



France launched a National Hydrogen Program

by François LE NAOUR

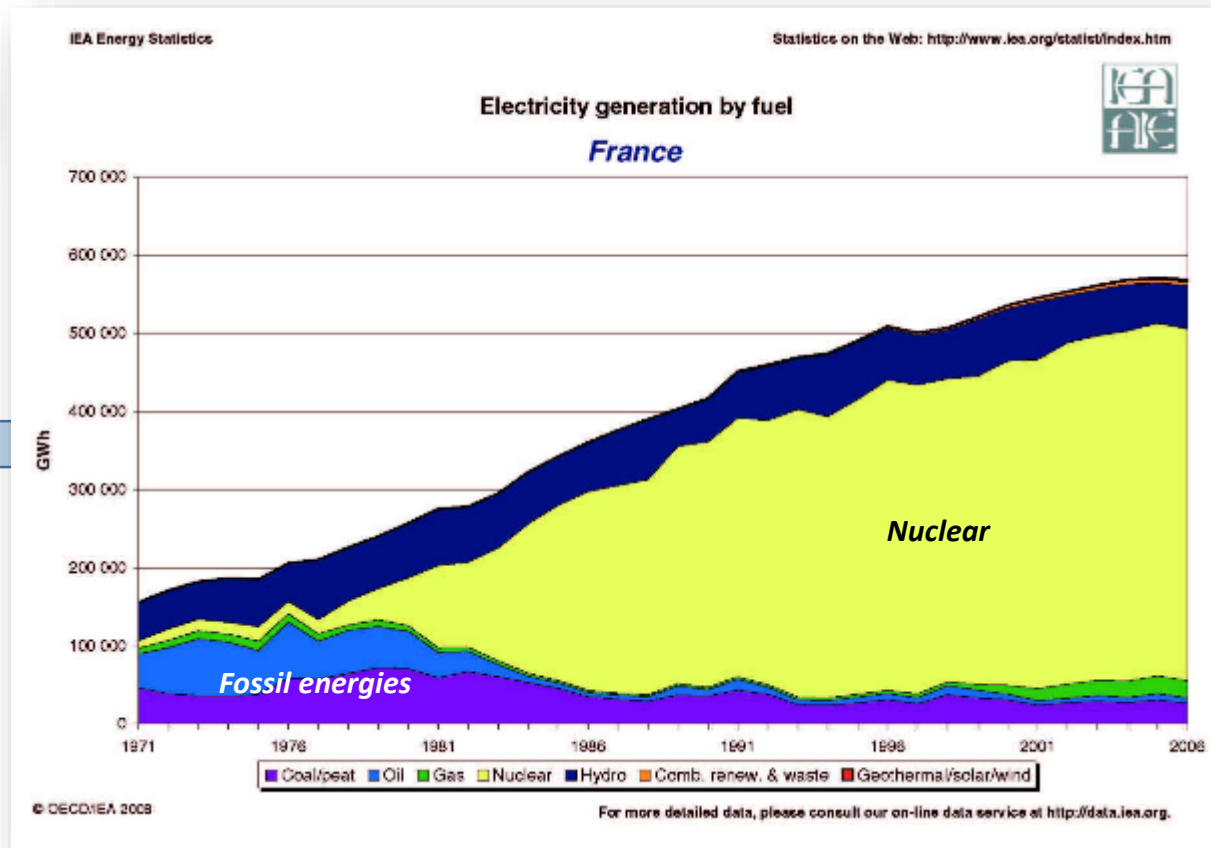
(French Atomic & Renewable Energies Commission)

France, a country historically committed to carbon-free energies



Charles De Gaulle – French President 1959 - 1969

1960's

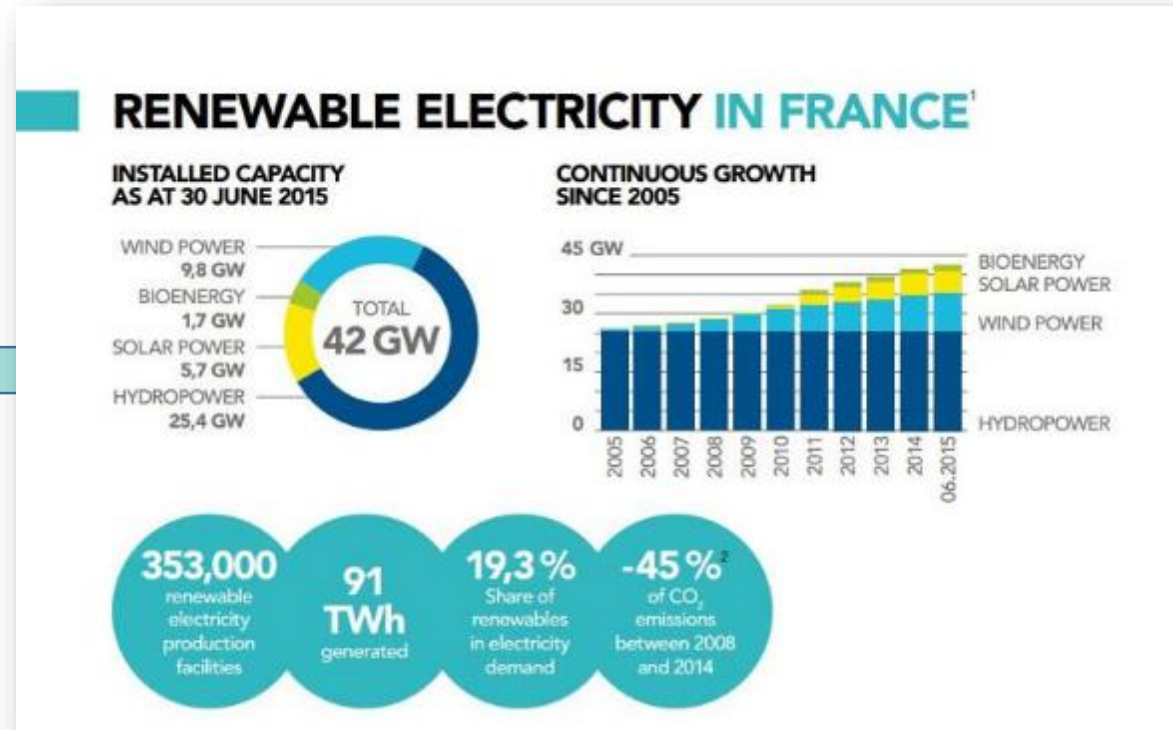


France, a country historically committed to carbon-free energies



François Hollande – French President 2012 – 2017
Laurent Fabius – COP21 President

2015

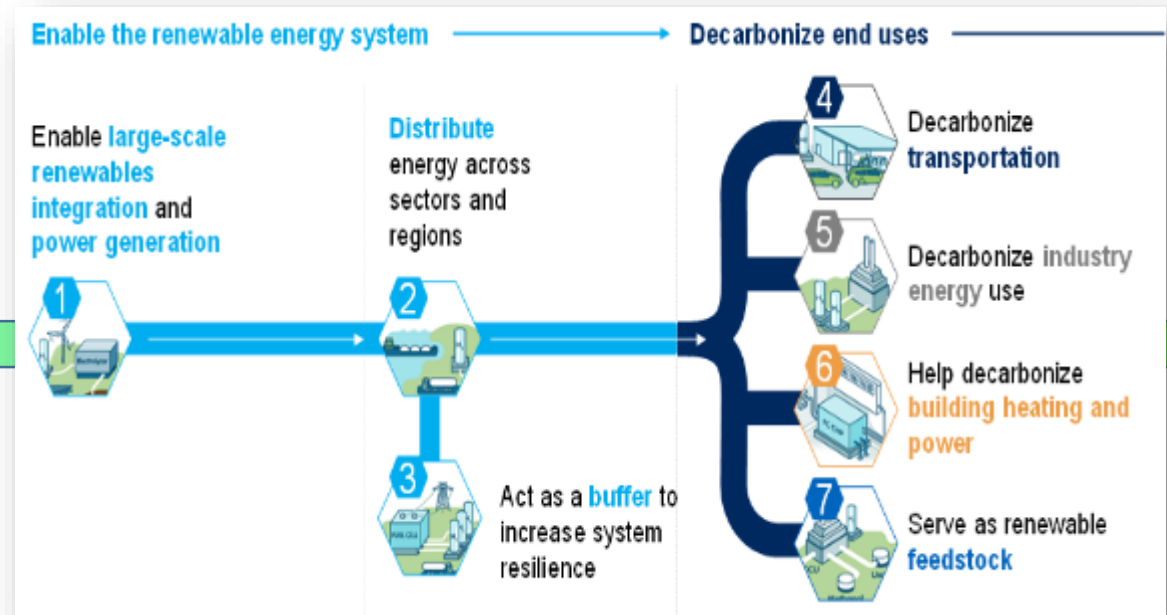


France, a country historically committed to carbon-free energies

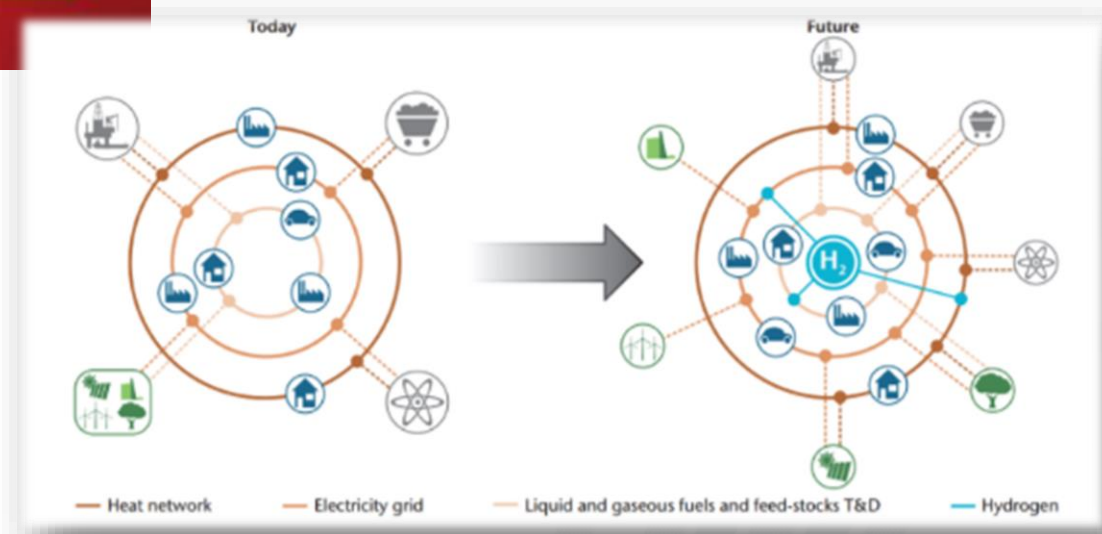


Nicolas Hulot - Minister of Ecological and Solidary Transition 2017-

2018



Hydrogen is a key issue for ENERGY 4.0



Mobility for individuals **Public transport** **Other mobilities**



Mobility

Energy management in buildings and districts



Ecodistricts

Energy Network Services



Heating grids

CO₂ valorization



E-fuels by cementeries



Power-to-Gas



Electricity grids



Renewables energies Management



Nuclear Power regulation

French energy policy



H2 roadmap



Decarbonized H2 production



H2 Mobility



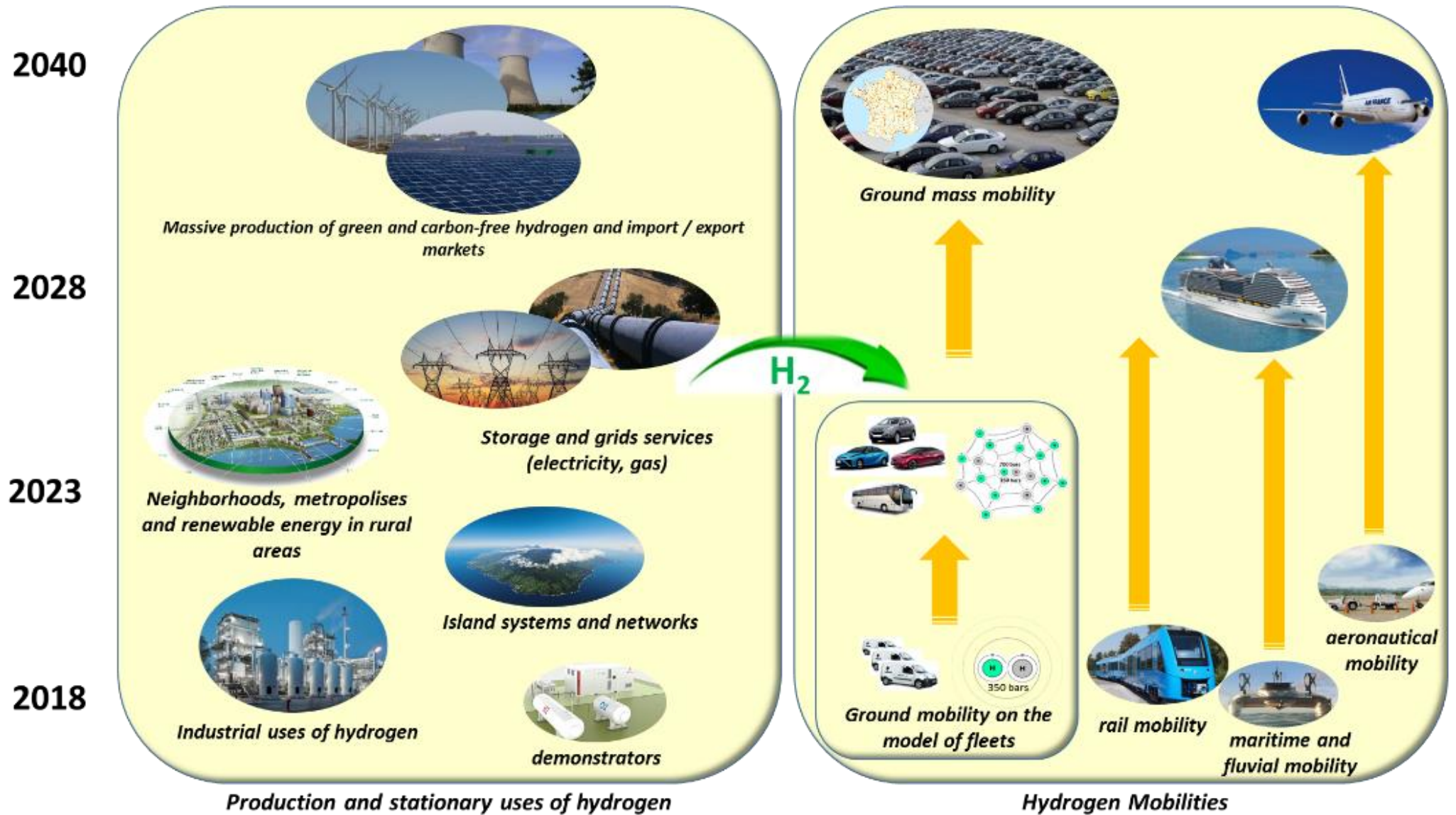
Energy storage



Conclusion



But how to develop these markets in the French context?



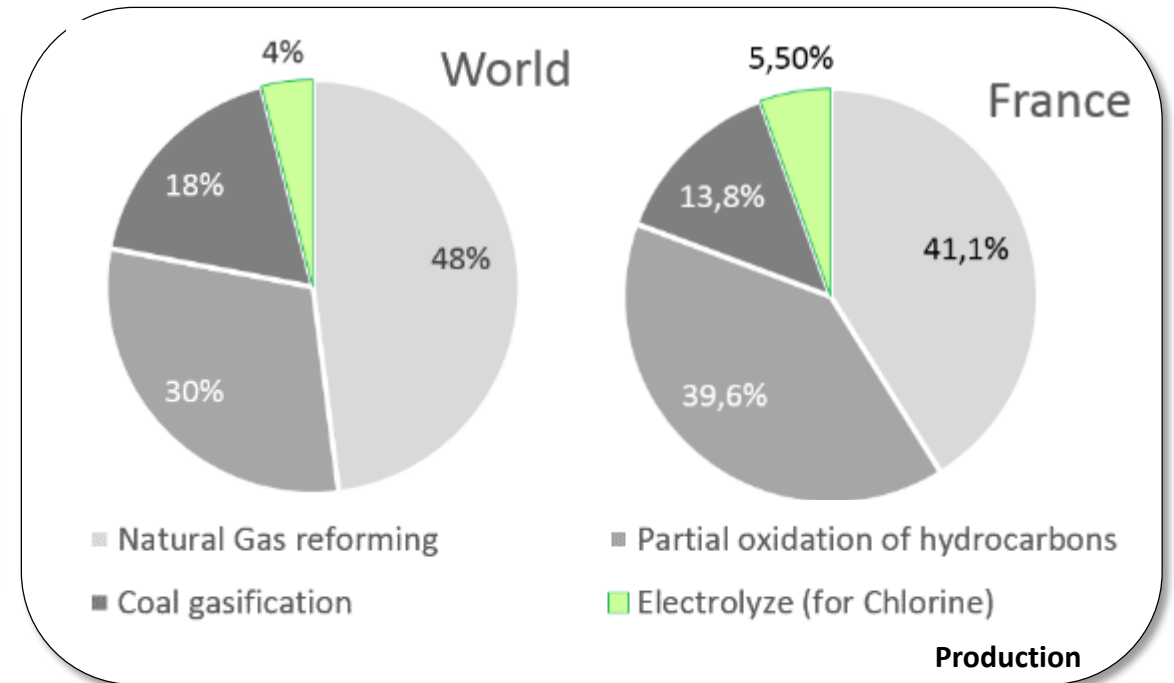
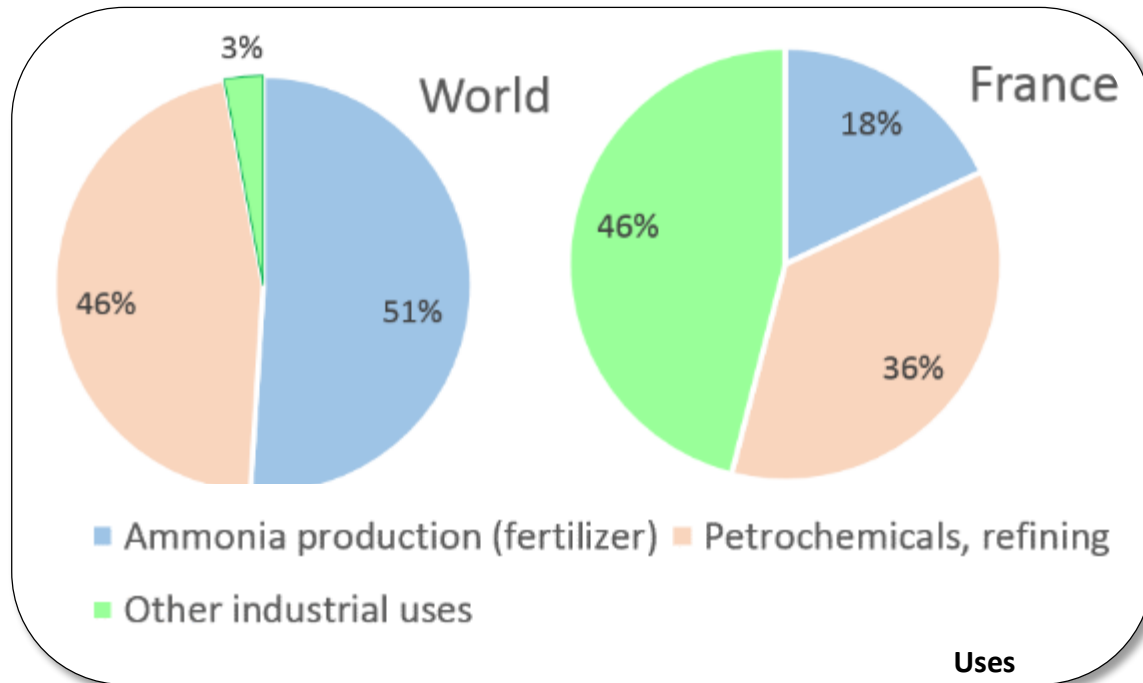
- Promote the emergence of green hydrogen by developing electrolysis using renewable energies



- **Develop domestic markets for this green hydrogen**
 - ✓ Industrial hydrogen: a directly accessible market with interesting volumes
 - ✓ The storage of renewable energy from residential to grids (ZNI, TEPCV, Power-to-Gas)
 - ✓ Mobility in all its forms, with a progressive strategy on land mobility based on bootstrapping on the model of fleets

First issue - Decarbonizing hydrogen production

The global H2 market is today mainly industrial (World 61 Mt, France 900kT)



■ Main uses

- Ammonia production
- Refining fuels
- Chemistry

■ with an fossil origin Hydrogen

- Methane reforming (10 kgCO₂ / kgH₂)
- Partial oxidation of hydrocarbons (15 kgCO₂ / kgH₂)
- Coal gasification (20 kgCO₂ / kgH₂)

Promote electrolysis - The penetration of renewable energies lowers the cost of electricity

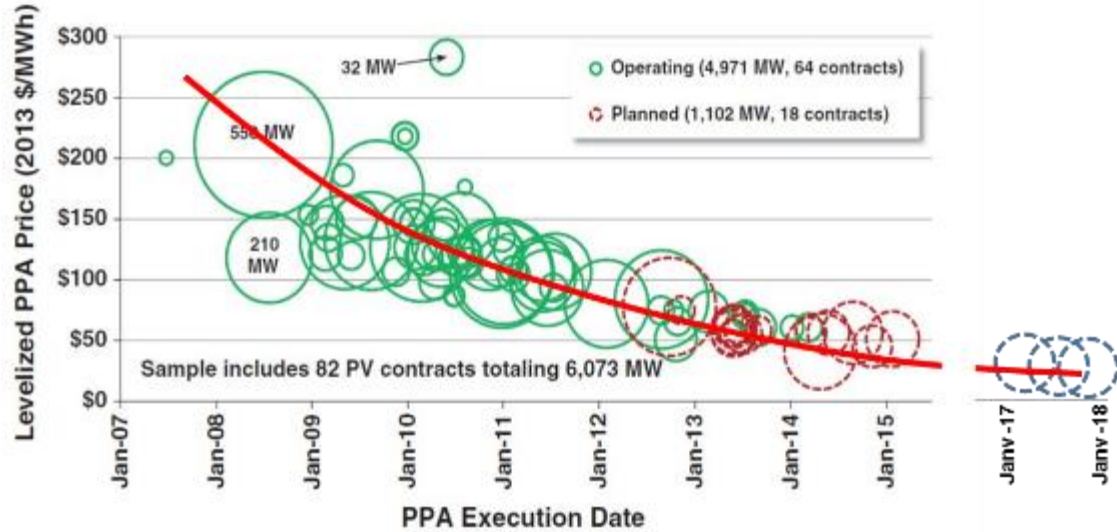
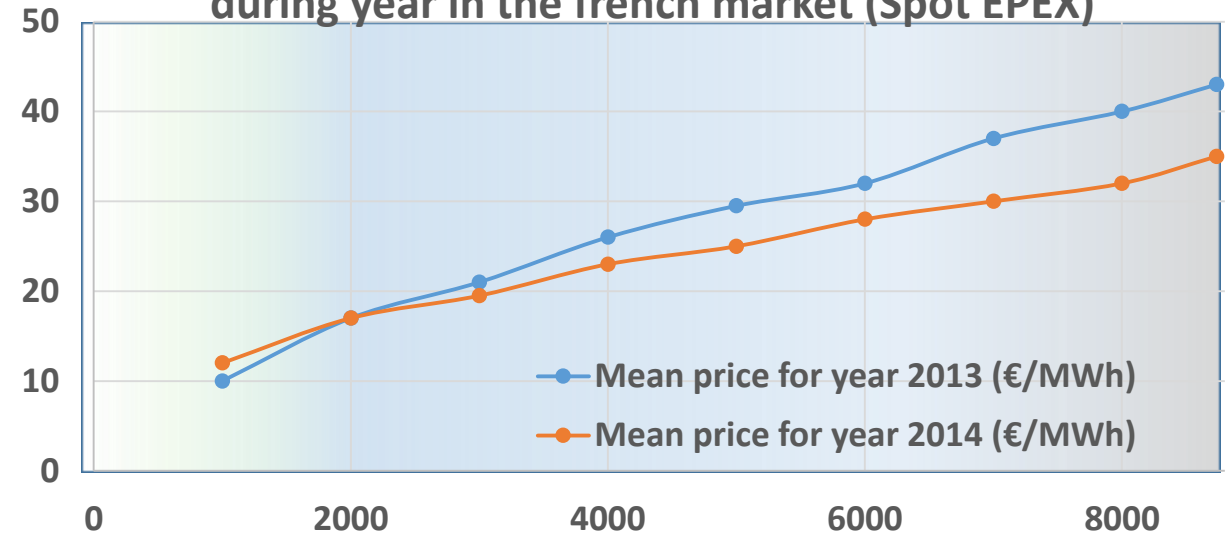


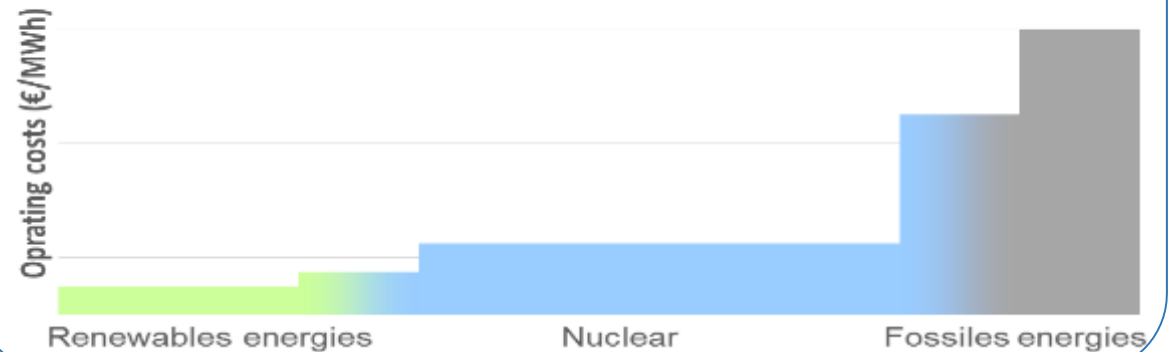
Figure 1. Levelized US utility-scale photovoltaic power purchase agreement (PPA) prices by operational status and PPA execution date.

begin 2017	United Arab Emirates	\$24,20 /MWh	20,33 €/MWh
Summer 2017	Chile	\$21,48 /MWh	18,04 €/MWh
Forcasted 2018	Saudi Arabia's	\$17,90 /MWh	15,04 €/MWh

Guaranteed Electricity Price vs time consumption during year in the french market (Spot EPEX)



Merit of order of electricity prices



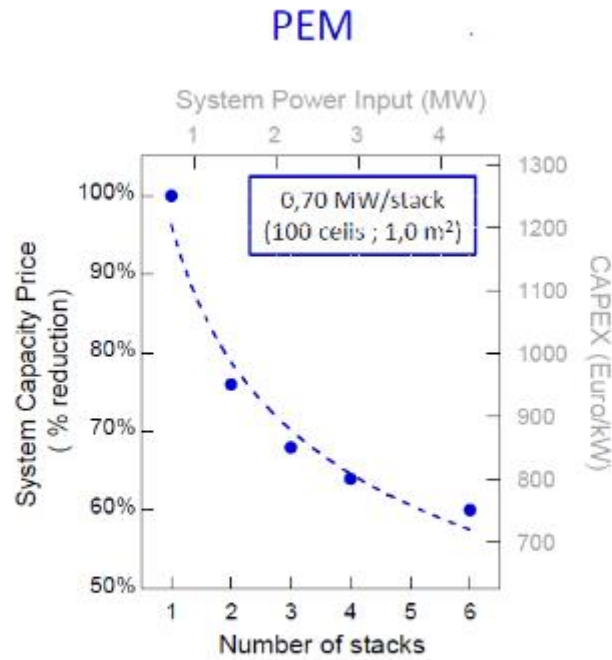
Promote electrolyze - Costs reduction for Alkaline and PEM Electrolyzers

Perspectives for further reduction in Euro/kW

ITM Electrolyzer

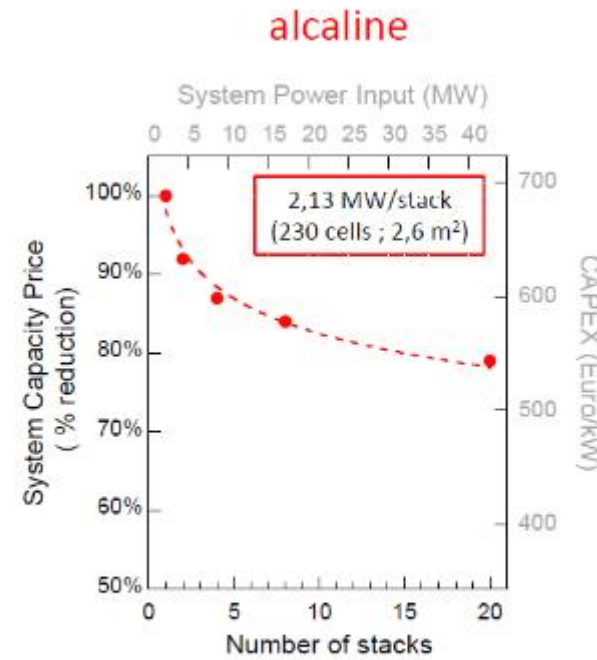


- From 60 kW to 1030 kW
- From 25 to 460 kilos per day.
- Pressure from 20 to 80



Data from ITM Power

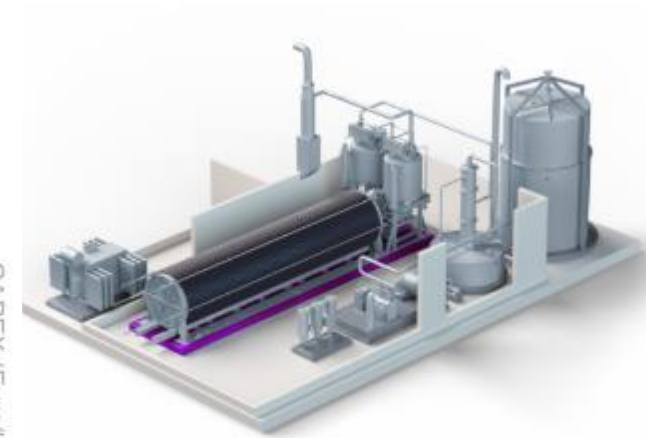
Down to 700 €/kW



Data from NEL

Down to 500 €/kW

NEL Electrolyzer



- Cell stack power consumption of down to 4 kWh/Nm³ H₂,
- up to 2.2 MW per stack
- 1000 kilos per day.

Markets are already available for hydrogen for industrial uses

Alcaline

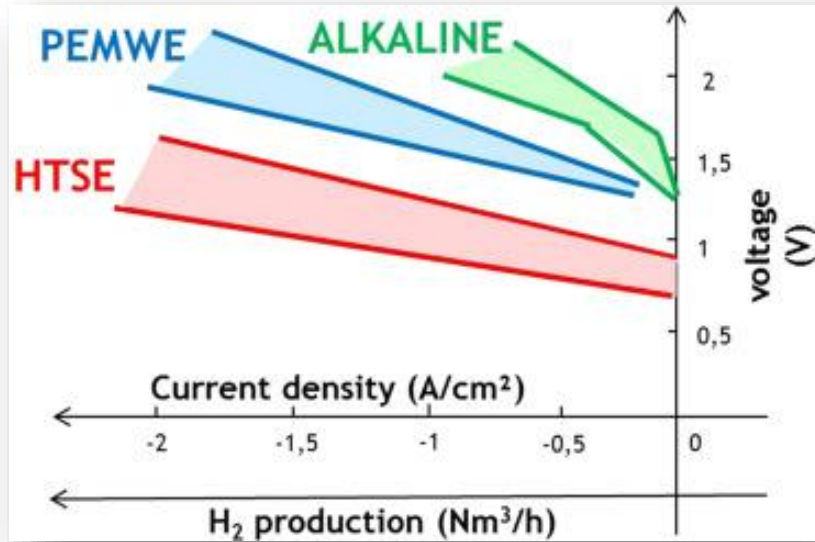
Massification of electrolyzers production (MW/year/plant)	CAPEX of electrolyzer system (€/kW)	Duration of operation by year			Electricity price (€/Mwh _{el})	
		8200 h	5000h	3000h	80	60
		40	40	30	40	30
1	1000	5,60	3,87	3,32	5,39	4,88
20	750	5,15	3,27	2,71	4,36	3,85
200	500	4,46	2,49	1,97	3,10	2,62
1000	350	3,95	1,93	1,44	2,19	1,75

cost of producing hydrogen today between 2 and 4,5 €/kg



- **Decarbonization of merchantable hydrogen: medium consumer (500 to 5000T / year)**
Replace a centralized carbon production with truck distribution by on-site production by electrolysis.
- **Decarbonization of highly CO2-emitting industries (recovery of CO2 in methane, e-fuel or other molecule of interest)**
Install electrolyzers on the site of cement works, steel mills, .., to combine H2 and CO2 (model cementery to territories)

Advanced Electrolyze at High Temperature (HTSE) to further reduce the cost of hydrogen production



CEA Solid Oxide Electrolyzer
HTSE

Rated electrical Power – 6 kW
 Load variation – 0% - 100%
 Electrical efficiency (HHV) – **85%**
 Specific electric Power – 3,5 kWh/Nm³
 H₂ Production – 2 Nm³/h
 H₂ pressure – 3 bar

cost of producing hydrogen in 2030
between 1 and 1,5 €/kg

Massification of electrolyzers production (MW/year/plant)	CAPEX of electrolyzer system (€/kW)	Duration of operation by year				
		8200 h	5000h	3000h		
		Electricity price (€/Mwh _{el})				
		80	60	40	40	30
1	4000	10,03	12,87	12,48	15,47	15,08
20	1500	4,59	4,15	3,78	4,82	4,45
200	1000	3,91	3,02	2,66	3,23	2,87
1000	400	3,06	1,49	1,14	1,32	0,97

Second issue - Decarbonizing mobility



2028
 Generalization of the infrastructure
 Greening of H2 production
 Market for private vehicles started

Deployment of coaches and vehicles for private individuals

Generalization of the model to all regions

H2 distribué

Electrolyse on site

H2 production Hub by HTSE

2023
 Air quality in metropolises
 Heavy-use mobility in urban and peri-urban areas

Increased supply of fleet vehicles (buses, heavy vehicles, ..)

Densification of stations in metropolitan cities and inter-metropolitan corridor

Distributed H2

Electrolyze on site

Shared H2 production for different uses by territorial hubs

2018
 Model captive fleets

Fleets of light commercial vehicles and taxis

1 refueling station by fleet

Distributed H2

Electrolyze on site

Second issue - Decarbonizing mobility

Propose a new offer of fleet vehicles



SAFRA

A French hydrogen bus manufacturer



A van-type multi-purpose vehicle

- Delivery vehicle last kilometer in urban and peri-urban sites
- Technical intervention vehicles for network operators (energy, water, telecommunications, ..)
- Emergency response vehicles (health, firefighters, ..)
- Passenger transport vehicles (9-17 seats) allowed to drive on roads and highways (unlike buses).



Symbio - A French hydrogen garbage dumpster

Second issue - Decarbonizing mobility

The refueling station with a green and competitive hydrogen



2030

€/kg_{H2}

	Distributed H2 (grids, vessels, trailers)		On site Production (Electrolysis)	
	Min	Max	Min	Max
H2 production (reforming, electrolysis,..)	1,00	2,00	1,50	2,00
H2 Transportation (grids, vessels, trailers)	0,50	2,00		
Distribution (compression, H2 storage, dispenser,..)	1,50	2,50	1,50	2,50
Full cost distributed H2	3,00	6,50	3,00	4,50

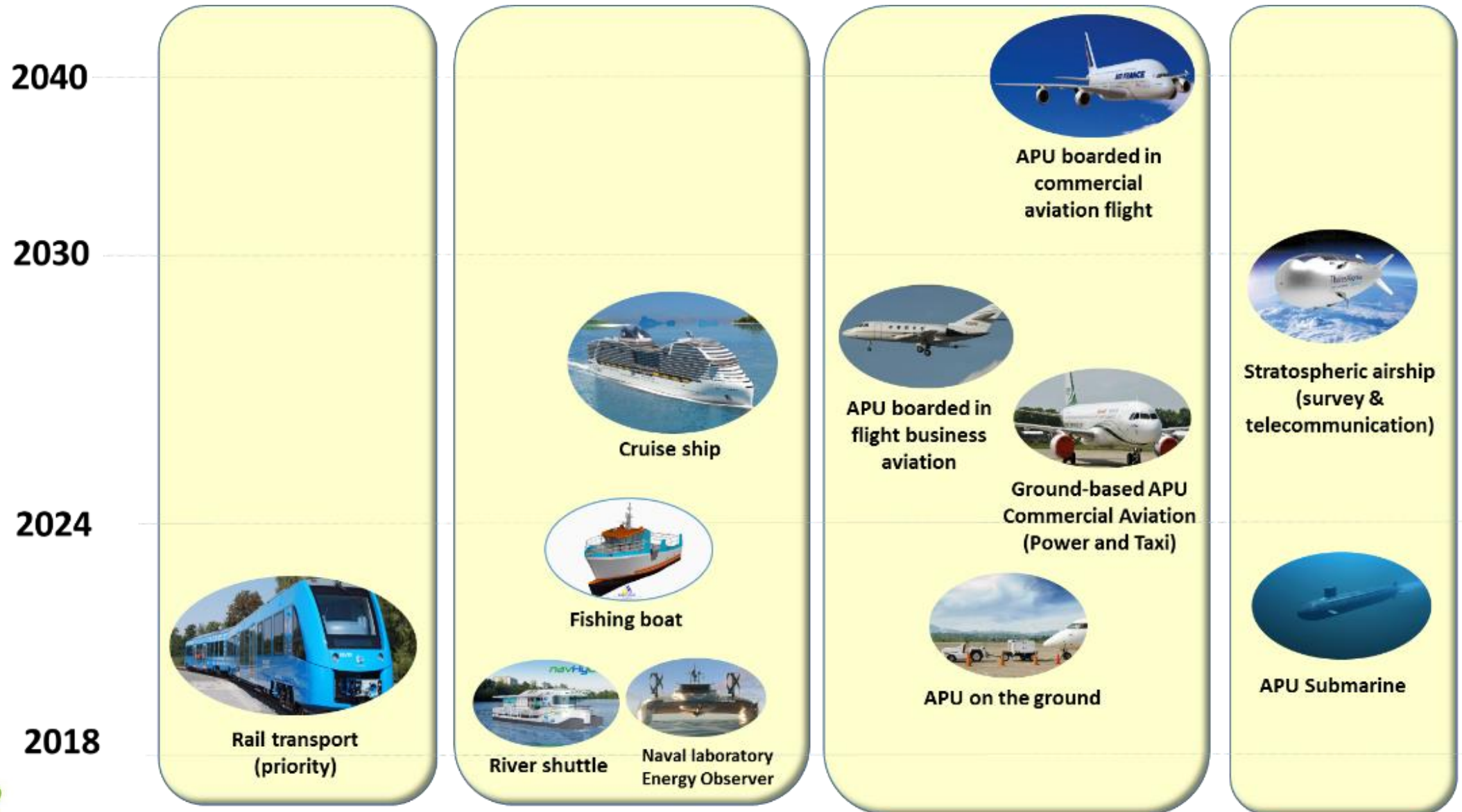
2018

€/kg_{H2}

	Distributed H2 (grids, vessels, trailers)		On site Production (Electrolysis)	
	Min	Max	Min	Max
H2 production (reforming, electrolysis,..)	2,00	6,00	4,00	6,00
H2 Transportation (grids, vessels, trailers)	1,00	3,00		
Distribution (compression, H2 storage, dispenser,..)	3,00	6,00	4,00	8,00
Full cost distributed H2	6,00	15,00	8,00	14,00



Other mobilities - strategic industrial sectors for France



Third issue - Storing renewable energies

Hydrogen to store renewable energy in island territories



La Nouvelle – isolated site of Reunion Island
Powidian facility in partnership with EDF SEI



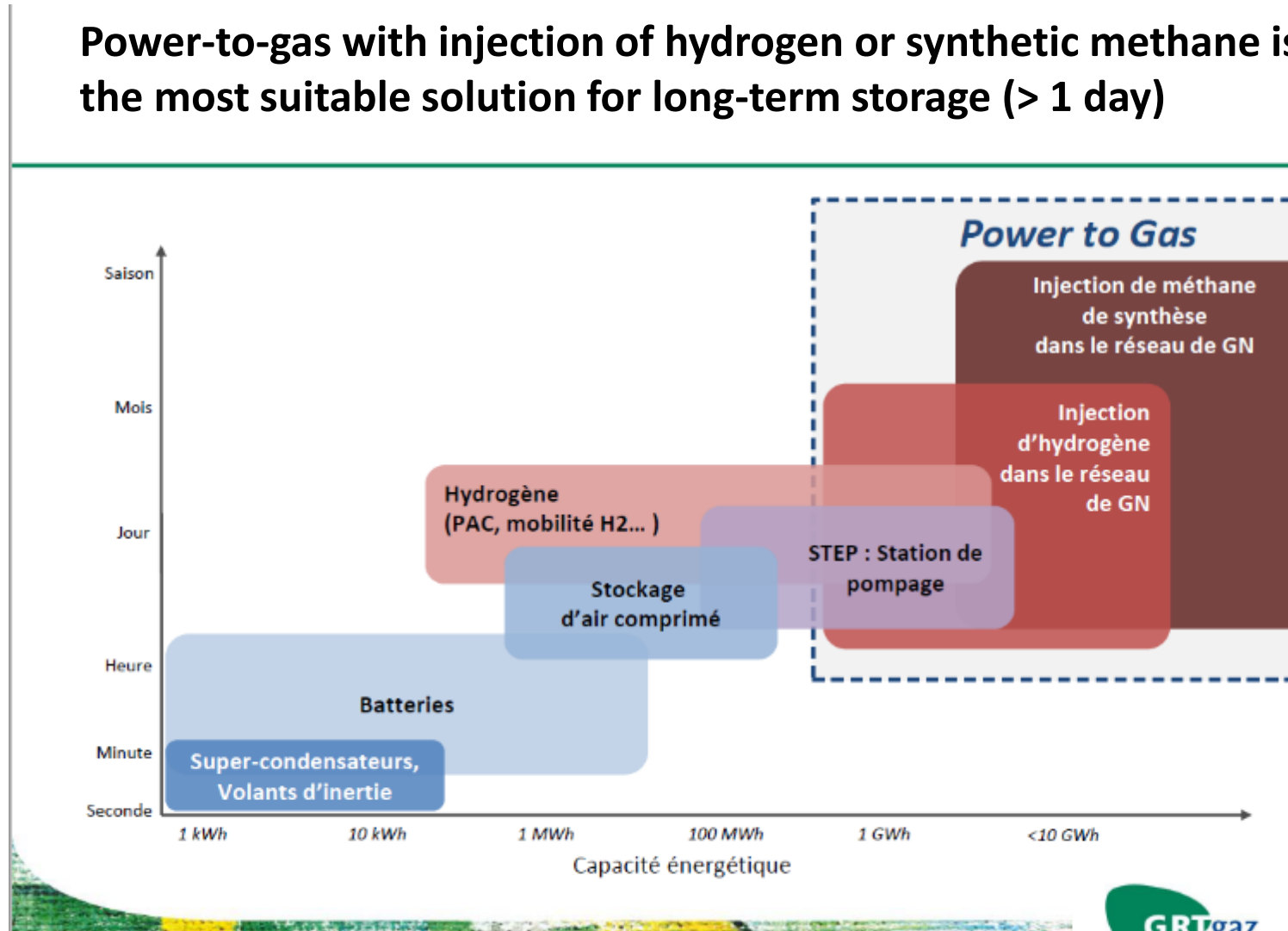
France is a highly insular country
(3 million inhabitants in the islands out of 67 million inhabitants)

Energy has a high carbon content and a production cost 4 to 5 times higher than in metropolitan France.
Renewable energies deployment requires various storage solution among which **hydrogen**

Third issue - Storing renewable energies

Power-to-Gas - A solution to massively store renewable energies

Power-to-gas with injection of hydrogen or synthetic methane is the most suitable solution for long-term storage (> 1 day)





Energy Observer - France's ambassador on clean technologies for energy for total autonomy



A naval laboratory integrating all clean energies (Solar, Wind, Batteries, Hydrogen) for a global autonomy.

A 6-years odyssey to visit 50 countries in 101 stopovers for a technological and evangelizing world tour

2017 – France

2018 - Mediterranean Sea

2019 - North Europe

2020 – Americas

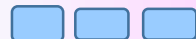
2021 - Oceania and Asia

2022 – Asia and Africa



Québec (Canada)
06-07/02/2019
French Hydrogen Program

French energy policy



H2 roadmap



Decarbonized H2 production



H2 Mobility



Energy storage



Conclusion



L'avenir n'est pas ce qui va arriver mais ce que nous allons faire.
Henri Bergson

The future is not what will happen but what we are going to do.
Henri Bergson

