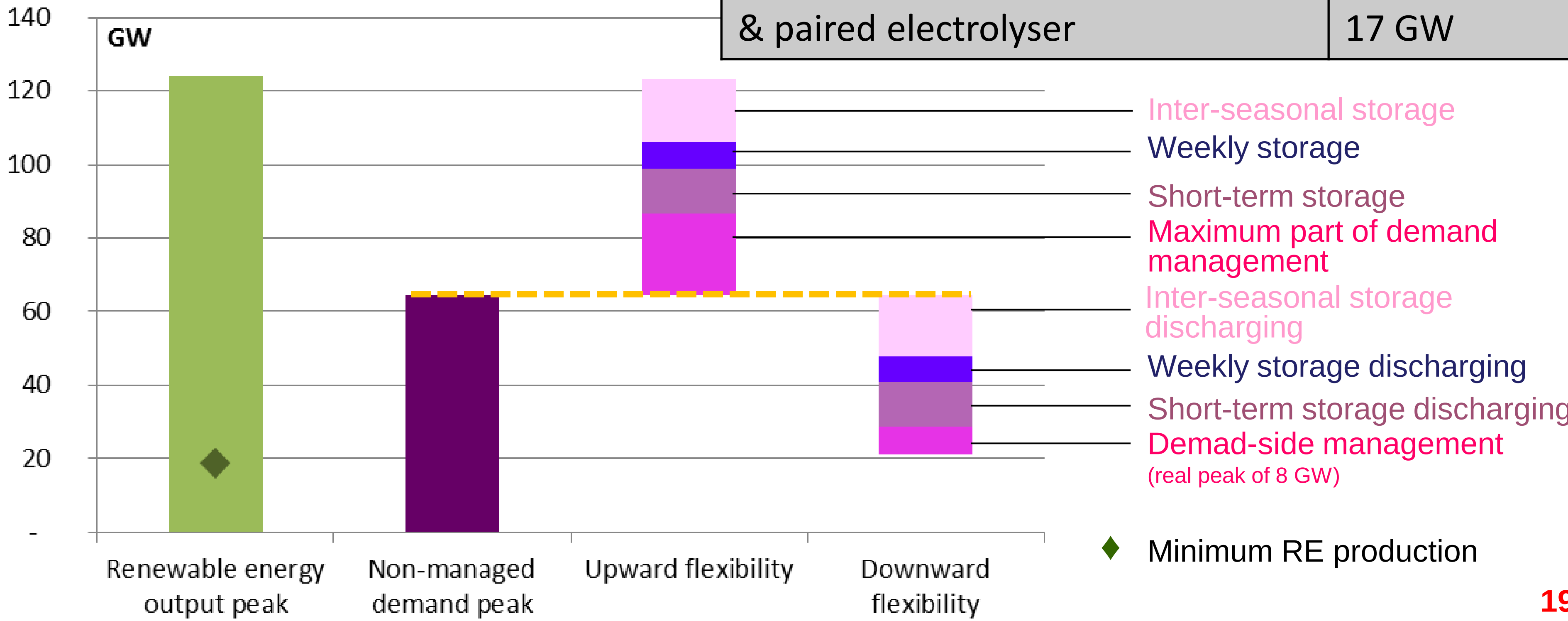




Different types of flexibility on different time scales

- **Inter-seasonal storage amounts to 19 TWh, 4% of annual production**

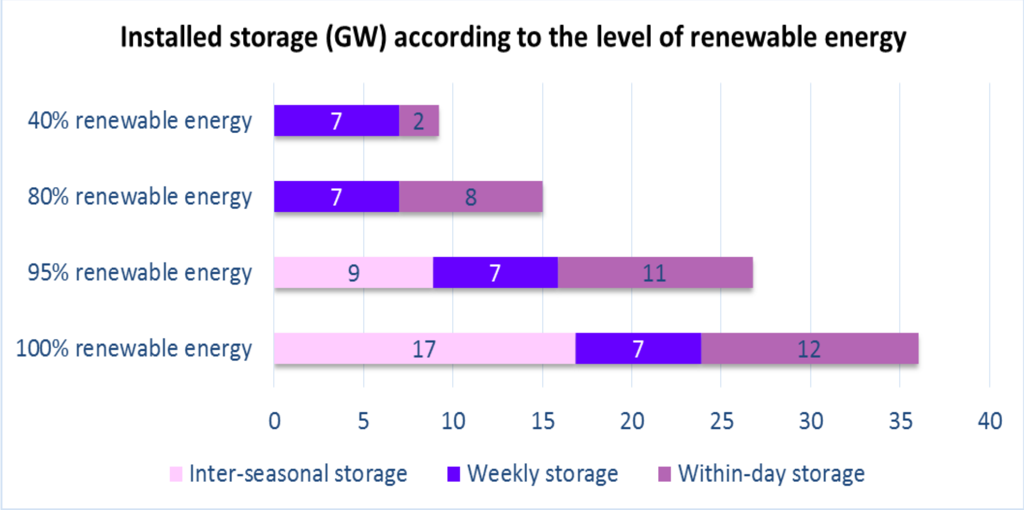
Demand-side management	-8 / +22 GW
Short-term storage (6 hours)	12 GW
Weekly storage - PSHP (30 hours)	7 GW
Inter-seasonal storage (gas) & paired electrolyser	16,8 GW 17 GW



Result 3

Flexibility and storage are essential

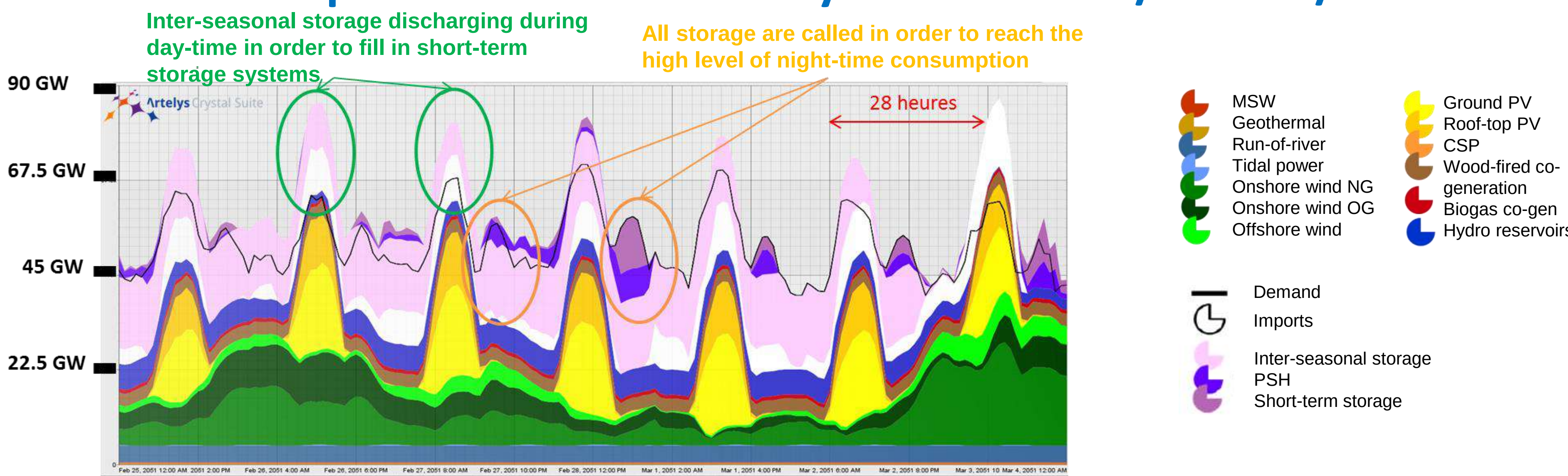
- **The market share of each storage type depends on mix constraints:**
  - **Short termestorage share increases with PV capacity:** about 20% (8 GW) of PV capacity for mixes above 80% RE.
  - **Inter-seasonnal storage is not necessary under 80%RE share in the mix,** if syngas is used only for electricity mix purpose

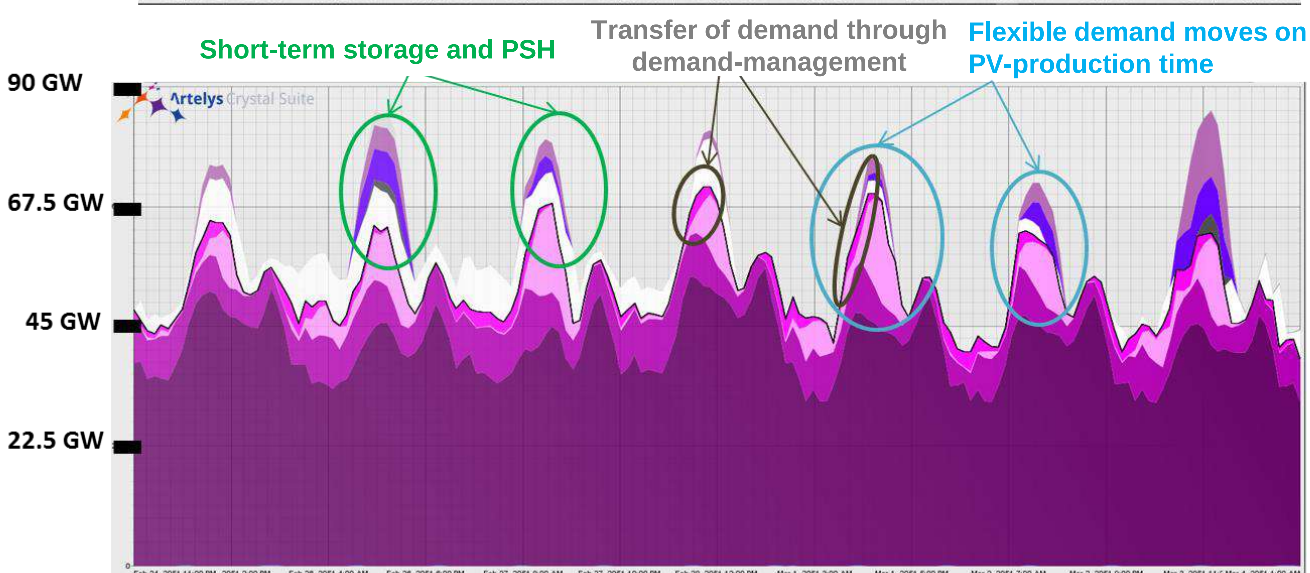


- **Dynamic Demand Side Management and short-term storage provide the same services for the system**

Flexibility and storage are key

- # Example of a week with very low wind: 24/02 → 3/03

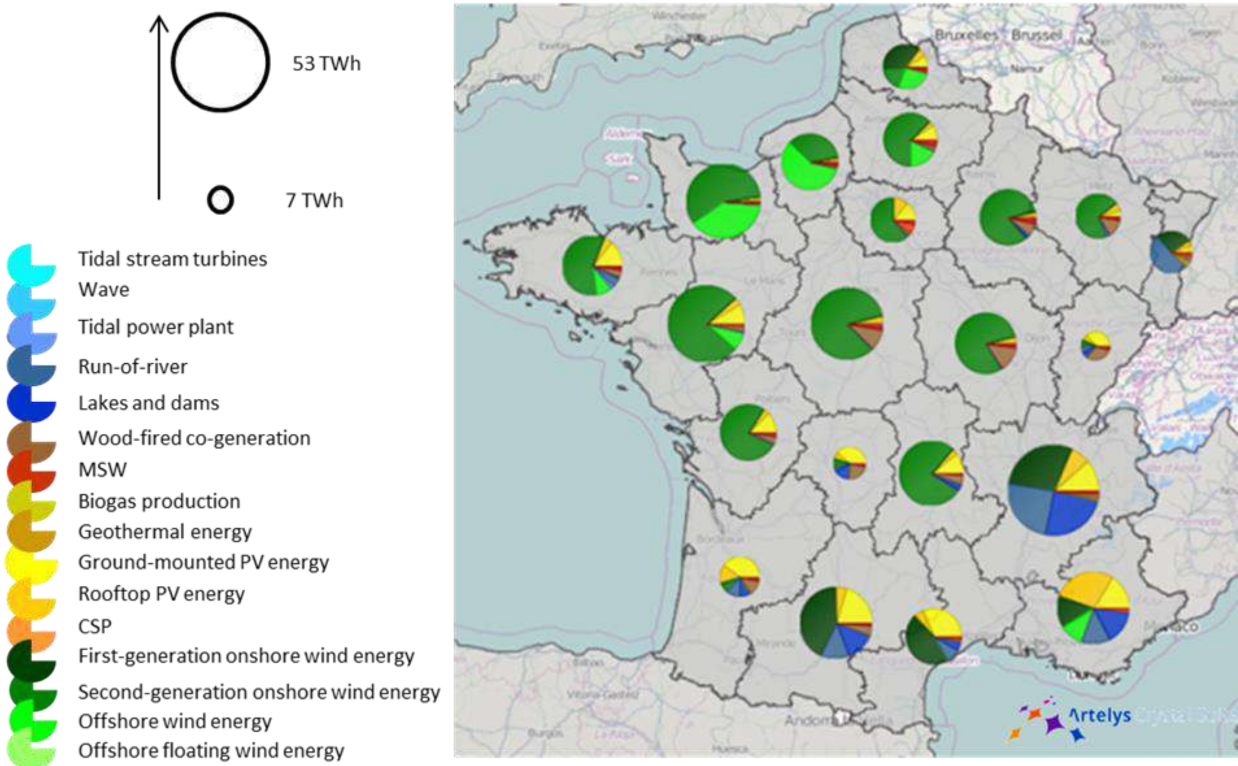




Result 4

Complementarity between renewable technologies is essential

- **Economic optimum does not only depend on technology costs, but also on benefits to the overall system operation**
- **The lowest cost technology is different according to the region**
- **Electricity system favours baseload profile technologies, even if they are more expensive**
  - Example bottom-fixed offshore wind power in the Mediterranean
- **In spite of wind power prevalence, each technology adds value to the system**



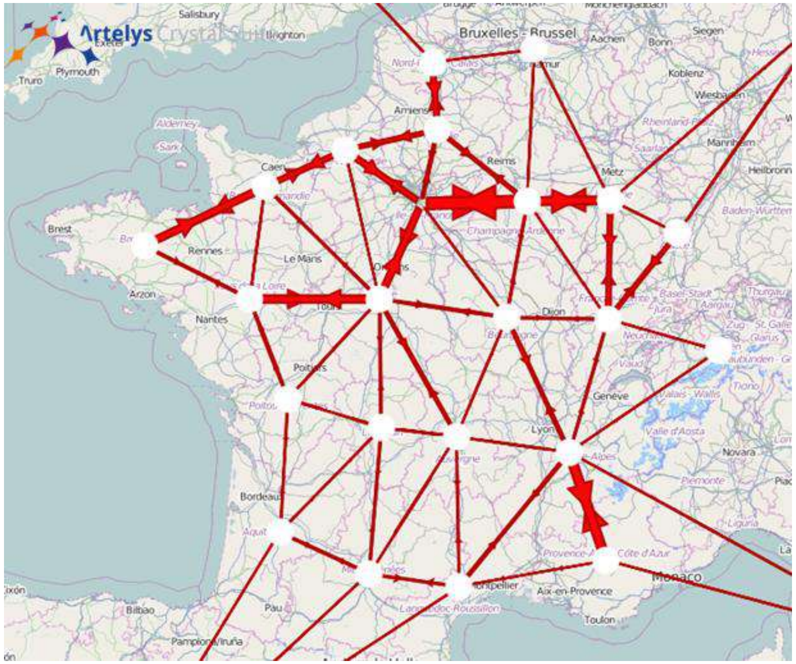
Result 5

The grid makes it possible to pool potentials

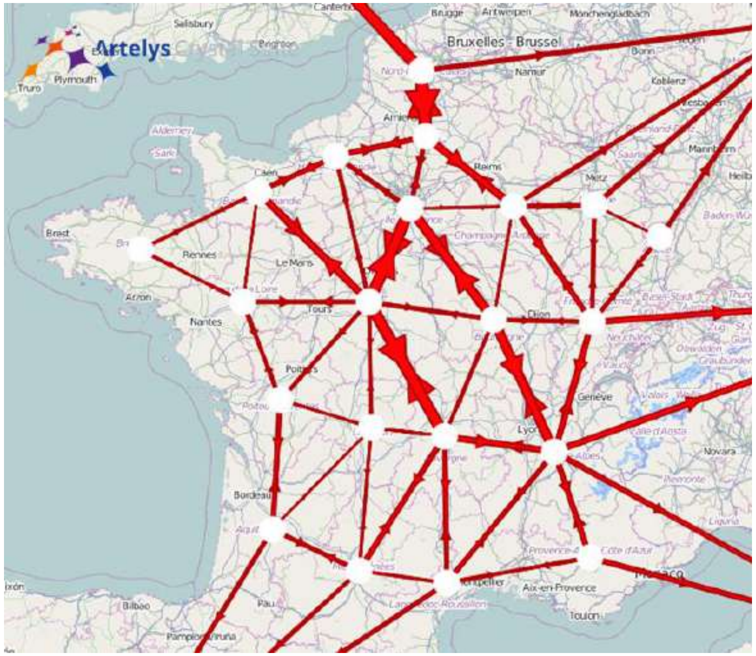
Network growth is necessary to pool potentials

- Transport network increases by 36% compared to today: 68 GW interregional capacity (50 GW currently)
- 23 GW exports and 16 GW imports with neighbouring countries

Inter-regional « virtual » grid 2013



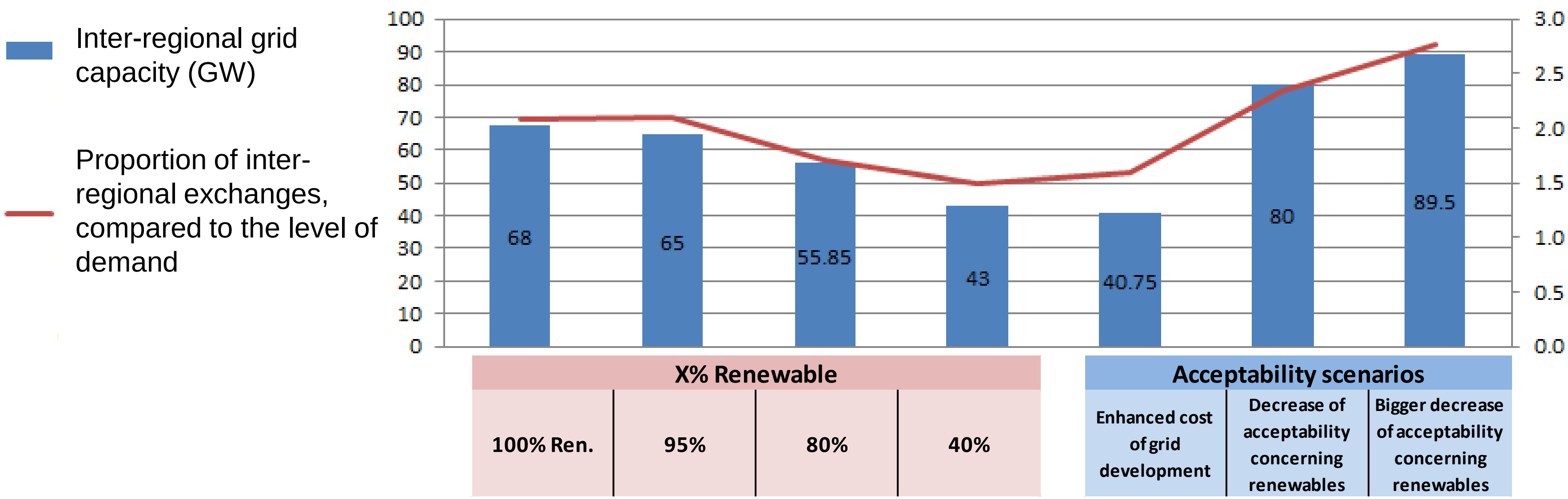
Inter-regional grid 2050



Result 5

The grid makes it possible to pool potentials

- **Need of a stronger inter-regional grid increases …**
  - **When acceptability of renewables decreases**
  - **When selected renewables are located far away from consumption centers (typically with a high development of offshore wind)**
- **Need of a strong inter-regional grid decreases…**
  - **When non-renewable units are selected and placed next to consumption centers**
  - **When the hypothesis of grid development cost is increased**



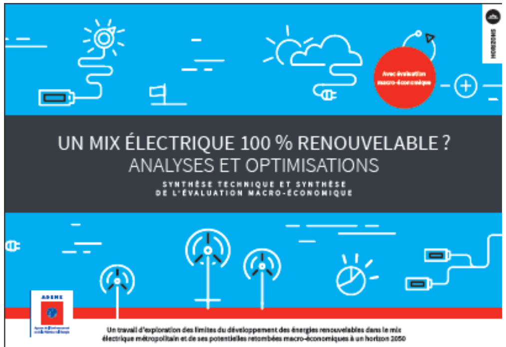
Agenda

« Testing the boundaries of renewable energy development in the French continental electricity mix by 2050 »

1. **Context and objectives**
2. **Methodology and main assumptions**
3. **Results**
4. **Conclusions**

- **Main results:**
  - **Three essential conditions to control the cost of an electricity mix with a high level of renewable electricity generation:**
    - High energy efficiency (& demand peak management)
    - A good social acceptance of renewable technologies
    - Lower costs of technologies
  - **A non-renewable part in the electricity mix improves robustness relating to social acceptance constraints on renewable technologies**
  - **Submitting RE productions to the «price signal» : an incentive to favour best profile technologies for system operation**
- **Further investigations:**
  - **Evaluation of macro-economic impacts**
  - **Power-to-X: how 100% RE electricity could make other energies greener?**
  - **Expanding study to Western Europe**
  - **Taking into account intra-hour dynamics**

Thank you for your attention



Contact: David.Marchal@ademe.fr

The main report is available on the ADEME website:

http://www.ademe.fr/mix-electrique-100-renouvelable-analyses-optimisations

(+datas, macro-economic analysis)

A detailed breakdown in hourly intervals:

http://mixenr.ademe.fr