Green and safe hydrogen solutions

The potential of Solid Hydrogen for Renewable Energy Storage & valorization

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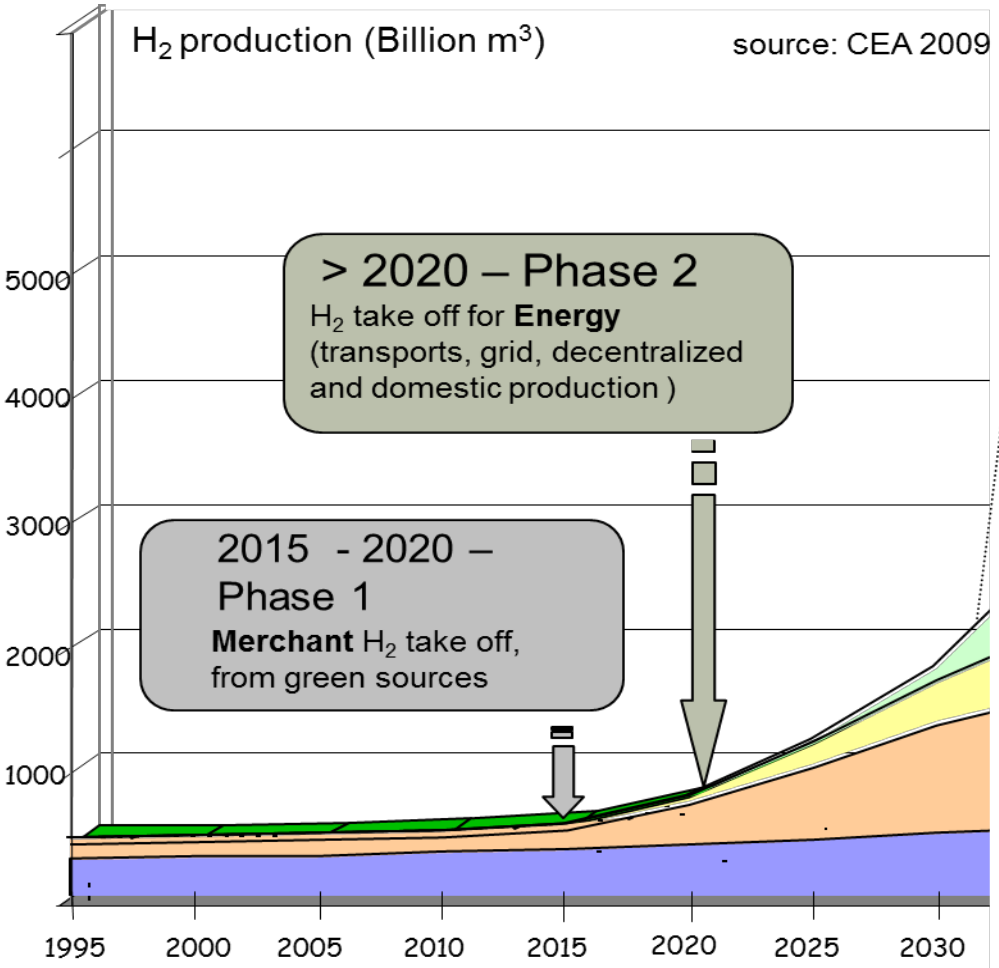
www.mcphy.com

Hydrogen uses perspectives



Two major take off announced:

After 2020 : H_2 use for energy applications as it is an excellent energetic vector

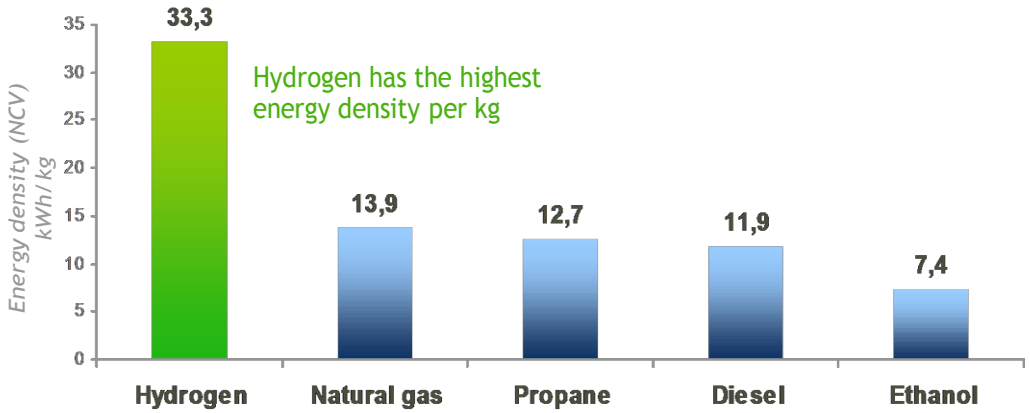
- **H_2 for transports (decentralized and massive production)**
- H_2 as energy storage

2015-2020 : merchant H_2 development. Originally from Methane, it will come more and more from REN sources

- H_2 low Carbon for industries
- H_2 industrial gas

Hydrogen a perfect fuel….

….hard to store



- H_2 offers ***an excellent energetic content per kg (33 kWh/kg)***
- But being a **very light gas**, its **densification requires ultra high pressure**, creating safety issues and a substantial waste of energy (20 to 25%)

Volume density (kgH_2/m^3)	
Liquid H_2	70
H_2 gas (700 bar)	42
MgH_2	106

McPhy technology advantages:

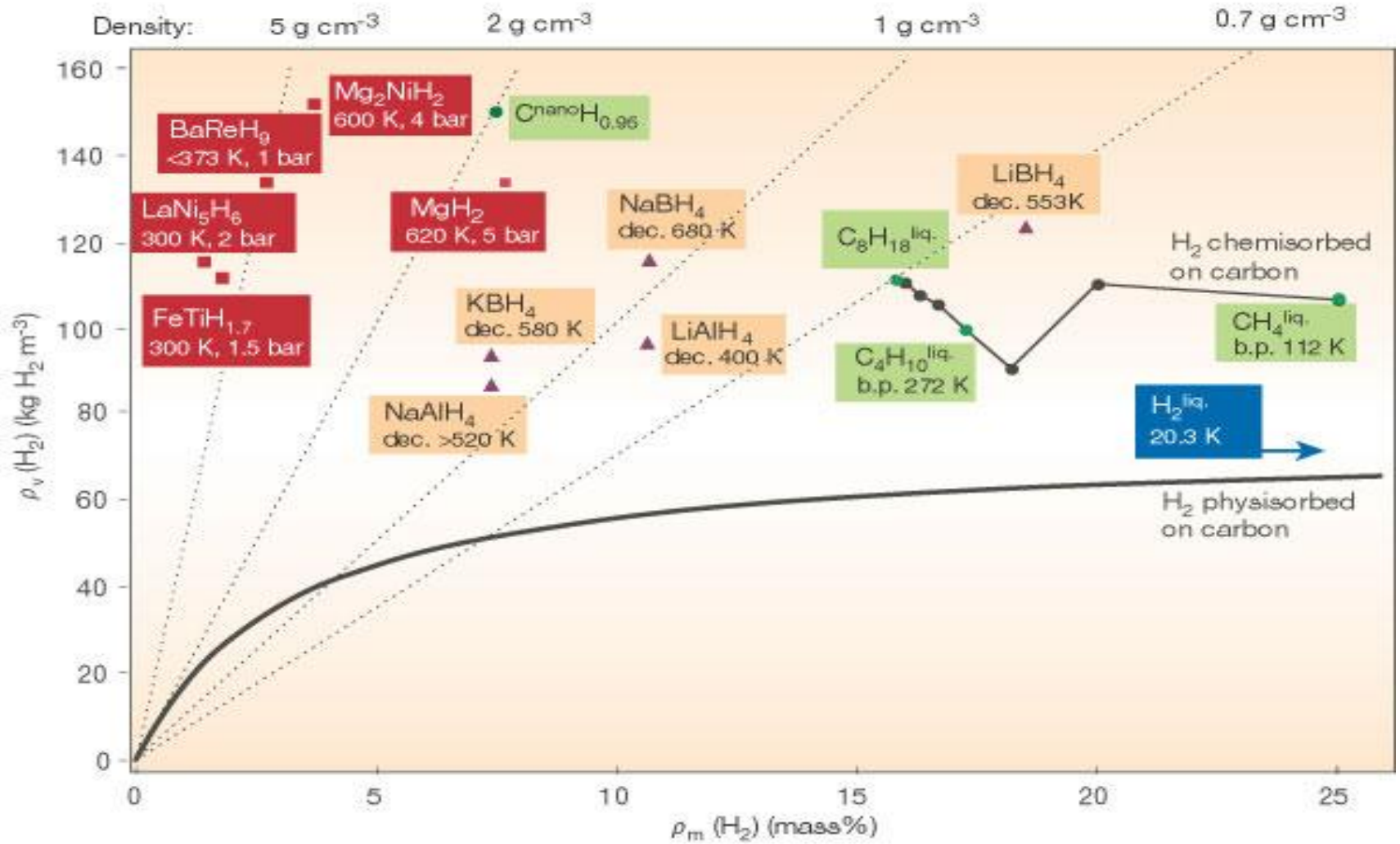
- No compression - 10 bar

- Energy savings

- Direct connection to an electrolyzer

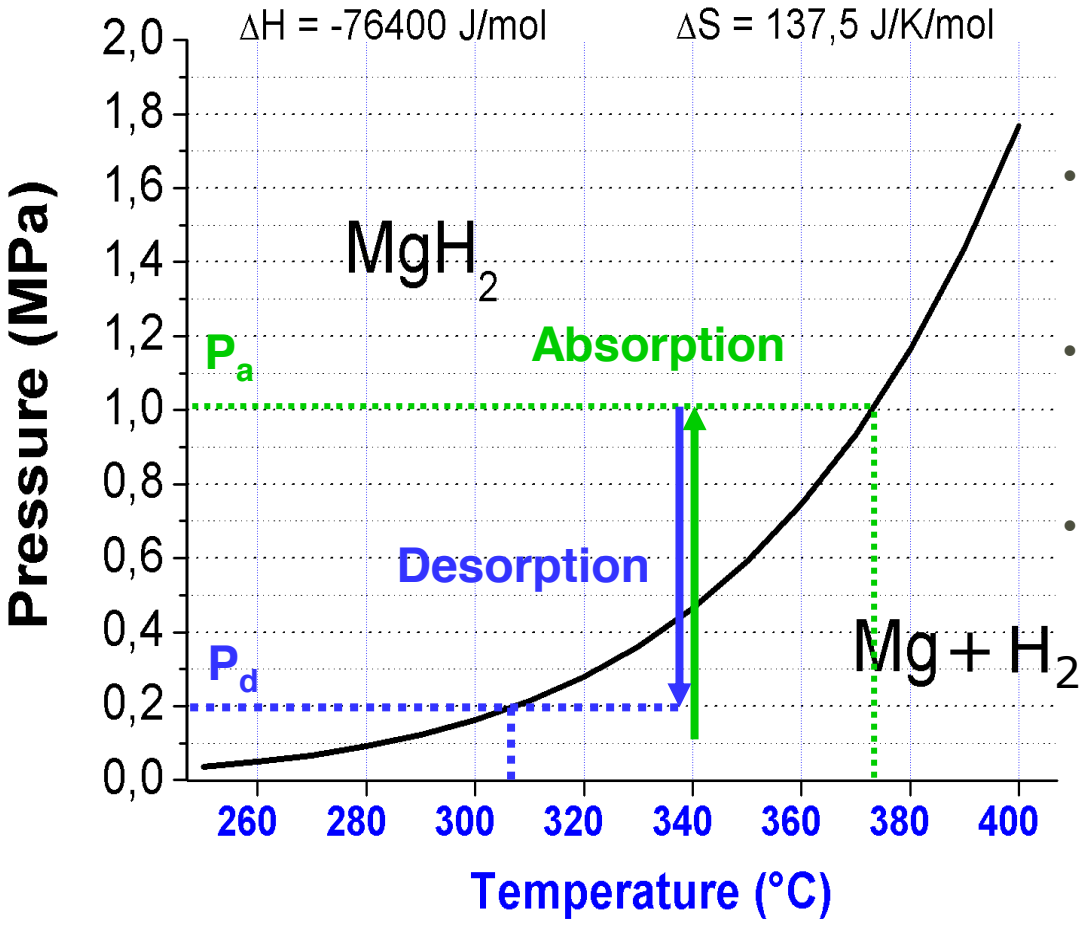
- Easy to use

H2 storage : Solid Hydrogen



"Hydrogen-storage materials for mobile applications", L. Schlapbach and A. Züttel, Nature 414, 353-358 (2001)

MgH_2 Hydrogen Storage System : A Hydrogen "Sponge"



- **Reversible storage**: Mg + H_2 ↔ MgH_2
- **Loading at electrolysis pressure** (10 bar)
- **Unloading at fuel cell pressure** (2 bar)

➔ ***No compression*** *(energy, cost, maintenance)*

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McPhy's Technology

McPhy has developed **unique techniques that solve the traditional limits of solid state hydrogen**.

Traditional challenges of MgH_2

- **Slow kinetics**
- **Low thermal conductivity**
- **No solution to store thermal energy**
- **Undesired mechanical properties and reversibility**

Uniqueness

- **Nano structuring of the MgH_2**
- **Proprietary catalysts**
- **Expanded Natural Graphite** increases conduction
- **Proprietary PCM** (Phase Change Material)
- Specific industrial **design**
- Use of a **single** element Mg

Characteristics

- **High density**
- **Safe** (low pressure, inert)
- **Negligible energy loss**
- **Mg is abundant and inexpensive**
- **No compression** (energy, cost, maintenance)
- **reversible**

Hydrogen Value Chain

McPhy technology ***induces a disruption*** *in the value chain enabling* ***"green" H_2*** *production* ***in existing and new markets***

Production

- **Steam Reforming of Natural Gas and other Thermal process**
  - **99 %** of the actual WW production
  - **> 10 t CO_2 /t H_2**

- **Electrolysis**
  - Only **1%** today
  - **> 70%** efficiency
  - **CO_2** content of the Electricity used

Storage

- **Pressure : Cylinders/Trailers**
  - High CO_2 foot print
  - Cumbersome logistic
  - Waste of Energy
- **Cryogenic**
  - Less efficient and even more difficult issues than pressure.
  - Niche market
- **Pipe line**
  - Heavy and Costly infrastructure
  - Limited networks

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- **Solid state**
  A game changing technology

Use

1. **Ammonia**
   Refineries
   Methanol

   Captive Users
   Most of the market

2. **Merchant Hydrogen**

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   initial market

3. **Energy** (new)

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   ramp up market

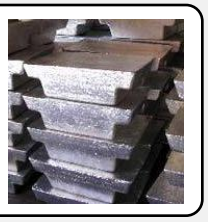
Product Range : McPhy Modular Solutions

In-House Production

Standard Modular Disks

- *43g or 0.5m³ of H_2*
- *Metallurgical processes*

Phase Change Material



- *Metallurgical processes*
- *Magnesium zinc alloy*

Outsourced

Standard Modular Cartridges

- *100 Disks*
- *5 Kg of H2*
- *2 versions with different kinetics*

End Products

PCM containers

Fully autonomous *Stationary adiabatic storage tank*

MGH containers

External Heat Exchange *Stationary storage tank*

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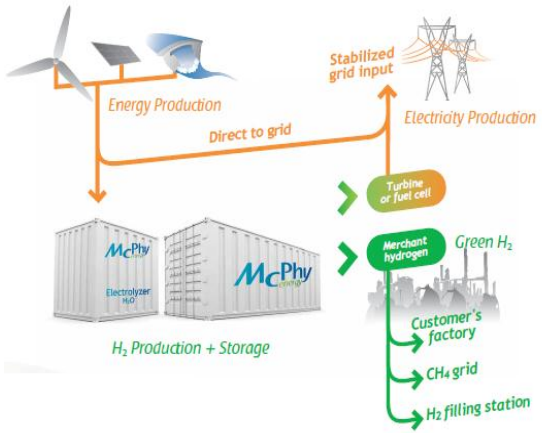
Our market focus

Provide hydrogen solutions for:

On site hydrogen

- ⇨ *Master your own hydrogen supply*
- ⇨ *Optimize the electrolyzer capacity*
- ⇨ *Manage your consumption profile with storage*
- ⇨ *Ensure back-up function*
- ⇨ *Manage your peak*

Renewable energy storage



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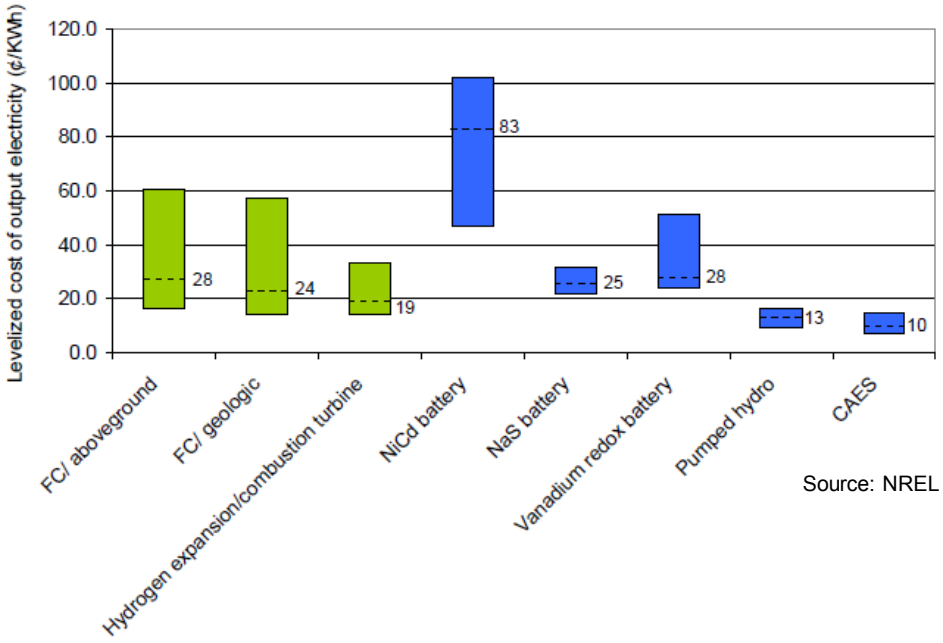
- ⇨ *Get the best of your MWh with H_2 storage*
- ⇨ *Match electricity delivery with grid demand*
- ⇨ *Participate to frequency and voltage regulation*
- ⇨ *Reduce CO_2 footprint of natural gas*

H_2

- ⇨ *Supply H_2 mobility with green H_2*
- ⇨ *Provide green H_2 to nearby industrial*

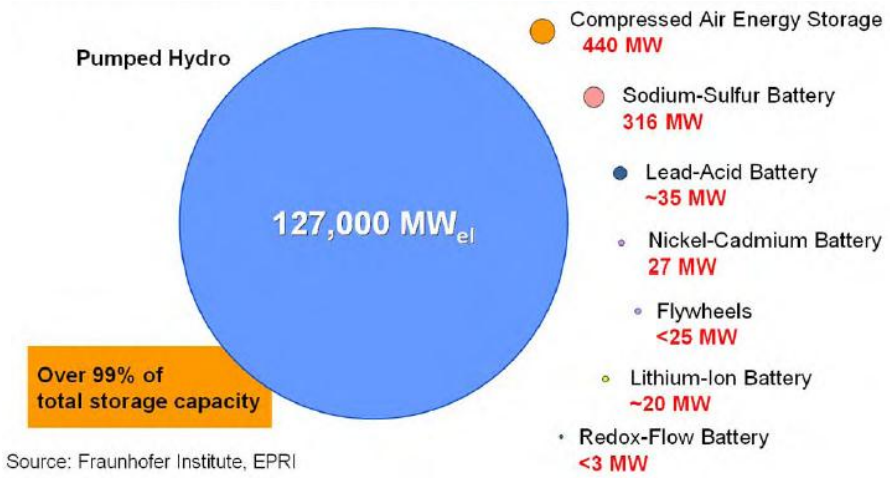
Energy Storage market…

…a large range of technologies…



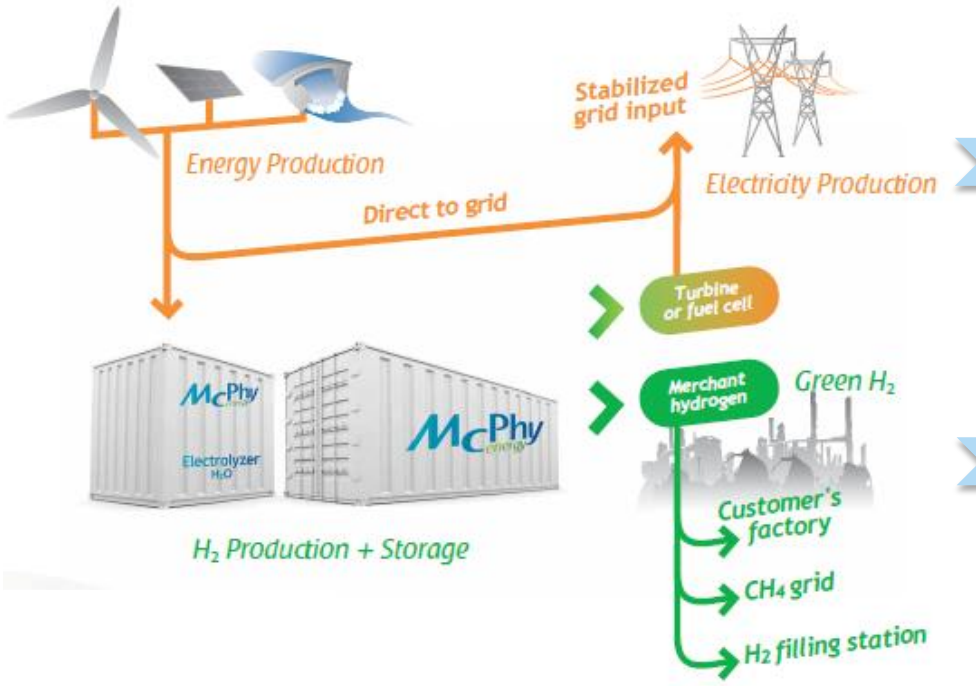
Source: NREL

…currently a niche market dominated by one technology!!!



Source: Fraunhofer Institute, EPRI

McPhy alternative: REN valorization through green hydrogen

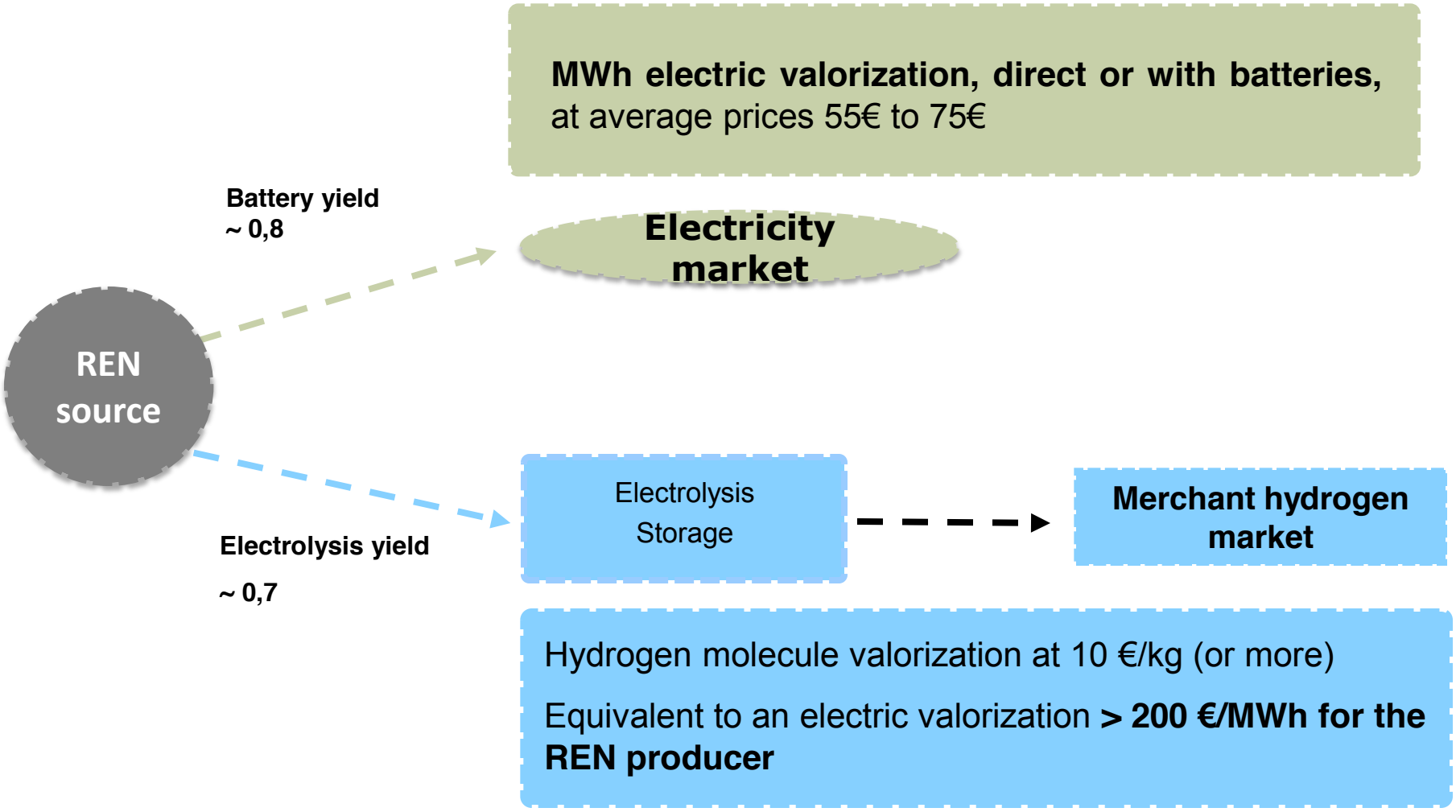


Hydrogen for pure electricity storage

Green Hydrogen

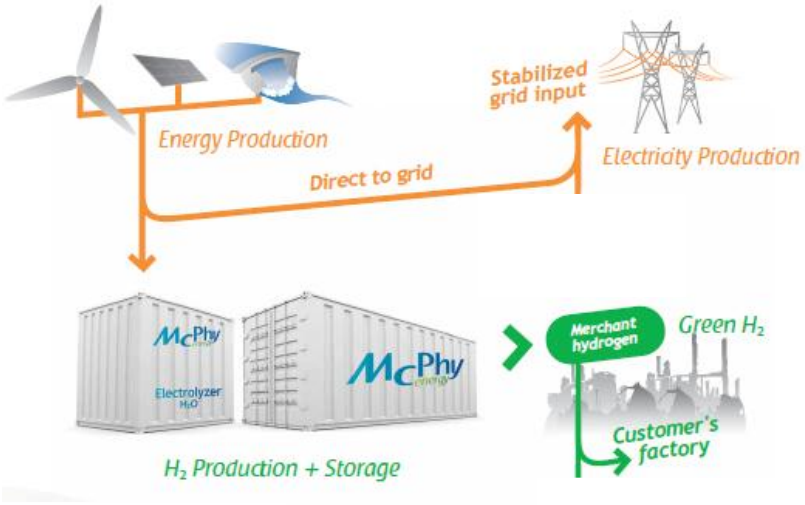
Unique engineered solution to optimize REN intermittency, grid demand and green H_2 distribution

REN valorization through Hydrogen



Business case : renewable energy valorization through hydrogen

- **REN producer invest in a the water electrolysis technology**
- **The gas distributor invests in the hydrogen storage**



Hydro production: **300 kW**
H_2 produced: **45 tons**
H_2 sold from REN producer to gas distributor: **5 €/kg**
H_2 sold by gas distributor to final customer: **10 €/kg**

	REN producer	Gas distributor
IRR 10 years	14,8 %	14,3 %
Payback	6 years	6 years

+++ frequency adjustment services to the grid, which is remunerated in some countries!

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Business Case – Elec to Elec

French call for tender

Project:

PV installation: 380kW$_c$

Elec. production: 1,5 MWh/day in average

Storage hypotheses:

Sun from 9am to 17pm

Pref max set by the producer estimated to 290 kW

McPhy proposal:

Electrolyzer: 100 kW

H_2 storage: 24 kg

Fuel Cell: 30 kW

Loading: 4h - 6h

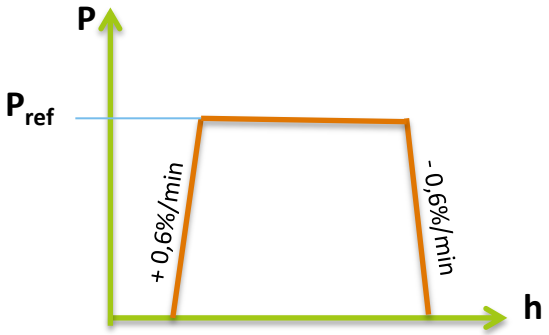
Unloading: 4h - 6h

Conditions for PV production + storage:

Power (Pref) to be announced to grid owner a day ahead

*Growth to Pref = +0,6%*Pref per minute*

Decrease to 0 = -0,6% Pref per minute*



Cost of storage: +75 €/MWH

The production line:

First Products sold & delivered to prestigious customers:


Enel Unit in operation in Italy

Nottingham unit on the test bench


Delivery of Iwatani in Japan

+ E.ON unit which will be delivered end of March

➔ 2 major references in Gas

➔ & 2 in Energy

«Yes, my friends, I believe that water will be one day used as fuel, that the hydrogen and the oxygen, which make it, used separately or simultaneously, will provide a source of inexhaustible heat and light and with an intensity the coal could never reach.»

Jules Verne, L'Ile mystérieuse - 1874

Thank you for your attention