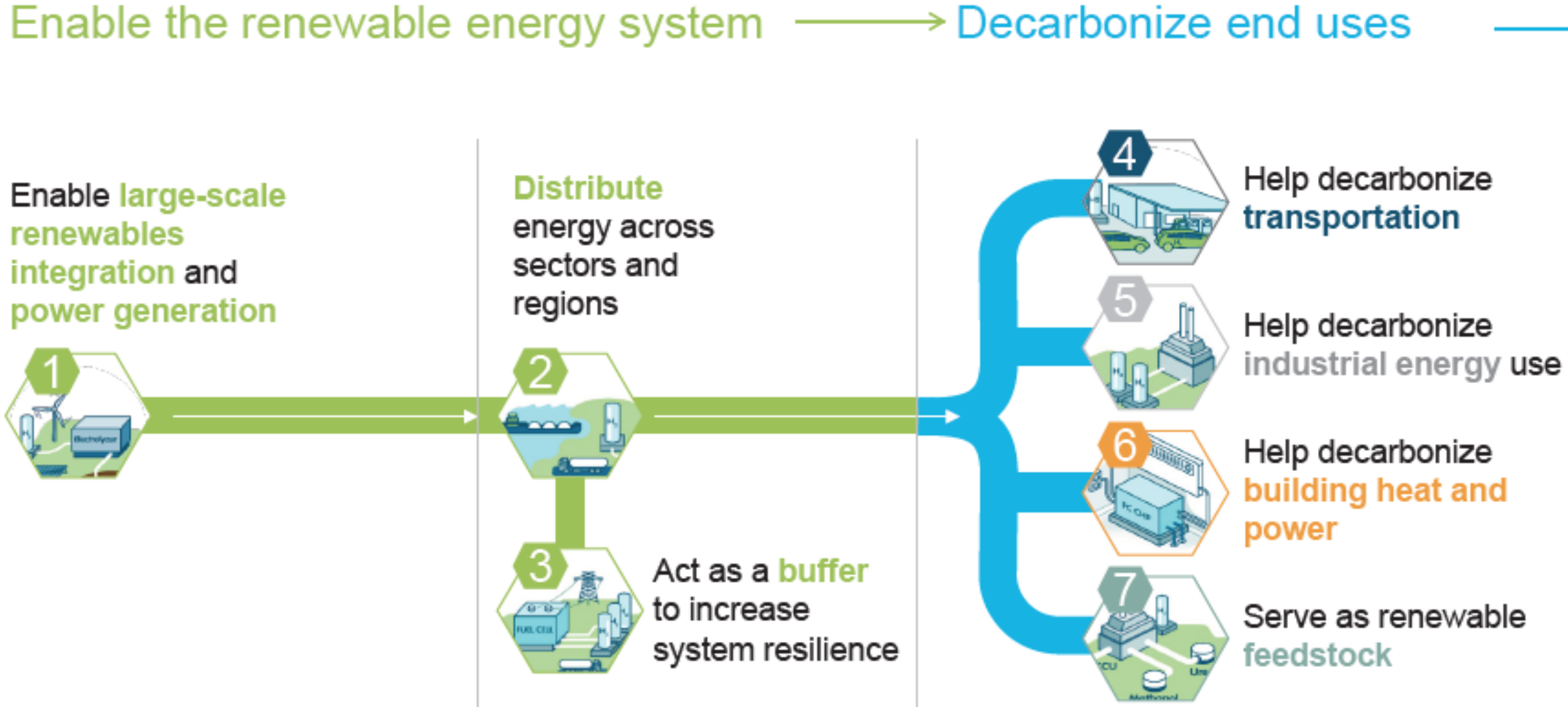
International Partnership for Hydrogen and Fuel Cells in the Economy

Hydrogen: a trigger for accelerating the development of renewable energies

Bernard Frois, IPHE Chair



The importance of Green Hydrogen

SOURCE: Hydrogen Council

The deployment of hydrogen will change the economics of energy and transport

Hydrogen will enable new linkages between energy supply and demand, in both a centralized or decentralized manner

Hydrogen use has the potential of enhancing overall energy system flexibility.

Hydrogen use has the potential of contributing to decarbonise the industry: refineries, steelmaking, cement industry.

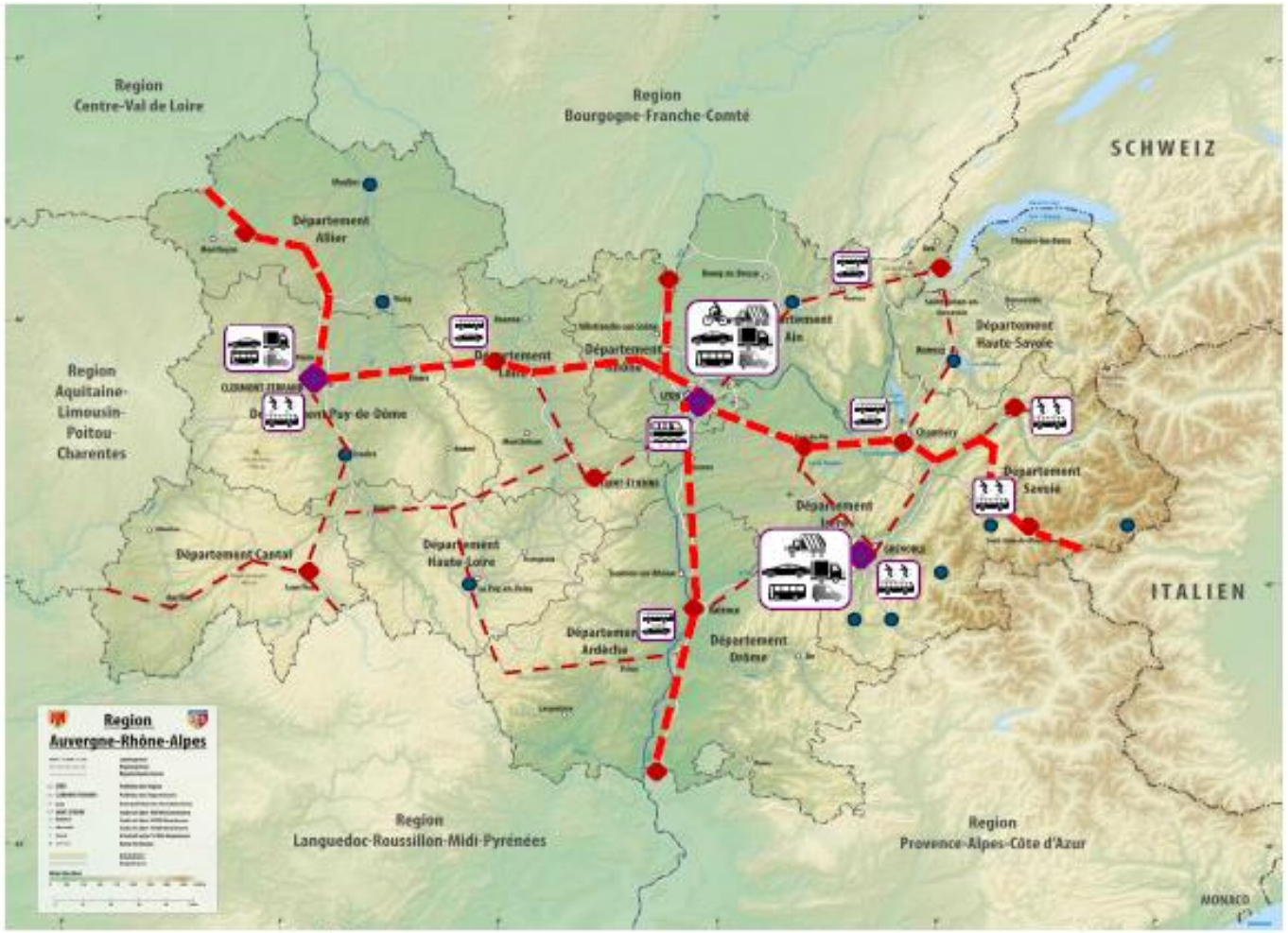
Fuel cell vehicles will provide the mobility service of today's conventional vehicles.

La Région
Auvergne-Rhône-Alpes

Zero Emission Valley : A new concept

around 3 cities: Clermont-Ferrand, Lyon, Grenoble

1000 Vehicles - 20 stations - 15 Electrolysers



Infrastructure

- Large stations (150-200kg/j)
- Medium stations (50-60kg/j)
- Small stations (15-20kg/j)

Vehicles *Connecting*

- Intercity buses
- Personal car
- River applications

Vehicles *Local usages*

- Buses and skibuses
- Utility vehicles
- Refuse trucks
- Urban logistics

Renewable energies are cheaper and cheaper

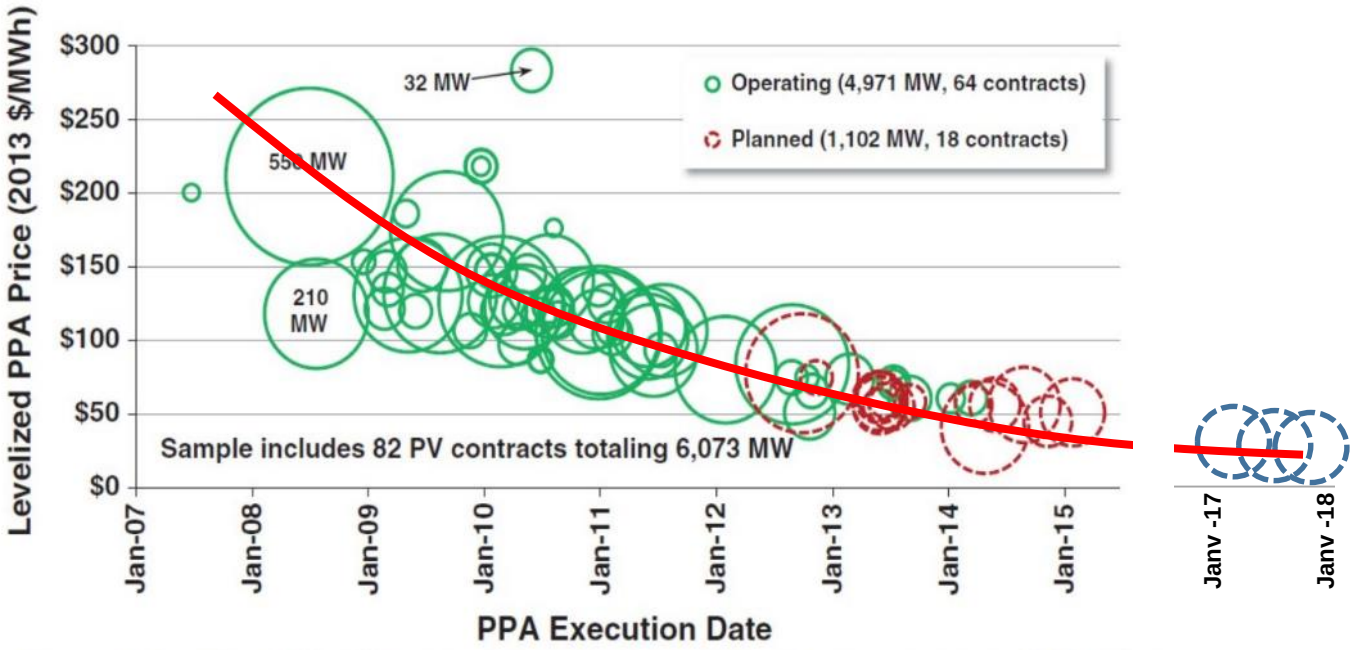


Figure 1. Levelized US utility-scale photovoltaic power purchase agreement (PPA) prices by operational status and PPA execution date.

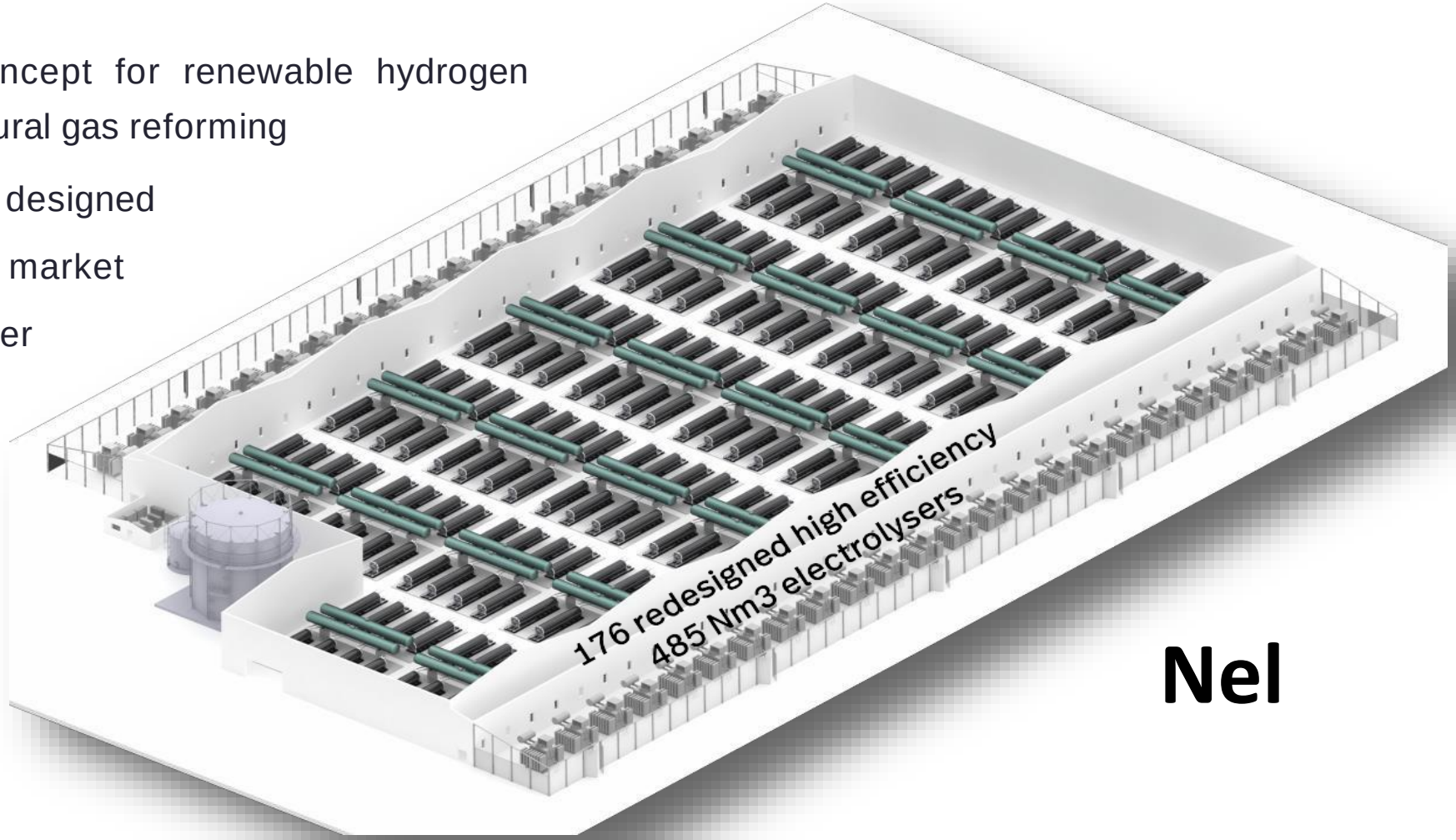
The latest energy auction in Chile has set a new record low for solar PV, coming in at just $US21.48/MWh ($A28/MWh).

Early 2017	**United Arab Emirates**	**$24,20 /MWh**	**20,33 €/MWh**
Summer 2017	**Chile**	**$21,48 /MWh**	**18,04 €/MWh**
Forecast 2018	**Saudi Arabia**	**$17,90 /MWh**	**15,04 €/MWh**

Project develop.: 400MW renewable H2 plant to outcompete natural gas reforming

Project examples

- Working on GIGA factory concept for renewable hydrogen production to outcompete natural gas reforming
- Largest electrolyser plant ever designed
- Addressing a USD ~ 150 billion market
- International industrial customer
- Tied to solar power
- CapEx of USD ~175 million
- Benchmark CapEx ratio:
  - 0.45 MUSD/MW

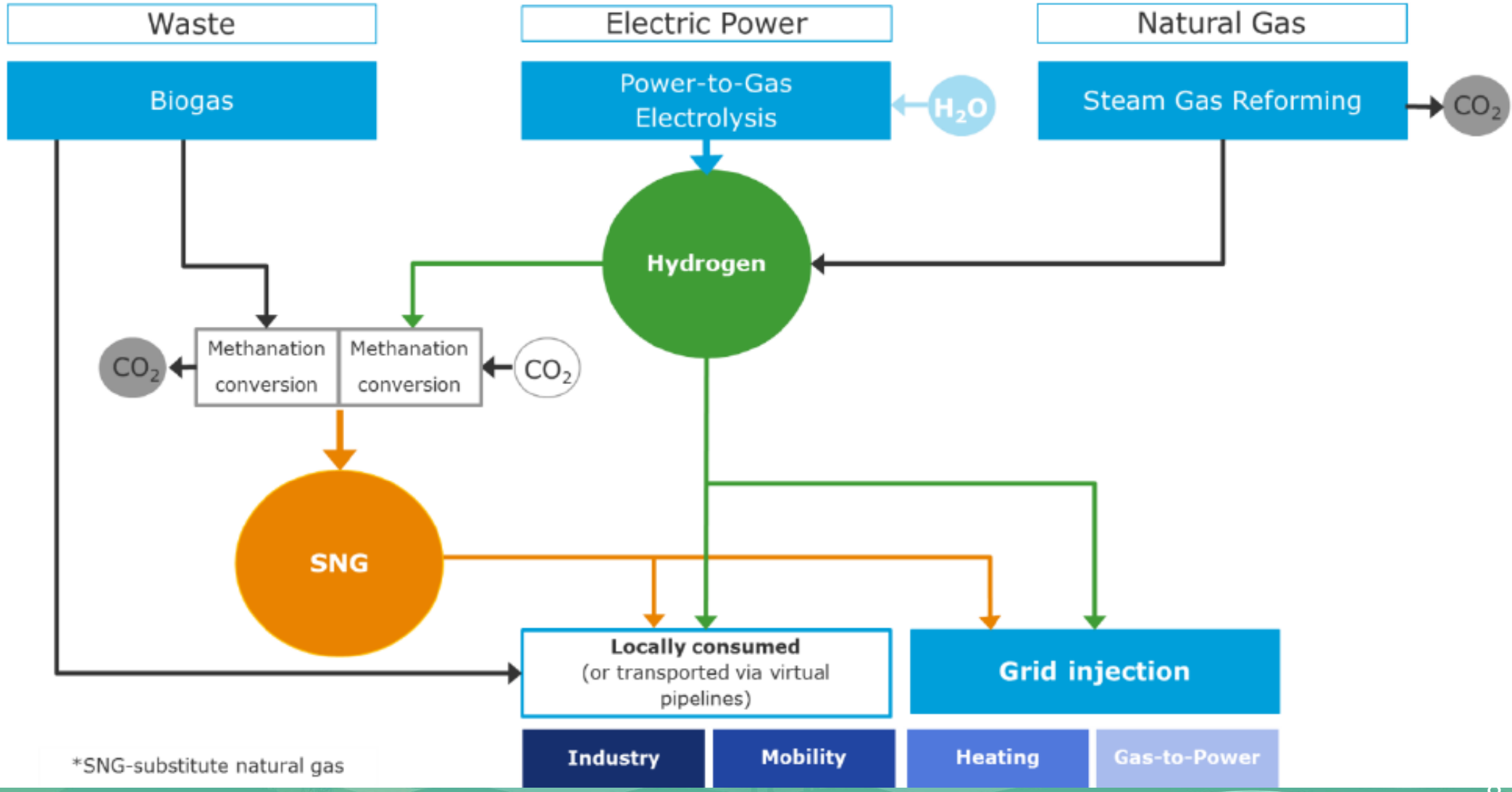


Cost of electrolyzers has decreased by a factor 4

2018
A 10 MW Electrolyser ITM Project In Shell Rhineland refinery

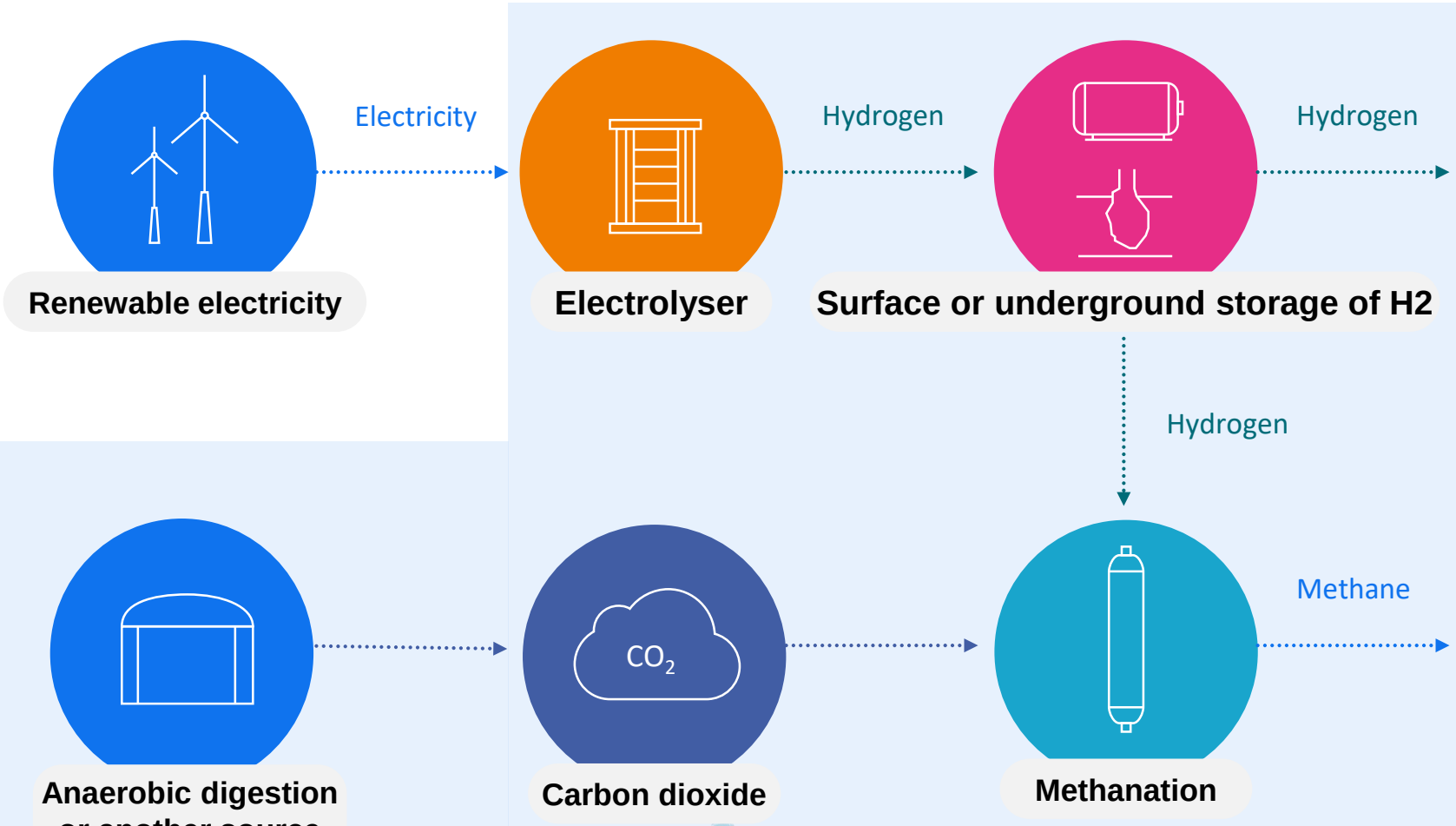
Different Forms of Supplies of Renewable Gases

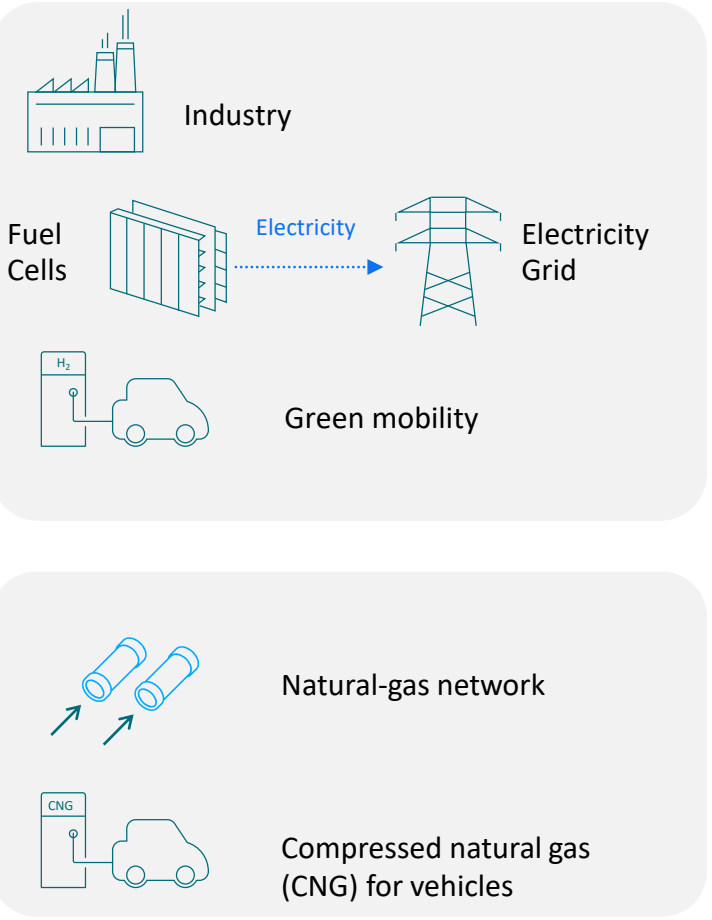
storengy
Une société de ENGIE



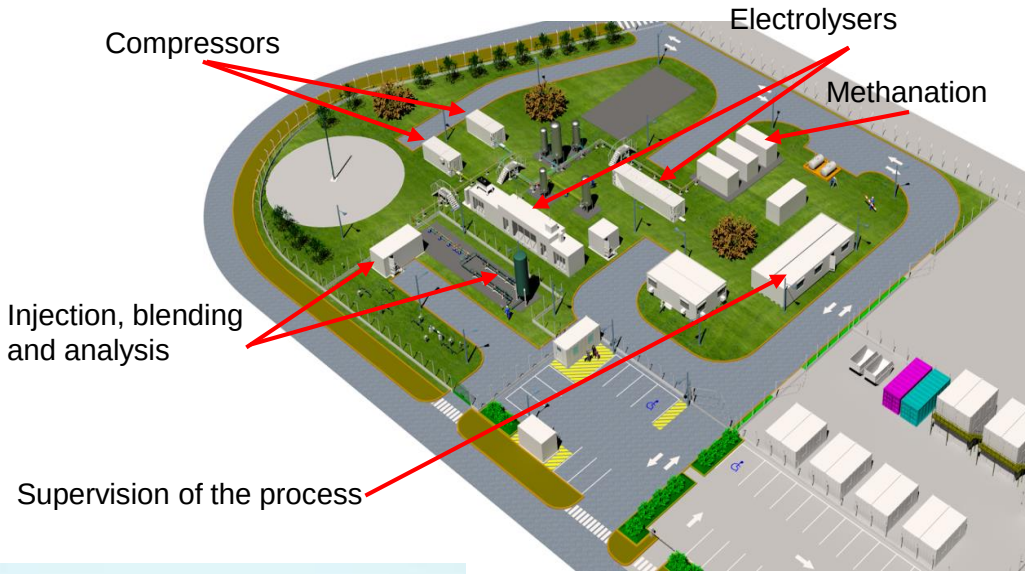
Source: DNV GL

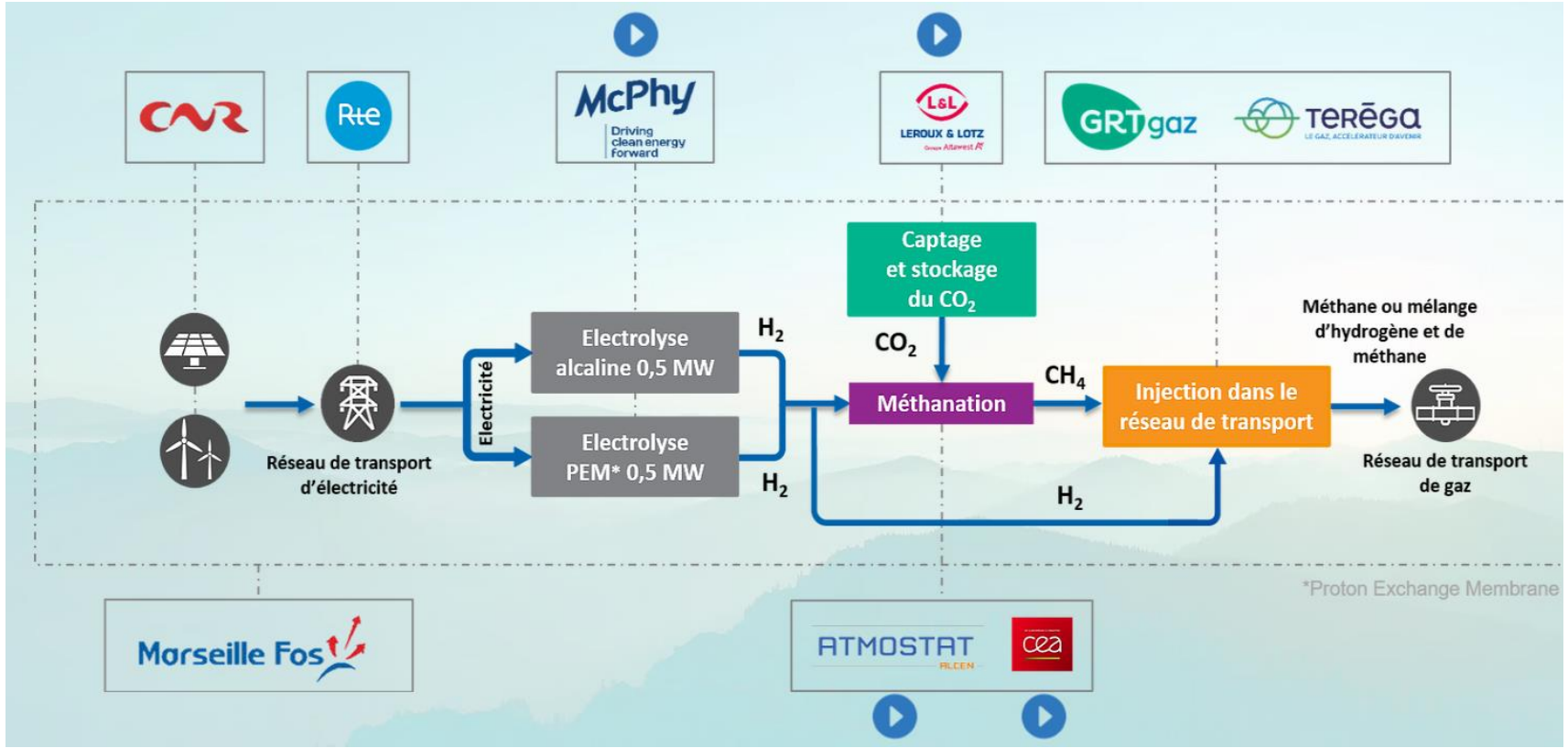
Hydrogen (H2): an efficient means of ensuring a low-carbon energy mix



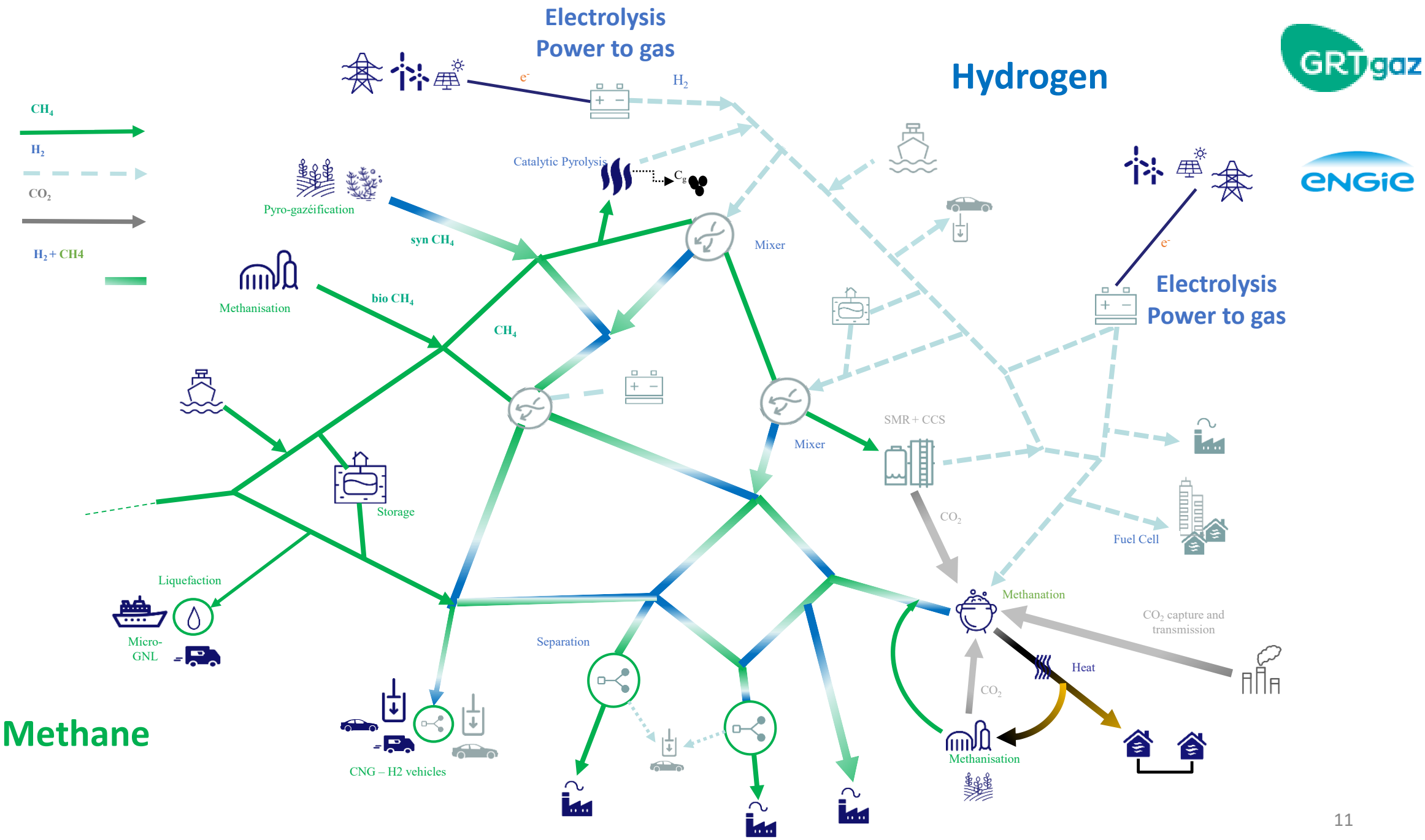


JUPITER 1000
Power to Gas Project
Marseille





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


Electrolysis
Power to gas
Hydrogen
CH_4
H_2
CO_2
H_2 + CH4
e-
H_2
Catalytic Pyrolysis
C_g
Pyro-gazéification
syn CH_4
Mixer
Methanisation
bio CH_4
CH_4
Electrolysis
Power to gas
Mixer
SMR + CCS
Storage
CO_2
Fuel Cell
Liquefaction
Micro-
GNL
Methanation
CO_2 capture and
transmission
Separation
Heat
CO_2
Methanisation
CNG – H2 vehicles
Methane

• In France, renewable gas is a nascent industry

GRTgaz (January 2018)

- **44 bio methane injection sites connected**
- **361 projects ongoing**
- **408 GWh injected in 2017 (+100%)**
  equivalent to 1 800 bioGNV buses or 34 000 households
- **France is the 5th producer in Europe in 2017**

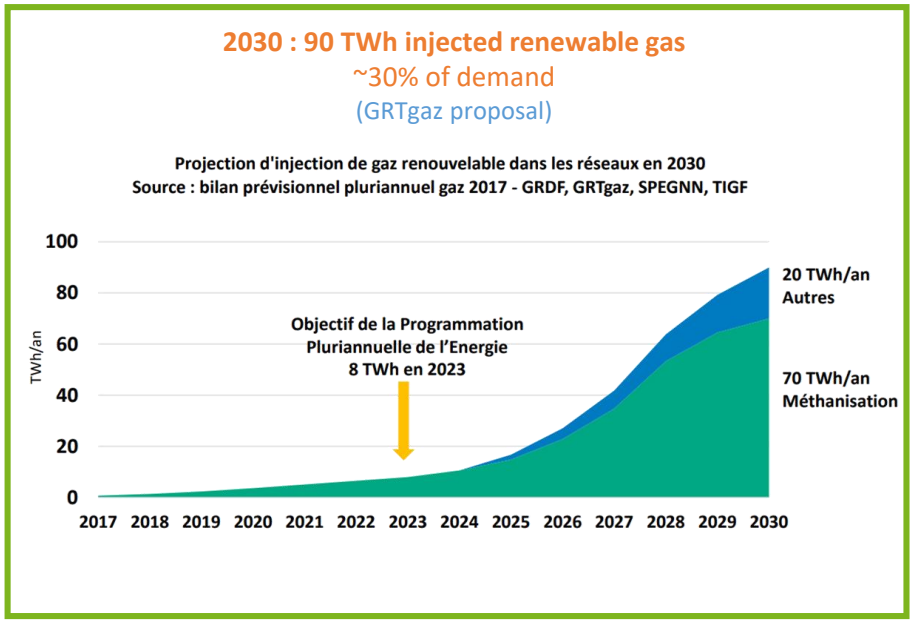
Programmation PLURIANNUELLE DE L'ÉNERGIE

Target for development of injection of biomethane in gas networks

LA TRANSITION ÉNERGÉTIQUE pour la CROISSANCE VERTE

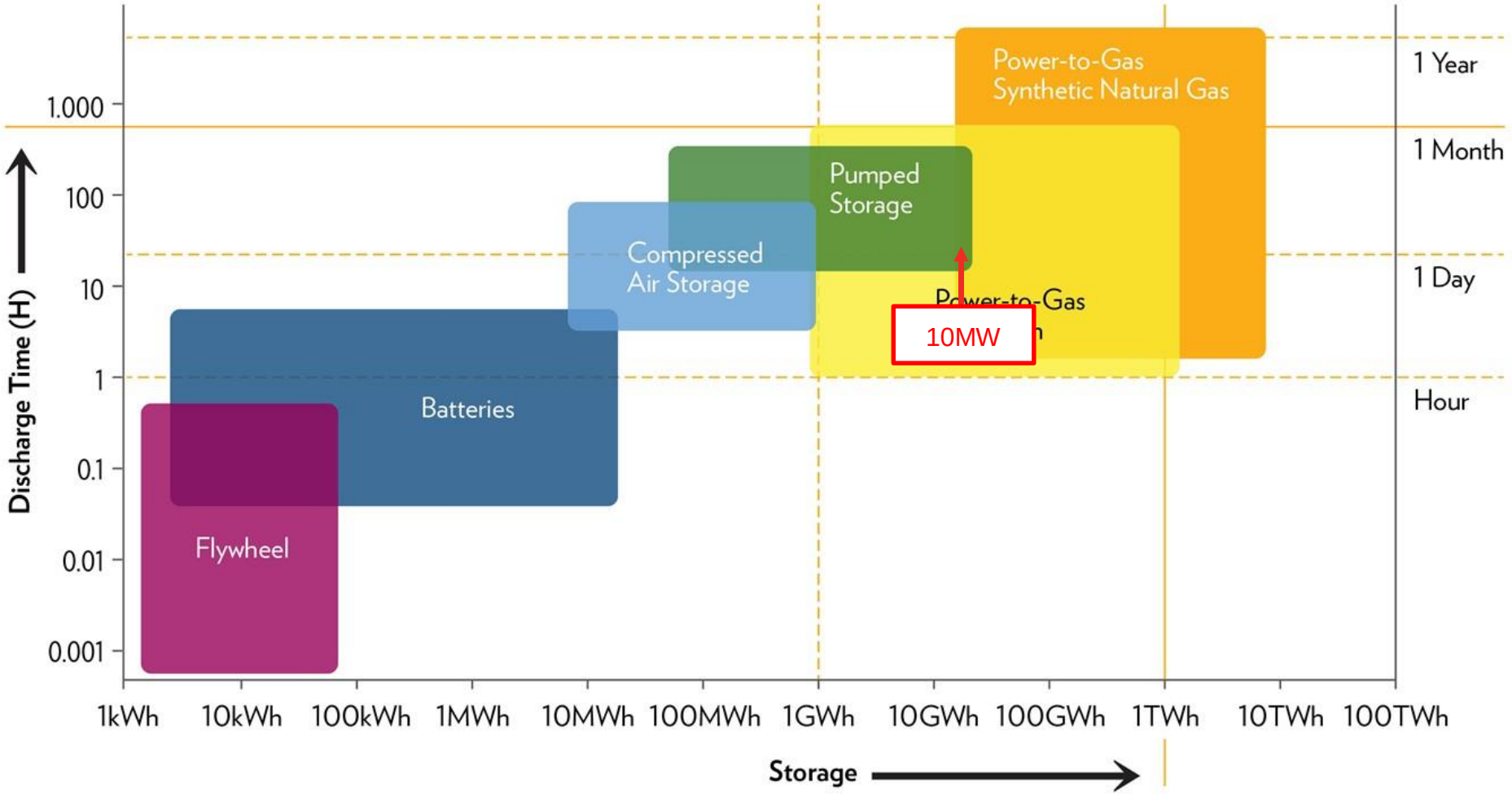
Target of the french law on Energy transition: biomethane shall represent 10% of gas consumption in 2030, i.e. 30 TWh

2030 : 90 TWh injected renewable gas
~30% of demand
(GRTgaz proposal)



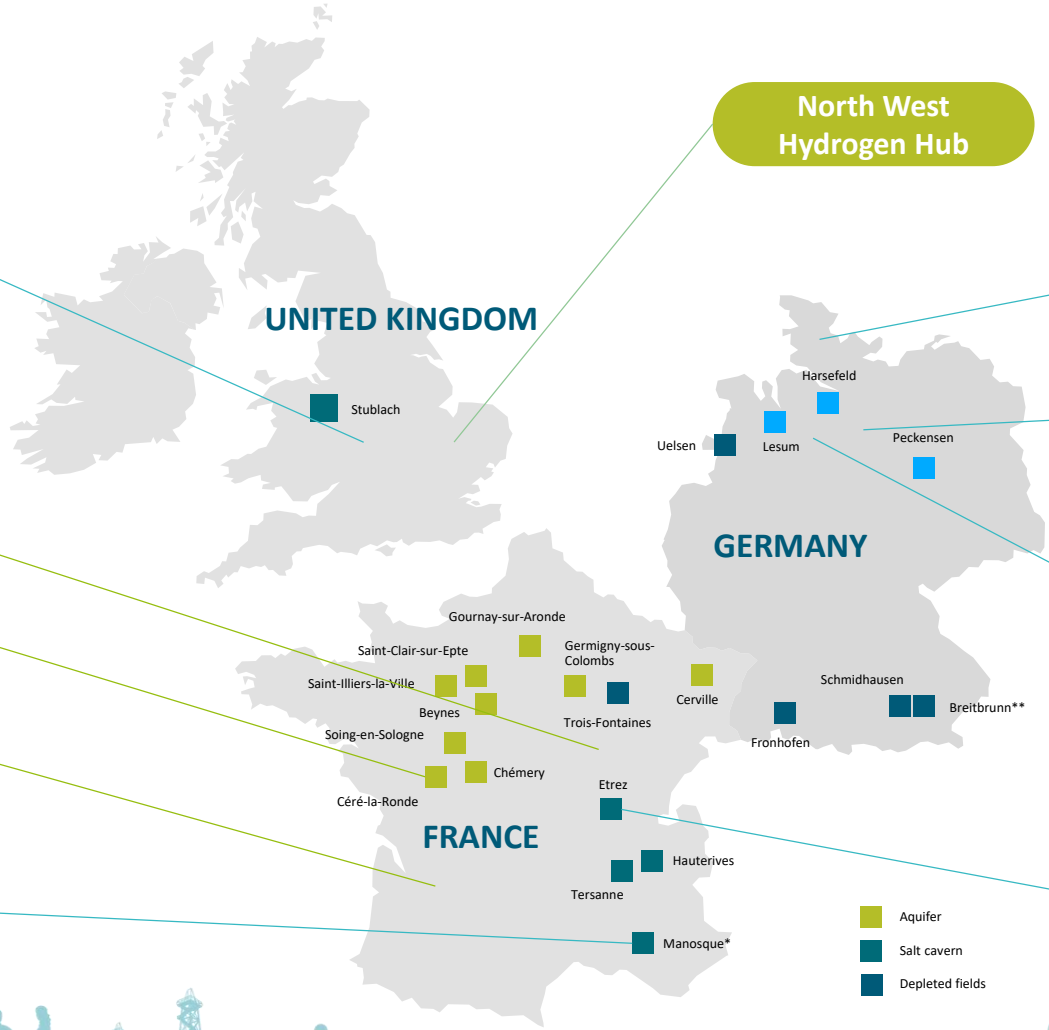
ENERGY STORAGE TECHNOLOGIES

Power-to-gas is efficient, long term, low energy cost



Storengy is strongly involved in different studies and projects on Power-to-Gas & Hydrogen

21 Underground storage facilities in Europe



- North West Hydrogen Hub
- H2 storage studies
- HYCAUNAIS
- METHYCENTRE
- RINGS
- HyGreen Provence
- ENTREE 100
- 2-10 MW P2G project (feasibility)
- Energy Triangle Thuringia
- H2 Boot Camp

Hydrogen

Synthetic methane or hydrogen/synthetic methane mixtures

Storengy participates in several working groups (WG) to boost green H2 and P2G development in Europe

Europe

Leader of Hydrogen & Power-to-Gas WG

Member of WG on Development of Business cases for FCH -JU applications for regions and cities

Germany

Members of P2G/H2 WG

France

Leader of Regulation WG,
Participation in Business Model WG

Contribution to multiannual energy program from DGEC “Energy storage offer”

Participation to prospect program on energy of CRE

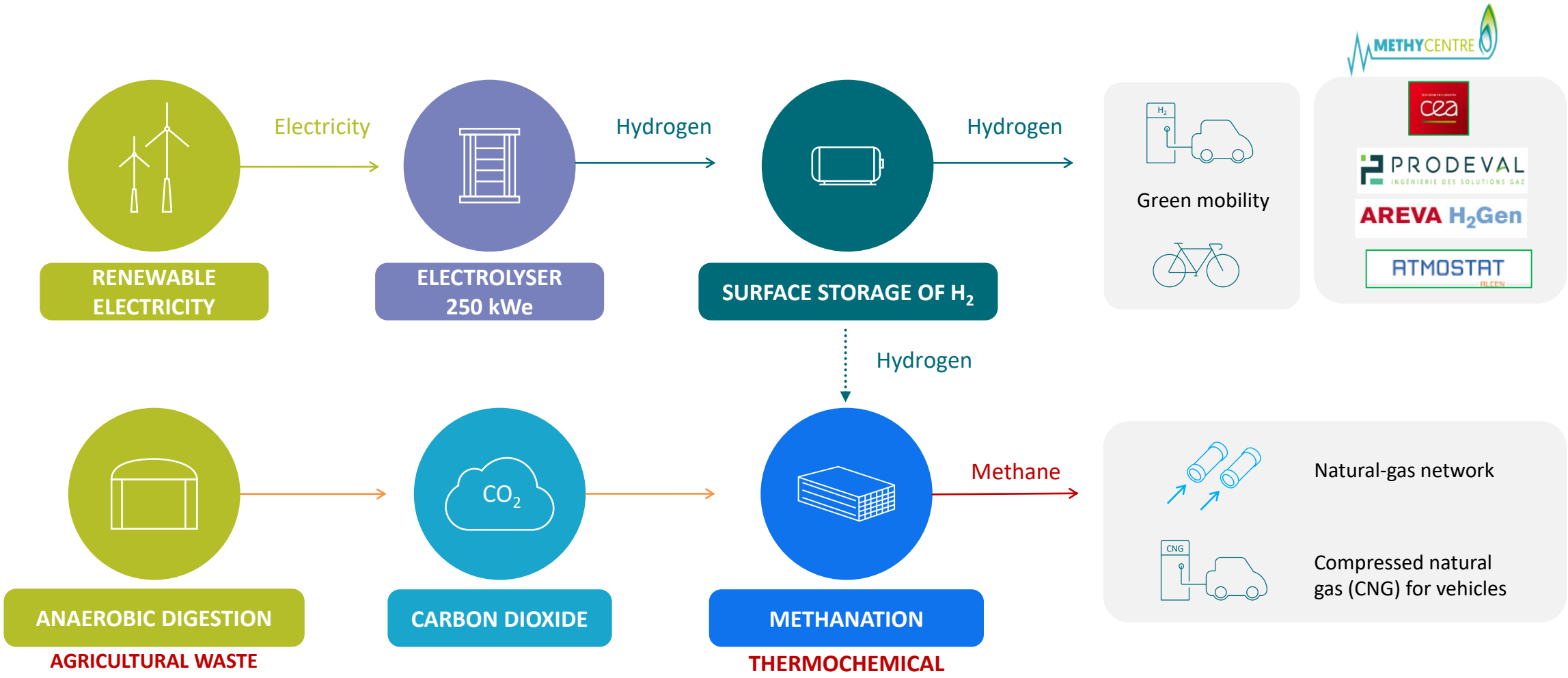
(GIE) : Gas infrastructure Europe
(FCH-JU) : Fuel Cell Hydrogen Joint Undertaking
(ATEE) : Technical association on energy and environment
(DGEC) : General Directorate of Energy and Climate, Ministry for the Ecological and Inclusive Transition
(CRE) : French Energy Regulatory Commission
(INES): German Association of Natural Gas Storage Operators
(DVW): German Hydrogen and Fuel Cell Association
(BDEW): Federal Association of the German Energy and Water Industries
(BVES) : German Energy Storage Association

Power-to-Gas in France: needs of today and tomorrow

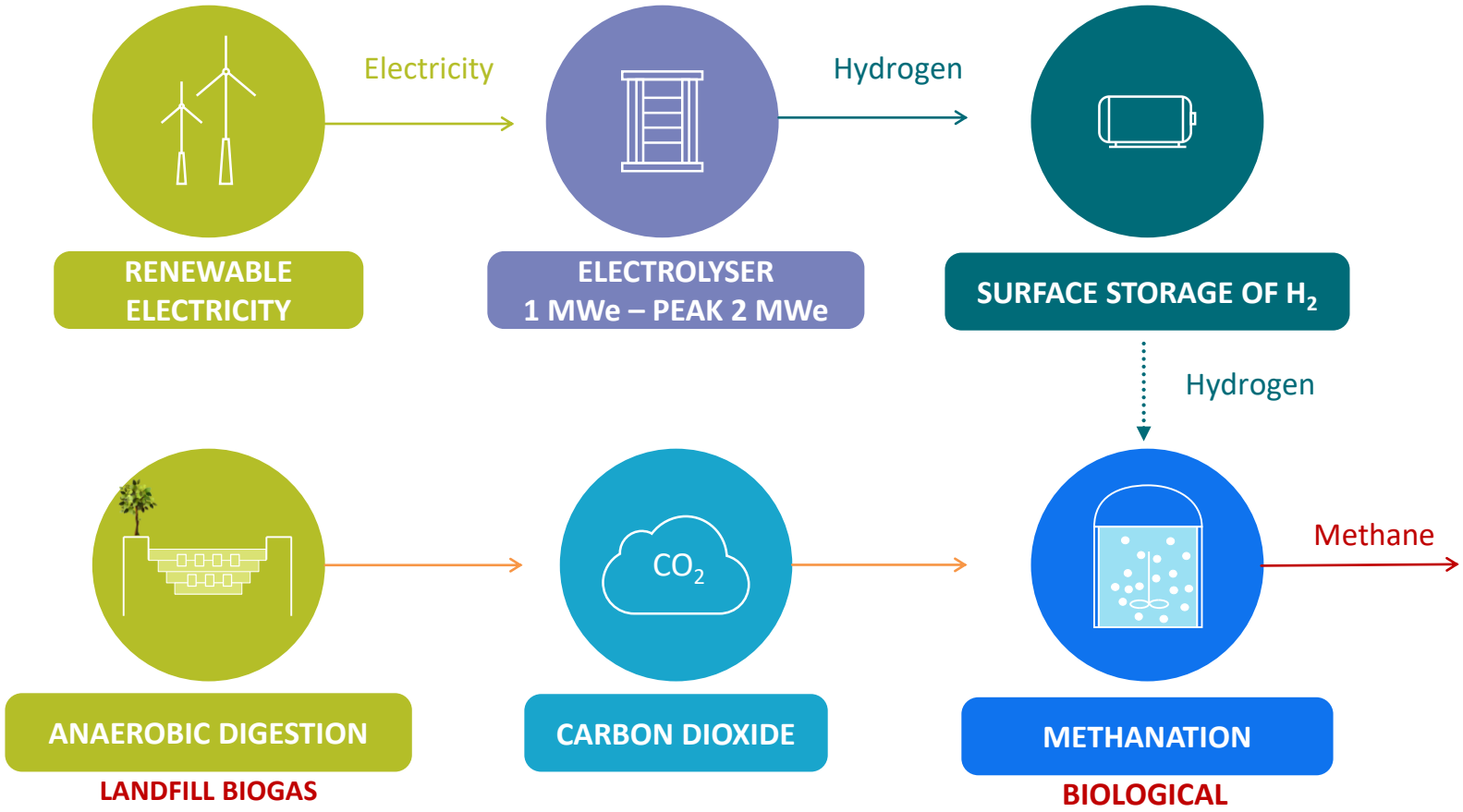
		Today	2020	2030	2050
Hydrogen	Companies(1)	0,9 Mt H2 **70-75 TWhe** P2G			
	Hydrogen-based mobility(2)			**3 TWhe**	
Synthetic Methane	Mobility using green gases(3)		3,2 TWh → **5 TWhe** P2G	25-40 TWh → **39-63 TWhe** P2G	
	Injection into storage facility or gas network			**2,5 - 3 TWhe** (4)	66 TWh → **103 TWhe** (5)

(1) Source : Fiche 1.3 Production et consommation d'hydrogène aujourd'hui (Afhypac)
(2) Source : Afhypac – Mobilité Hydrogène France
(3) Source : La mobilité gaz – GRTgaz
(4) Source : Etude portant sur l'hydrogène et la méthanation comme procédé de valorisation de l'électricité excédentaire (Ademe, GRTgaz, GRDF)
(5) Source : scénario central de l'étude Ademe de 09/2017 - Mix électrique 100% EnR en 2050 : quelles opportunités pour décarboner les systèmes gaz et chaleur ?

MÉTHYCENTRE PROJECT (Céré-la-Ronde storage site – Centre region)



HYCAUNAIS PROJECT (Near Auxerre – Yonne department – Burgundy area)



sdey Syndicat Départemental d'Énergies de l'Yonne

Electrochaea

ENGIE Lab

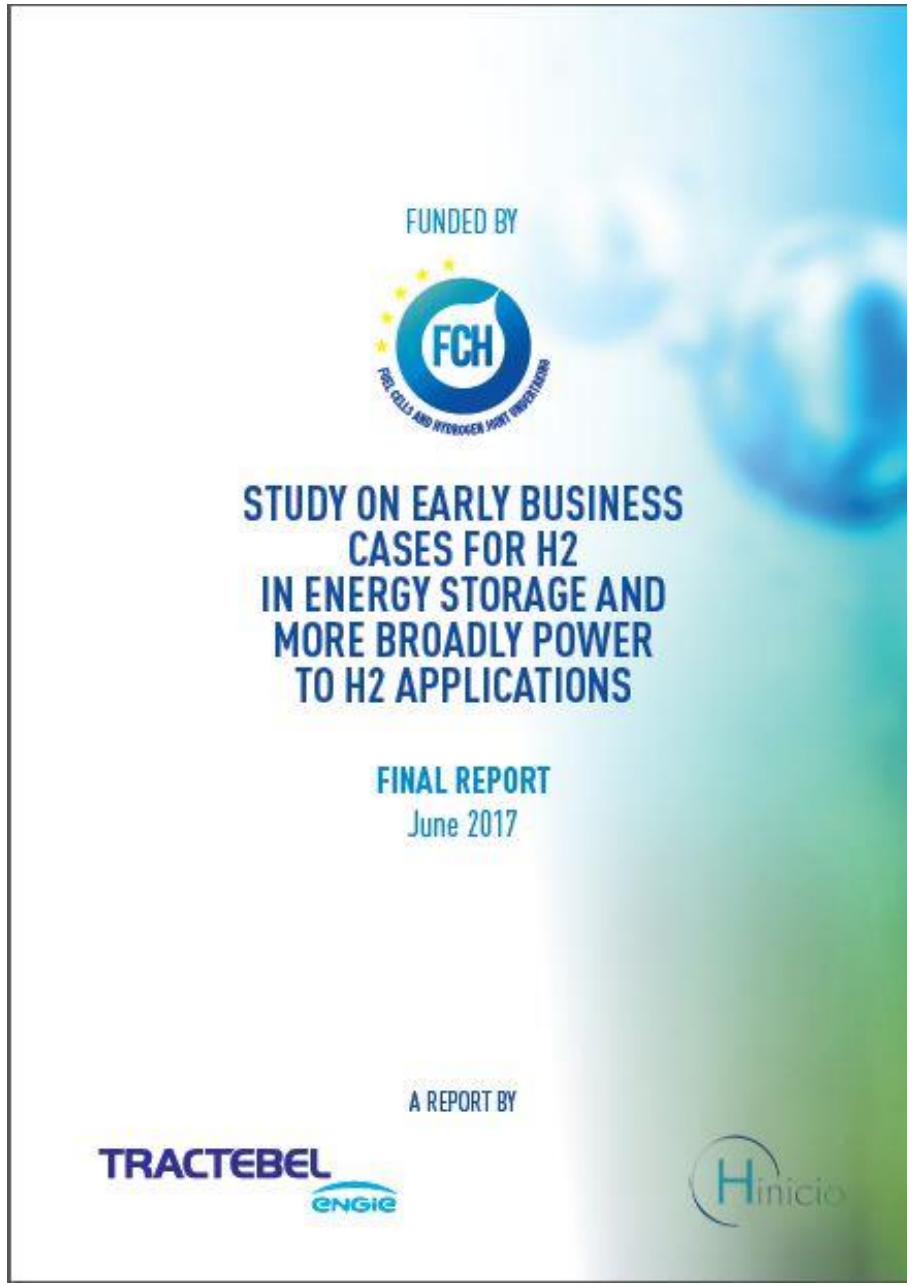
AREVA H_2Gen

FC LAB Research

ENGIE Green

Natural-gas network

Compressed natural gas (CNG) for vehicles



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iea Energy Technology Network

ON.ERGHY

RESEARCH ON FUEL CELLS & HYDROGEN

The key conclusion of this study is that Power-to-Hydrogen is bankable in Europe already today.

By 2025, an estimated cumulative electrolyser capacity of 2.8 GW could be installed in Europe based on sound economics, **representing a market value of €4.2 bn**.

Even today, the aggregate amount of profitable business cases would amount to 1.4 GW and €2.6 bn, if all cases were realized.

CONCLUSIONS

- Renewable intermittent energy will increase and will need to be stored on a large scale, both at centralized and decentralized level.
- Storing large amount of energy requires to go for power to gas.
- Power to gas works for both mid scale and large scale systems needing to store energy for more than a day.
- Using Hydrogen is a very flexible solution for storing energy.
- Hydrogen produced from renewable power via water electrolysis enables the transition to a cleaner future across all energy sectors and applications.


Thank You