hydrogenious LOHC TECHNOLOGIES

Hydrogen stored as an oil!

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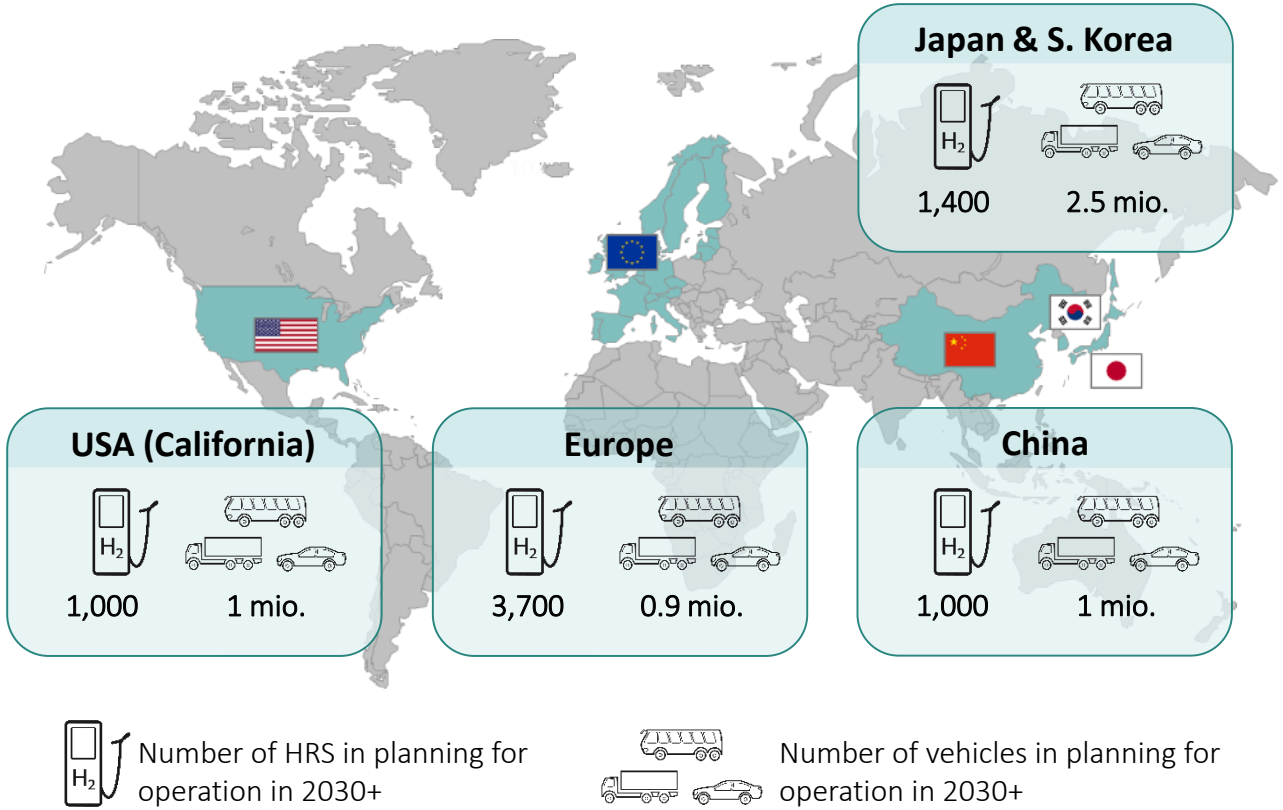
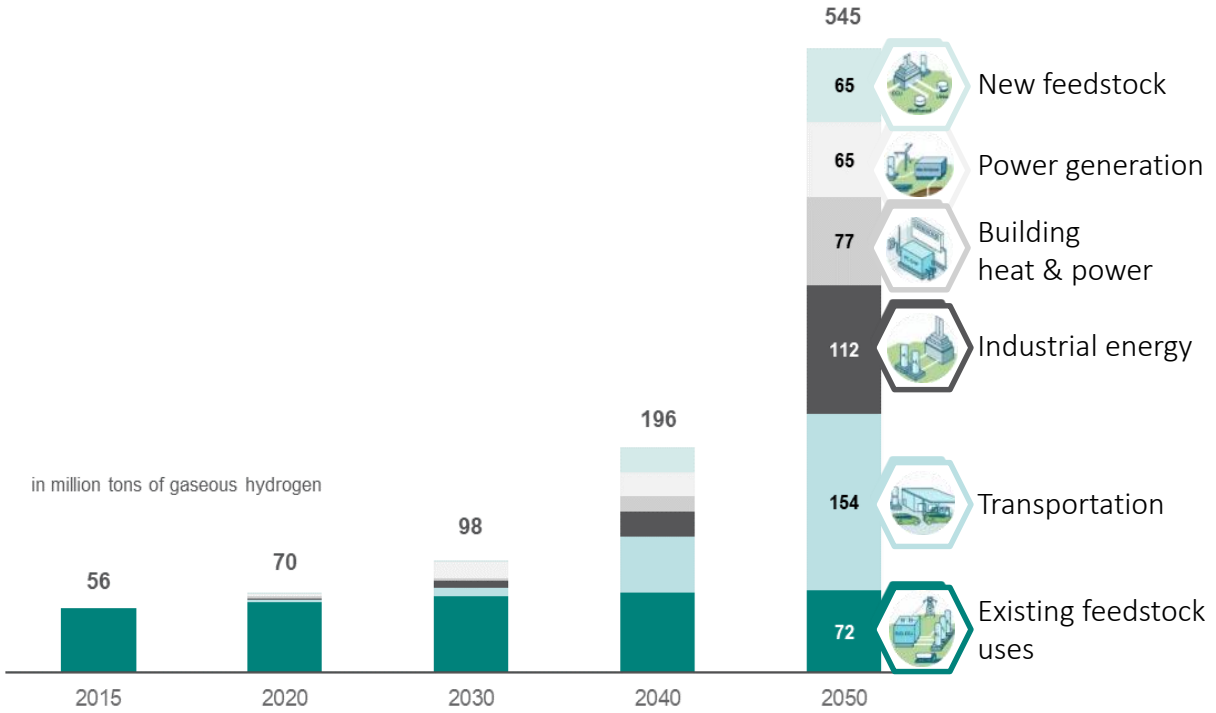
With hydrogen becoming a fuel, global volumes will increase significantly taking hydrogen from a regional industrial gas to a globally traded commodity



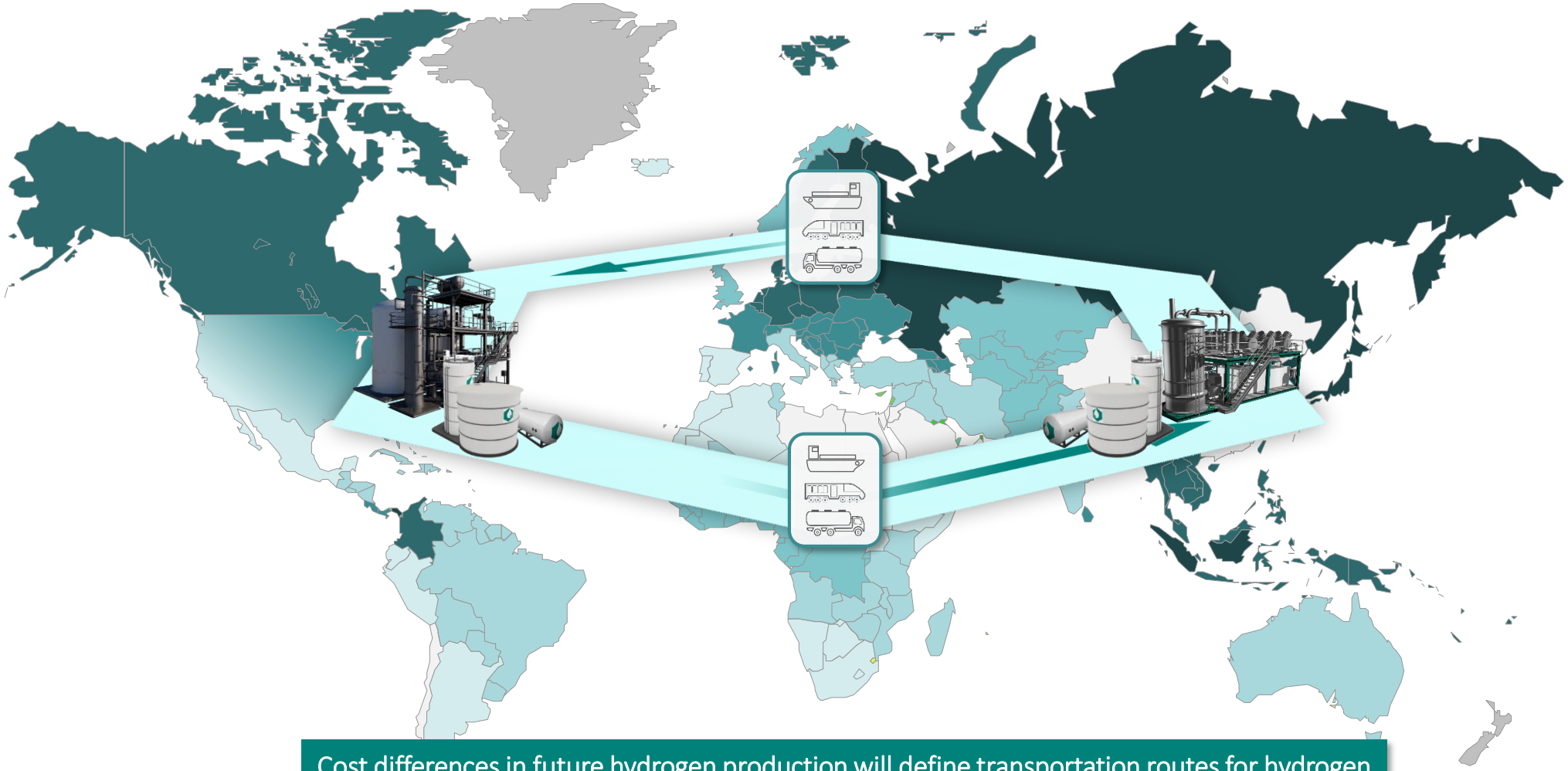
Number of HRS in planning for operation in 2030+

Number of vehicles in planning for operation in 2030+



Global hydrogen demand forecast (Source: Hydrogen Council)

Differences in hydrogen production cost will transfer hydrogen to a globally traded commodity - creating demand for intercontinental large scale transport of hydrogen…



1.0 $/kgH2*
1.5 $/kgH2
2.0 $/kgH2
2.5 $/kgH2
3.0 $/kgH2
3.5 $/kgH2
4.0 $/kgH2

Cost differences in future hydrogen production will define transportation routes for hydrogen transport and create natural demand for large scale and long distance hydrogen transport.

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

…but existing transport technologies are not suited for large-scale international transport and thus the transition of hydrogen to a fuel

	Compressed Gas CGH_2	Cryogenic (Liquid) LH_2
		
Transport Condition / State	**250 – 500 bar**	**-253°C**
Hydrogen (H_2) / truck	**up to 350kg / up to 1,100kg**	**up to 3,300kg**
Hazardous Material		
Boil-Off	**0%**	**1 - 3%**
Energy required / kg H_2 (excl. transport)	**2 – 6 kWh** *(electric)*	**7 – 10 kWh** *(electric)*
Transport capex per truck / trailer)	**> EUR 0.4m / > EUR 1.0m**	**> EUR 1.4m**

Hydrogenious LOHC Technologies GmbH – a global technology leader for Liquid Organic Hydrogen Carriers

Vision

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

Mission

Hydrogenious LOHC and its partners are committed to deploy their resources to make the hydrogen-fueled society a reality.

- 70 Employees
- >31 Patent families filed
- 10 Systems in field
- 2016 First system delivered
- € 20.5m Last fundraising round

Investors

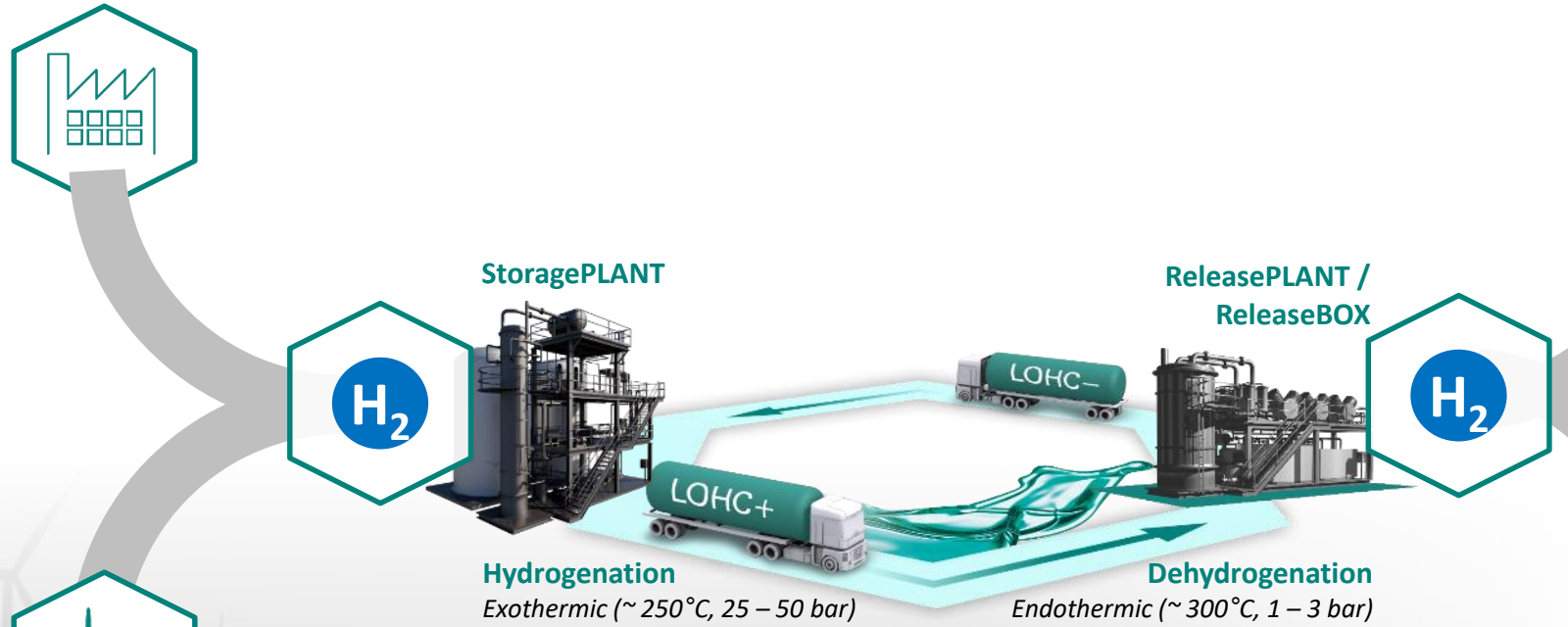
- ANGLO PLATINUM – VC fund of world leading platinum mining company
- APVentures – ADVANCE & PIONEER
- Winkelmann Group – German holding providing solutions for automotive and heat industry
- covestro – World leading provider of polymeric material
- Vopak – World leading oil terminal operator
- Mitsubishi Corporation – The trading division of Mitsubishi group

Key Partners

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

LOHC enable a safe and efficient transport of hydrogen at ambient conditions for industrial, mobility and energy end users…

Industrial Hydrogen Supplier
(e.g. steam methane reforming, etc.)



Industrial Hydrogen Consumer
(e.g. fuels, chemicals, fertilizers, metal refining, food, etc.)

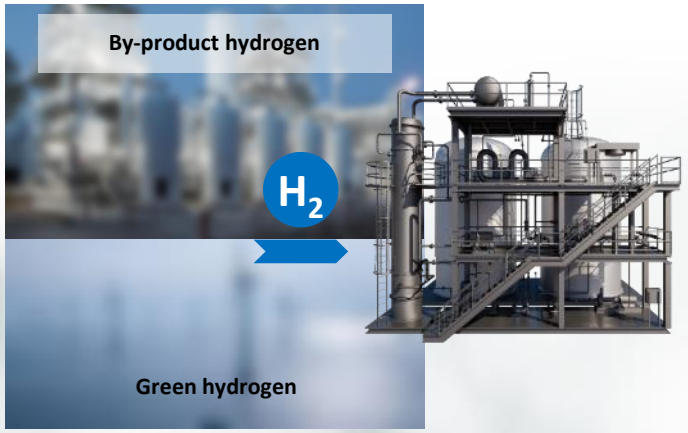
Energy
(e.g. on-grid, off-grid)

Mobility
(e.g. cars, buses trucks, trains, ships, etc.)

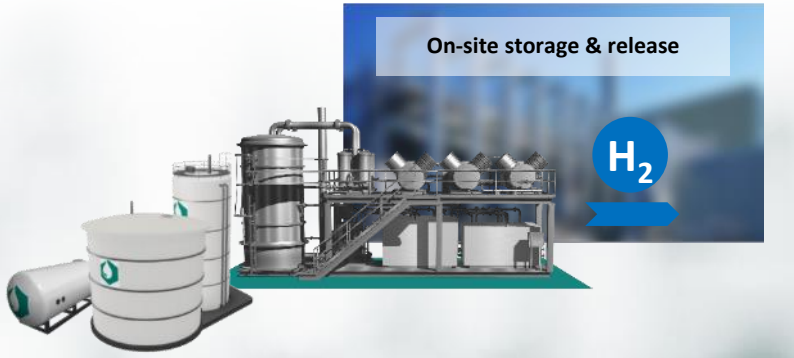
Renewable Energies
(e.g. via electrolysis)

… leading to benefits for both: the supplier as well as the hydrogen consumer

Hydrogen Source



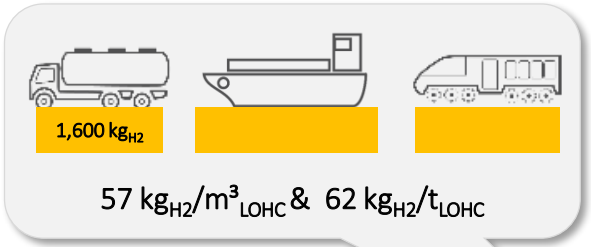
Industrial Hydrogen Consumer / HRS

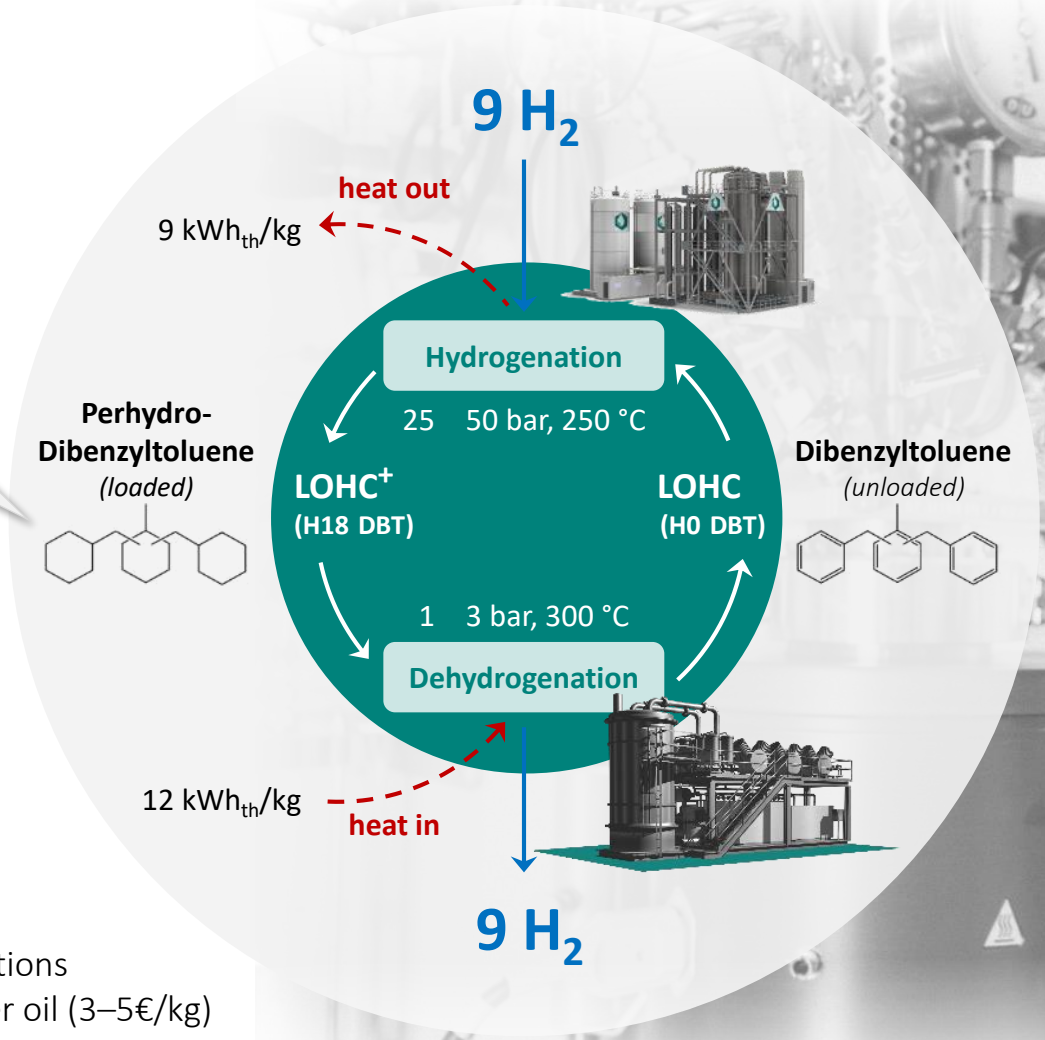


Hydrogenious LOHC' Value Add

- >20% lower TCO for large-scale settings
- Increased modes of transport – road, train, ship
- Lower prices from supplier possible
- Increased on-site safety
- Enhanced flexibility and back-up buffer storage
- No ADR qualification required for drivers
- Easy increase of on-site storage capacity possible
- Small footprint due to reduced safety zones and high storage density

Technology deep-dive: The LOHC technology is based on a reversible hydrogenation / dehydrogenation process





Perhydro-Dibenzyltoluene has same characteristics

Dibenzyltoluene

- Non-explosive
- Diesel-like liquid
- Hardly flammable
- Liquid state until -39 °C
- Stored at ambient conditions
- Commercial heat transfer oil (3–5€/kg)

1) One VLCC ship can carry up to 350,000 DWT which would be equivalent to 17,000 tH2

2) One train in Europe can pull up to 35 wagons which would be equivalent to 59 tH2

The StoragePLANT: A product offering for low cost / large scale hydrogen storage in LOHC to enable cost efficient distribution

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	StoragePLANT 5tpd	StoragePLANT 12tpd
Hydrogen capacity[a]	5 t/d // 210 kg_{H2}/h	12 t/d // 500 kg_{H2}/h
LOHC production[a]	4,500 l/h	11,000 l/h
Heat production[a]	1,900 kW_{th}	4,500 kW_{th}
Load range	50 – 100 %	
Footprint	Skid-based	
Inlet hydrogen stream	30 – 50 bar, 99.99 % purity	
Inlet LOHC stream	≥ 0.1 barg, T ≥ 15 °C	
Power connection	400 V AC, 3 phase, 50 Hz	

[a] under nominal load

Engineered and build in cooperation with:

MAN Energy Solutions

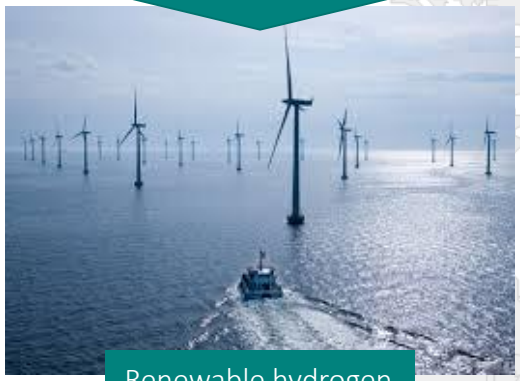
FRAMES

The ReleasePLANT: LOHC release system designed at sweet spot scale

	ReleasePLANT 1.5tpd
Hydrogen outlet[a]	1.5 t/d // 65 kg_{H2}/h
LOHC demand[a]	1,400 l/h
Heat demand[a]	780 kW_{th}
Load range	50 – 100 %
	[a] under nominal load
Footprint	Skid-based
Inlet LOHC stream	≥ 0.1 barg, T ≥ 15 °C
Power connection	400 V AC, 3 phase, 50 Hz

Hydrogenious LOHC' mission is the establishment of a global LOHC infrastructure to enable a hydrogen fuelled society

Sustainable hydrogen sourcing



Renewable hydrogen

- Wind & hydro @ <3 ct./kWh
- >5.000 h/year production

By product hydrogen

- Chlor-alkali electrolysis
- Others

Global hydrogen distribution

1 Ship Transport
International

- Use of existing oil tankers / fuel storage infrastructure
- International trans-ocean transport

2 Rail Transport
(Inter)-national

- Multi-ton transport on existing infrastructure
- Flexibility of rail network

3 Road Transport
National / regional

- High capacity road delivery to distributed customers

Diversified demand sites

1 Pipeline hubs
International

- Green hydrogen from international sources for pipeline distribution

2 Large industry
International

- Large-scale industrial customers with renewable heat demand
- Green hydrogen as base chemical

3 HRS & medium scale industry
Distributed national

- High-capacity HRS
- Hydrogen as base chemical and utility

Hydrogenious LOHC has the first systems in the field since 2016

Fraunhofer IAO (Germany)

- ReleaseBox 33 with autarkic hydrogen heating (hydrogen burner) and 25 kW PEM-fuel cell (output 600V DC)
- Integration into a smart grid
- Delivery date: July 2016

United Hydrogen Systems (USA)

- StorageBox 100 and ReleaseBox 2.5 commissioned at UHG site in Charleston (Tennessee, USA) in Q1 2018
- Daily test operations of ReleaseBox 2.5
- Commercial testing of RB 2.5 at customer site ongoing. Valuable results of continuous operation and interaction with industry process are gained.

Hydrogenious LOHC has gathered a strong consortium for the first European LOHC-based HRS project ‘HySTOC’

Project description

- Design and build-up of StorageBOX 10 and ReleaseBOX 10 delivering hydrogen according to ISO 14 687-2
- 1st step: Performance testing of ReleaseBOX 10 at VTT test facility (energy balances, hydrogen purity)
- 2nd step: Connection of ReleaseBOX 10 to HRS in Woikoski
- Total funding: EUR 2.5m

Key Partners

Grant number: 779694

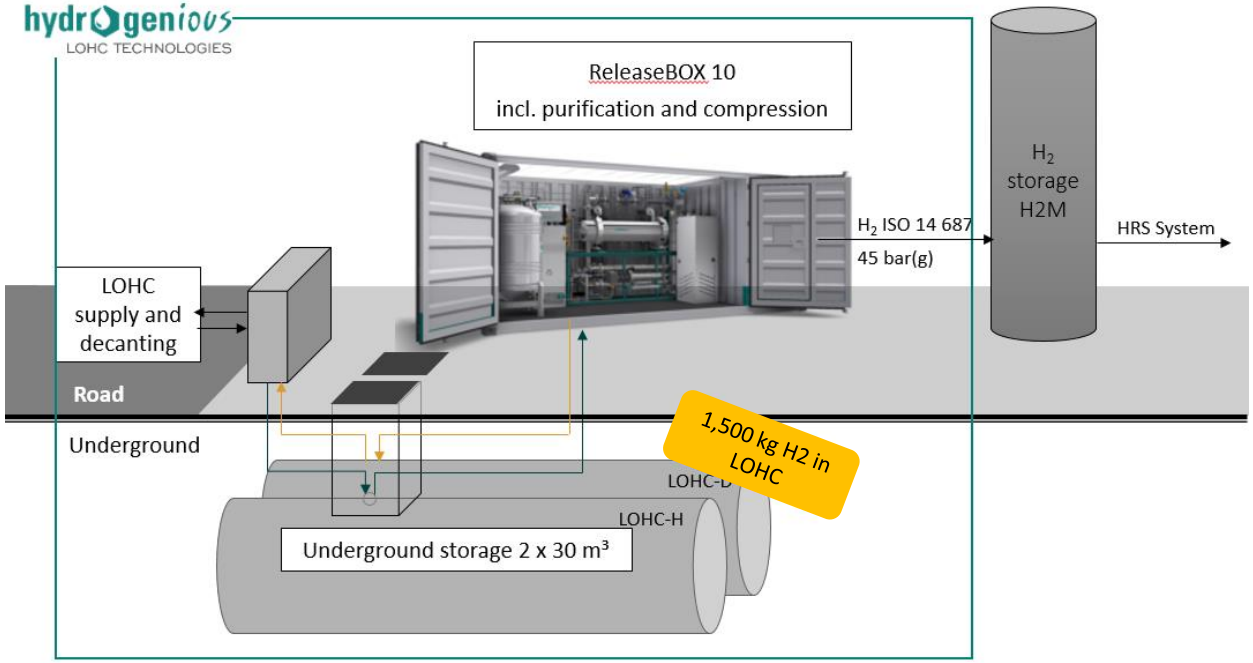
StorageBOX 10
(currently under construction)

ReleaseBOX 10
(currently under construction)

Hydrogenious LOHC will demonstrate large-scale hydrogen storage in LOHC at the H_2Mobility refuelling station in Erlangen in 2020

Project description

- Implementation of first German LOHC HRS in Erlangen
- Worldwide first 1.5 t hydrogen underground storage by LOHC
- Dehydrogenated with ReleaseBOX 10
- Delivering hydrogen according to ISO 14 687-2



Key Partners

H_2 MOBILITY WASSERSTOFF TANKEN

SIEMENS Ingenuity for life

Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie nip

Hydrogenious LOHC successfully placed LOHC in the Federal Program: “Real-World Laboratories”

Project description

- Hydrogenious LOHC connects a “Green H_2” production (PEM electrolysis) in Kaisersesch and a HRS in Essen
- For the project Hydrogenious LOHC will deliver Storage- and ReleaseBOX
- Sector coupling excess heat (PtG, StorageBOX) goes to heat grid of the city Kaisersesch
- Sector coupling: ReleaseBOX will provide hydrogen for public transport bus fleet

Reallabore
Testräume für Innovation und Regulierung

H2 production with economic green electricity

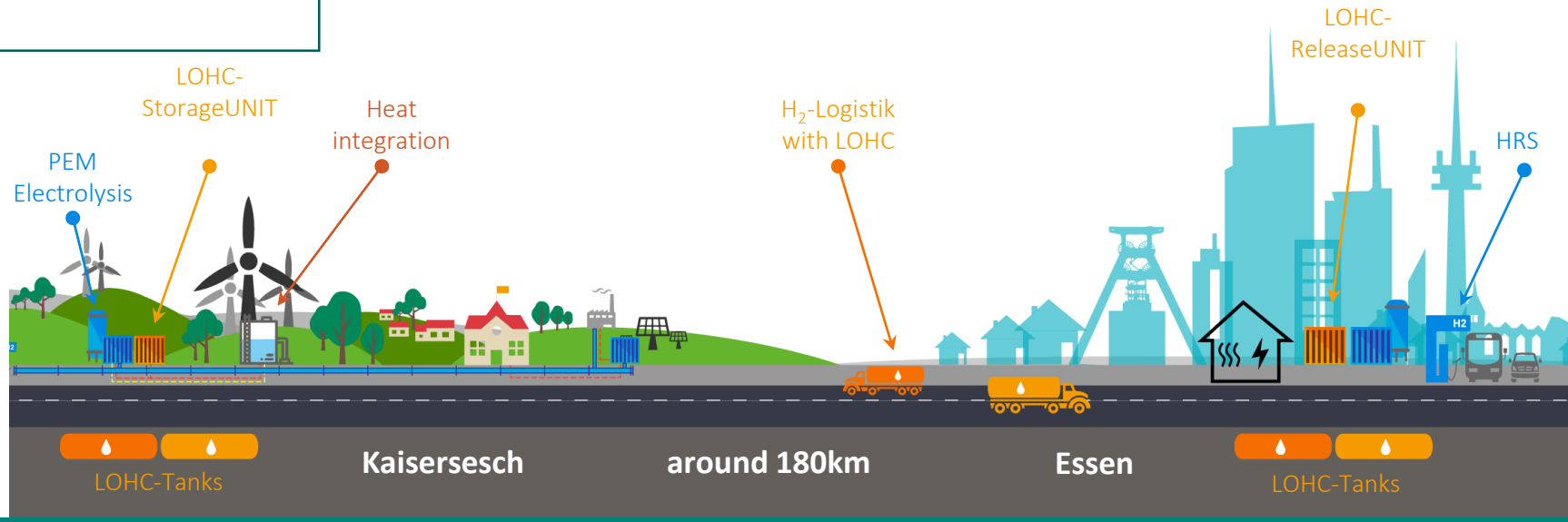
250 kg_{H2} / Day

High H2 transport capacity by truck

1,500 kg_{H2} / Truck

Key Partners

innogy · RWTH AACHEN UNIVERSITY · ESSEN · OFB Projektentwicklung · VIESMANN



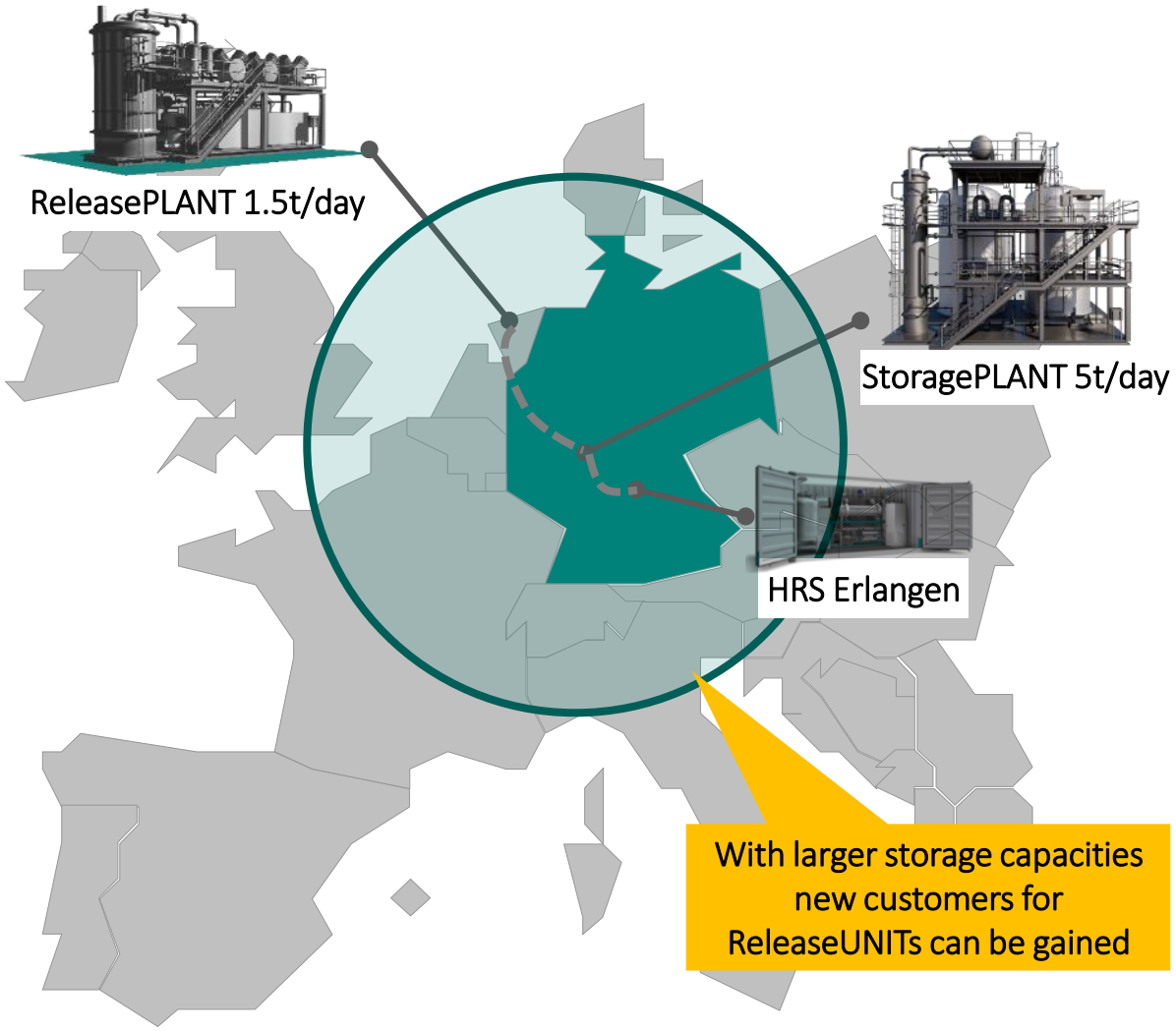
First target sized systems planned to implement first European LOHC network and to prove scale and economics

Project description

- Implementation of first LOHC network with CO2 neutral hydrogen
- Prove of technology and economics of large scale LOHC units and transportation
- StoragePLANT has higher capacity – acquisition of further customers planned
- Expansion with ship and rail transport planned

Key Partners

to be announced as part of market communication



Blue Danube: Hydrogen shipped with river ships from Romania and Bulgaria upwards the river Danube

Project description

- Offgrid green hydrogen production in Romania and Bulgaria with final development of 2 GW
- Transport via river Danube with LOHC and e-fuels
- Delivery to offtakers along the river with high hydrogen demand
- Danube Commission explicitly excluded the transport of LH2 and NH3

Key Partners

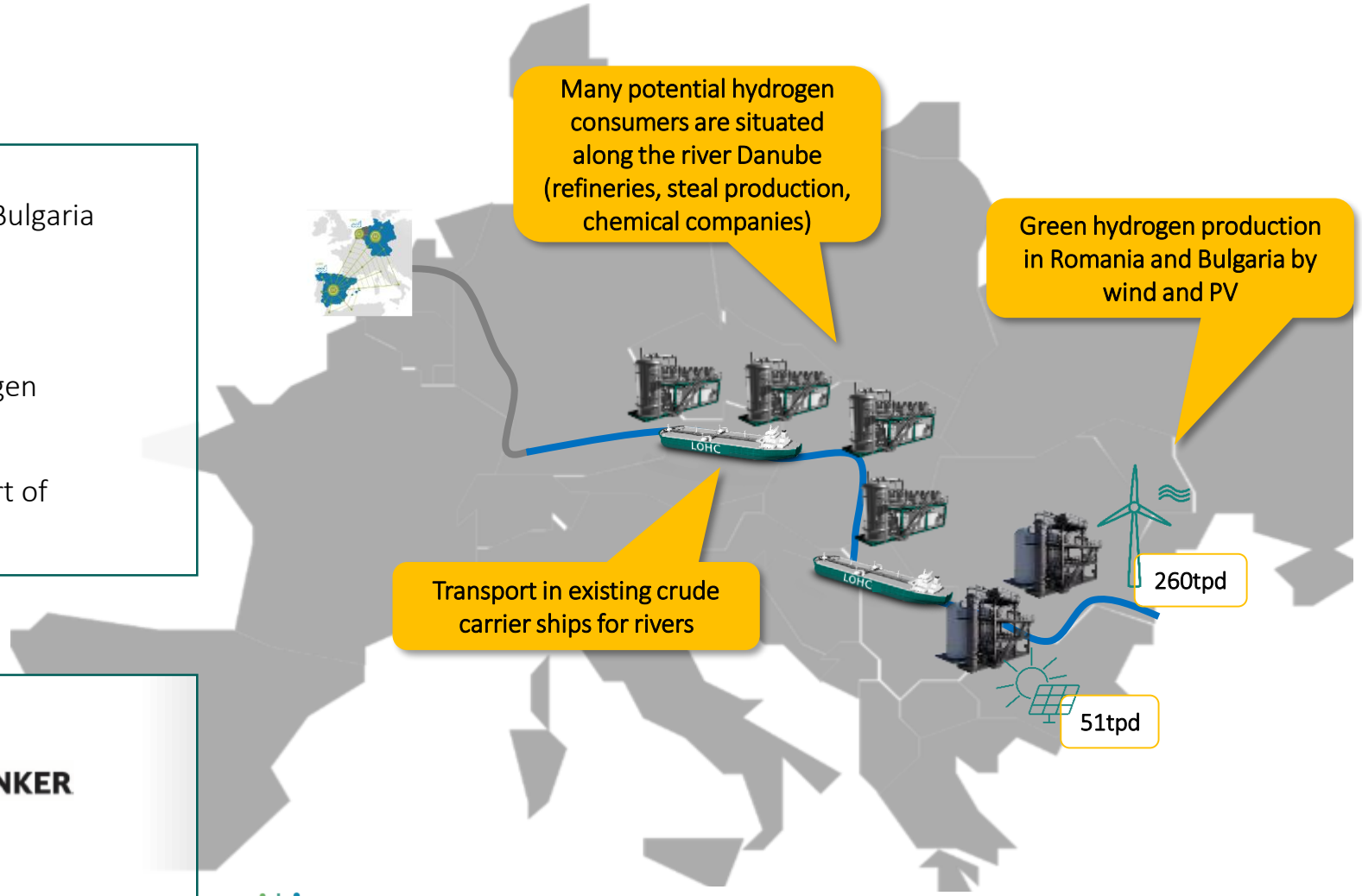
Verbund

DB SCHENKER

elringklinger

SIEMENS Ingenuity for life

ÖBB



1,800 MW electrolysis for **hydrogen production**

2,000 MW off-grid wind and solar **energy production**

40 hydrogen **transport barges**

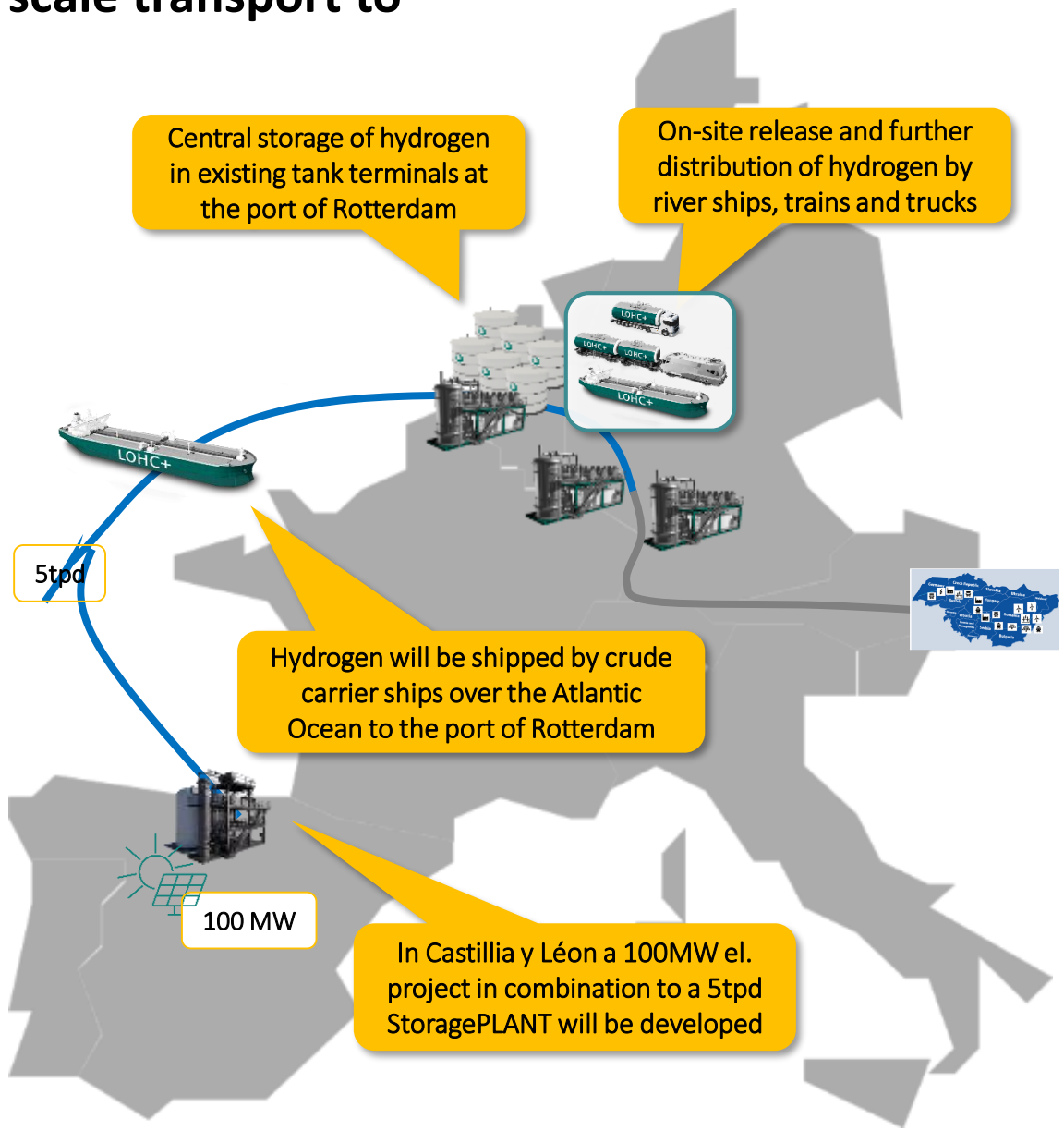
80,000 tonnes of hydrogen for **industry, power + mobility hubs (500 trucks / 100 HRS) along the Danube**

Green Spider: Hydrogen production in Spain and large scale transport to Rotterdam by ship over the Atlantic ocean

Project description

- Central hydrogen production with 100 MW PV electrolysis in the region of Castillia y Léon supported by grid access
- Central 5tpd StoragePLANT as first development step
- Shipment to the port of Rotterdam
- Distribution to offtakers in the port and in the region
- Further transportation along the river Rhine in discussion

Key Partners



With Dragon: Fully integrated supply of electricity and heat by using LOHC as long time storage combined with solid oxide electrolysis and fuel-cells

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In search for project leader

Project description

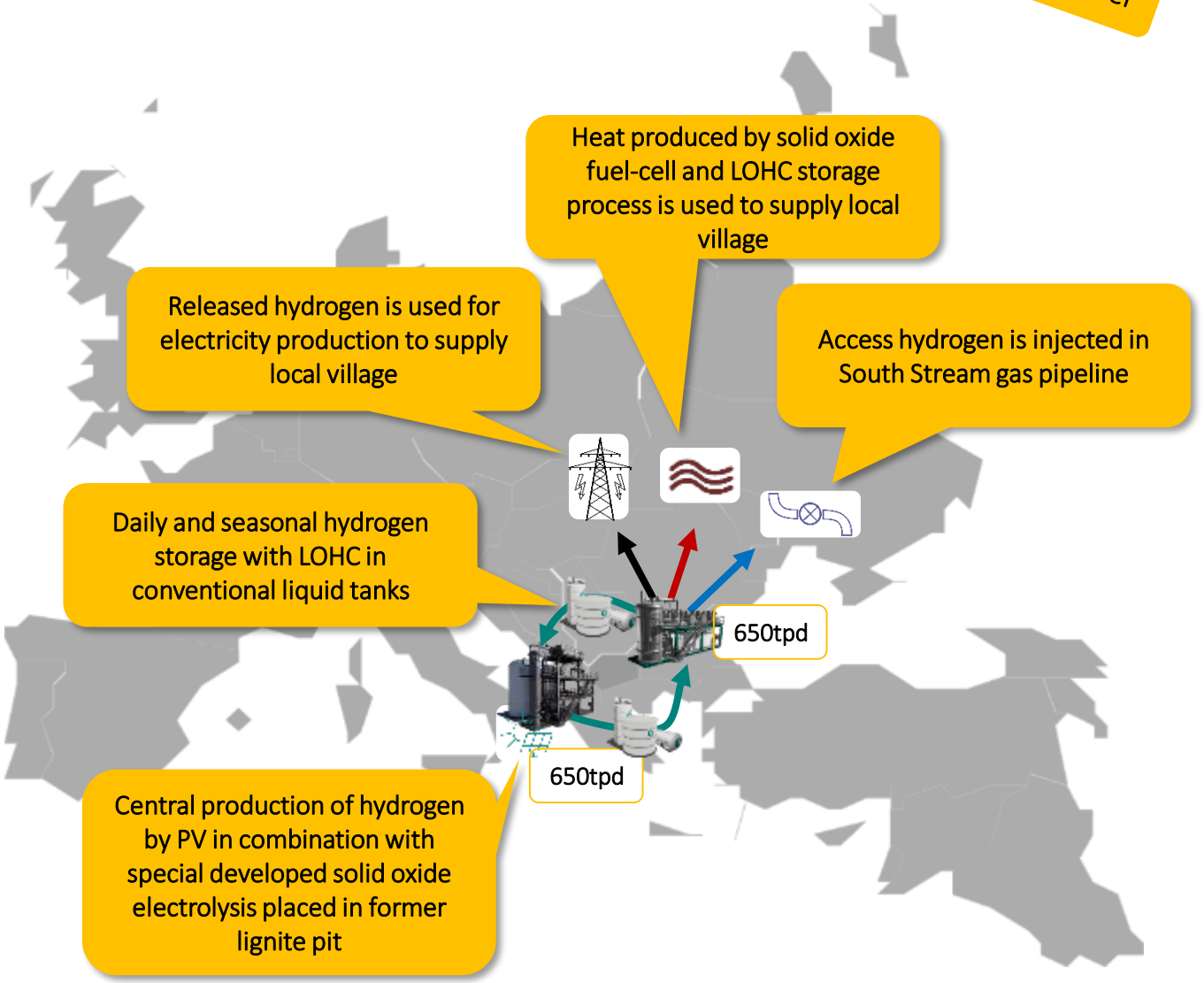
- Local hydrogen production in old lignite plant by pv in Noth Macedonia
- Supply of local cities with electricity and heat
- LOHC for long term storage
- Sophisticated heat integration of solid oxide FC and EC with LOHC process will provide high efficiency

Key Partners

SOLID POWER

Public Power Corporation S.A.- Hellas
Energy for everyone

Hellenic Republic
Region of Western Macedonia



We make hydrogen handling easy!

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