European Commission

EU OPEN FOR BUSINESS–
A NEW COMPASS FOR SMEs

26-28 MAY 2021

hydrogenious LOHC TECHNOLOGIES

European Commission

From start-up and university spin-off to a leading hydrogen transport company

The Story of Hydrogenious LOHC Technologies

via

the SME instrument „Enabling the Hydrogen Economy“

Ralf Ott, Head of Policy and Regulation

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Hydrogenious LOHC Technologies GmbH

Global technology leader for Liquid Organic Hydrogen Carrier (founded 2013)

Vision

A global hydrogen fueled society – truly sustainable and emission-free

- >110 Employees
- >40 Patent families filed - growing number
- 10 Operating Systems
- 2016 First system delivered
- € >30m Total funding raised → New round started

Investors

- ANGLO PLATINUM — VC fund of world leading platinum mining company
- APVentures — ADVANCE & PIONEER
- covestro — World leading chemical compay
- Winkelmann Group — German automotive supplier
- HYUNDAI — World class car manufacturer
- Vopak — World leading oil terminal operator
- Mitsubishi Corporation — The trading division of Mitsubishi group

Key Partners

MAN Energy Solutions, CLARIANT, ARKEMA, FAU, HI ERN Helmholtz Institute Erlangen-Nürnberg, EASTMAN

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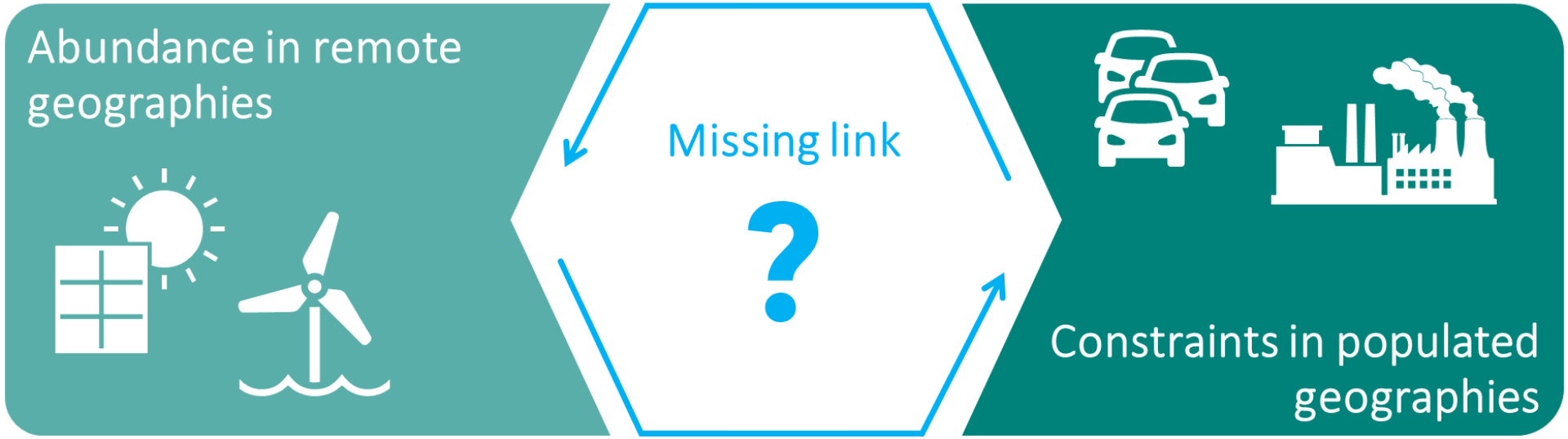
Hydrogen as the "Missing link" for large-scale renewable energy imports

Disconnected supply and demand centers



RES Energy Supply

RES Energy Demand

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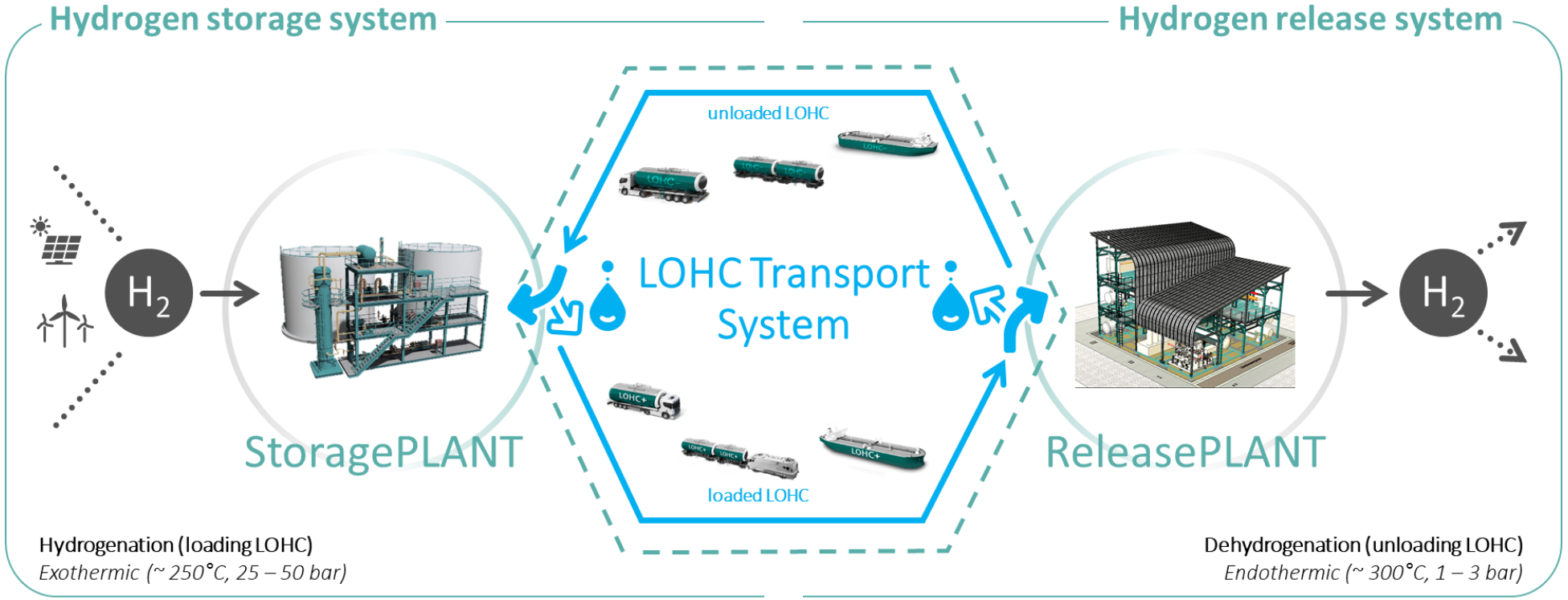
LOHC technology leverages the existing liquid-fuel infrastructure by transporting hydrogen in a liquid at ambient conditions



Safe: Hardly flammable liquid

Efficient: High energy density

Flexible: Use of existing infrastructure

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The SME instrument „Enabling the Hydrogen Economy“ was very important for developing the LOHC technology further

Hydrogenation box (0,017 tpd)

Missing link

?

Dehydrogenation box (0,022 tpd)

- SME Instrument: „Enabling the Hydrogen Economy“
- Project start: 01.02.2017
- Project success: Dehydrogenation: 19.07.2018
- Project end: 31.01.2019

→ Next step: industrial scale-up of LOHC technology by factor 100-300

Conclusion - EU Funding vital for the success of Hydrogenious (and other SMEs)

- Start-ups need initial seed money European support very helpful
- The European SME instrument was vital for Hydrogenious LOHC Technologies´ success and get through the „Valley of Death“ of start-ups
- Other European programmes (e.g. FCH) helped to further develop the technology
- Further steps to be undertaken for climate start-ups:
  - Especially climate tech start-ups need to scale up their technology which means high capital requirements
  - Furthermore, stable regulatory conditions which also take into account innovative and disruptive technologies are a core requirement

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Future Projects: Hydrogenious is already part of several leading hydrogen production and transportation projects

Current pipeline of advanced projects

Green Crane (IPCEI)

Hydrogen production from renewables in **Northern Spain**, storage in LOHC and transport via ship to the **Netherlands**. Distribution to off-takers in the region with possible extension along the Rhine river to **Germany**

12 tpd **storage plant** and **release plant** as first development step

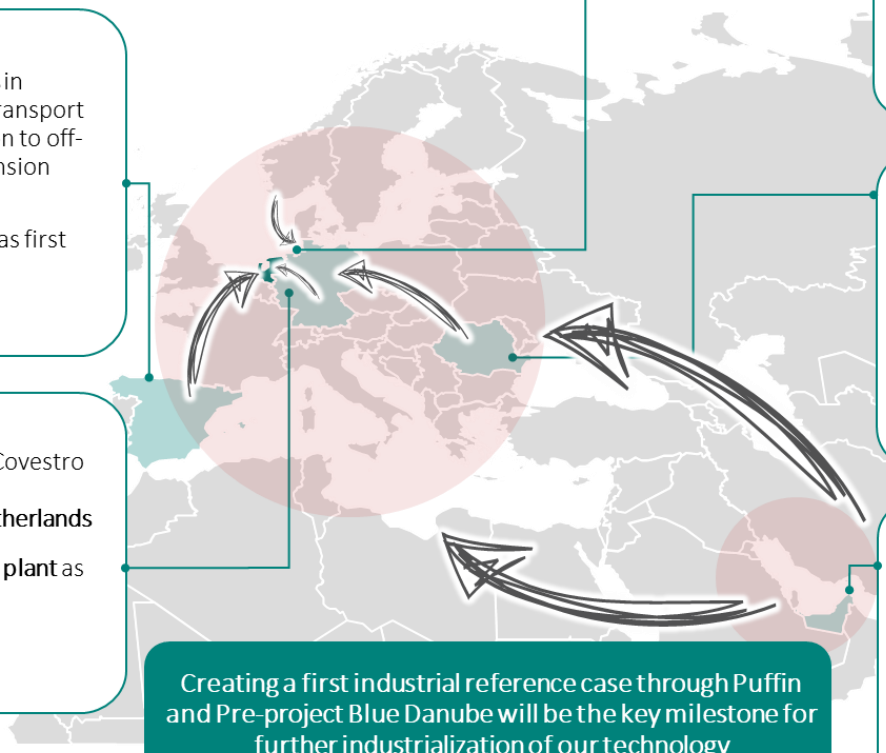
enagas Vopak Naturgy

Hector/Puffin

Storage of **by-product hydrogen** from Covestro site in Western **Germany** in LOHC and transport via truck to Vopak in the **Netherlands**

5 tpd storage plant and **1.5 tpd release plant** as first development step

covestro



AquaVentus (AquaPortus)

Hydrogen production from offshore wind energy located in the North Sea

Storage plant located at Helgoland and release plant in the port of Hamburg

AquaVentus

Green Hydrogen @ Blue Danube (IPCEI)

Hydrogen production from renewables in **Romania**, storage in LOHC and transport via ship to off-takers in **Austria** and **Germany**

Blue Danube demonstrator in first development step. **Several storage plants** in initial stage, **and release plants**

Verbund

Green H2 from Middle East

Cooperation with ESCO in **UAE** to develop **green hydrogen export business**

Large-scale storage plants

ESCO

Creating a first industrial reference case through Puffin and Pre-project Blue Danube will be the key milestone for further industrialization of our technology

Project description | Capacity | Key partner(s)

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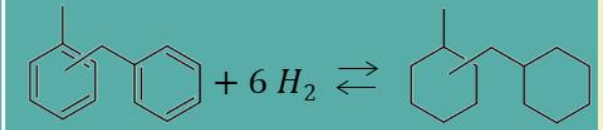
We enable a safe and efficient green hydrogen economy

… and our LOHC offers the best combination in terms of handling and safety without major weaknesses

	Storage Density	Safety	Storage	Emissions
LOHC	~1 m³ (57 kg_{H2}/m^3_{LOHC}) 	Just system area affected by accident 	Integrated in existing conventional fuel infrastructure (at ambient conditions) without H_2 loss 	Release of H2 without direct CO_2-emissions 
VS	VS	VS	VS	
Other H_2 technologies	CGH2[1]  Volume factor[2]: ~12x Weight factor: ~10x	Ammonia  In case of accident large areas have to be evacuated because of acid vapours (esp. in urban setting)	LH2  New, expensive infrastructure due to extreme conditions (-253 °C) and H_2 boil-off losses (1-3 %/day)[3]	Methanol $2\ CH_3OH + 3\ O_2 \rightarrow 4\ H_2 + CO_2$ H2 release with direct CO_2-emission

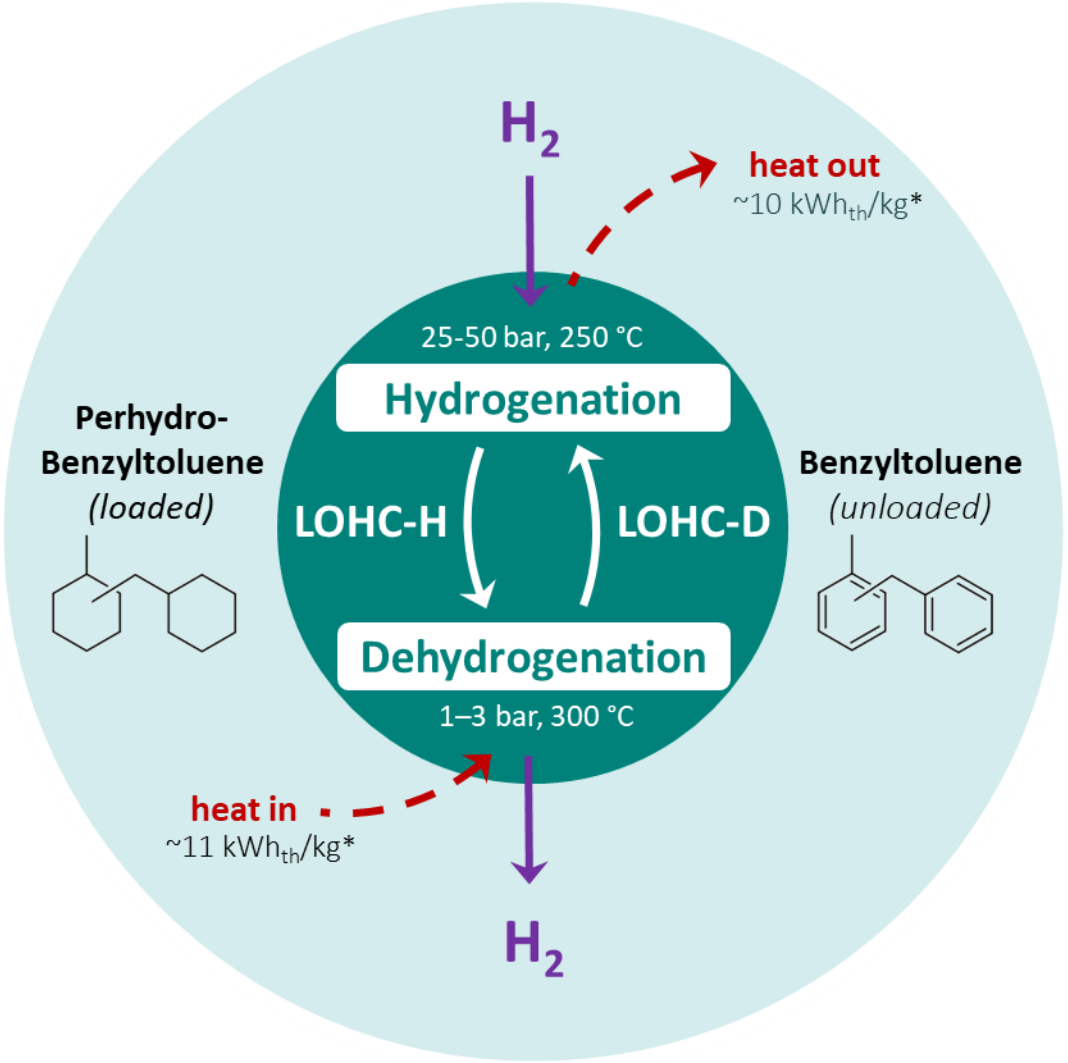
The LOHC technology offers significant advantages in all decisive characteristic parameter and is therefore the "game changer" towards a hydrogen society

1) Compressed gas @200 bar, density 15kg/m³ 2) Technical volume of containers 3) Even higher at each tank-to-tank transfer

Chemical conversion process of the LOHC technology

(Perhydro-)Benzyltoluene

- Non-explosive
- Diesel-like liquid
- Hardly flammable
- Pour point < -30 °C
- Stored at ambient conditions
- 54 kg_{H2}/m^3_{LOHC} and 62 kg_{H2}/t_{LOHC}
- Commercial available product



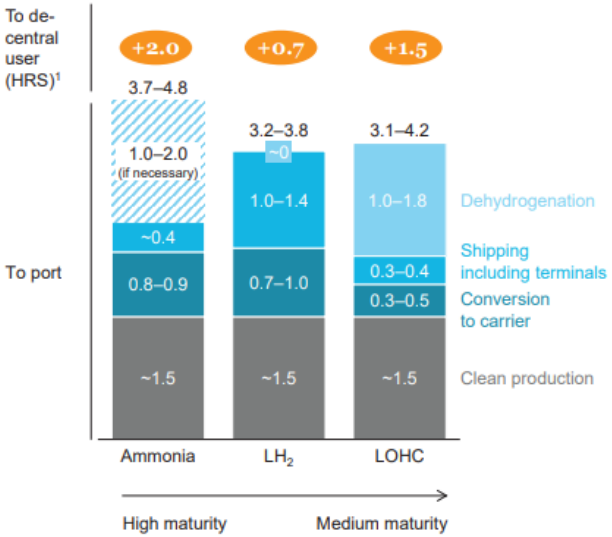
LOHC competitive with other hydrogen carriers (e.g. ammonia and liquid hydrogen) …

Exhibit 15: Landed costs at port of renewable H2 shipped from Saudi Arabia to Europe

Cost for at scale production and shipping transportation in 2030

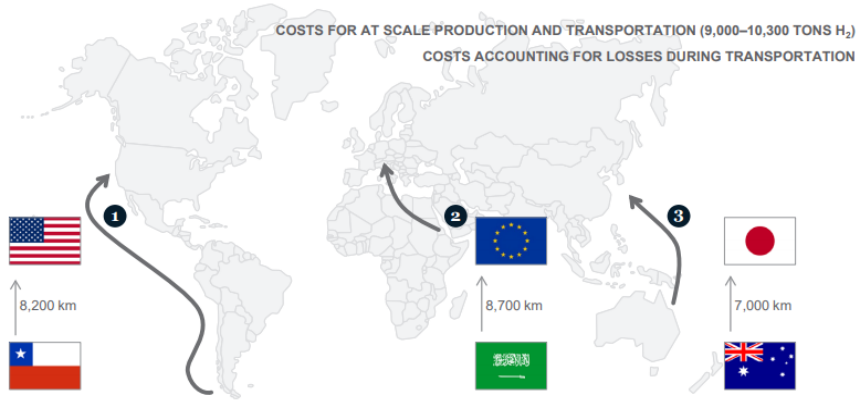
Shipping route from Saudia Arabia to Europe through Suez Canal, 8,700km

Costs, USD/kg H_2

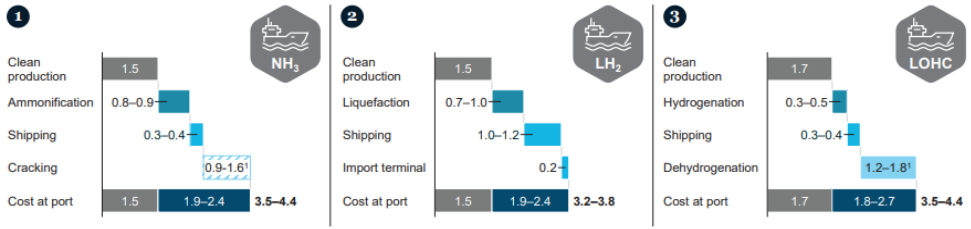


1. Assumes liquid (for LH_2) or gaseous (for ammonia, LOHC) distribution with truck for 300km, also includes: purification to FCEV standard using a PSA for LOHC and NH_3, boil-off losses for LH_2, storage costs at port and HRS operating costs

Exhibit 16: Landed costs of hydrogen at port for selected global transport routes



Illustrative routes modeled, USD/kg H_2



1. Dependent on whether hydrogen feedstock or heat from grid is used for dehydrogenation heating requirement

[9] While BT includes toluene, it is does not fall under toxicity regulations given the limited toluene content per ton of BT.