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***Hydrogen stored as an oil!***

Connecting Powerfuel Hubs 2021 - Hubs for powerfuel transport and distribution

June 2021

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Weidenweg 13
91058 Erlangen

# Hydrogenious LOHC Technologies GmbH

Global technology leader for Liquid Organic Hydrogen Carrier

**Vision**

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

**Mission**

Hydrogenious LOHC and its partners are fully committed to establish the hydrogen based energy world of tomorrow

>110 Employees

>31 Patent families filed - growing number

10 Operating Systems

2016 First system delivered

€ >30m Total funding raised

**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**

FAU

MAN Energy Solutions

CLARIANT

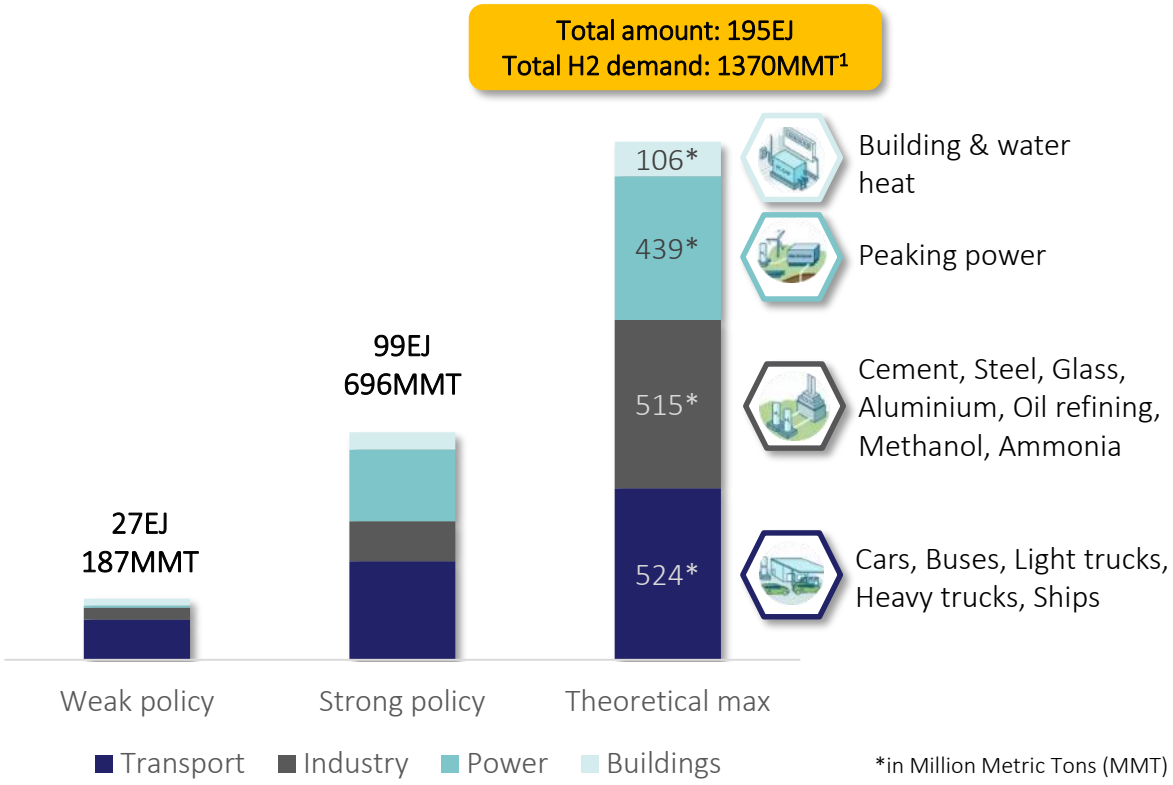
HI ERN Helmholtz Institute Erlangen-Nürnberg

EASTMAN

ARKEMA INNOVATIVE CHEMISTRY

# Decarbonise the world: Hydrogen demand will increase dramatically

## Potential global demand for hydrogen by 2050




## Prognosis of hydrogen imports for Germany by 2050


**Europe: Large scale hydrogen import will be mandatory due to limited national H2 production capacities**

1) BloombergNEF, 2020

2) Juelich Institute, M.Robinius et al. „Wege für die Energiewende“, 2019

# Global $H_2$ value chain and transport options needed due to cost differences in $H_2$ production – LOHC as the "Missing link"

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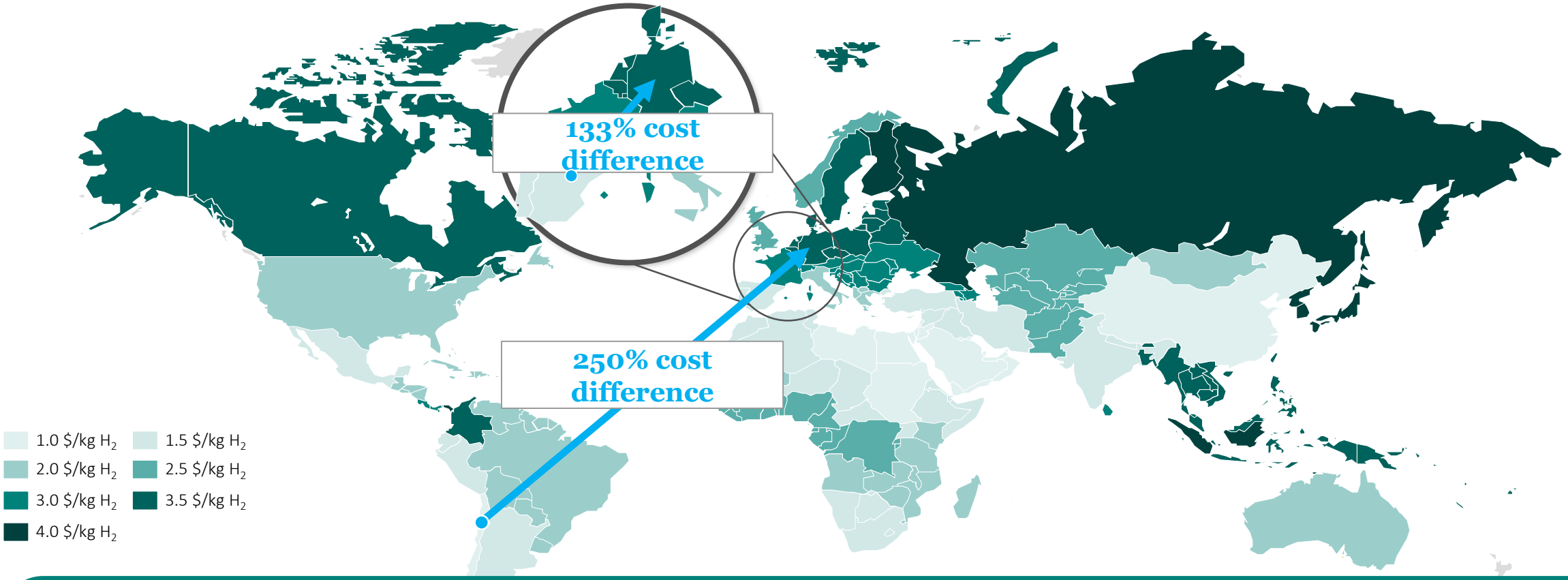
Significant hydrogen production cost delta[1]




Cost differences in future hydrogen production will define sourcing strategies and global distribution
Efficient, safe and flexible handling of $H_2$ to connect supply and demand across the globe

1) Source: IEA 2019, The future of hydrogen and *IEA 2019, Hydrogen: A renewable energy prospective (value PV costs 2050)

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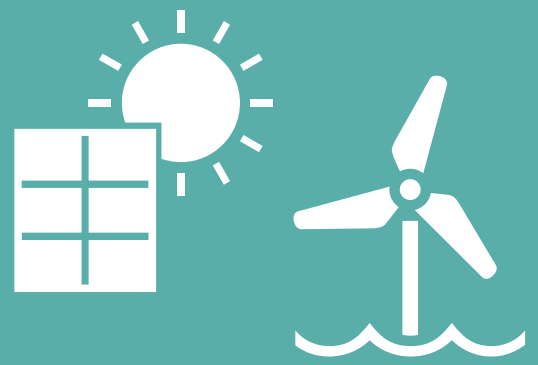
# Hydrogen as the "Missing link" for large-scale renewable energy imports

Disconnected supply and demand centers

Abundance in remote geographies



Missing link

?

Constraints in populated geographies

RES Energy Supply

RES Energy Demand

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

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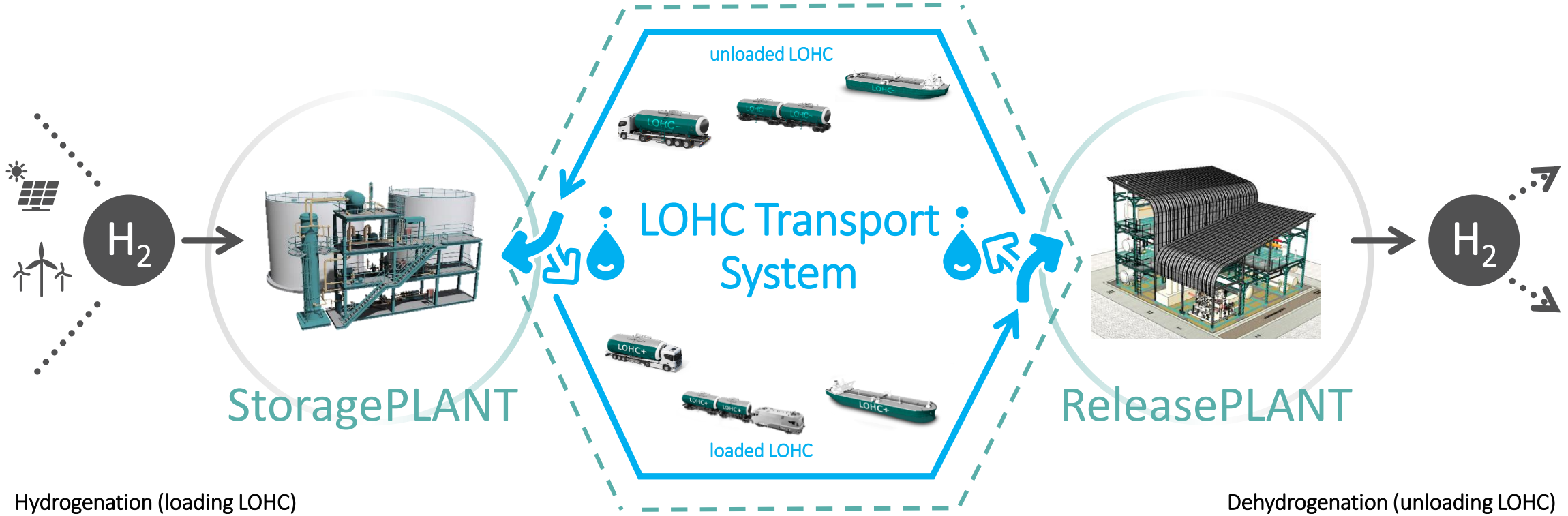
## Hydrogen storage system

## Hydrogen release system




Hydrogenation (loading LOHC)
*Exothermic (~ 250°C, 25 – 50 bar)*

Dehydrogenation (unloading LOHC)
*Endothermic (~ 300°C, 1 – 3 bar)*

**Safe:**
Hardly flammable liquid

**Efficient:**
High energy density

**Flexible:**
Use of existing infrastructure

# 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

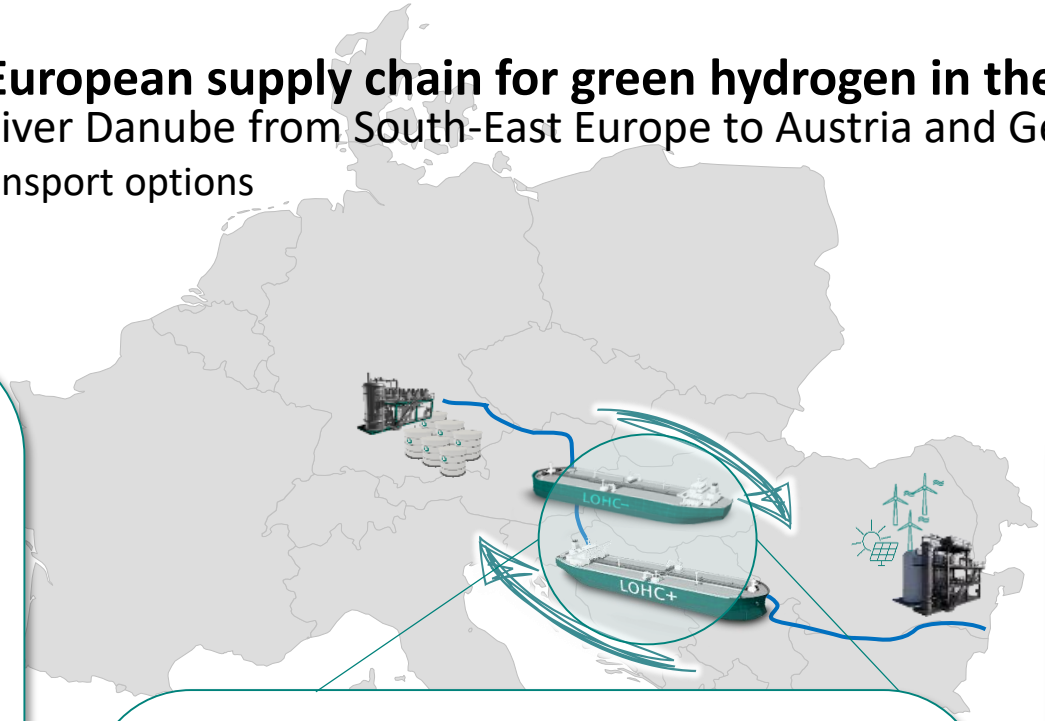
Project description | Capacity | Key partner(s)

Source: Hydrogenious

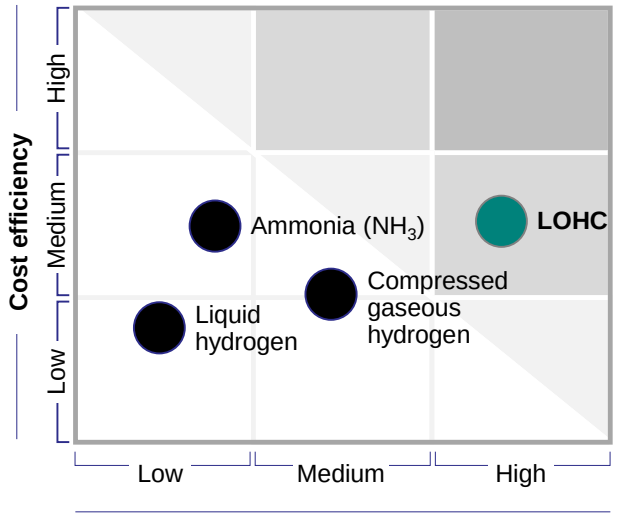
# Project Blue Danube: A pan-European supply chain for green hydrogen in the Danube region

## Hydrogen-LOHC distribution via river Danube from South-East Europe to Austria and Germany

Assessment of different hydrogen transport options




### Conditioning*




(incl. safety/permitting, technology readiness, etc.)

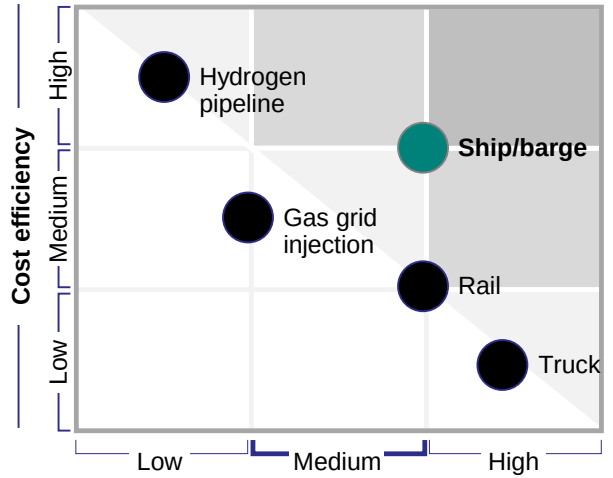
### Advantages of H2 transport in LOHC river ships

- Transport in existing infrastructure
- Usage of existing transport routes
- Large inland transport capacity
- Safe transport

**Convoy on river Danube: 1 push-boat and 2 barges**

**186.000 $kg_{H2}$**

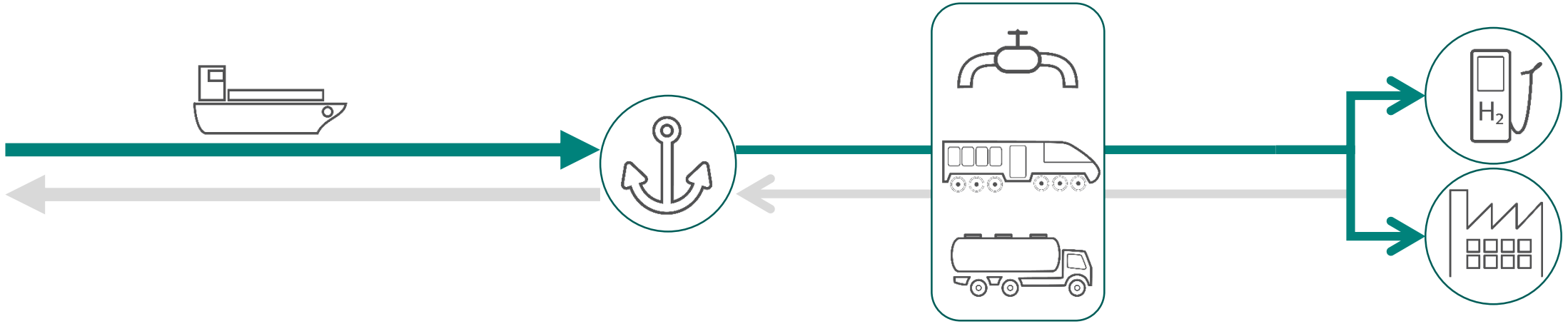
### Transport mode/infrastructure*




(incl. permitting, technology readiness, regulatory readiness, etc.)

*Source: Roland Berger

# Harbors will play a central role in future hydrogen supply chain – Focusing on local industry and distribution




## Import

- >50-100% Import of (green) H2 demand
- Low cost (green) H2 production does not regionally overlap with H2 demand
- Import by ship due to long distances

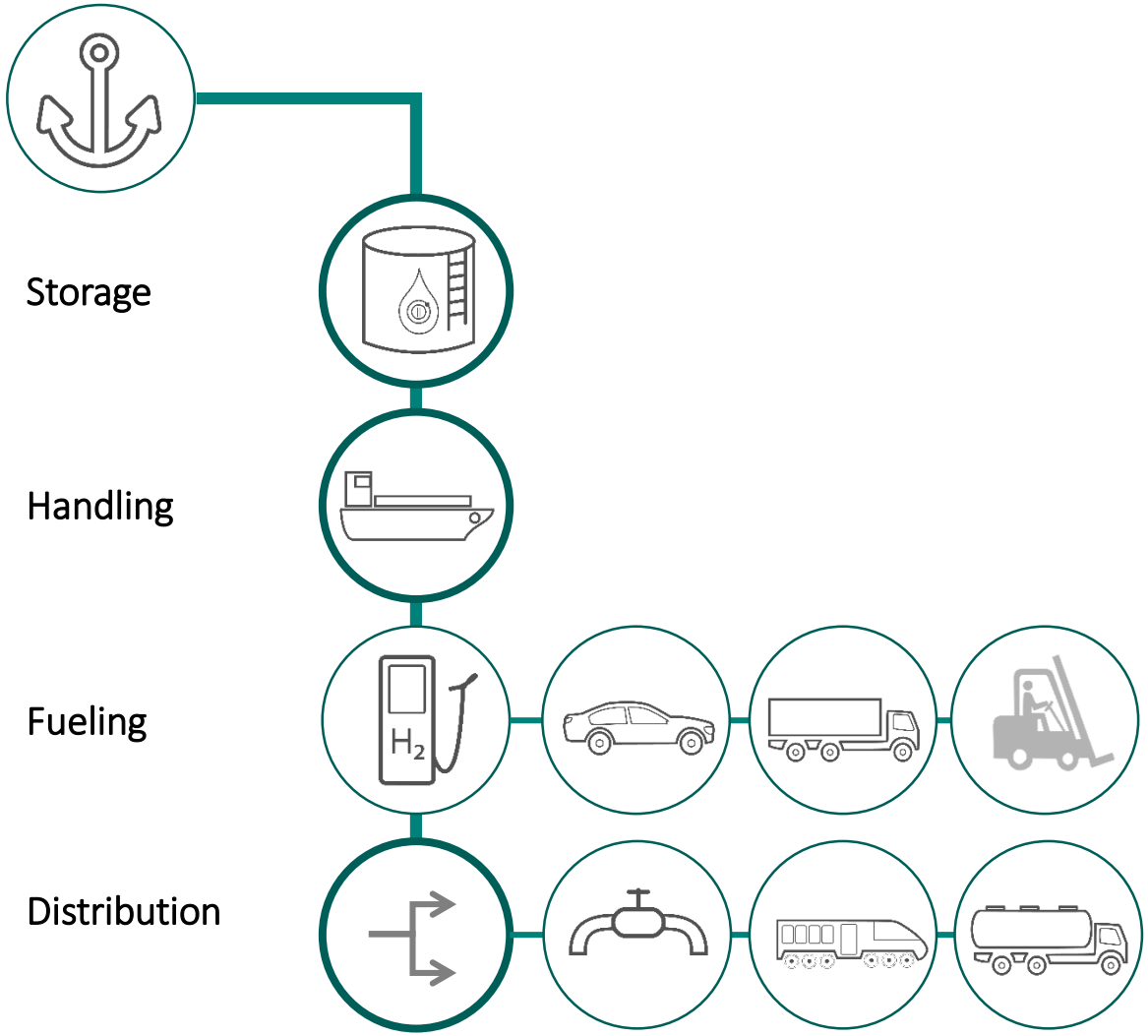
## Role of Harbors

- Hub function for large scale (green) H2 import
- Industrial cluster for industry with high (green) H2 demand
- Decarbonization of local activities (material handling, energy demand, etc.)

## Distribution

- Only minor H2 demand at harbors - H2 must be distributed to demand centers
- Access to infrastructure for transport will be essential for harbors

# Habors will face significant investments in infrastructure to become a hydrogen hub and to decarbonize based on hydrogen




Hydrogenious LOHC technology reduces necessary investments in ports and can increase safety of handling and storage

hydrogenious
LOHC TECHNOLOGIES

# We enable a safe and efficient hydrogen economy!

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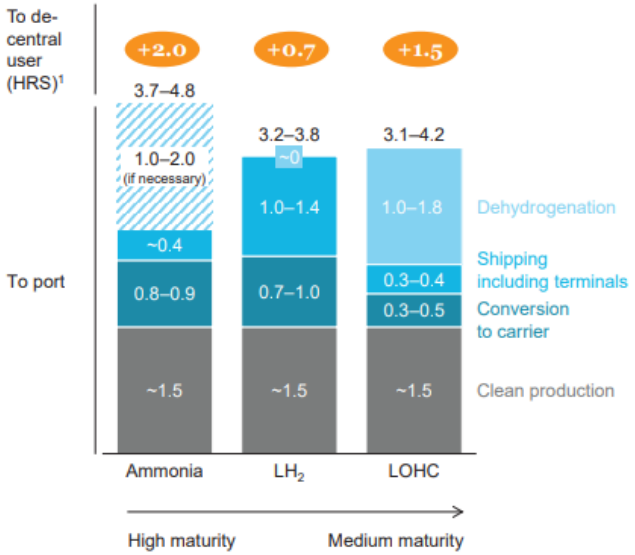
# LOHC competitive with ammonia and liquid hydrogen

## 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

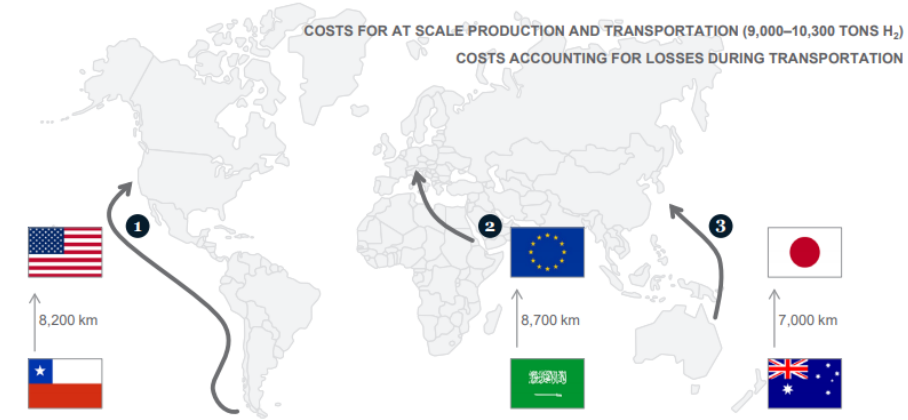
**Shipping route from Saudia Arabia to Europe through Suez Canal,** 8,700km


**Costs,** USD/kg $H_2$

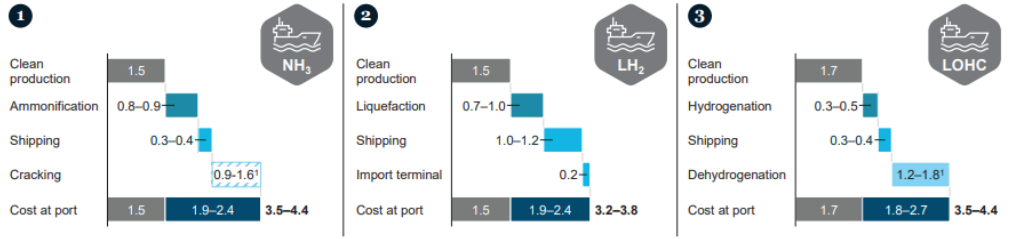



1. Assumes liquid (for $LH_2$) or gaseous (for ammonia, LOHC) distribution with truck for 300km, also includes: purification to FCEV standard using a PSA for LOHC and $NH_3$, boil-off losses for $LH_2$, storage costs at port and HRS operating costs

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



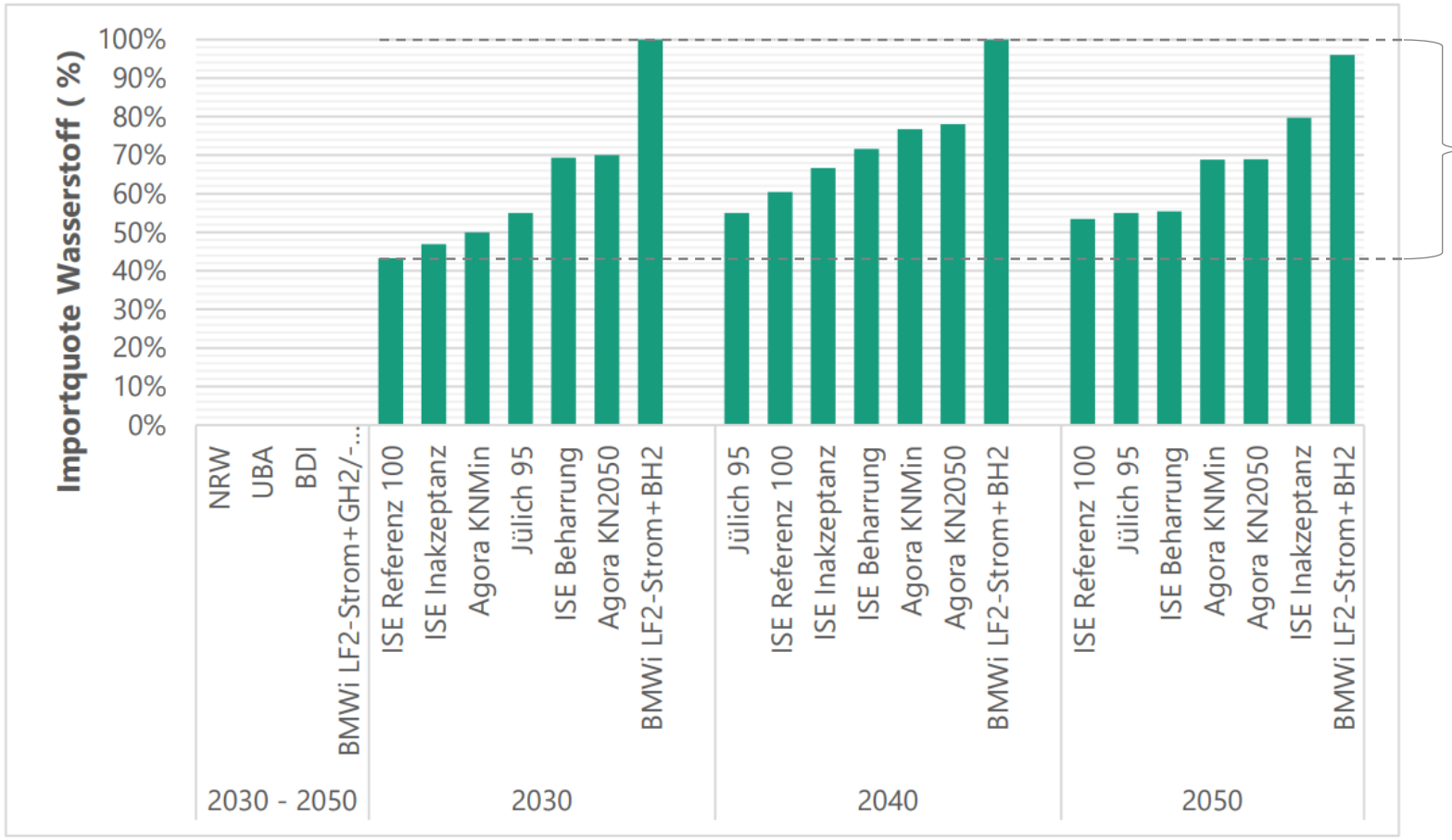

**Illustrative routes modeled,** USD/kg $H_2$




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.

# Meta-Study H2 Import Demand by Fraunhofer ISI 2021-06 Germany




~45-100% H2 Import Demand