Hydrogen – stored as an oil

Erlangen, January 2018
Hydrogenious Technologies

LOHC Technology

Applications

Products & Projects
Hydrogenious Technologies GmbH – a pioneer in chemical hydrogen storage

• Founded in 2013 by Dr. Daniel Teichmann and Profs. Arlt, Schlücker and Wasserscheid; staff of 45; 25 patent families filed

• Global technology leader for Liquid Organic Hydrogen Carriers (LOHC) – the revolution in hydrogen storage and transport

• Focus on commercialization of hydrogen storage and release systems for industrial and mobile applications

Our systems (details in next chapter)

StorageBOX

hydrogen stored as an oil!

ReleaseBOX

H₂ in

hydrogen

H₂ out

Key Partners:
Hydrogenious has secured successful partnerships in commercialization and development of LOHC systems

Hydrogenious has closed the first commercial projects, ...

- Partnership with United Hydrogen Group
- Realization of first commercial applications in USA
- System delivery in Q3 2017

... commenced development of industrial-scale storage systems, ...

- Partnership with MAN Diesel&Turbo SE
- Development of industrial-scale LOHC hydrogenation reactors for central storage
- First system engineering to be finalized in 2017

... and continues in-house development of release systems.

- Supported by EUR 2.3 Mio. SME Instrument funding under Horizon 2020
- In-house build-up and operations of test systems
- Focus on modularization, standardization and system performance
Hydrogenious has the first LOHC-based hydrogen transport project in operation since June 2016.

**Hydrogenious HQ (Erlangen)**
- 98kWp PV @ Hydrogenious HQ
- Excess heat 10kW
- 50kW Siemens PEM Electrolyzer
- StorageBOX 10

**Fraunhofer IAO (Stuttgart)**
- ReleaseBOX 33
- PEM Fuel Cell
- Electric car filling station

Transport of loaded LOHC
Hydrogenious Technologies’ management team combines scientific and business experience

Total team: 45 FTE

Dr. Daniel Teichmann
CEO & Founder

Dr. Daniel Teichmann
LEONI
Strategy, Technology, Entrepreneurship

Dr. Cornelius von der Heydt
Head of Business Development
Strategy, Finance, Entrepreneurship

Dr. Martin Schneider
Head of Product Management
Project management, Industry

Dr. Berthold Melcher
Head of Engineering & Ops
Industrial projects, Product engineering, Project roll-out

Dr. Caspar Paetz
Head of Product Development
Process design & optimization, Plant development

Dr. Martin Schneider
Areva

Dr. Berthold Melcher
Siemens

Dr. Caspar Paetz
thyssenkrupp

Deutsche Bank
Hydrogenious Technologies

LOHC Technology

Applications

Products & Projects
Liquid Organic Hydrogen Carrier (LOHC) enable a safe and efficient transport of hydrogen at ambient conditions.

Dehydrogenation
- Endothermic – ca. 300°C
- 1 - 3 bara

Hydrogenation
- Exothermic – ca. 250°C
- 25 - 50 bar

Dibenzyltoluene (dehydrogenated)

Perhydro – Dibenzyltoluene (hydrogenated)
Our LOHC technology has significant advantages in performance and handling compared to competing technologies.

**CGH2** vs **LOHC**

- **Efficient**
  - 630 Nm³ H₂ / m³ LOHC → 6.23 wt%
  - 57 kg H₂ / m³ LOHC

- **Safe**
  - Non-explosive
  - Not classified as dangerous good (ADR, etc.)

- **Easy to handle**
  - Diesel-like liquid
  - Ambient conditions

- **Low priced**
  - <5 €/kg
  - Reusable

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Our LOHC is...
Our systems: containerized and easy to install on-site
Hydrogenious Technologies

LOHC Technology

Applications

Products & Projects
The flexibility of hydrogen makes it a key resource in numerous applications and industries...

**Industry**
- Fuels
- Chemicals
- Fertilizer
- Metal refining
- Food

**Mobility**
- buses
- Trucks
- Trains
- Ships
- Cars

**Special applications**
- Spacecraft
- Submarines
- Military

**Energy**
- On-grid
- Off-grid
- Sectoral integration
... which can easily, safely and efficiently be connected by our LOHC technology to enable a sustainable hydrogen world.
The LOHC technology offers clear advantages in safety and transport compared to conventional technologies...

Capex for trucks & trailers
~ EUR 2,000,000

~ EUR 250,000
The LOHC technology offers significant advantages for large scale HRS – e.g. for bus, train or captive fleet supply...

Advantages of LOHC

- Low delivery frequency to HRS
- Lowest cost for H₂ bulk storage
- No boil-off losses / discharge
- Safe handling
- Small footprint through underground storage
- Highest social acceptance through oil handling
Hydrogenious Technologies

LOHC Technology

Applications

Products & Projects
Hydrogenious’ product portfolio: The StorageBOX Series

### Interfaces

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>H\textsubscript{2} inlet pressure</td>
<td>30 bar</td>
</tr>
<tr>
<td>Electr. Connection</td>
<td>400V</td>
</tr>
<tr>
<td>Cooling</td>
<td>10 kWh / kg H\textsubscript{2}</td>
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## Series 100

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>H\textsubscript{2} storage</td>
<td>100 Nm\textsuperscript{3} / h</td>
</tr>
<tr>
<td>LOHC production</td>
<td>160 l / h</td>
</tr>
<tr>
<td>Housing</td>
<td>skid-mounted</td>
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## Series 200

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<tbody>
<tr>
<td>H\textsubscript{2} storage</td>
<td>200 Nm\textsuperscript{3} / h</td>
</tr>
<tr>
<td>LOHC production</td>
<td>320 l / h</td>
</tr>
<tr>
<td>Housing</td>
<td>skid-mounted</td>
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## Series 400

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<tbody>
<tr>
<td>H\textsubscript{2} storage</td>
<td>400 Nm\textsuperscript{3} / h</td>
</tr>
<tr>
<td>LOHC production</td>
<td>640 l / h</td>
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<tr>
<td>Housing</td>
<td>skid-mounted</td>
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Development of industrial scale hydrogenation plants started together with MAN Diesel & Turbo
Hydrogenious’ product portfolio: The ReleaseBOX Series

<table>
<thead>
<tr>
<th>Series 10</th>
<th>Series 33</th>
<th>Series 110</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂ outlet</strong></td>
<td>10 Nm³ / h</td>
<td>33 Nm³ / h</td>
</tr>
<tr>
<td><strong>LOHC throughput</strong></td>
<td>16 l / h</td>
<td>53 l / h</td>
</tr>
<tr>
<td><strong>Housing</strong></td>
<td>20’ container</td>
<td>20’ container</td>
</tr>
</tbody>
</table>

**Interfaces**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>H₂ purity</strong></td>
<td>up to 99.999%</td>
</tr>
<tr>
<td><strong>H₂ outlet pressure</strong></td>
<td>up to 10 bar</td>
</tr>
<tr>
<td><strong>Electr. connection</strong></td>
<td>400V</td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td>~10kWh / kg H₂ (Natural gas or electricity)</td>
</tr>
</tbody>
</table>

**Targeted system scale-up:** hydrogen release capacities of up to 1,000 Nm³/h
Commercial project: US market entry started with industrial demo project together with United Hydrogen Group

- Regional U.S. hydrogen distributor with >50 customers (Industry and mobility)

- **Current situation:** Limited distribution radius due to low transport capacities of pressure tube trailer technology

- **Targeted setting:** Expansion of supply radius through use of high-capacity LOHC technology → Win-Win setting for UHG and its customers

- Initial pilot systems contracted by UHG
  - StorageBOX 100 (9.1 kg/h $\text{H}_2$) - Centralized $\text{H}_2$ production
  - ReleaseBOX 33 (3 kg/h $\text{H}_2$) - Industry customers
  - ReleaseBOX 2.5 (0.23 kg/h $\text{H}_2$) - Power Plants

LOHC technology expands current $\text{H}_2$ supply radius from 300 km to approx. 700 km
Strategic cooperation with MAN Diesel&Turbo focusses on product development for merchant hydrogen infrastructure...

MAN Diesel&Turbo is a global technology leader for large scale reactor systems for the chemical and petro-chemical industry.

Cooperation for development of industrial-scale LOHC hydrogenation reactors based on MAN’s proprietary salt bed reactor technology.

Engineering and design of first pilot test reactor targeted for 2017.
The “Kopernikus Projects” form Germany’s largest coordinated research program
   - Funded by the German Ministry of Research
   - > 90 companies and (research) institutes involved
   - Four specific excellence clusters

“Decentral H₂-logistics” project with focus on LOHC based H₂ refueling stations
   - Budget of ~4 Mio. EUR over next three years
   - 12 partners involved including Linde, ThyssenKrupp, Clariant and AREVA
Thank you for your interest!

Head of Business Development & Sales
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