Hydrogen Refuelling Stations –
Construction Experience From Germany

Conference on Hydrogen Safety from Production to Filling Station

Zagreb, Hotel International

H2saar
SAARLÄNDISCHE WASSERSTOFFAGENTUR GMBH

Dr. Bodo Groß
b.gross@h2-saarland.de

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www.h2-saarland.de

Today’s Agenda

1. Introduction
2. Status of Hydrogen Refuelling Stations in Germany
3. Different Types of Hydrogen Refuelling Stations
4. Costs of Hydrogen Refuelling Stations
5. How to Build a Hydrogen Refuelling Station?
6. Risks and Hazards

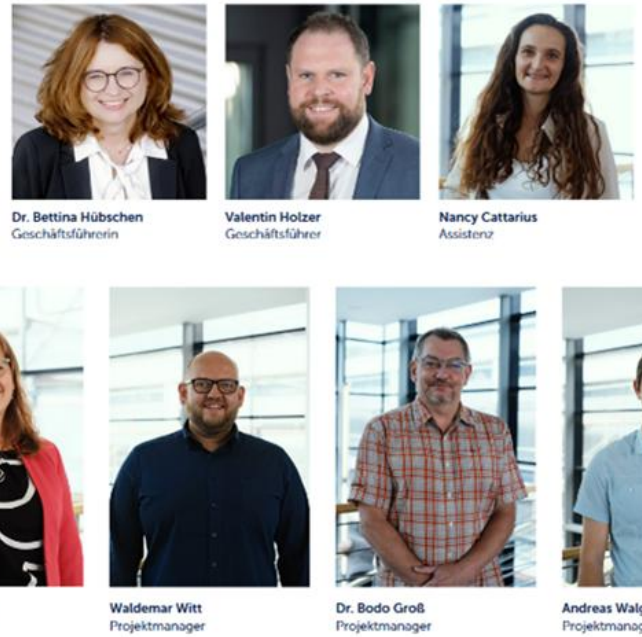
1. Introduction

i. The Saarland Hydrogen Agency – H_2-Saar

H_2-Saar – Our Team

Who we are!

1. Established in May 2023, we are a 100% subsidiary of the Federal State Saarland, located in the South-West part of Germany; bordering France in the south and Luxembourg in the west
2. We are a small team of 4 project managers, 1 assistant, 2 managing directors and are occasionally supported by bachelor and master students as well as from interns



What we do!

1. We act as first contact for hydrogen related questions in the so-called Greater Region **(GR)**
2. We connect players along the whole H_2 value chain by organising conferences and networking events
3. We support the development of strategies to kick-start the H_2 economy, especially in the GR
4. We analyse the related market and help to find individual funding schemes
5. We consult companies, policy makers, citizens and other interested parties in H_2 applications, safety and technology questions and help to increase acceptance for hydrogen and hydrogen technologies

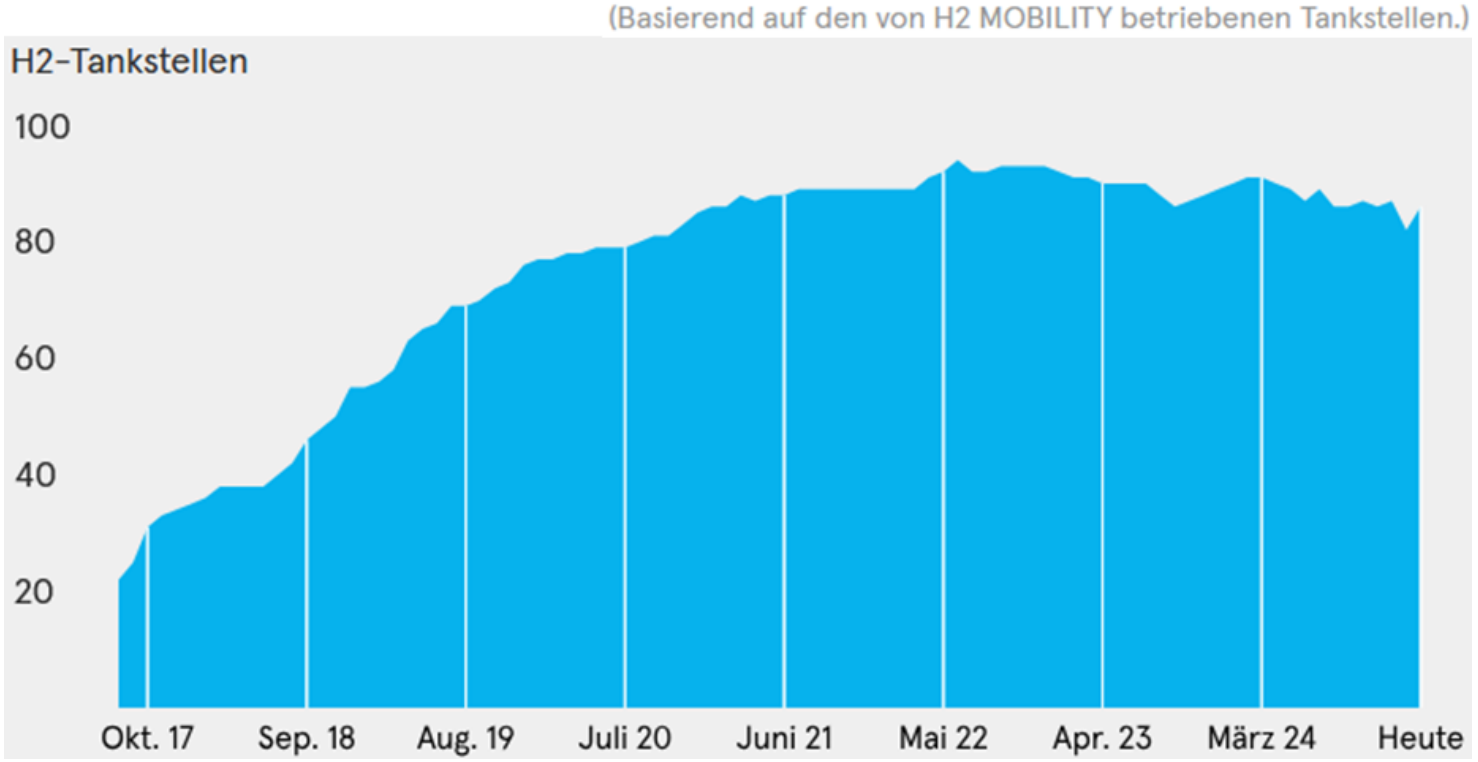
2. Status of Hydrogen Refuelling Stations in Germany

i. Number of hydrogen refuelling stations in Germany
ii. Hydrogen demand at hydrogen refuelling stations in Germany
iii. General trend for the coming years

Number of Hydrogen Refuelling Stations in Germany

- As of February 24th 2025, the H2 MOBILITY hydrogen refuelling station network in Germany comprises of 86 stations
- Refuelling at 700 bar is possible at all stations; selected stations are currently being upgraded to a pressure level of 350 bar taking into account the needs of the market
- These statistics do not include private or "not H2 MOBILITY" hydrogen refuelling stations

- In addition to the H2 MOBILITY stations, around 50 (*based on own research*) other stations are operated in Germany
- **A total of around 130 – 140 HRS are in operation in Germany**

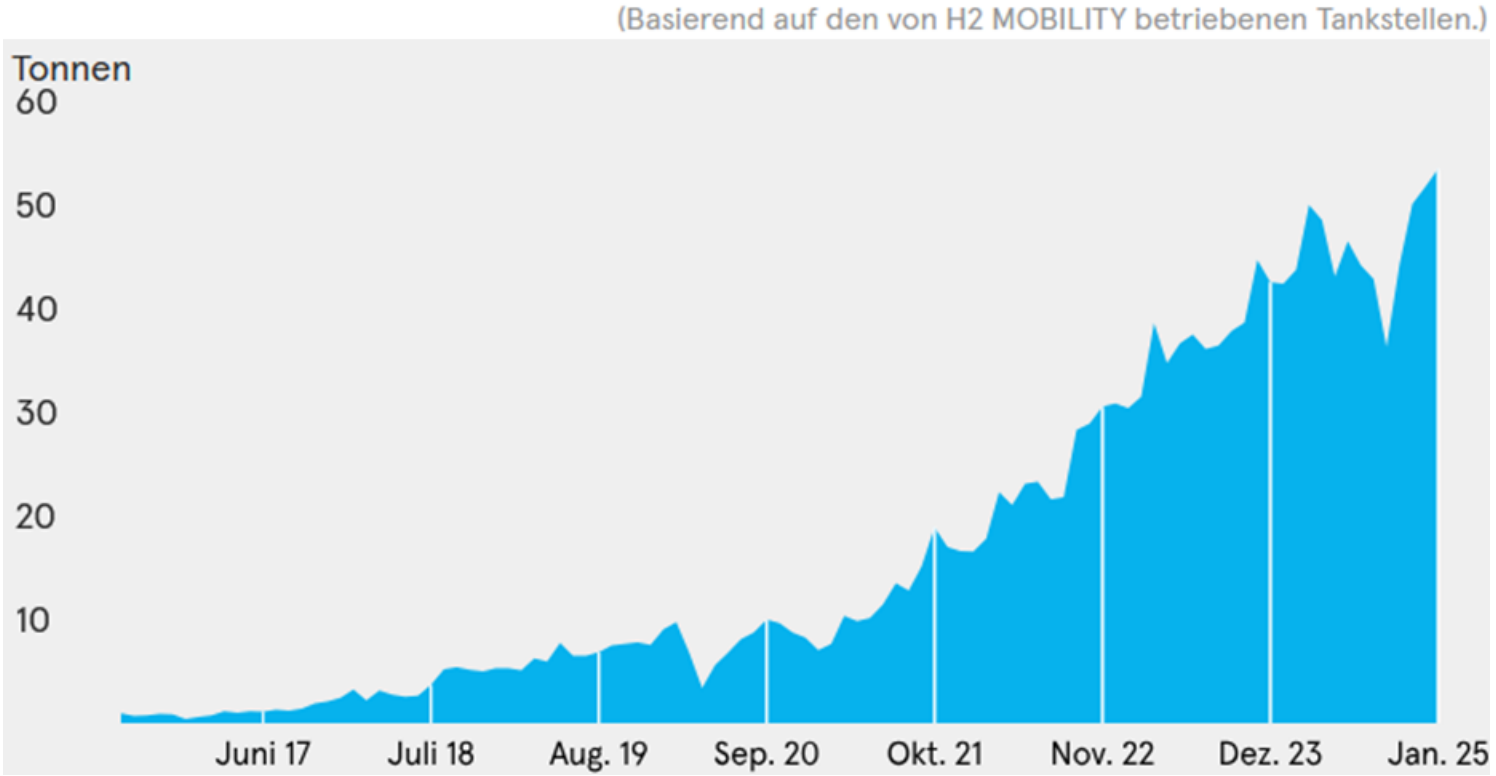


Source: https://h2.live/, visited February 24th 2025

Hydrogen Demand at Hydrogen Refuelling Stations in Germany

- The hydrogen requirement at the 86 H2 MOBILITY stations in January 2025 was around 53.5 tonnes
- The demand of the additional (around 50) HRS is **unknown**
- Assuming that around **250*** HDVs currently run on H_2, and are mostly refuelled at private HRS, this results in a further demand of around **150** tonnes per month (20 d/month operation, 30 kg/d consumption)

- **The total demand of hydrogen is around 200 tonnes per month (around 53.5 tonnes at H2-MOBILITY stations plus additional around 150 tonnes at other stations)**



Source image: https://h2.live/, visited February 24th 2025 // *https://www.verkehrsrundschau.de/nachrichten/nfz-fuhrpark/wasserstoff-lkw-hohe-reichweiten-und-kurze-tankzeiten-3607688

General Trend for the Coming Years

- Small hydrogen refuelling stations, operated by H2 MOBILITY and designed exclusively for 700 bar, will most likely be dismantled or closed → **plan for 2025: 22 stations will be affected**
- Larger hydrogen refuelling stations, operated by H2 MOBILITY and designed exclusively for 700 bar, will most likely also be equipped with a refuelling option for 350 bar → **market demand is changing from passenger cars (usually equipped with 700 bar technology) to buses and lorries (usually equipped with 350 bar technology)**
- H2 MOBILITY plans to fully switch its refuelling station network to green hydrogen in accordance with the RFNBO – Renewable Fuels of Non-Biological Origin – standard by 2028
- Most probably, the number of non-public company operated hydrogen refuelling stations will increase → **For fleet operators, it may make economic sense to have their own hydrogen refuelling station on the company premises**
- Hydrogen-powered vehicles compete with battery-powered vehicles → **the decision of which technology is favoured by fleet operators depends largely on the existing infrastructure and security of supply at the time of the decision**

3. Different Types of Hydrogen Refuelling Stations

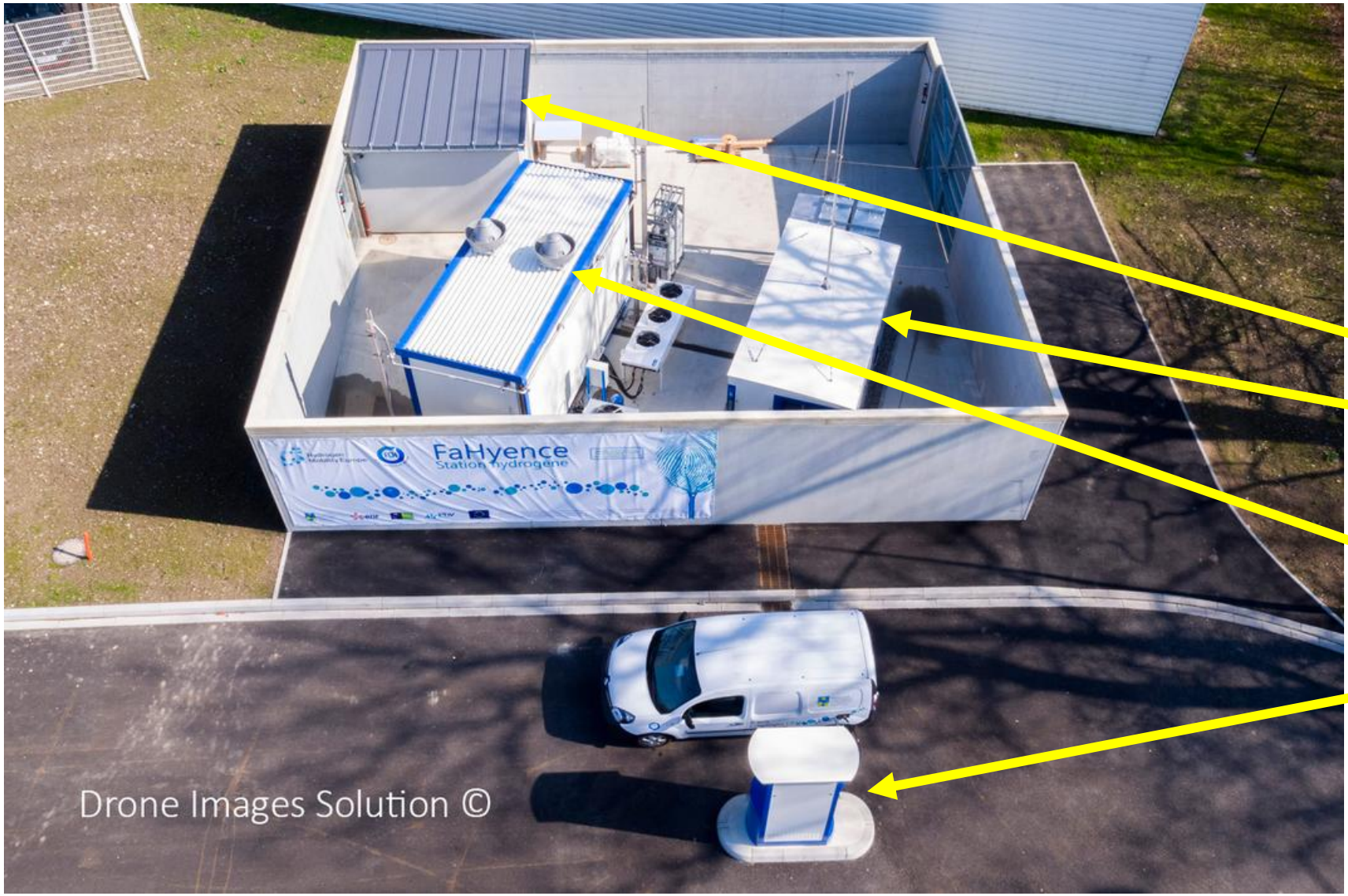
i. Hydrogen refuelling stations without on-site production for gaseous hydrogen
    a. Trailer
    b. Compressor
    c. Storage tanks
    d. Chiller
    e. Dispenser
ii. Hydrogen refuelling stations with on-site production for gaseous hydrogen
    a. Renewable energy production
    b. Water purification
    c. Electrolyser
    d. Electrical cabinet
iii. Other technologies

Hydrogen Refuelling Station without on-site Production for Gaseous Hydrogen

Space requirement:
20 x 50 m
Capacity:
500 kg/d

Source: https://tyczka-hydrogen.de/unser-portfolio/anwendungstechnik/, visited March 19th, 2025

Hydrogen Refuelling Station with on-site Production for Gaseous Hydrogen



Space requirement:
15 x 20 m
Capacity:
40 kg/d

Electrical/control cabinet

Compressor and hydrogen storage

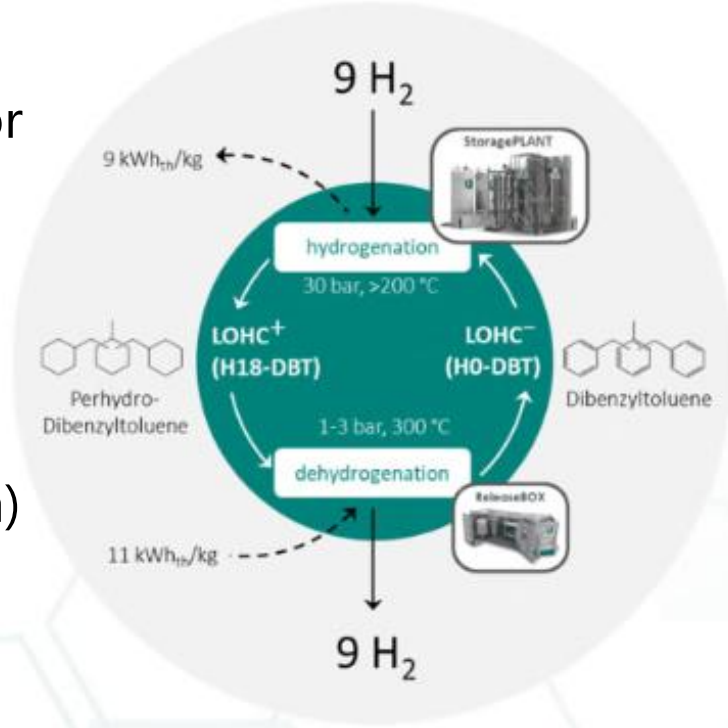
Container for water purification system and electrolyser

Separated single dispenser for 350 bar

Source:
https://mcphy.com/de/wasserstoffmobilitaet/fahyence/?cn-reloaded=1,
visited March 19th, 2025

Other Technologies

- Liquified Hydrogen (two options: only cooled or cooled & compressed) → **currently favoured by Daimler and Linde**
  - Pilot refuelling station in operation for one year in the city of Wörth am Rhein (Rhineland Palatine)
  - Used only for (Daimler) Lorries
  - With regard to hydrogen losses (boil-off), there are advantages for cooled and compressed hydrogen, but the technology is technically more complex
- Liquid Organic Hydrogen Carrier → **besides other molecules dibenzyltoluene (DBT) $C_{21}H_{20}$ ←→ $C_{21}H_{38}$ is used as LOHC**
  - Pilot refuelling station in operation in the city of Erlangen (Bavaria)
  - Advantages regarding storage and transport (DBT is liquid at normal outside temperatures)
  - Niche technology and most likely rapid reduction of the storage capacity due to the "breaking" of the complex DBT molecules



Source: https://www.kalorimetrietage.ptb.de/fileadmin/documents/kalorimetrietage/23Kaltage_2019/Vortragsabstracts/Paetz_-_HT_Abstract-23nd-Kalorimetrietage_2019-05-27_Paetz.pdf, visited March 19th, 2025

4. Costs of Hydrogen Refuelling Stations

i. Hydrogen costs at refuelling stations
ii. Cost (CAPEX and OPEX) of hydrogen refuelling stations

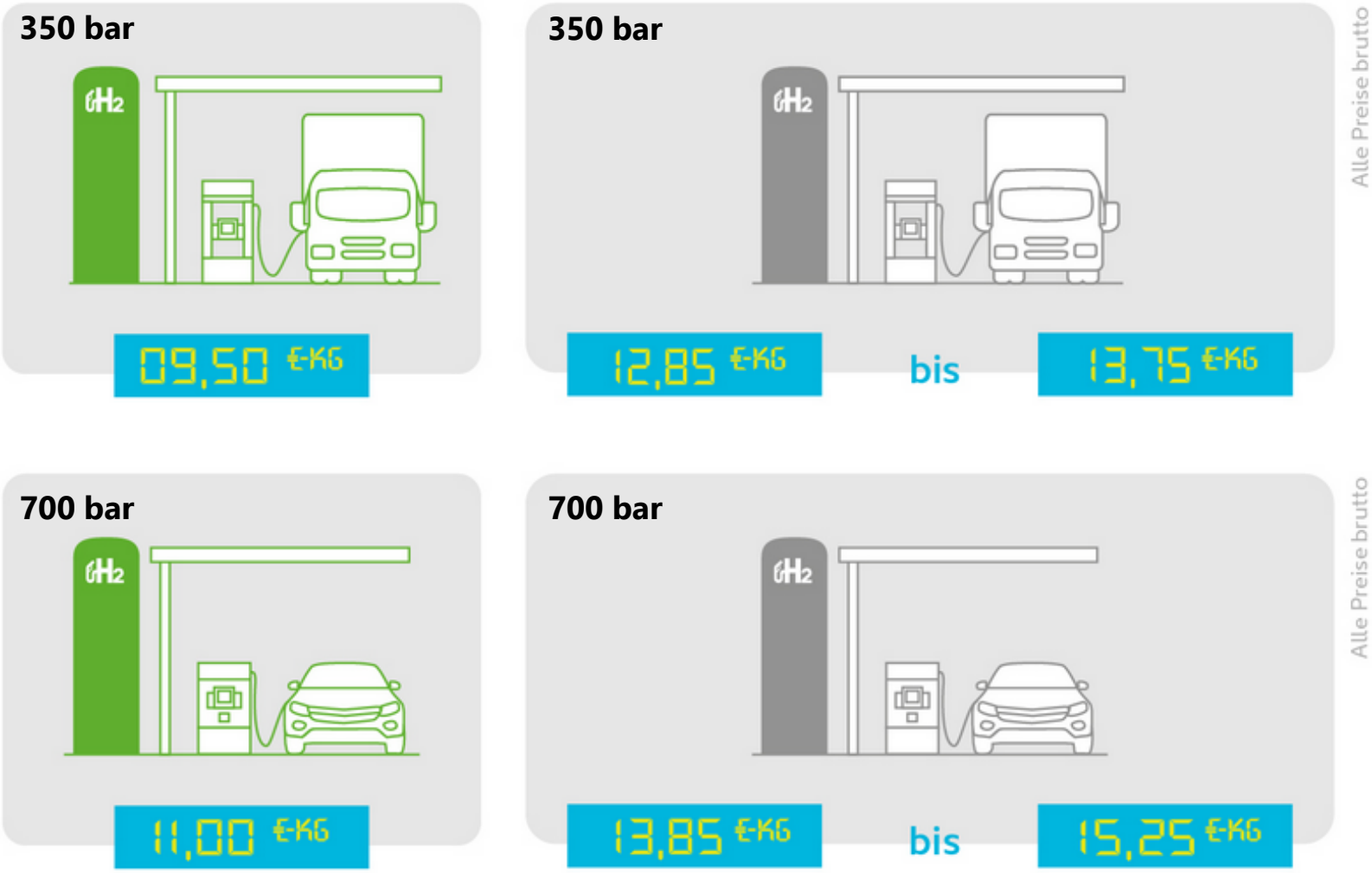
Hydrogen Price at H2 MOBILITY Refuelling Stations in Germany

Historical Hydrogen Prices (from around 2013)

- The initial hydrogen price in 2012/2013 was € 9.50 per kilogramme
- The price was increased to € 12.85 per kilogramme on June 7th 2022
- There was no differentiation in terms of pressure level and source of the hydrogen

Source: https://www.bayreuther-tagblatt.de/nachrichten-meldungen-news/alles-einsteigen-bayreuths-neue-wasserstoff-tankstelle-alles-einsteigen-zur-probefahrt/, visited March 18th 2025

Hydrogen Prize at H2 MOBILITY Refuelling Stations in Germany

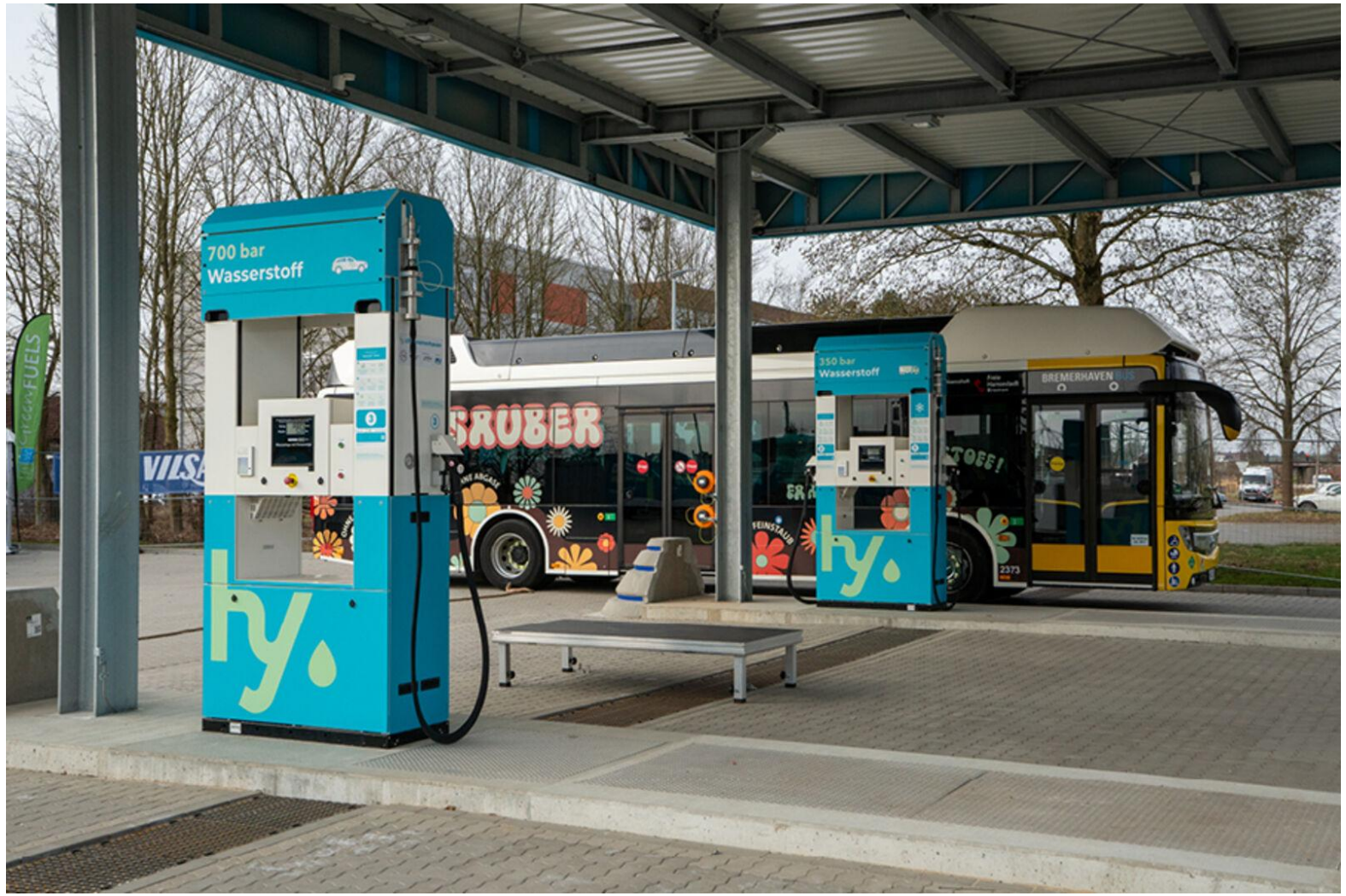


From Oct. 1st 2023, H2 MOBILITY introduced a dynamic pricing model

- differentiated according to pressure level (350 or 700 bar)
- differentiated according to hydrogen source (green or grey)
- Location-independent fixed price for green hydrogen
- Grey hydrogen additionally differentiated according to the location

Source: https://h2-mobility.de/news/3125/, visited on February 12th 2025

Hydrogen Refuelling Station in Bremerhaven



General information

- Commissioning: Feb. 20th 2025
- Designed for both pressure levels; 350 and 700 bar
- Production capacity: up to 900 kilogramme per day (30 HDV or 200 passenger cars)
- Green hydrogen source: 2 MW electrolyser operated with wind energy
- Realisation time: a total of five years for planning and construction of the HRS
- Project budget: total € 12.7 million (€ 5.5 million funding) , including planning, R&D, HRS, electrolyser & hydrogen trailers

Source: https://www.ds-bremen.com/gemeinsam-besser/eroeffnung-wasserstofftankstelle; visited March18th, 2025

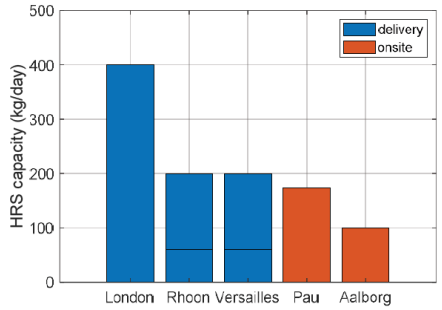
OPEX of Hydrogen Refuelling Stations

OPEX – consisting of many parameters and depends also on the types of the used components

- maintenance costs (HRS & BOP)
- costs for electrical power
- personal costs
- fire alarm system…

€ ??

Site	Hydrogen source		Nominal Capacity	Supply scheme	Compressor pressures	Compressor max. throughput	Storage capacity	Storage pressure*	Dispenser pressure
			kg/day	onsite/delivery	bar_{in}/bar_{out}	Nm^3/h	kg	kg @ bar	bar
London	Delivery trailer **	450 kg/trailer @ 350 bar	400 kg/day ≈300 km	2 del./week	350/500	Integrated in trailer	1250 kg	900 kg @350 bar trailer 350 kg @500 bar onsite	1x 350 bar
Rhoon RET	Delivery pipeline	@30 bar from SMR plant	200 kg/day ≈100 km	Upon request	2x 30/495 1x 350/900	100 Nm^3/h	250 kg	90 kg @495 bar 65 kg @877 bar	1x 350 bar
Rhoon PZH								95 kg @495 bar	1x 350 bar
Versailles SAVAC	Delivery trailer **	350 kg/trailer @ 200 bar	200 kg/day ≈200 km	3 del./week	1x 10/1080 (2-stage)	150 Nm^3/h	600 kg	350 kg @200 bar trailer 100 kg @495 bar onsite 60 kg @877 bar	350/700 bar
Versailles BE Green									1x 350/700 bar 1x 350 bar
Pau SMTU	On-site electrolysis + delivery trailer	PEMEL: 425 kW Trailer: 330 kg @200 bar	174 kg/day***	24/24h	2x 7-20/920 (5-stage)	2x 275 Nm^3/h	860 kg	230 kg @20 bar 630 kg @600 bar (330 kg @200 bar trailer optional)	8x 350 bar
Aalborg	On-site electrolysis	PEMEL: 355 kW	100 kg/day	≈80% capacity factor	1x 35/450 (3-stage)	60 Nm^3/h	242 kg	10 kg @30 bar 114 kg @300 bar 118 kg @450 bar	1x 350 bar



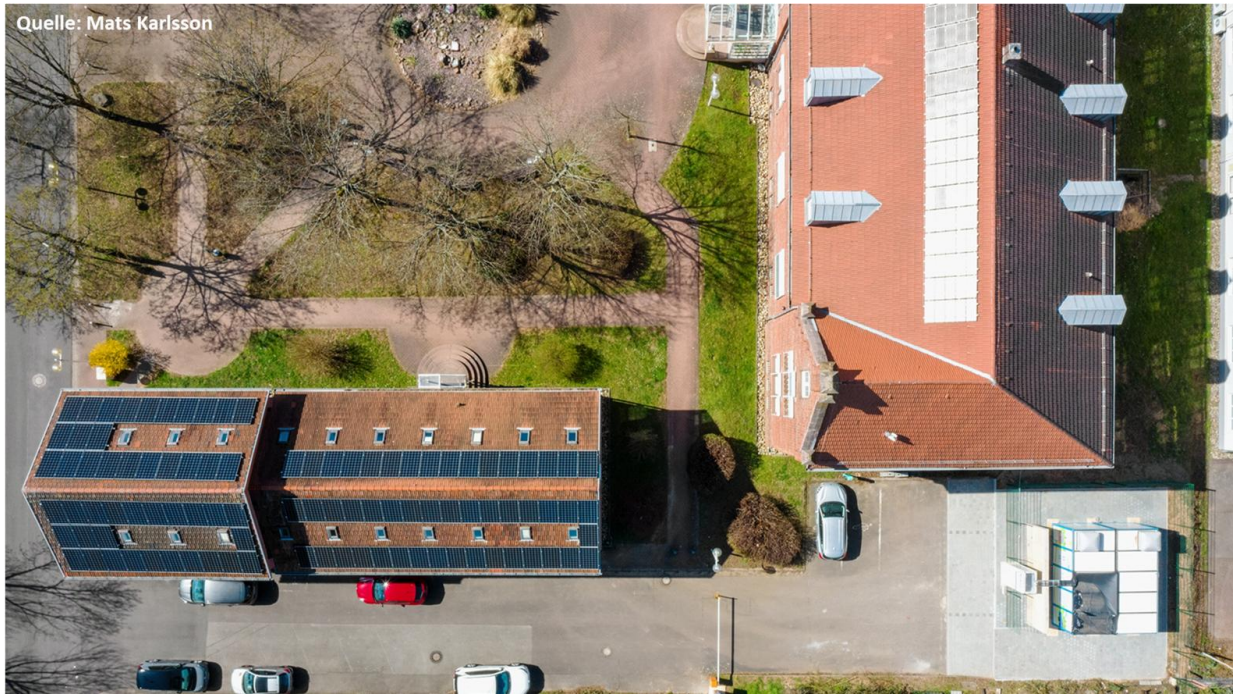
	CAPEX (k€)	OPEX (k€/year)	LCOH (€/kg)	$LCOH_{CAPEX}$ (€/kg)	$LCOH_{OPEX}$ (€/kg)	$C_{HRS,CAPEX}$ (k€/(kg/day))
London	414	469	8.81	0.78	8.03	4.26
Rhoon	701	375	6.19	1.05	5.14	5.77
Versailles	714	570	8.88 €	1.07	7.81	5.88
Pau	2,004	544	12.02	3.46	8.56	18.97
Aalborg	632	268	10.57	2.84	7.73	10.37

Source: Roberta Caponi, Andrea Monforti Ferrario, Luca Del Zotto and Enrico Bocci; Hydrogen refuelling station cost model applied to five real case studies for fuel cell buses; E3S Web of Conferences 312, 07010 (2021) https://doi.org/10.1051/e3sconf/202131207010; 76° Italian National Congress ATI

5. How to Build a Hydrogen Refuelling Station?

i. Solar powered hydrogen refuelling station at IZES
ii. Standards, regulations, and ordinances
iii. Construction plan of the HRS at IZES in Saarbrücken

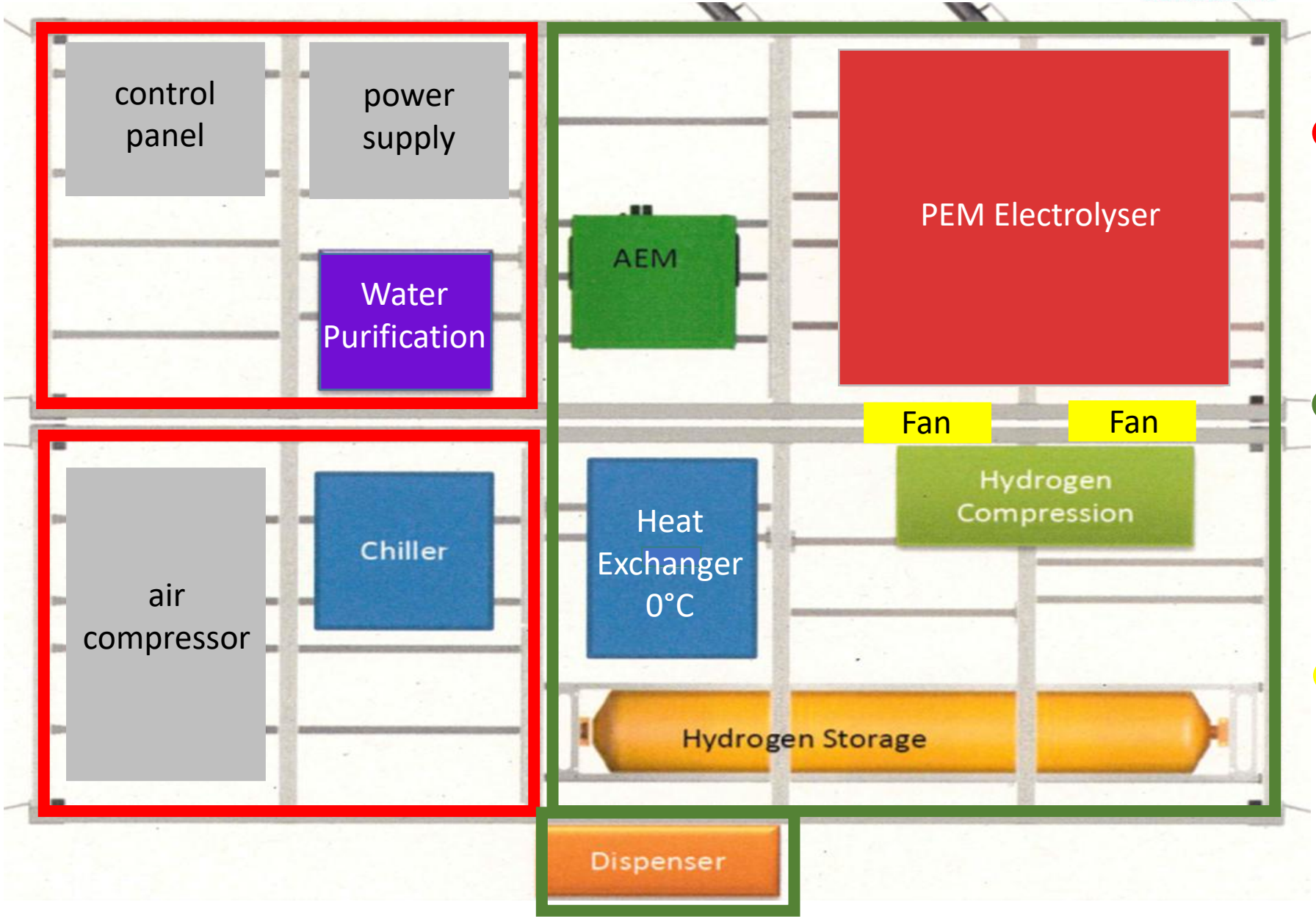
Solar Powered Hydrogen Refuelling Station (HRS) at IZES in Saarbrücken



- Research station, designed for a pressure level of 700 bar
- Production capacity: 6 Nm^3/h
- Hydrogen source: Two different electrolyser technologies; AEM and PEM
- H_2 storage capacity: 50 kg at 450 bar and 8 kg at 950 bar

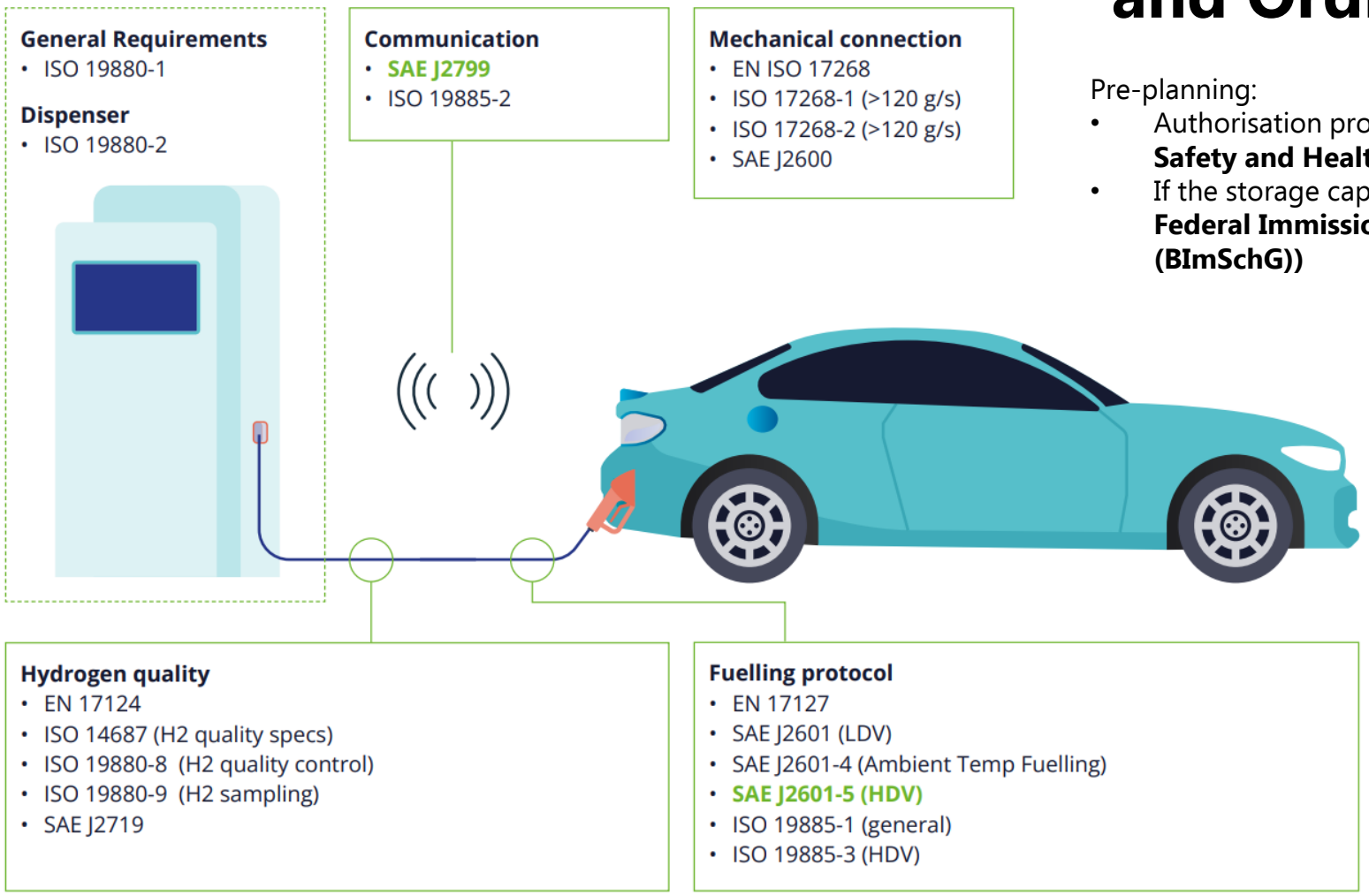
- Components inside the two 20 feet containers: Power supply, control system, air compressor, cooling systems, water purification system, two electrolysers, fans, H_2 compressor, storage tanks
- Components outside the two 20 feet containers: Fire protection wall and the separated single dispenser for 700 bar

Installation Plan and EX Zones



- Control panel, water purification, power supply, air compressor and chiller are not declared as EX zones
- Hydrogen production, compression, storage tanks, dispenser and chiller are declared as EX zones
- The two containers are connected by two fans; the roof of the storage area is an open mesh

Standards on Inter-Operability between Vehicle & Dispenser for Compressed Gaseous Hydrogen & used Standards Regulations and Ordinances in Germany



Pre-planning:

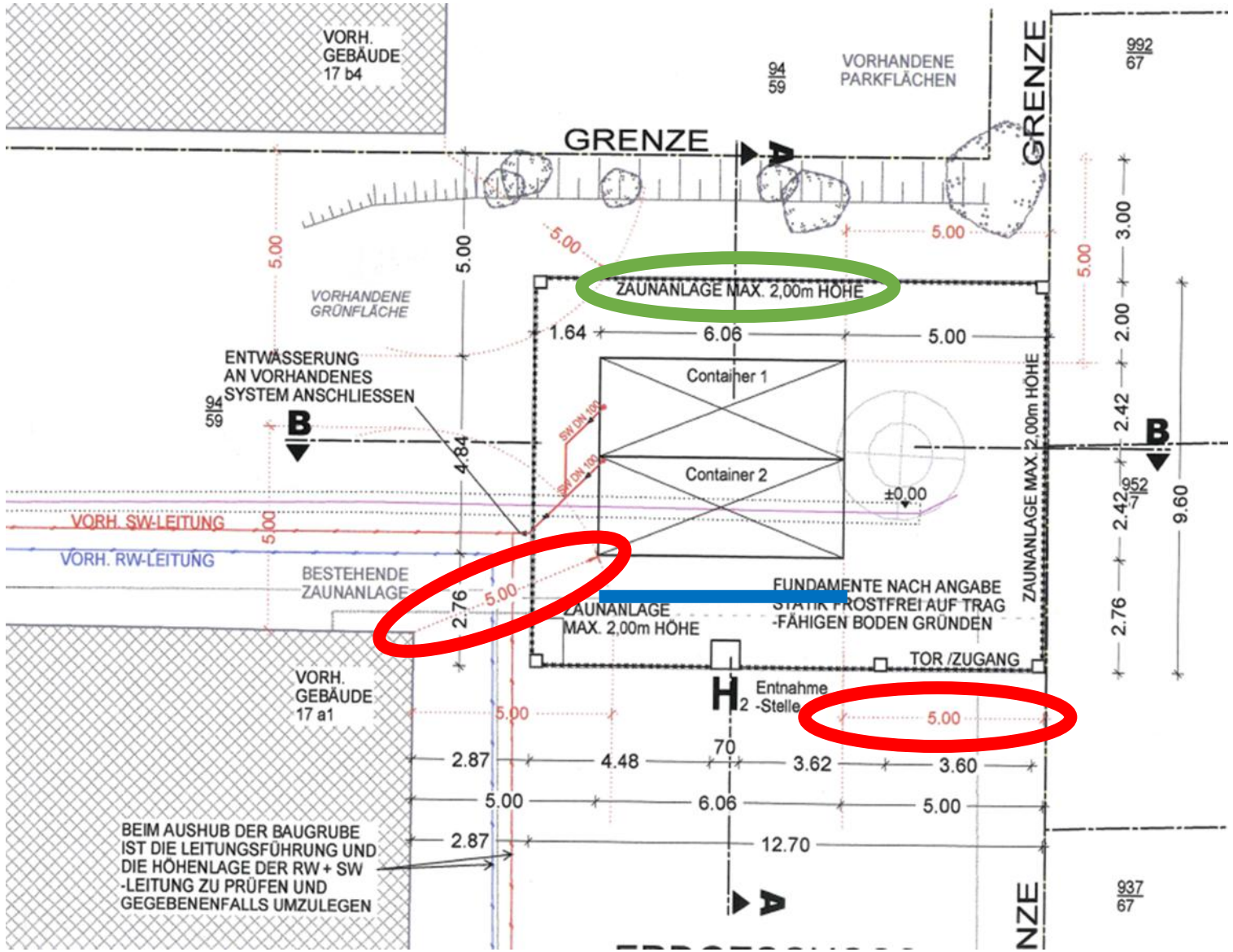
- Authorisation procedure in accordance with the **Ordinance on Industrial Safety and Health (in German: Betriebssicherheitsverordnung (BetrSichV))**
- If the storage capacity is larger than 3 tonnes: Procedure in accordance with the **Federal Immission Control Act (in German: Bundesimmissionsschutzgesetz (BImSchG))**

Some 'papers' for the main-planning:

- ISO 19880 ("umbrella standard" for hydrogen refuelling stations for gaseous hydrogen)
- ISO 19885 (standard for gaseous H_2 – refuelling protocols for H_2 operated vehicles)
- **BetrSichV and BImSchG** (depends on the storage capacity of the station)
- **TRBS 3146 / TRGS 726 (Stationary pressurised systems for gases, including hydrogen)**
- **LASI LV 49**
- **TRBS (Technical rules for operational safety) No. 1111, 1201, 1203, 2131, 2141, 2152 and 2153, 3151**
- **TRGS (Technical rules for hazardous substances) 751**
- SAE TIR J2601/ SAE J2799 (Refuelling protocols for gaseous hydrogen surface vehicles and requirements for station-to-vehicle communication hardware and software)
- **DIN EN 17124, DIN EN 17127**
- **DGUV-R113-001**
- **VD-TÜV Merkblatt 965**

Source: Clean Energy Partnership's public webinar: TIR SAE J2601-5 Refuelling Protocol, delivered by Vincent Matteaer from Toyota Motor Europe, copied from Hydrogen Energy Association Position Paper on Hydrogen Refuelling Infrastructure: Standardisation

Construction Plan of the HRS at IZES in Saarbrücken



Exemplary requests from the building permit

- Hydrogen production and storage tanks or the technology containers must be at least five metres away from surrounding buildings and the property boundary
- A fence (2 m high) was requested to protect the HRS against vandalism
- The fire protection wall (6000x2630x25) was mandatory in order to protect the HRS from a vehicle that caught fire at the refuelling point.

Source: IZES gGmbH

Fire Brigade Access as Part of the Fire Protection Plan

Exemplary requests from the fire protection plan

- A no-parking zone had to be set up in the area of the road junction
- An automatic fire alarm system had to be installed, including a key-box and a direct line to the fire brigade

Source: IZES gGmbH

6: Risks and Hazards

i. Don’t be afraid!!
ii. Remember the first internal combustion engines!
iii. We are gaining experience in the use of hydrogen and hydrogen technologies every day, therefore we are also improving the safety and reliability of the technology

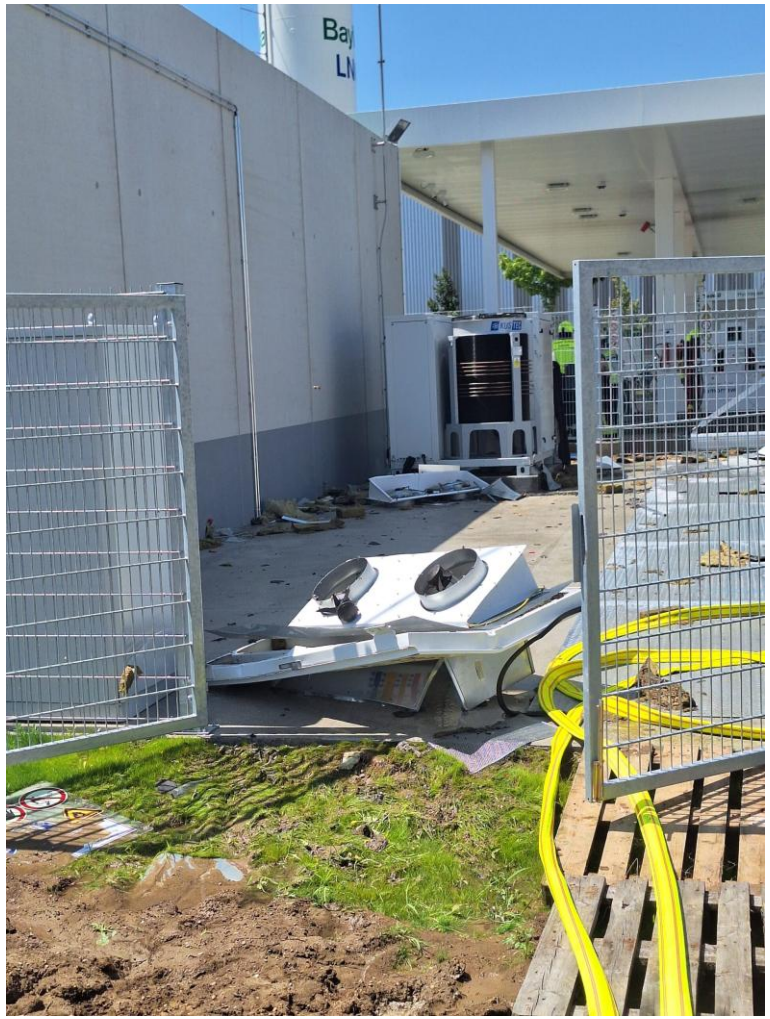
Hydrogen Refuelling Station in Norway (Kjørbo) – Shortly after the Accident on June 10th 2019

General Information

- Operating company: NEL Hydrogen
- No personal injuries
- Static charging of dust particles was identified as the most likely ignition source
- The cause of the accident was an improperly mounted flange on a high-pressure tank

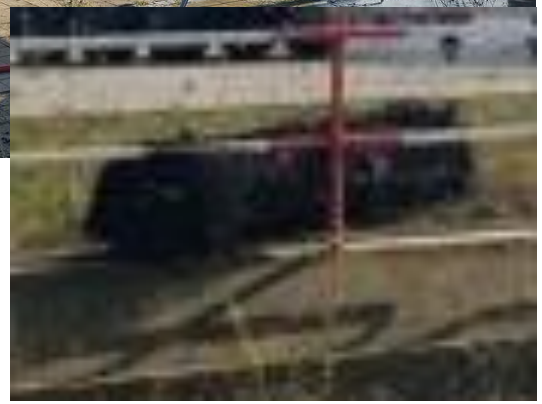
Source: https://reneweconomy.com.au/hydrogen-re-fuelling-station-explodes-in-norway-hyundai-and-toyota-suspend-fuel-cell-sales-99377/, visited September 17th, 2019

Hydrogen Refuelling Station in Augsburg Gersthofen, Germany Shortly after the Accident on June 25th 2024



Sources: rights: https://www.augsburger-allgemeine.de/augsburg-land/gersthofen-feuerwehr-rueckt-zu-brand-bei-wasserstoff-tankstelle-in-gersthofen-aus-id71181441.html, Foto: Günter Bugar, Feuerwehr Gersthofen; left https://feuerwehr-taefertingen.de/einsatzberichte/abc-b-brand-wasserstoff-tankstelle/, visited September 12th, 2024

Filling Station for Hydrogen Trailers at Infraleuna in Leuna Germany – Shortly after the Accident on August 26th 2024



Source:
https://www.infraleuna.de/news/news-detail/verpuffung-auf-dem-gelaende-der-linde-gmbh-am-chemiestandort-leuna,
visited September 12th, 2024

Thank you for listening!

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