The HyCARE Project

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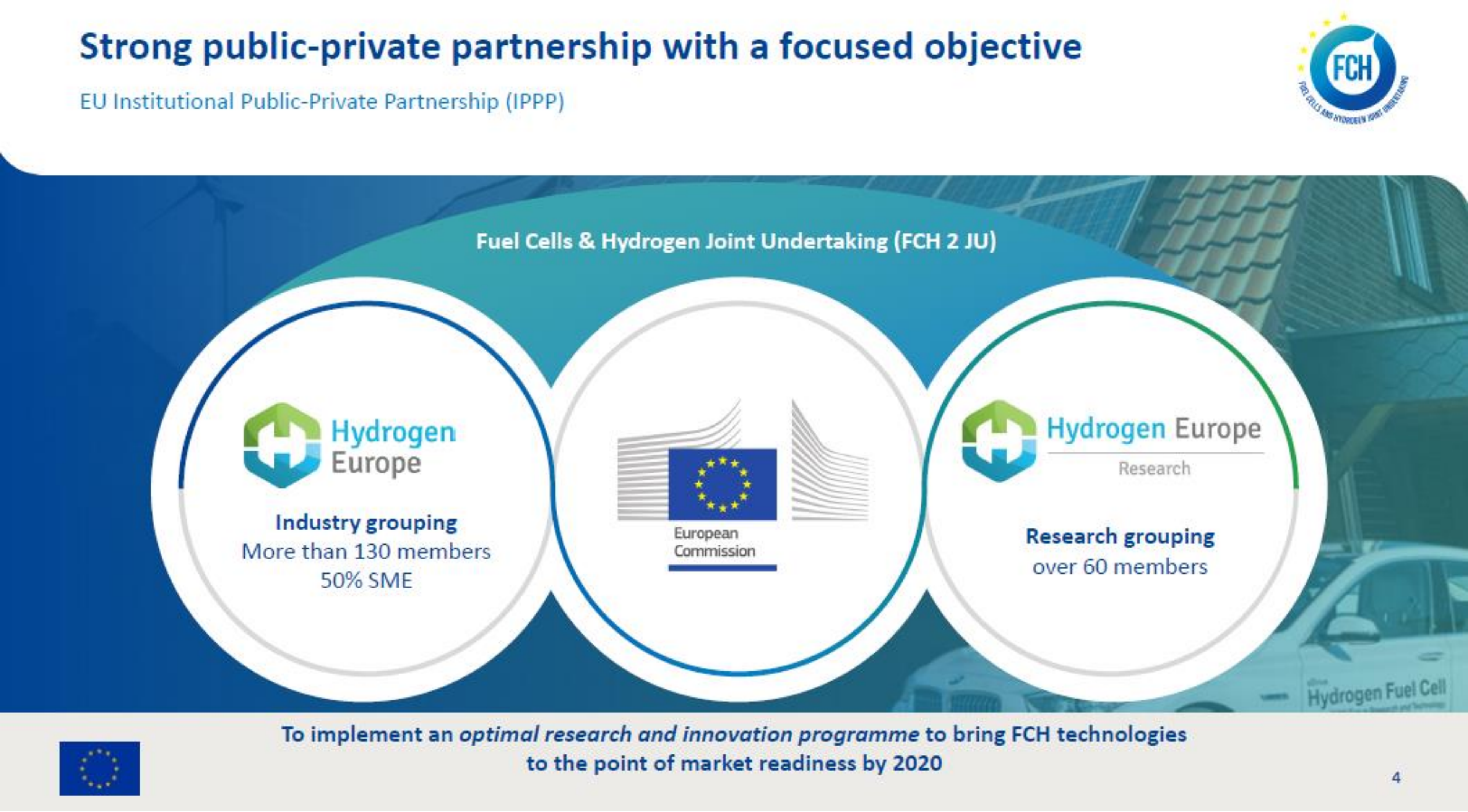
Marcello BARICCO

- PhD in Chemistry in 1987
- Full professor in Materials Science and Technology at the Department of Chemistry of the University of Torino (Italy).
- Coordinator of European projects (EU H2020 FCH JU HyCARE project)
- Expert in the Task 40 of the IEA-HIA
- Member of HER - Scientific Committee of FCH-JU
- Coordinator of SP7 on Hydrogen Storage of JP on Fuel Cells and Hydrogen of EERA
- Member of Scientific Committee of Italian Hydrogen Association - H2IT.

FCH JU


Strong public-private partnership with a focused objective
EU Institutional Public-Private Partnership (IPPP)
FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING
Fuel Cells & Hydrogen Joint Undertaking (FCH 2 JU)
Hydrogen Europe
Industry grouping
More than 130 members
50% SME
European Commission
Hydrogen Europe
Research
Research grouping
over 60 members
Hydrogen Fuel Cell
To implement an *optimal research and innovation programme* to bring FCH technologies
to the point of market readiness by 2020
4

FCH JU

FCH 2 JU Objectives

Market readiness of a portfolio of clean, efficient and affordable solutions for our energy and transport systems

Clean Transport
Reduce fuel cell system costs for transport applications

H_2 storage for grid balancing
Demonstrate on a large-scale hydrogen's capacity to harness power from renewables and support its integration into the energy system

Green hydrogen production
Increase efficiency and reduce costs of hydrogen production, mainly from water electrolysis and renewables

Heat & electricity production
Increase fuel cell efficiency and lifetime

Minimal use of critical raw materials
Reduce platinum loading

FCH JU

FCH JU programme implementation

Energy

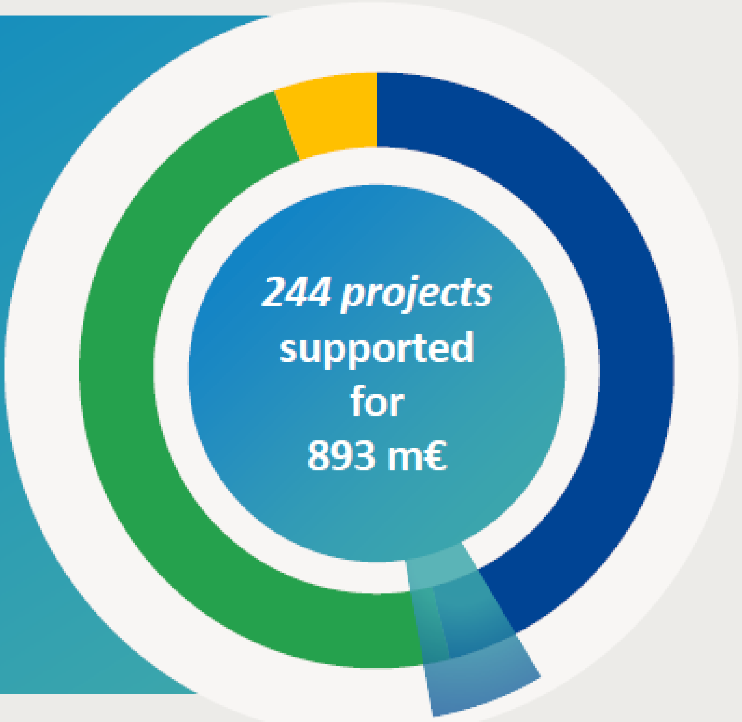
- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

Transport

- Road vehicles
- Non-road vehicles and machinery
- Refuelling infrastructure
- Maritime rail and aviation applications

Cross-cutting

- E.g. standards, safety, education, consumer awareness …



47 %
418 million euros
135 projects

42 %
376 million euros
65 projects

6 %
53 million euros
40 projects

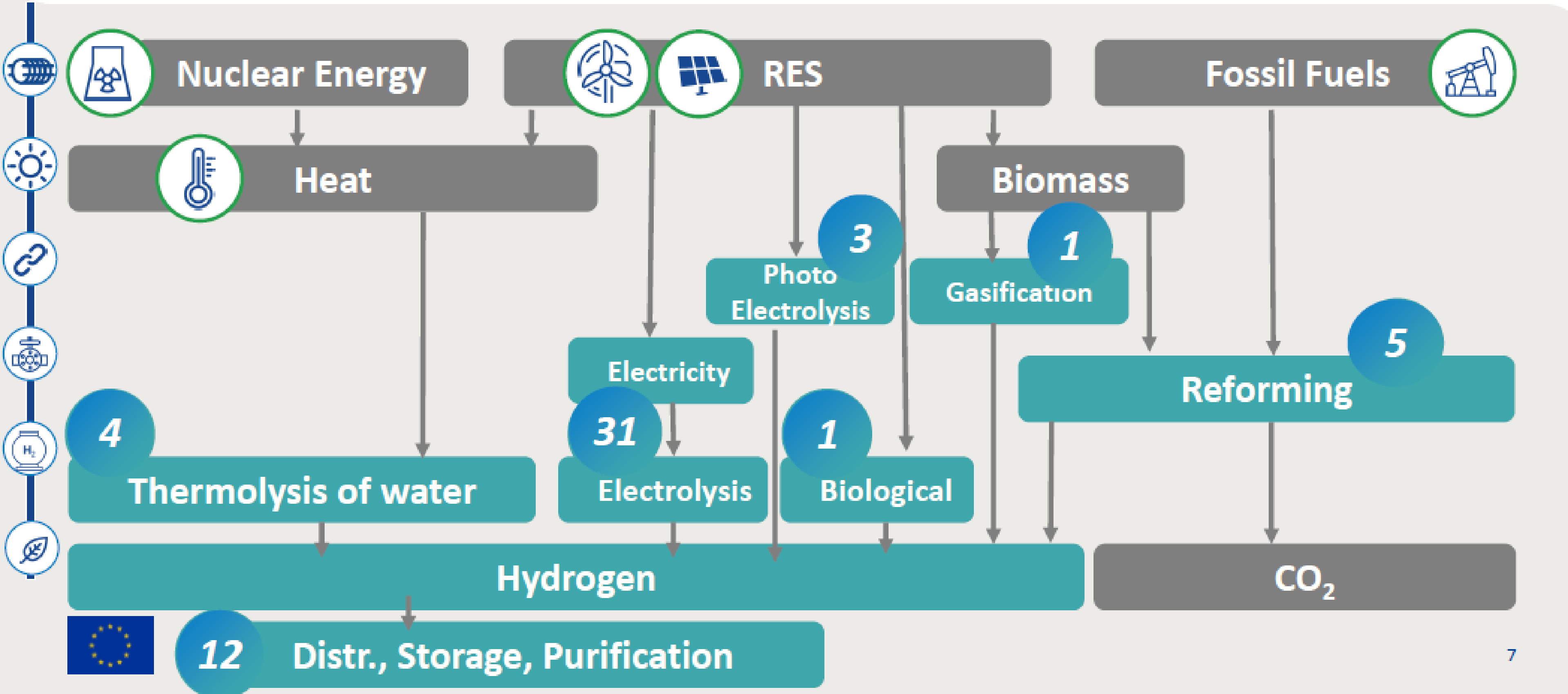
5 %
46 million euros
4 projects

Similar leverage of other sources of funding: 892 m€

FCH JU

Hydrogen Production Technical Coverage

95% of FCH JU support to green Hydrogen production



THE CALL

AWP 2018 – Topic 02-5-2018

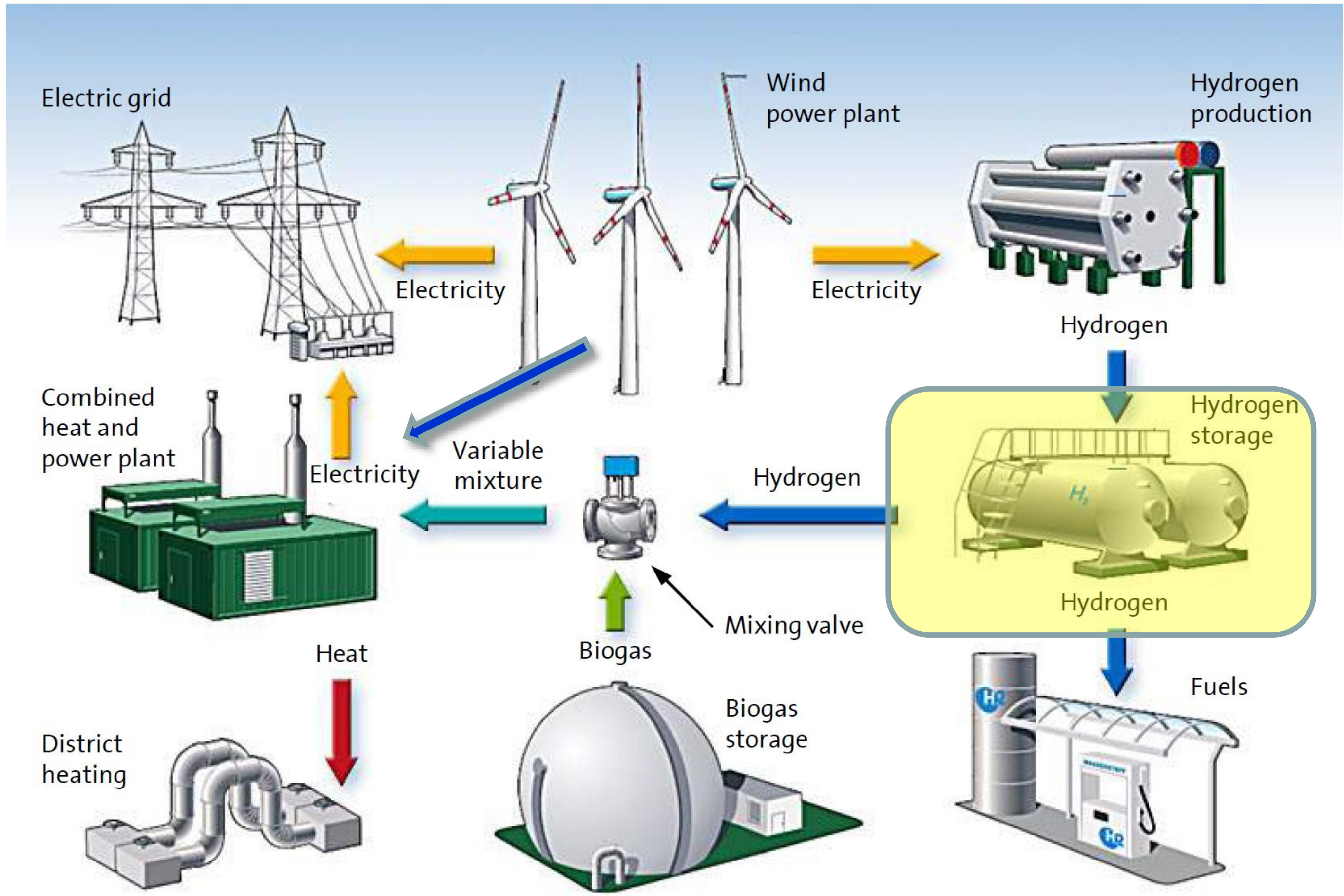
Hydrogen carriers for stationary storage of excess renewable energy

- ***Challenge***

  Low cost H_2 storage:
  - use of low-pressure (i.e. lower than 50 bar) storage based on hydrogen carriers could decrease CAPEX and OPEX of hydrogen storage significantly
  - Demonstrate efficient storage and delivery of H_2
- ***Scope***
  - demonstrate a prototype of a storage system for an application with significant market potential
  - integration of the prototype system from H_2 production to delivery is required within the project
  - achieve a break-through in increased energy efficiency and compactness

  Impact:
  - medium-scale prototype system with a capacity of > 50 kg H_2
  - Discharge energy < 5.0 kWh/kg H_2 ; Total round-trip energy efficiency > 70%
  - at least 250 cycles demonstrated, <0.2% loss of storage capacity per cycle
  - H_2 purity at point of delivery at least 99.99 %
- ***TRL 3 -> 5, FCH contribution of 2 MEuro, RIA***

Green hydrogen from renewables



An innovative approach for renewable energy storage by a combination of hydrogen carriers and heat storage

What?	An innovative approach using **hydrogen carriers and Phase Change Materials** for the storage of renewable energy.
Why?	Current approaches for renewable energy storage in Europe are not efficient and require a large **footprint**. No suitable systems are available up to now and hydrogen carriers have the potential to solve these problems, but **large-scale applications** need to be demonstrated.
Who?	European leading research groups on solid-state hydrogen carriers (**UNITO, CNRS, IFE**) and technology innovators (**HZG, FBK**), joining large companies on materials (**GKN**) and energy (**ENGIE**) together with small-medium enterprises (**STH, TD**).
Where?	The use of the developed system will be demonstrated at the **Living Lab of ENGIE** in Paris.
For whom?	For companies, regions and cities aiming to extend the use of renewable energies.
Next?	The developed system will be **exploited** by companies for commercial applications and by research centres for knowledge-based developments on hydrogen storage.

Hydrogen CArrier for Renewable Energy Storage

FCH | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HORIZON 2020

The HyCARE Project

UNIVERSITÀ DEGLI STUDI DI TORINO

ENGIE

GKN

TECNO DELTA

Stühff GmbH

HyCARE

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

FONDAZIONE BRUNO KESSLER

cnrs

IFE

ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

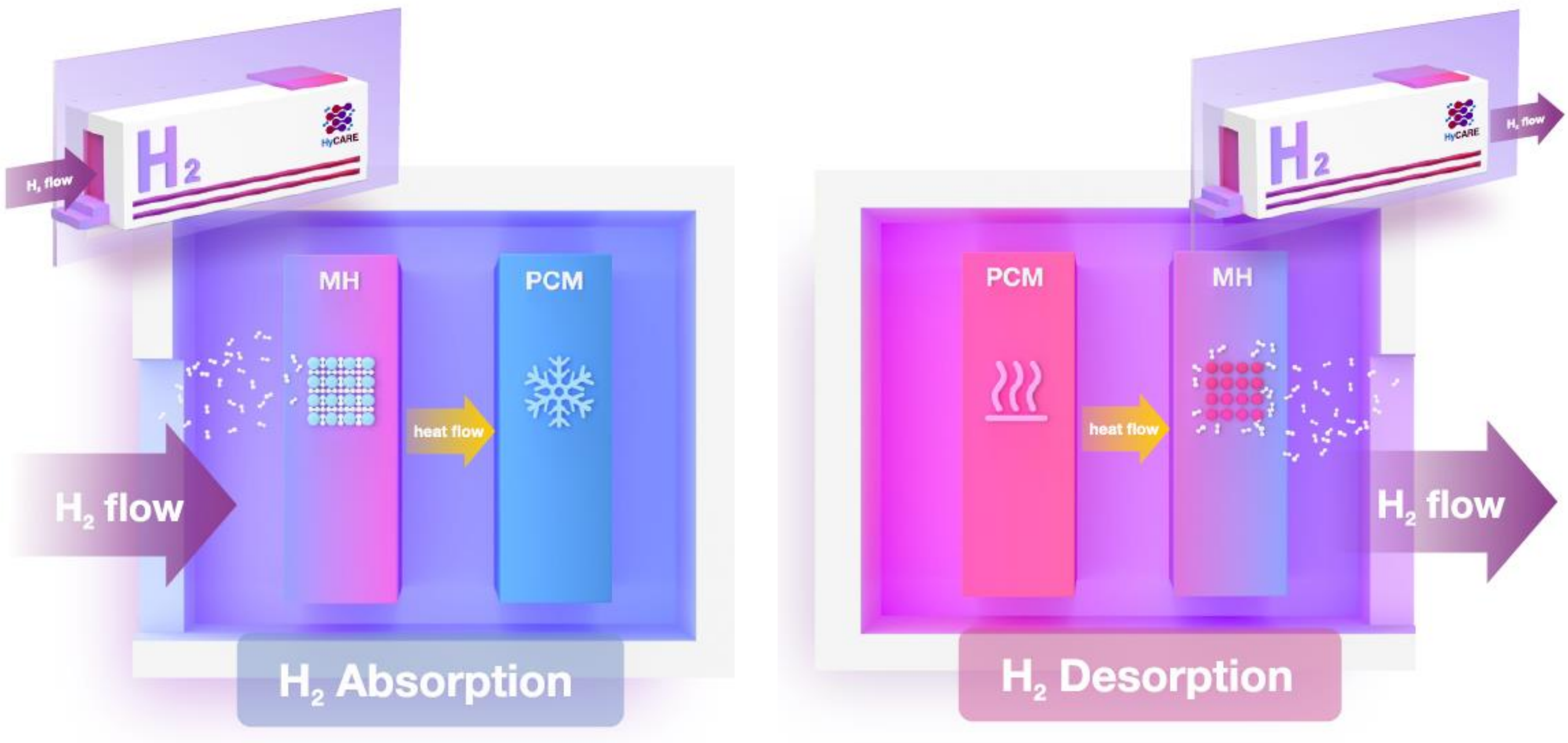
2019-2021

HyCARE

The goals

- **High quantity of stored hydrogen** >= 50 kg
- **Low pressure** < 50 bar and **low temperature** < 100°C
- **Low foot print**, comparable to liquid hydrogen storage
- **Innovative design**
- **Hydrogen storage coupled with thermal energy storage**
- Improved **energy efficiency**
- **Integration** with an **electrolyser** (EL) and a **fuel cell** (FC)
- Demonstration in **real application**
- Improved **safety**
- **Techno-economical evaluation** of the innovative solution
- Analysis of the environmental impact via **Life Cycle Analysis** (LCA)
- Exploitation of **possible industrial applications**
- **Dissemination** of results at various levels
- **Engagement** of local people and institution in the demonstration site

The concept



H2 flow
MH
PCM
heat flow
H2 flow
H2 Absorption
H2 flow
PCM
MH
heat flow
H2 flow
H2 Desorption

H_2-carrier and PCM

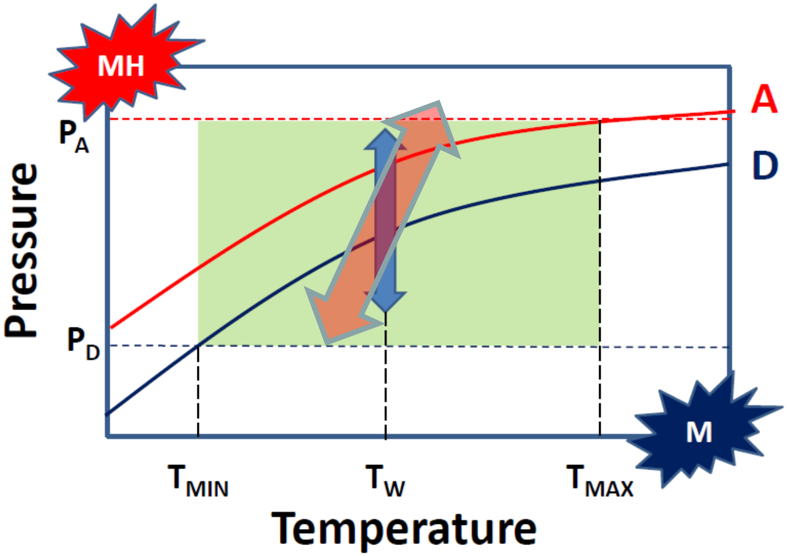


Figure 1 P-T relationship of the hydrogen carrier during the absorption and desorption steps.

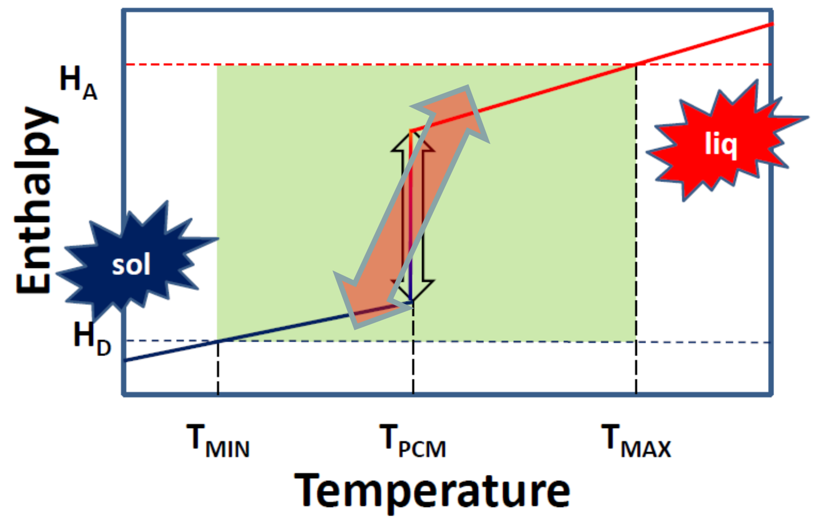
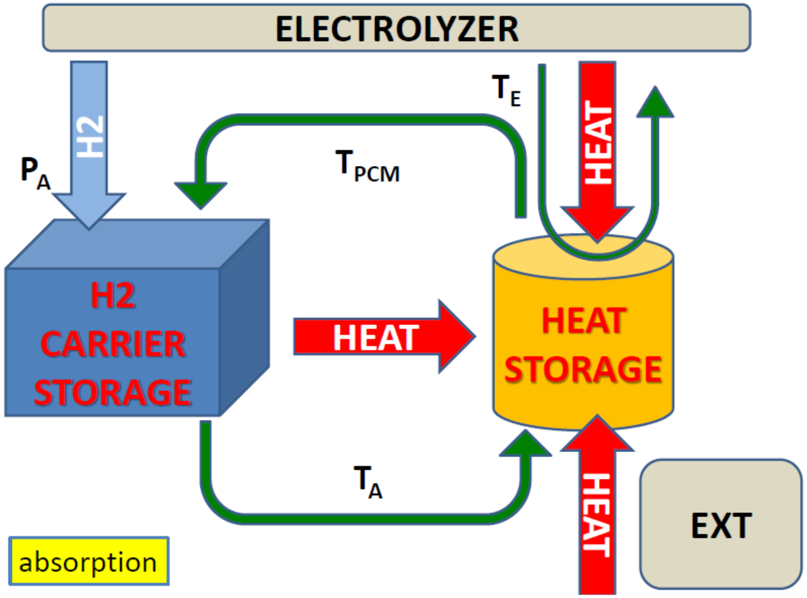


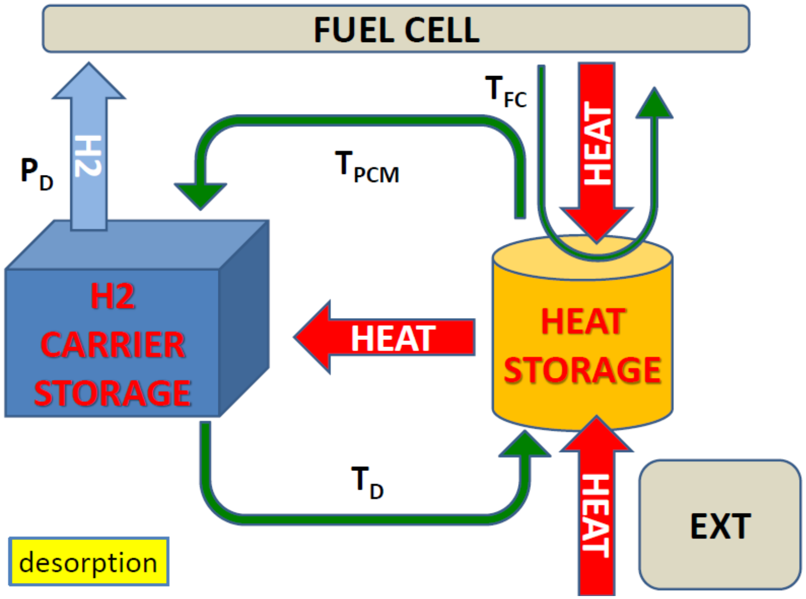
Figure 2 E-T relationship for a phase change material during the solid-liquid phase transformation.

The integration



(a)

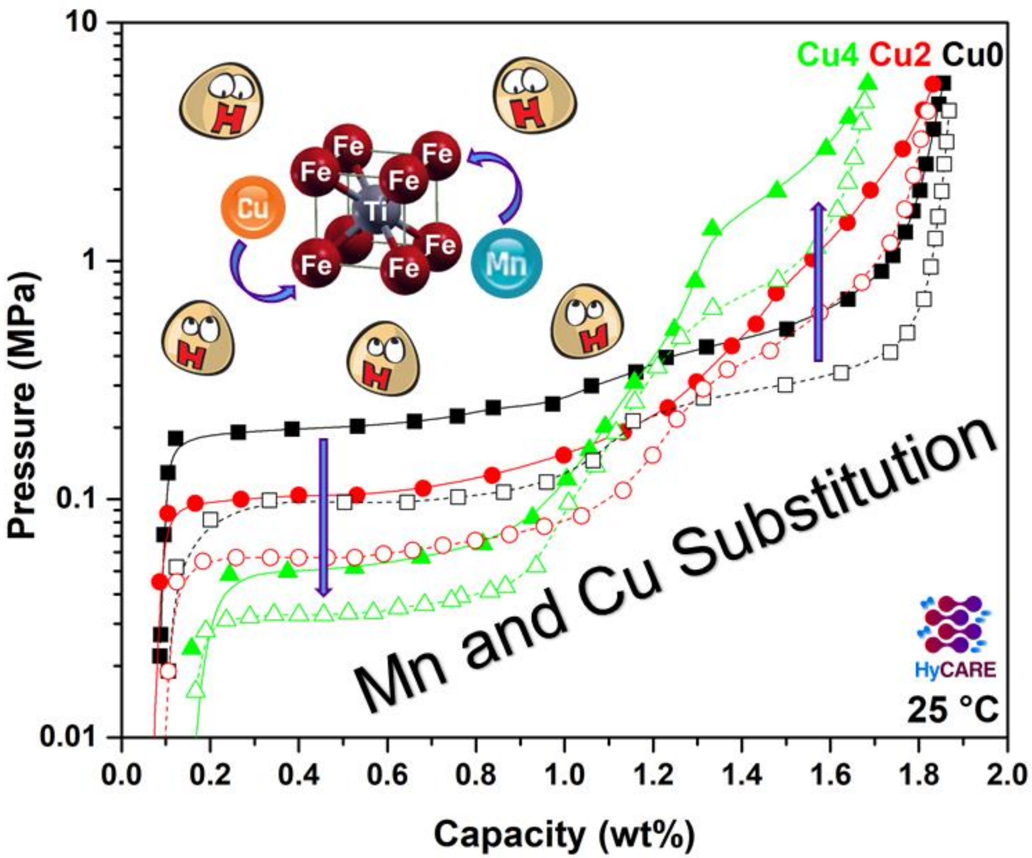
Figure 1 Thermal management during the hydrogen absorption step from the electrolyzer.



(b)

Figure 2 Thermal management during the hydrogen desorption step to the fuel cell.

Tailoring TiFe



Cu0: $TiFe_{0.88}Mn_{0.02}$
Cu2: $TiFe_{0.86}Mn_{0.02}Cu_{0.02}$
Cu4: $TiFe_{0.84}Mn_{0.02}Cu_{0.04}$

Multi-phase alloys: TiFe, β-Ti, Ti_4Fe_2O
Good activation
Fast kinetic
Suitable hydrogen capacity

↑ Mn,Cu cause:

↑ secondary phase amount
↑ TiFe cell parameter
↓ 1^{st} plateau pressure
↑ 2^{nd} plateau pressure

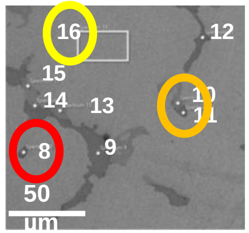
Dematteis et al., JALCOM, 851 (2021) 156075
https://doi.org/10.1016/j.jallcom.2020.156075

"This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826352. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and Hydrogen Europe Research".

Industrially produced TiFe-alloy

EDX on embedded with FEG-SEM instrument

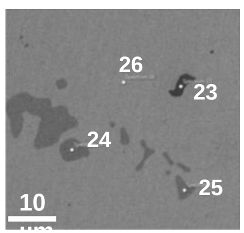
Elemental map (Values in atomic%)



	Sp. 8	Sp. 9	Sp. 10	Sp. 11	Sp. 12	Sp. 13	Sp. 14	Sp. 15	Sp. 16
O	11.65	11.75	12.22	13.01	11.30	12.44	12.16	11.66	5.22
Al	0.40	0.29		0.35	0.40	0.13			
Si	0.29	0.20	0.26	0.27	0.24	0.25	0.34	0.33	
Ti	69.14	67.60	57.09	68.13	68.83	57.06	57.67	57.60	46.74
Mn	3.26	3.32	2.71	2.92	3.14	2.51	2.82	2.70	1.93
Fe	15.26	16.85	27.72	15.33	16.09	27.62	27.02	27.70	46.10

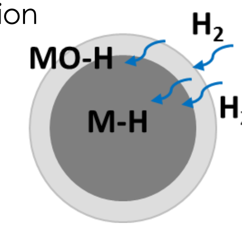
Legend:

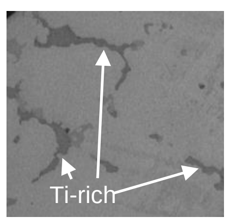
- TiFe
- $Ti_{80}(FeMn)_{20}$
- Ti_4Fe_2O

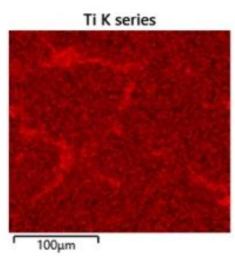


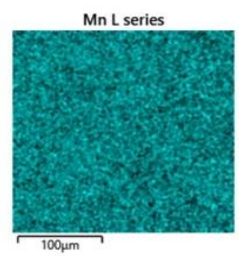
	Sp. 23	Sp. 24	Sp. 25	Sp. 26
O	10.31	16.23	16.52	4.75
Al	0.34		0.16	0.13
Si	0.16	0.17	0.19	
Ti	72.21	53.25	50.95	47.33
Mn	2.78	2.43	2.02	2.32
Fe	14.19	27.91	30.17	45.47

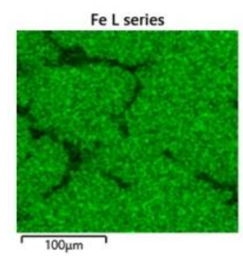
Inhomogeneity of composition











Highlight of the Ti-rich phase

Produced by

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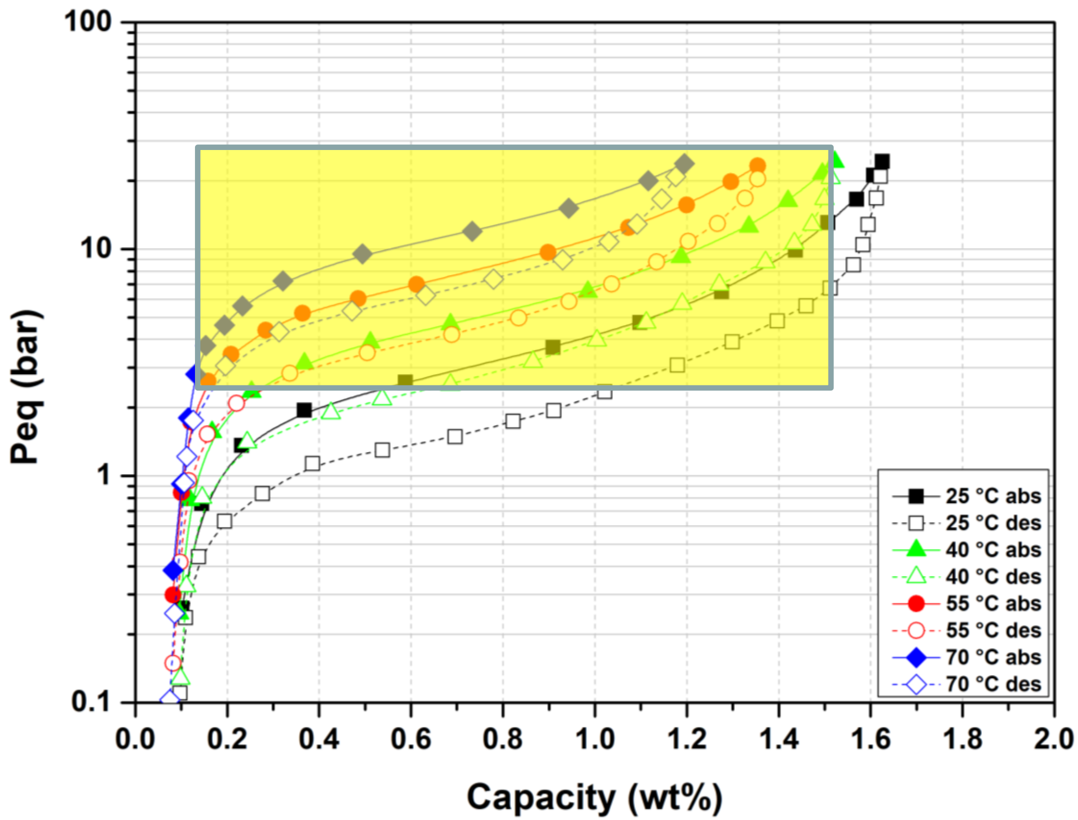
Thermodynamics

ACTIVATION

- 90 °C 6 h of vacuum
- 90 °C + 50 bar for 4 h
- Cooling down in 50 bar to RT

- Desorption at 90 °C under vacuum
- 10 cycles at 55 °C & 25-2bar (plant condition)

During initial activation cycling: fast kinetic (t_{90} of few minutes)



Safety

< 30 bar

Low pressure storage

Safety

< 70 °C

Low temperature storage

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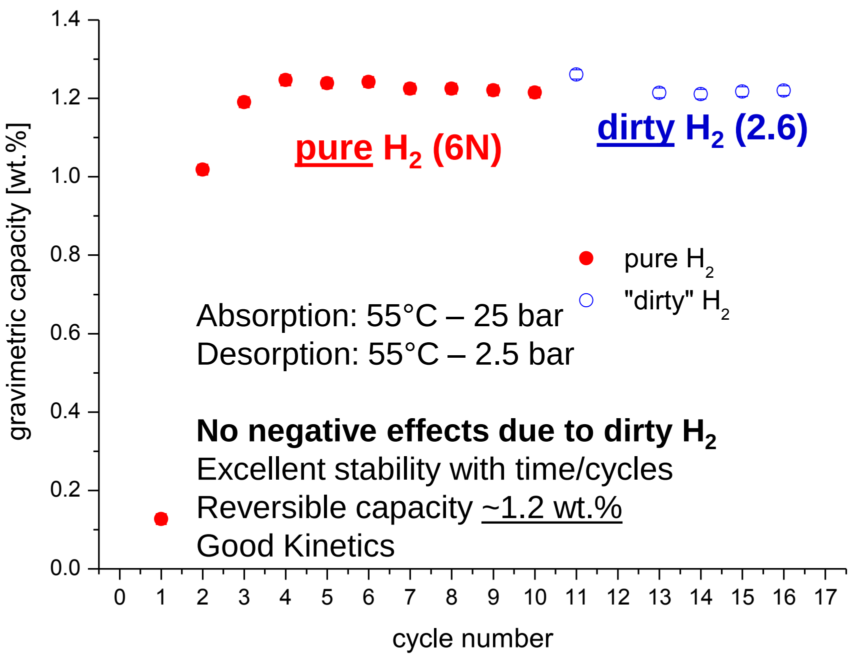
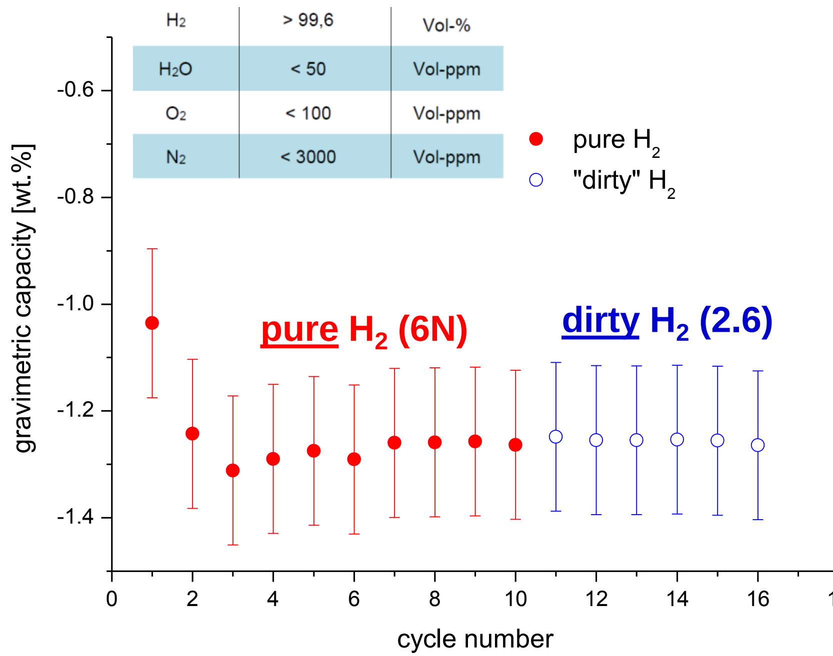
Cycling in clean and dirty H_2

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Absorption capacity after 240 min



Desorption capacity after 240 min



H_2	> 99,6	Vol-%
H_2O	< 50	Vol-ppm
O_2	< 100	Vol-ppm
N_2	< 3000	Vol-ppm

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HyCARE

System design & prototype test

System design

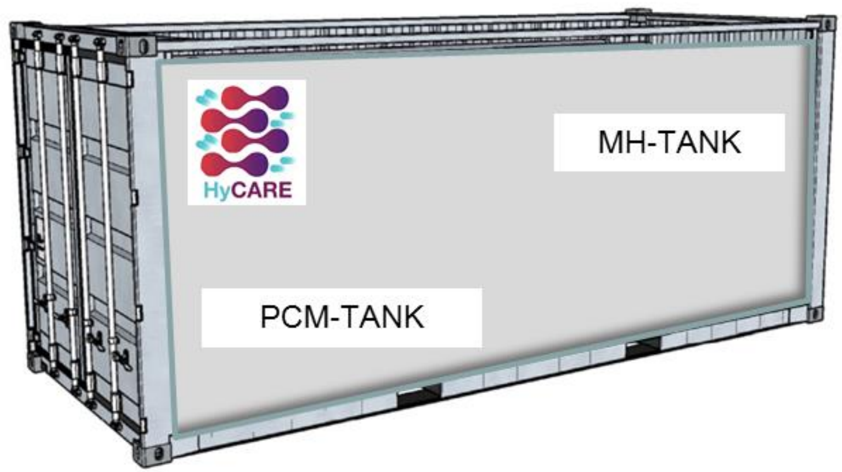
Metal hydride

- 4 ton of TiFe-alloy - ≈ 40-44 kg of H_2

PCM

- 2.7 ton of CRODA

Std. ISO Container



GKN POWDER METALLURGY

TECNO DELTA S.r.l.

Stühff GmbH Präzision für Werkstoffe

Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung

Prototype design

Metal hydride module

- 60 kg of TiFe-alloy
- pellets

PCM module

- 30 kg of PCM

Prototype test

- Models validation
- Optimization of the final design

HyCARE

GKN POWDER METALLURGY

TECNODELTA

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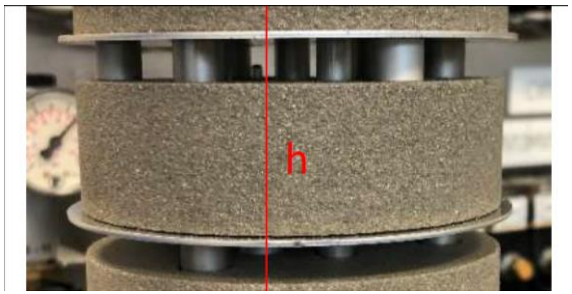
FONDAZIONE BRUNO KESSLER

Amount of stored hydrogen



Quantity

50 kgH_2

High quantity
of stored hydrogen

Energy efficency

Efficiency

< 70 %

Total round trip
energy efficiency

Environmental impact

< 5.0 kWh/kg H_2

External energy source with
innovative design
for large scale storage and use
of non-critical raw materials

Expected Impact

Exploitation

SSERR

Support Services for Exploitation of Research Results

HORIZON RESULTS BOOSTER

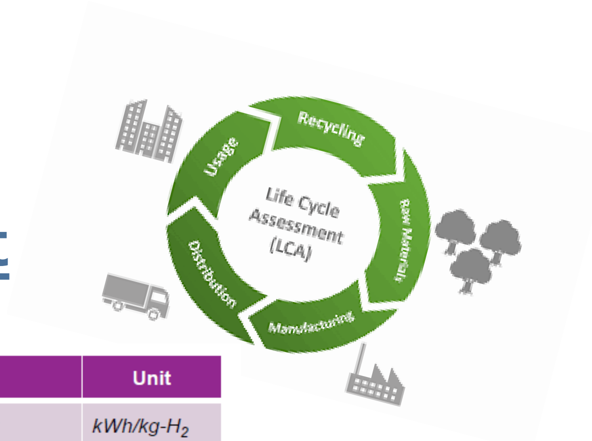
An initiative of the European Commission

SERVICE 1
PORTFOLIO DISSEMINATION & EXPLOITATION STRATEGY:

SERVICE 2
BUSINESS PLAN DEVELOPMENT:

SERVICE 3
GO-TO-MARKET SUPPORT:

Impact



	KPIs	Unit
TECHNICAL	Storage efficiency	$kWh/kg\text{-}H_2$
	Gravimetric capacity	$kg\text{-}H_2/kg$
	Volumetric capacity	$kg\text{-}H_2/m^3$
	Nominal flowrate	kg/h
ECONOMIC	CAPEX	€
	OPEX	€/yr
	Cost of hydrogen (LCoH)	$€/kg\text{-}H_2$
	Lifetime	yrs
	Availability	%

TRUST

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Communications and Dissemination Activities

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Acknowledgments

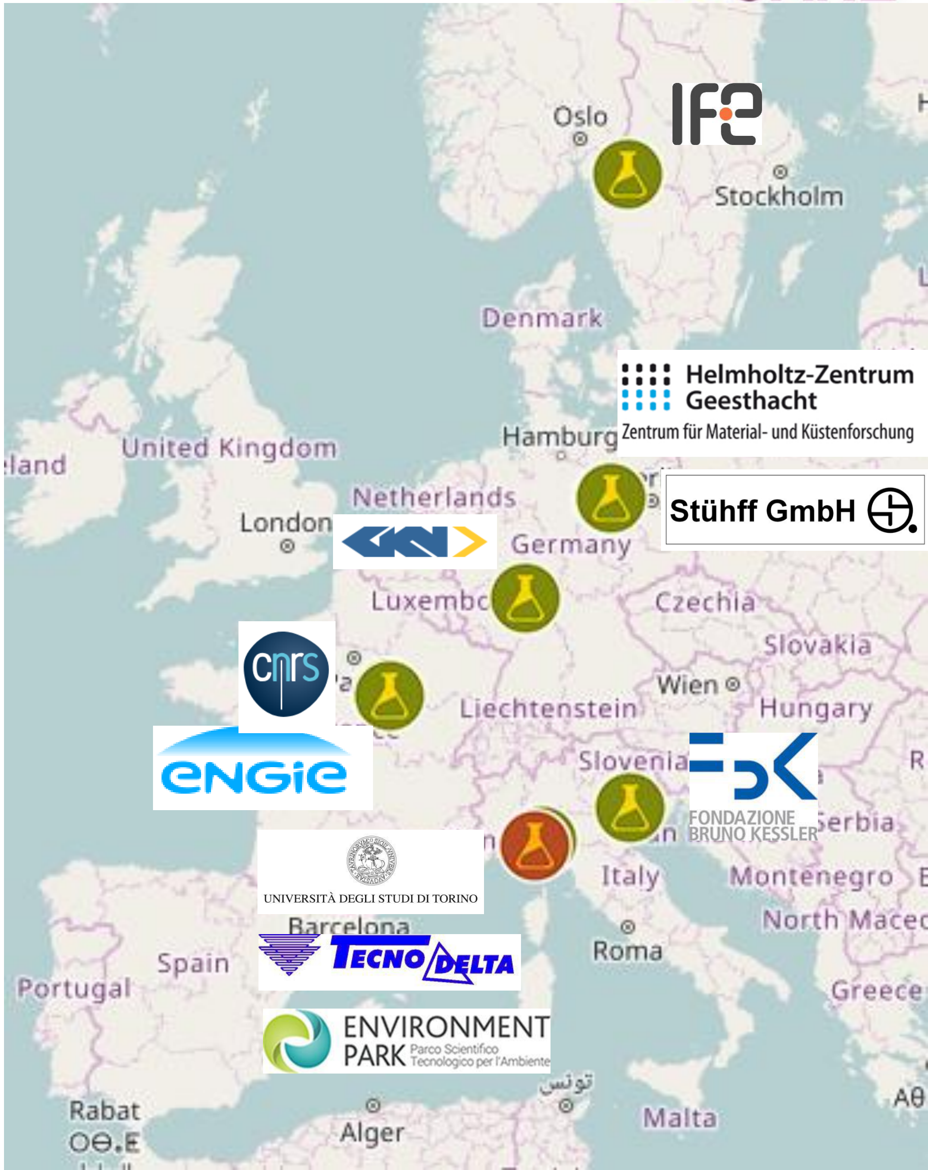
HyCARE

TakeCARE

Università degli Studi di Torino
nis CENTRE FOR NANOSTRUCTURED INTERFACES AND SURFACES

UNIVERSITÀ DEGLI STUDI DI TORINO

E.Dematteis,
J.Barale,
P.Rizzi



FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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