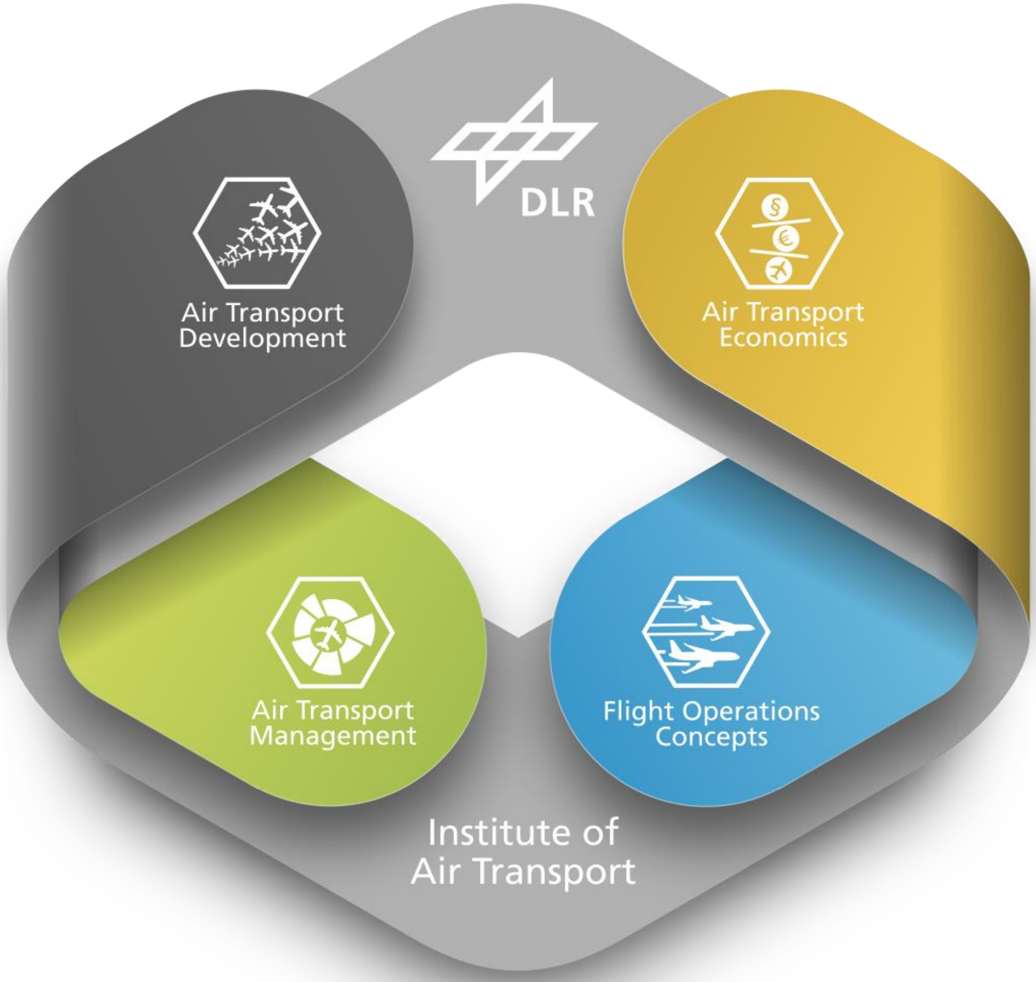
# HYDROGEN AT AIRPORTS

**Infrastructure for Ground Handling of Hydrogen Aircraft at Airports**



Tim Schunkert, Institute of Air Transport, 10.04.2025

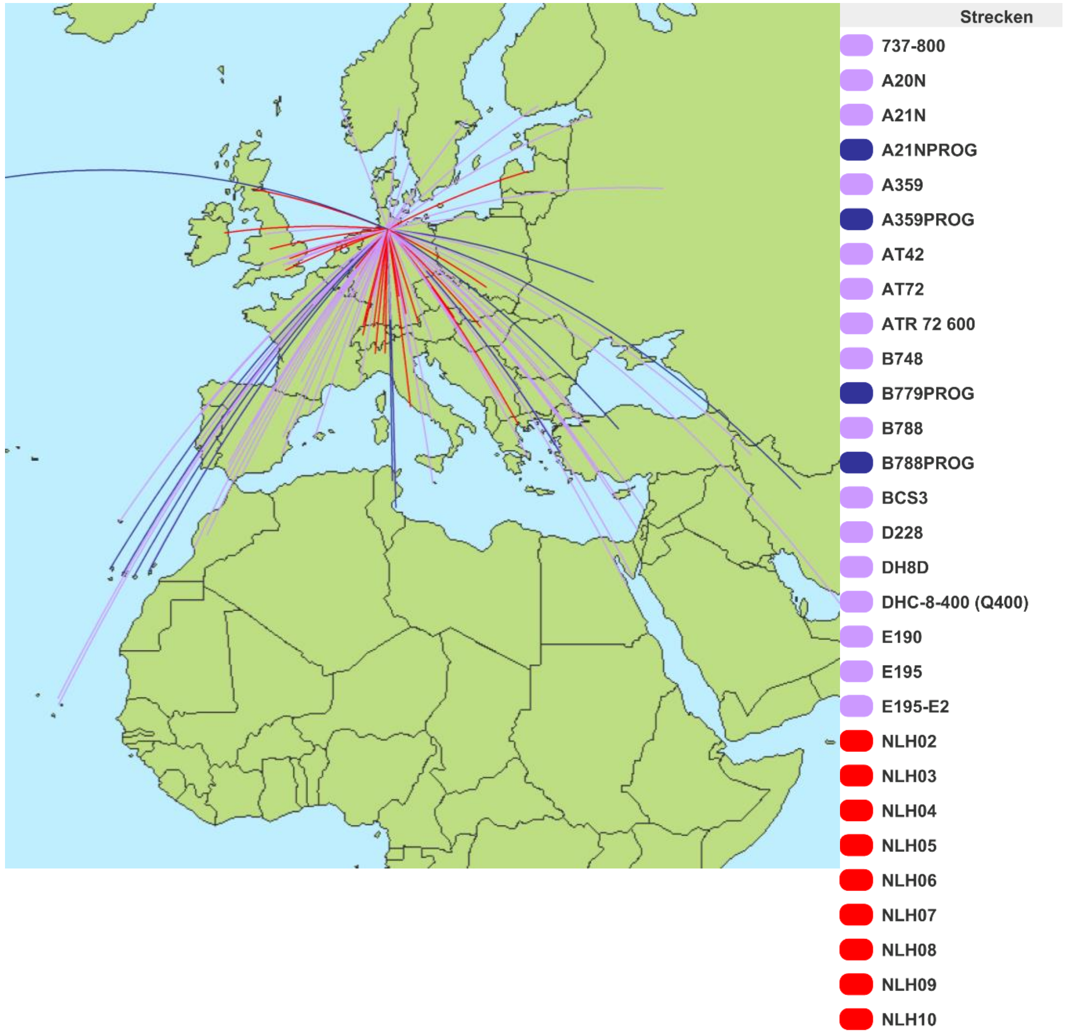
# New Institute of Air Transport




- Established on 1st April 2023
- Merger of DLR Air Transportation Systems Lab and the Institute of Air Transport and Airport Research
- Locations in Hamburg and Cologne
- Mission: Forecasting, designing, and evaluating the air transport system as part of the overall transport system
- **Four departments complement the extensive technological portfolio of the DLR with operational, economic, and regulatory expertise**

# Department Air Transport Development
# Example: Flight Schedule

| | Week | Dep | Arr | DepDay | ArrDay | DepTime | ArrTime | Aircraft |
|---|---|---|---|---|---|---|---|---|
| 0 | W05 | BRN | HAM | 0 | 0 | 18:30:00 | 20:15:00 | NLH02 |
| 1 | W05 | DRS | HAM | 0 | 0 | 08:40:00 | 09:45:00 | ATR 72 600 |
| 2 | W05 | DRS | HAM | 0 | 0 | 20:05:00 | 21:10:00 | ATR 72 600 |
| 3 | W05 | FKB | HAM | 0 | 0 | 08:35:00 | 09:50:00 | AT72 |
| 4 | W05 | FKB | HAM | 0 | 0 | 20:55:00 | 22:10:00 | NLH04 |
| 5 | W05 | HAM | BRN | 0 | 0 | 20:45:00 | 22:30:00 | AT42 |
| 6 | W05 | HAM | DRS | 0 | 0 | 07:00:00 | 08:05:00 | AT72 |
| 7 | W05 | HAM | DRS | 0 | 0 | 18:25:00 | 19:30:00 | AT72 |
| 8 | W05 | HAM | EWR | 0 | 0 | 09:00:00 | 12:15:00 | A359PROG |
| 9 | W05 | HAM | FKB | 0 | 0 | 06:45:00 | 08:00:00 | AT72 |
| 10 | W05 | HAM | FKB | 0 | 0 | 19:05:00 | 20:20:00 | NLH04 |
| 11 | W05 | HAM | LCY | 0 | 0 | 07:05:00 | 07:50:00 | AT42 |
| 12 | W05 | HAM | LCY | 0 | 0 | 17:00:00 | 17:50:00 | NLH02 |
| 13 | W05 | HAM | LTN | 0 | 0 | 10:20:00 | 10:55:00 | A21N |
| 14 | W05 | HAM | NCE | 0 | 0 | 13:40:00 | 15:50:00 | A20N |
| 15 | W05 | HAM | TLS | 0 | 0 | 10:10:00 | 12:20:00 | E195-E2 |
| 16 | W05 | LCY | HAM | 0 | 0 | 08:20:00 | 11:10:00 | AT42 |
| 17 | W05 | LCY | HAM | 0 | 0 | 18:20:00 | 21:10:00 | AT42 |
| 18 | W05 | LTN | HAM | 0 | 0 | 07:20:00 | 09:45:00 | A21N |
| 19 | W05 | NCE | HAM | 0 | 0 | 16:20:00 | 18:30:00 | A20N |
| 20 | W05 | TLS | HAM | 0 | 0 | 12:55:00 | 15:10:00 | E195-E2 |

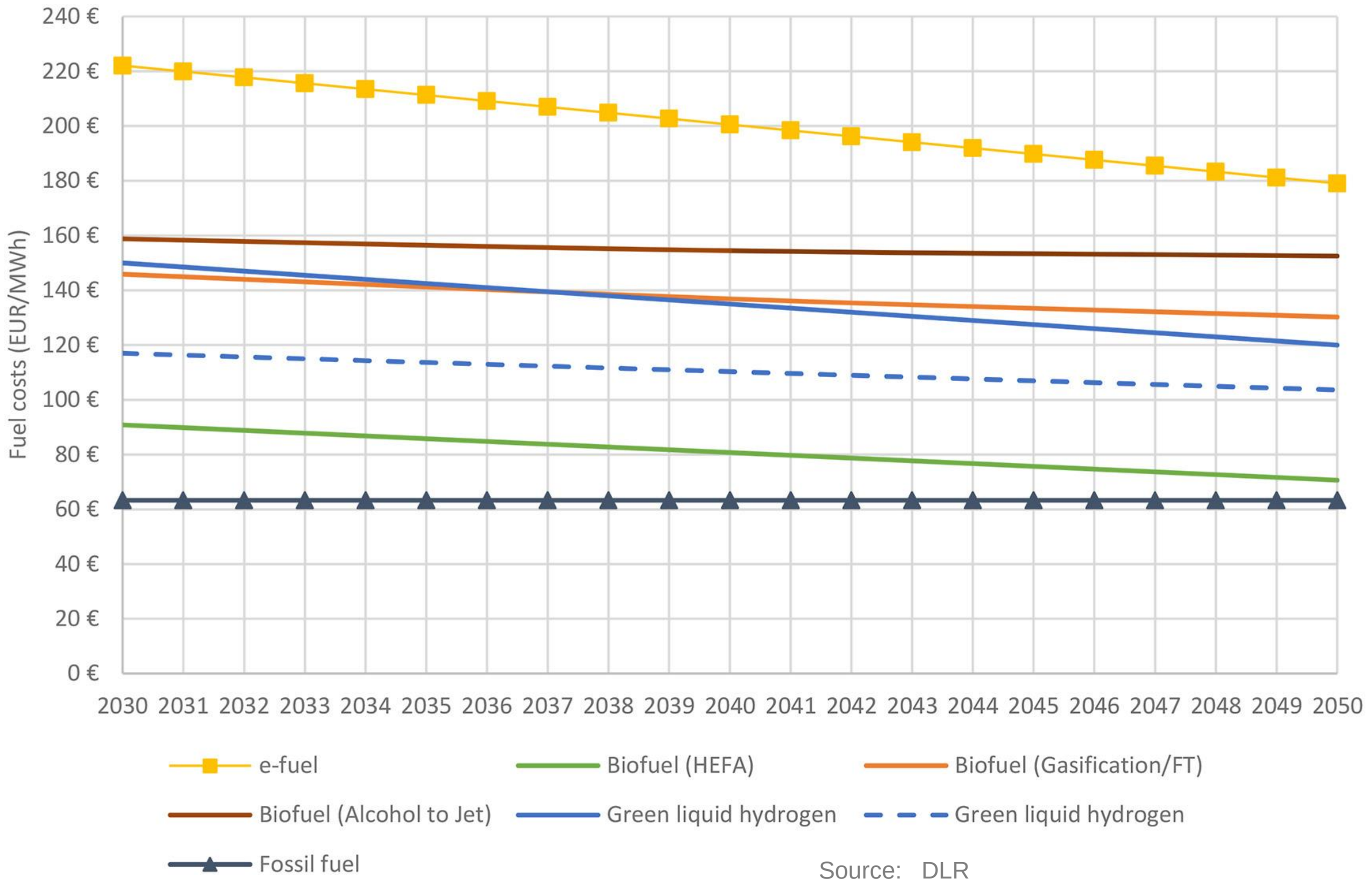



**Representative winter- and summer week**
**Week 5 (factor 21,3832781)**
**Week 30 (factor 31,1090253)**

# 1. POTENTIAL OF LIQUID HYDROGEN (LH2)

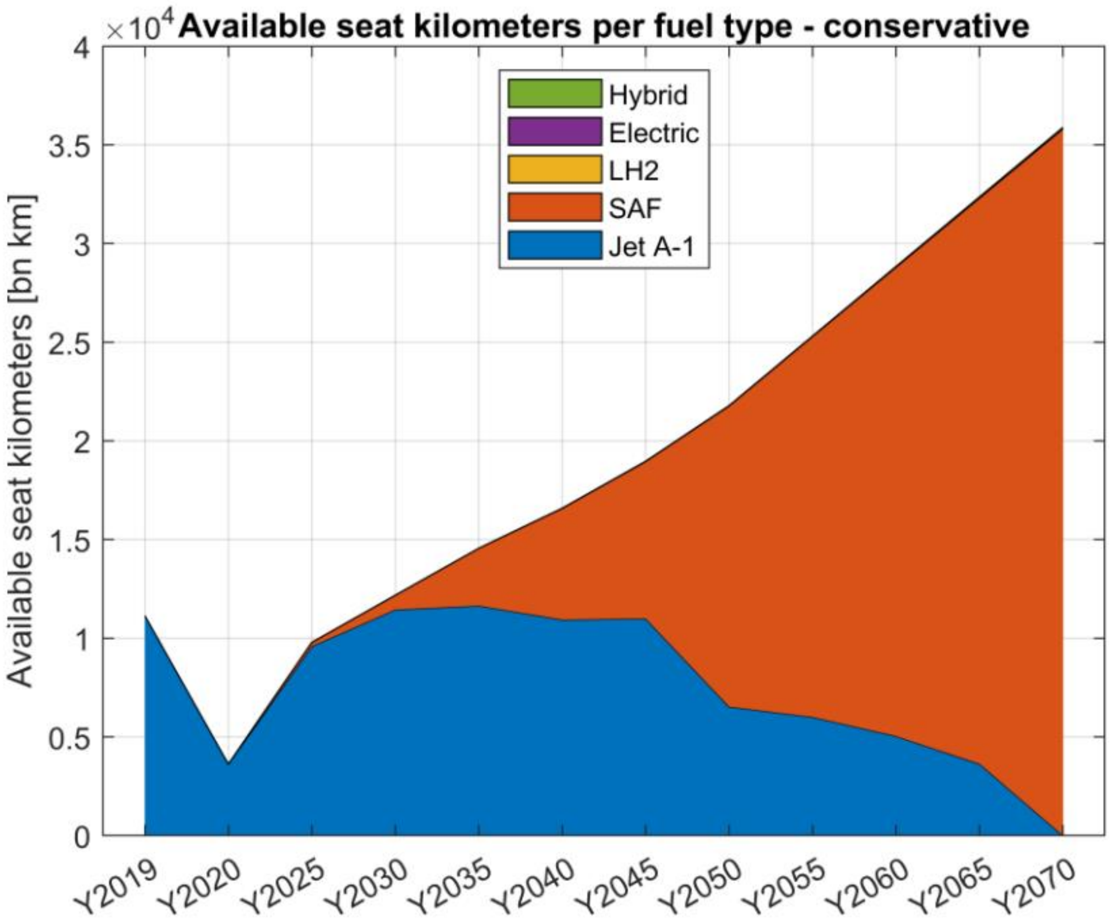
# Potential of LH2
# Cost-Effective Emission Mitigation

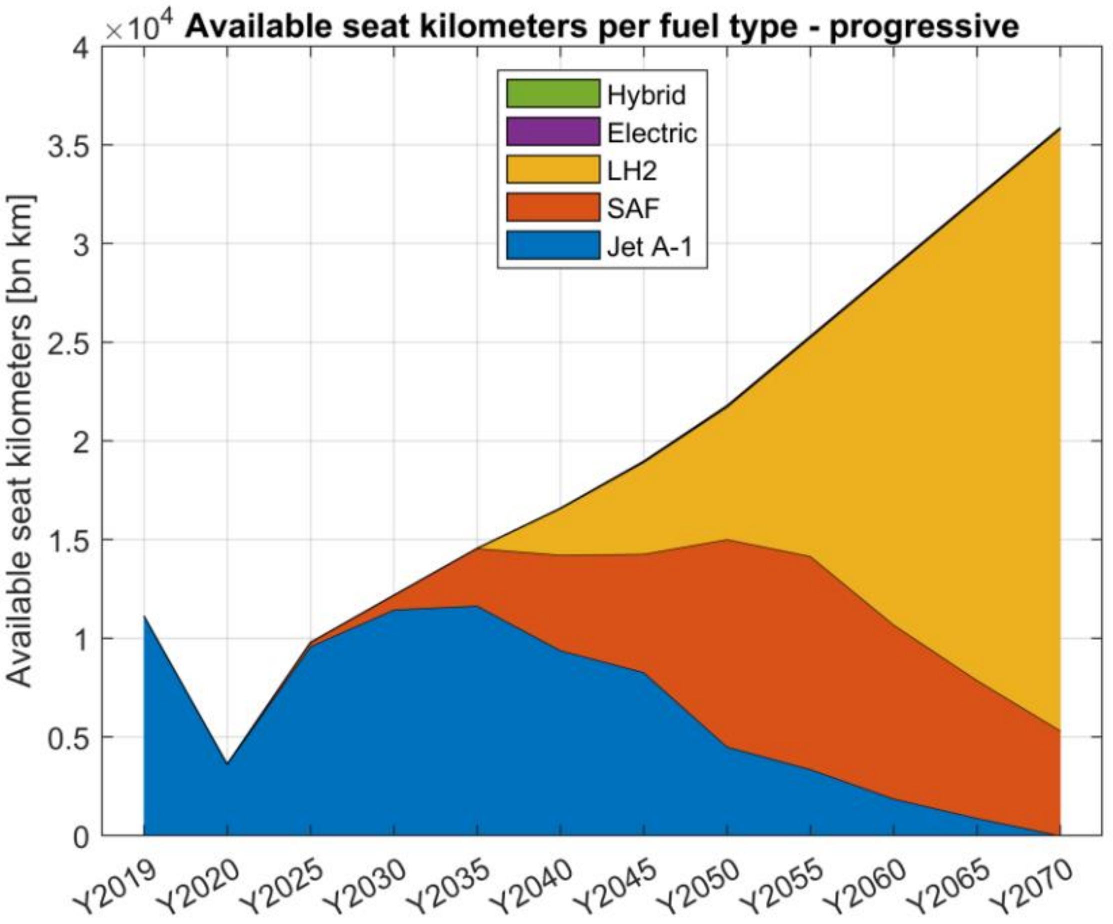
- **Fuel cost** account for about **30 %** of total airline costs
- Fossil Fuels with Carbon Price and Tax would be much higher
- Costs for liquid hydrogen including infrastructure measures are projected to be **104 and 120 € / MWh in 2050** based on two different assumptions




Source: DLR
Hydrogen in aviation: A simulation of demand, price dynamics, and CO2 emission reduction potentials - ScienceDirect

# Potential of LH2 Market Share




Source: DLR DEPA 2070


# 2. INFRASTRUCTURE MEASURES

# Liquid Hydrogen (LH2)

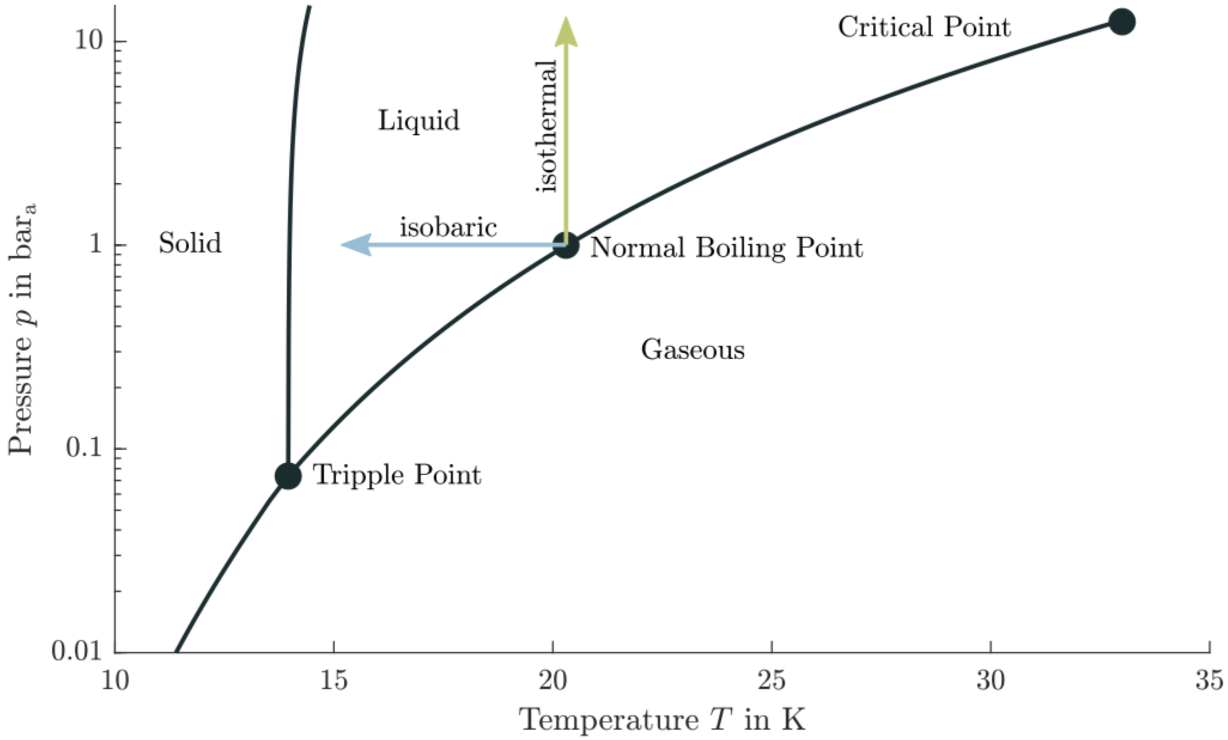
## 1. Cryogenic Temperature ($T_{NBP}$= ~20 K* or -253 °C*)

- Within this temperature range, almost all other molecules freeze out

## 2. Low Density ($\rho_{liquid}$ = ~ 71 kg / $m^3$ *)

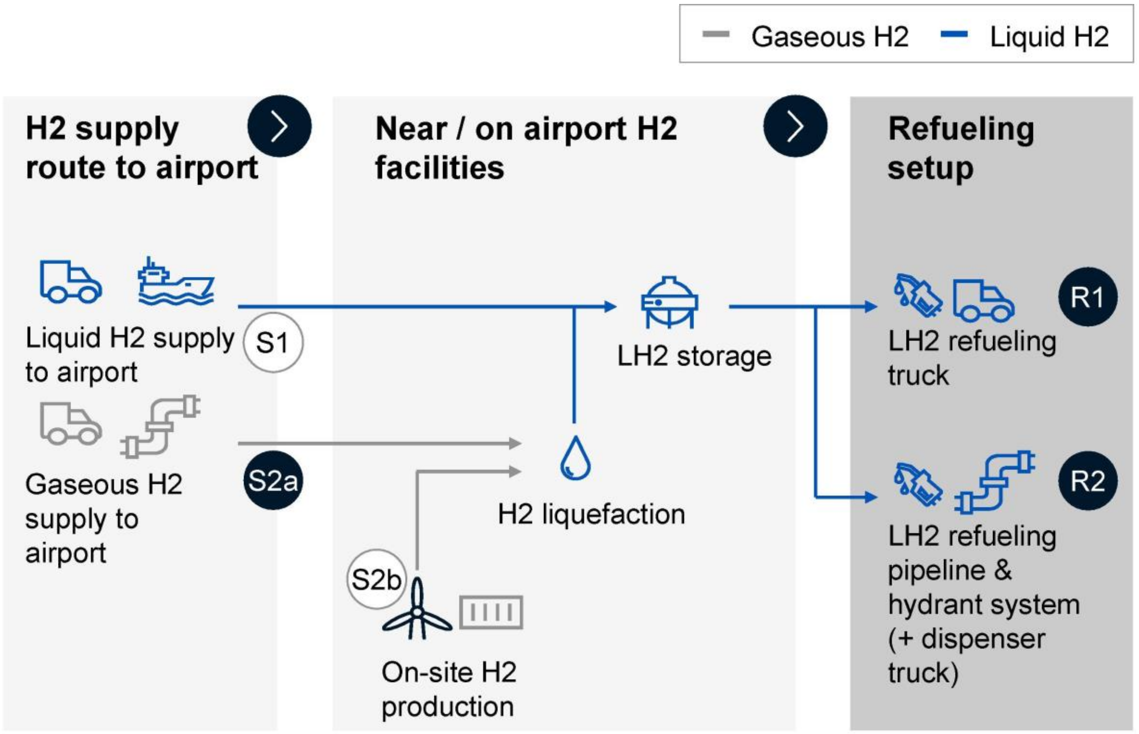
- Higher Space and Volume Requirements
- 4× Higher Volume for Equivalent Energy Compared to Hydrocarbon-Based Fuels (Jet-A1)

*at 1 bar




Source: Lemmon, Marcia L Huber, Mark O McLinden u. a. "NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP". In: National Institute of Standards and Technology 9 (2010)

# Hydrogen Fuel Supply Route to Airport




Source: H2-powered aviation at airports – Design and economics of LH2 refueling systems - ScienceDirect

## S1: Transportation in its liquid form

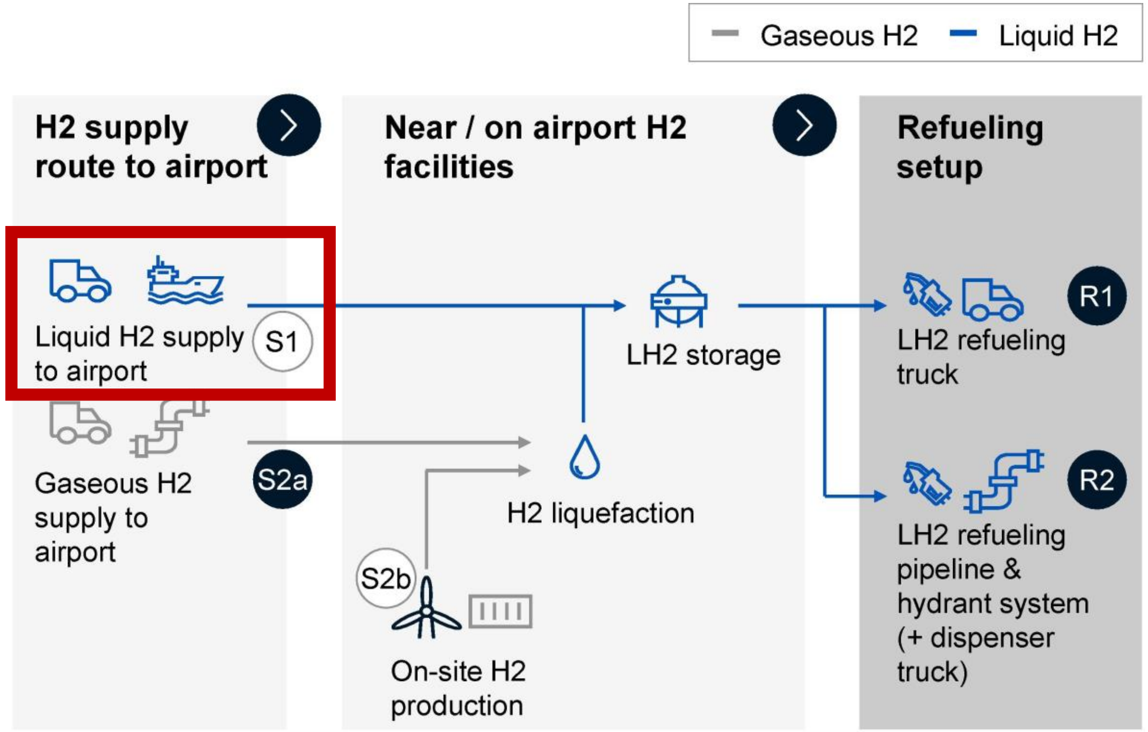
- Remote liquefiers
- Delivery in single packages (containers / trailers)

## S2a: Transportation in its gaseous form

- Local GH2 pipeline
- On-site liquefier

## S2b: Production nearby the airport

# Hydrogen Fuel Supply Route to Airport




Source: H2-powered aviation at airports – Design and economics of LH2 refueling systems - ScienceDirect

## Container / Trucks:

- Net Capacity 2.615 kg

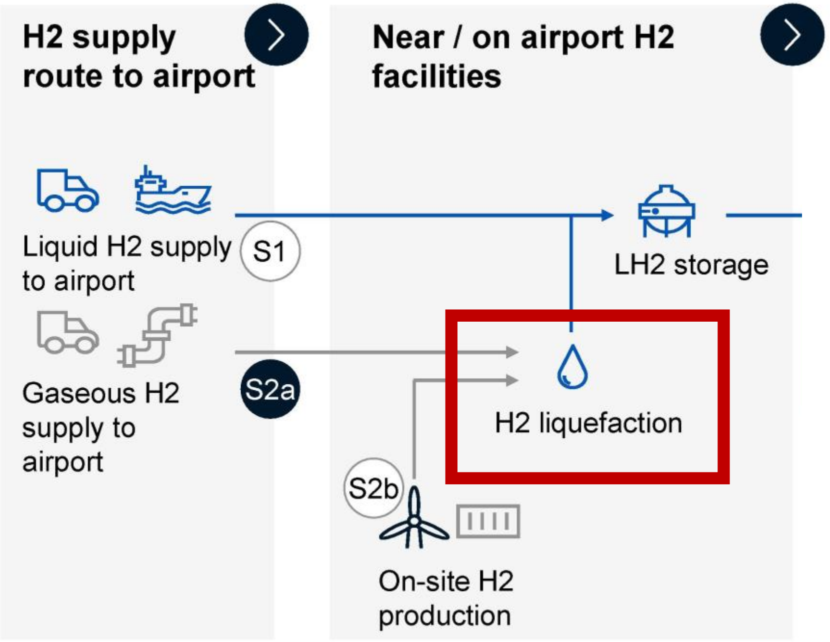

Picture Hydrogen-technologies_brochure.pdf

## LH2 Trucks:

- 3.5 t – 4.5 t


Picture Hydrogen Liquefaction Engineering and Liquid Hydrogen Storage & Transportation - Electrolytic Hydrogen Production System and Electrolytic Hydrogen Alk

# On-Site Airport Facilities




Source: H2-powered aviation at airports – Design and economics of LH2 refueling systems - ScienceDirect

- Deliver H2 in its gaseous state
- Energy Demand: 7 – 11 kWh / kg

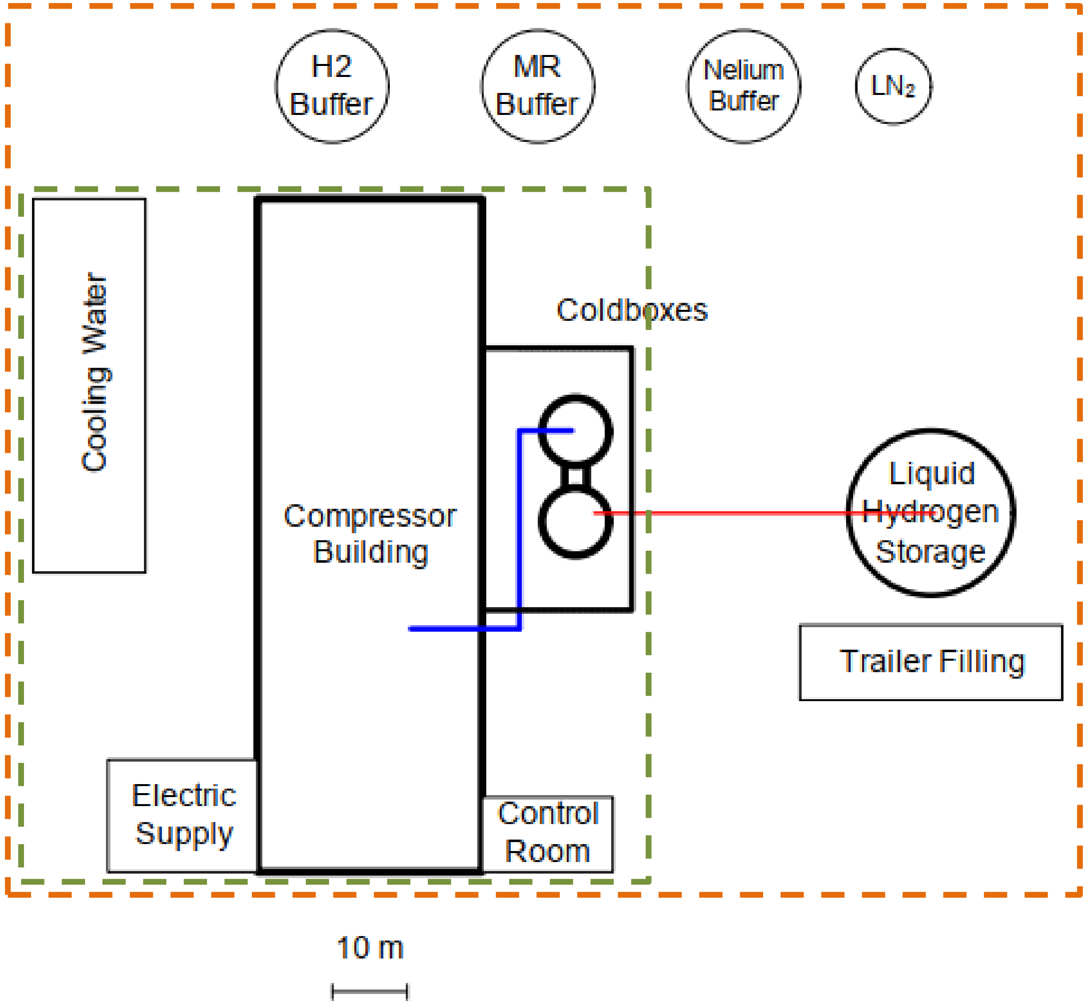
Place Demand Example for 40 TPD:

80m x 90m

7.200m²

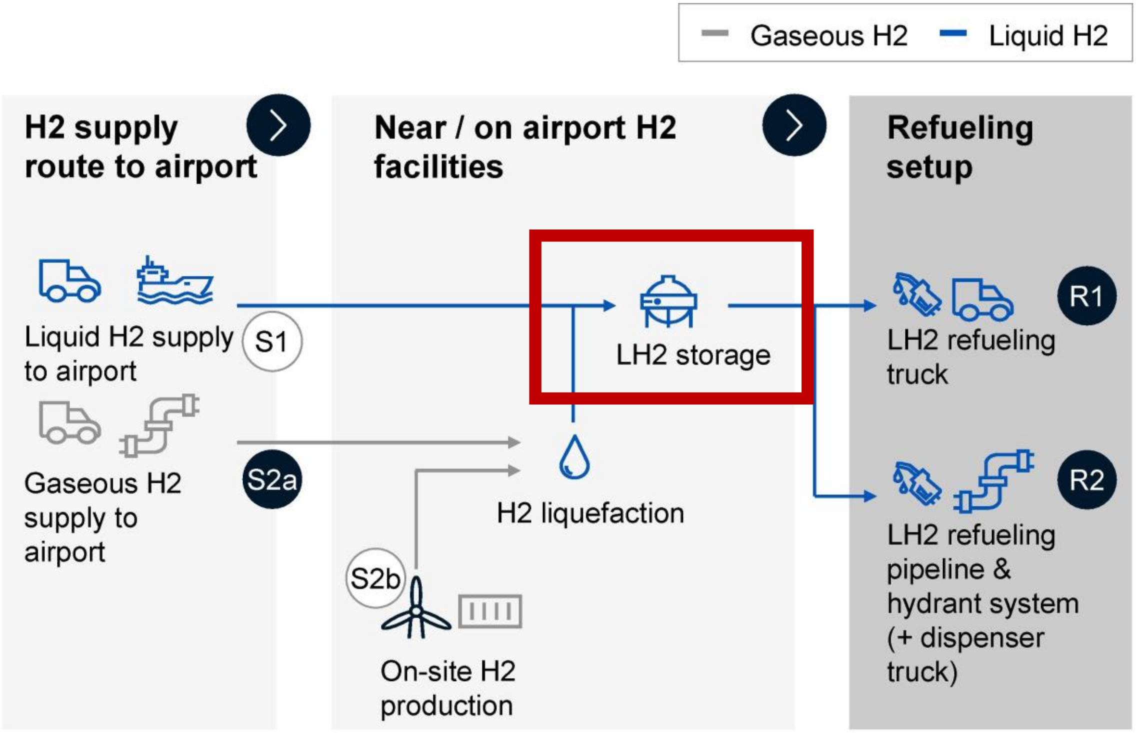
140m x 120m

16.800m²




Source: idealhy.eu

# On-Site Airport Facilities



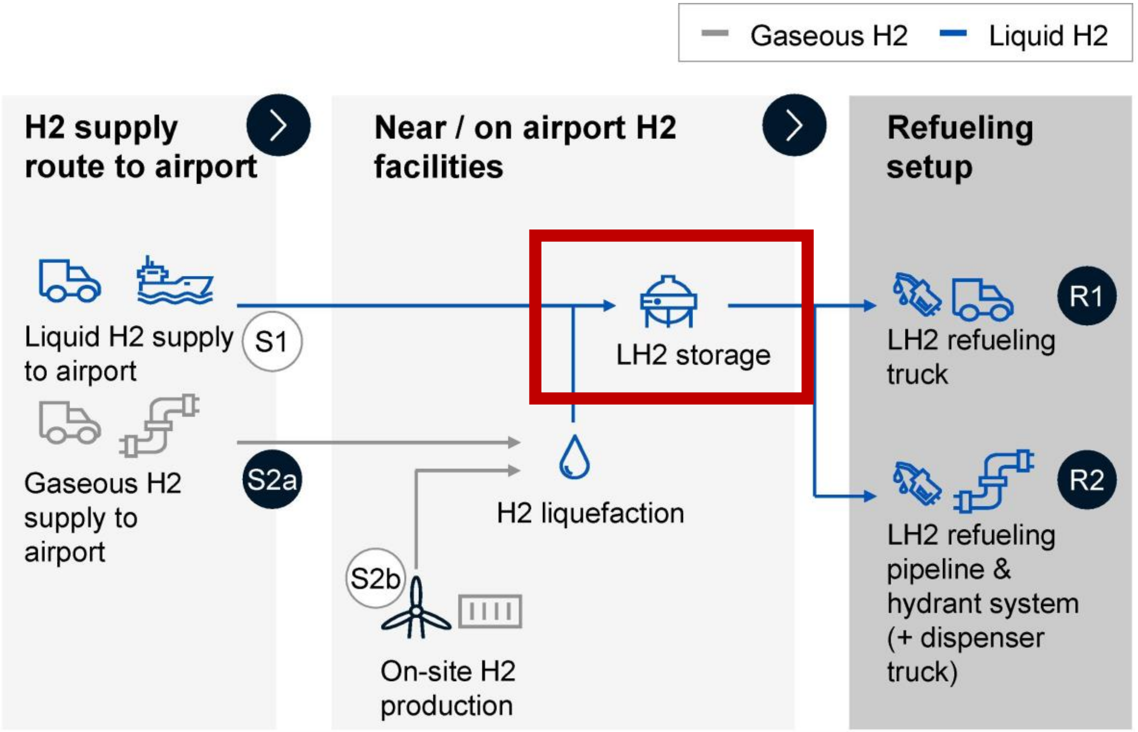

Source: H2-powered aviation at airports – Design and economics of LH2 refueling systems - ScienceDirect

## Spherical Tanks

- Storage Capacity currently < 4,700 m³ / 400t LH2
- Diameter for 400t LH2 storage: 25.3 m


Source: NASA

# On-Site Airport Facilities




Source: [H2-powered aviation at airports – Design and economics of LH2 refueling systems - ScienceDirect]

**Spherical Tank Place Demand Example**

Copyright: DLR

# Existing Liquefaction Plants

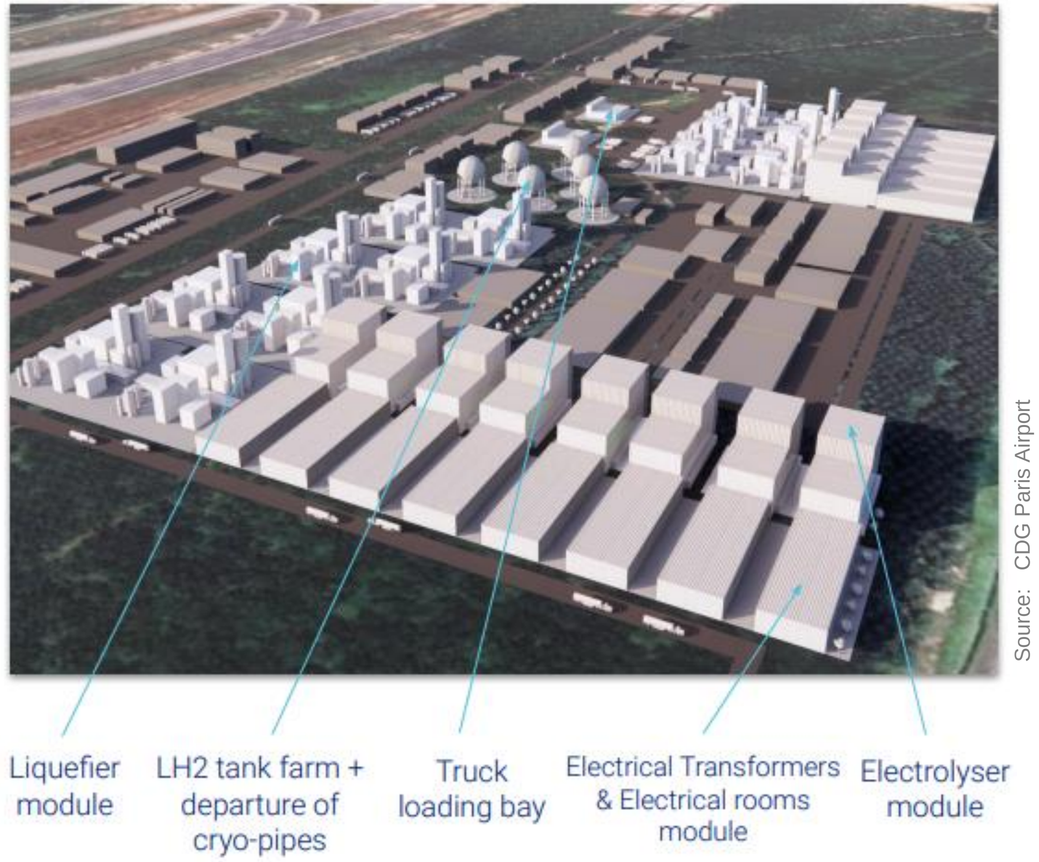
Filling bays


Source: Google Maps / Earth Screenshot


LH2 storages

# Exemplary On-Site Airport Facilities

**Example 700 TPD**
**Production + Liquefaction + Storage**




Source: CDG Paris Airport

**Example 300 TPD**
**Liquefaction + Storage**


Own illustration place demand example

- Place demand: < 6.2 ha
- Energy demand: ~ 2.700 MWh / d

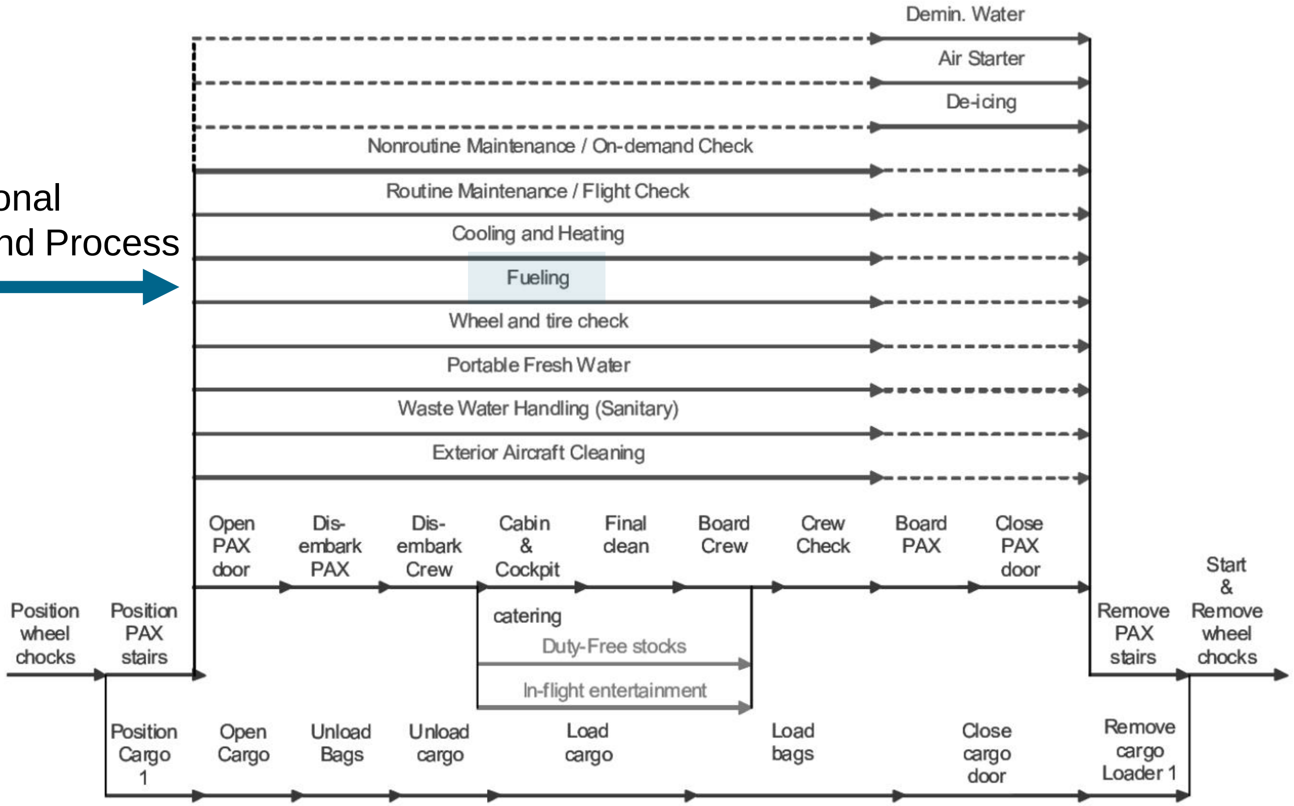
# 3. GROUND HANDLING

Stock Adobe

# Sequential and Parallel Turnaround Processes

Own Picture

Conventional Turnaround Process →

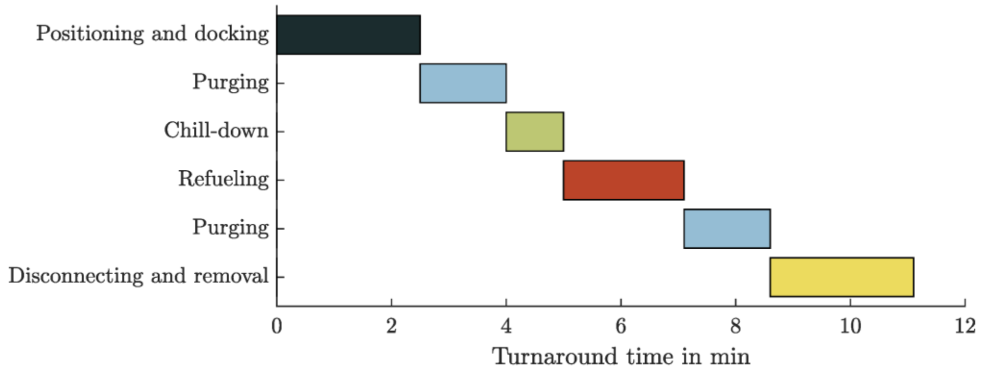



Source: Significant Turnaround Process Variations due to Airport Characteristics

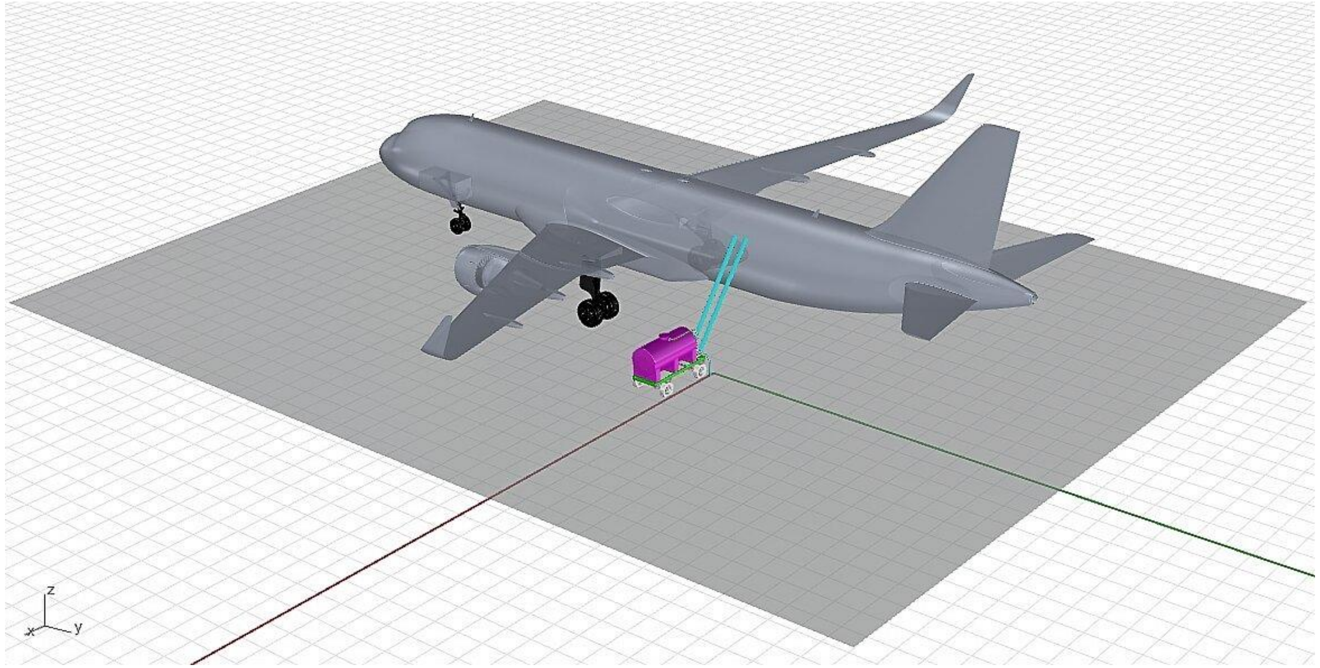
Source: AIRBUS

LH2 Turnaround Process → ?

# Refueling Process




Source: Jonas Mangold et al. - Refueling of LH2 Aircraft—Assessment of Turnaround Procedures and Aircraft Design Implication





**Connecting**

- Johnston coupling
- Clean break disconnect

**Purging**

- Remove foreign gases from hose and disconnect
- Extension of refueling time

- Critical factors: High volume flow and low pressure – parallel refueling required
- Losses can not be avoided

# Refueling Process
# Possible LH2 Spills

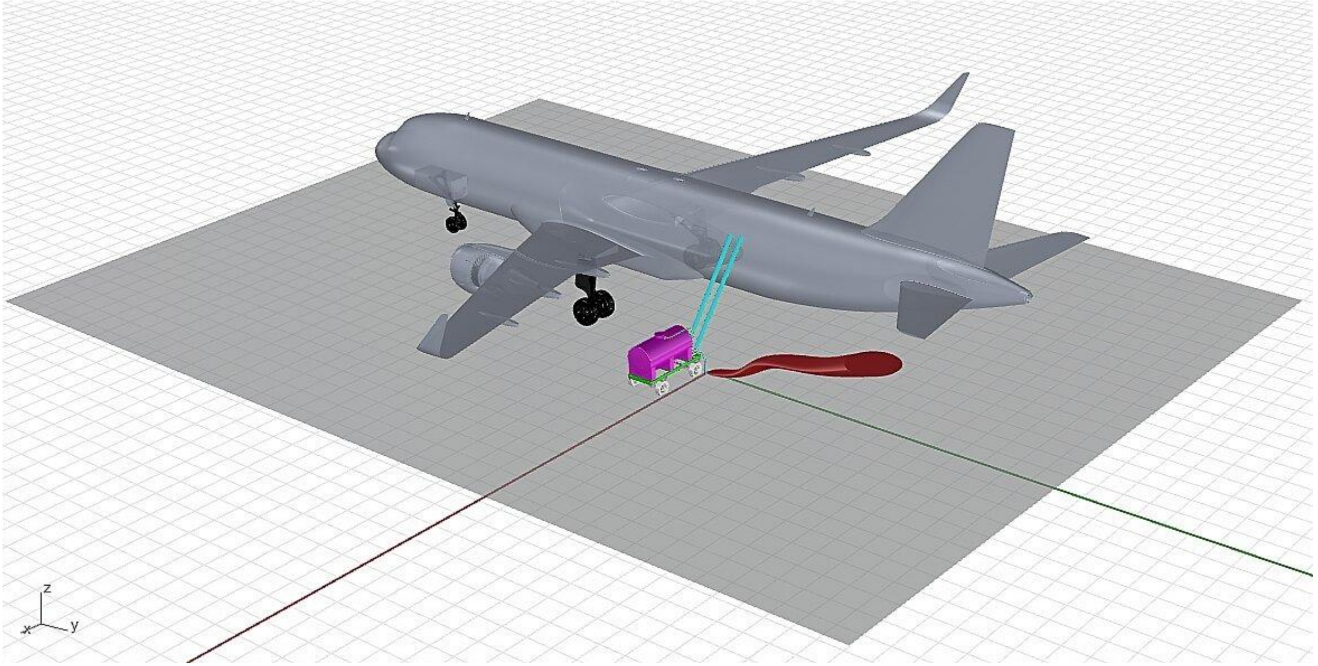
**Normal Conditions:**

- Connecting / Disconnecting
- Boil-Off
- Purging process
- Accumulation of hydrogen in hidden areas

**Incidents during Refueling:**

Historical incidents which had resulted in fuel spills occurring during fuelling of an aircraft

- Failure of valve
- Couplings becoming detached from the aircraft
- Vehicle impact damage to hydrant couplers
- Failure of hydrant couplers due to incorrect re-assembly



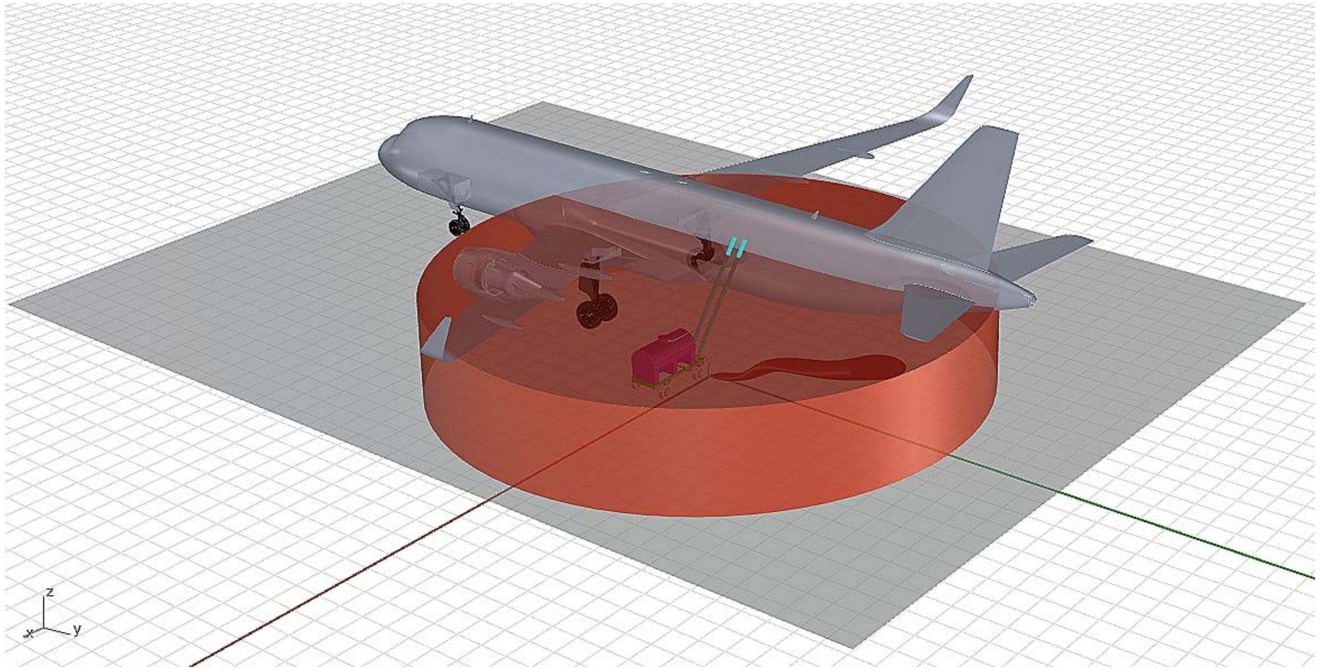



Determination of hazardous quantities of LH2 spills

# Refueling Process
# Potential Harmful Effects

**Fire Hazards**

- Explosive Atmosphere
- Lower flammability limit (LFL): 3.6 vol.%
- Upper flammability limit (UFL): 77 vol.%
- Minimum ignition energy: 0.017 mJ 30 vol.% (Jet A1: 0.2 mJ)





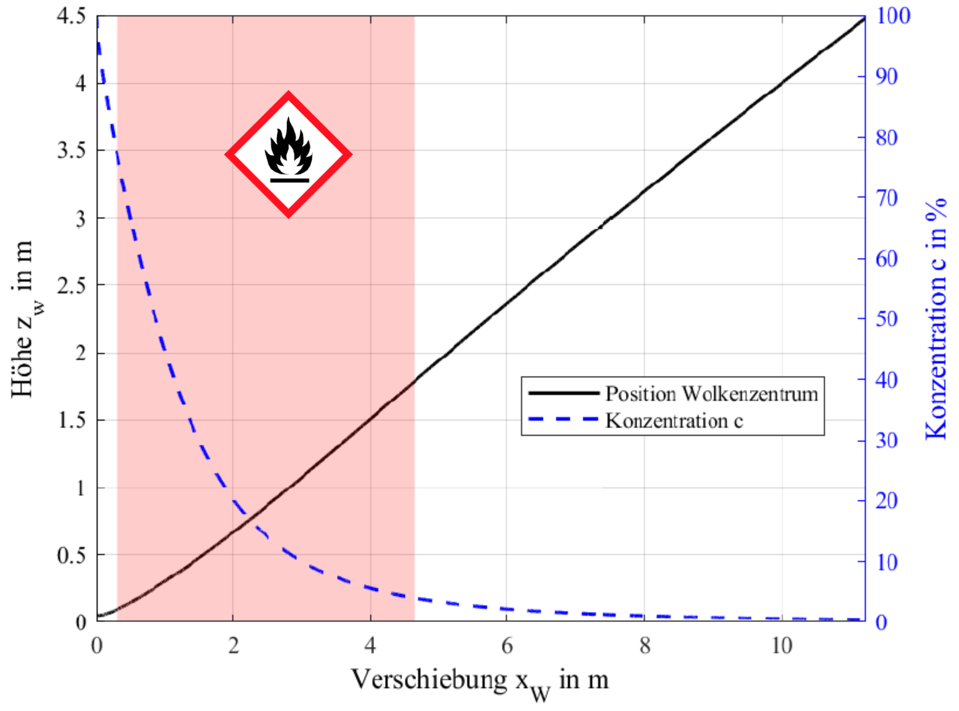
**Cryogenic Hazards**

- Cryogenic Temperature can cause cold burns
- Protective measures: gloves with face shield and eye protection

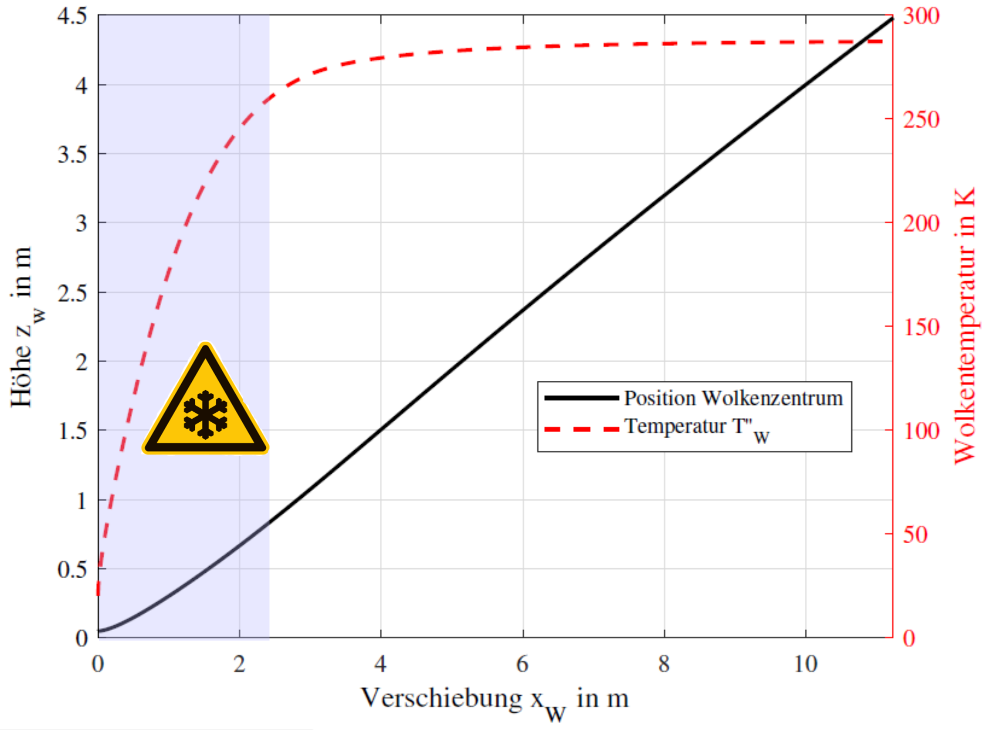
All H2 threats conditions should be considered

# Hydrogen Dispersion Resulting from Leakage

Hydrogen Concentration



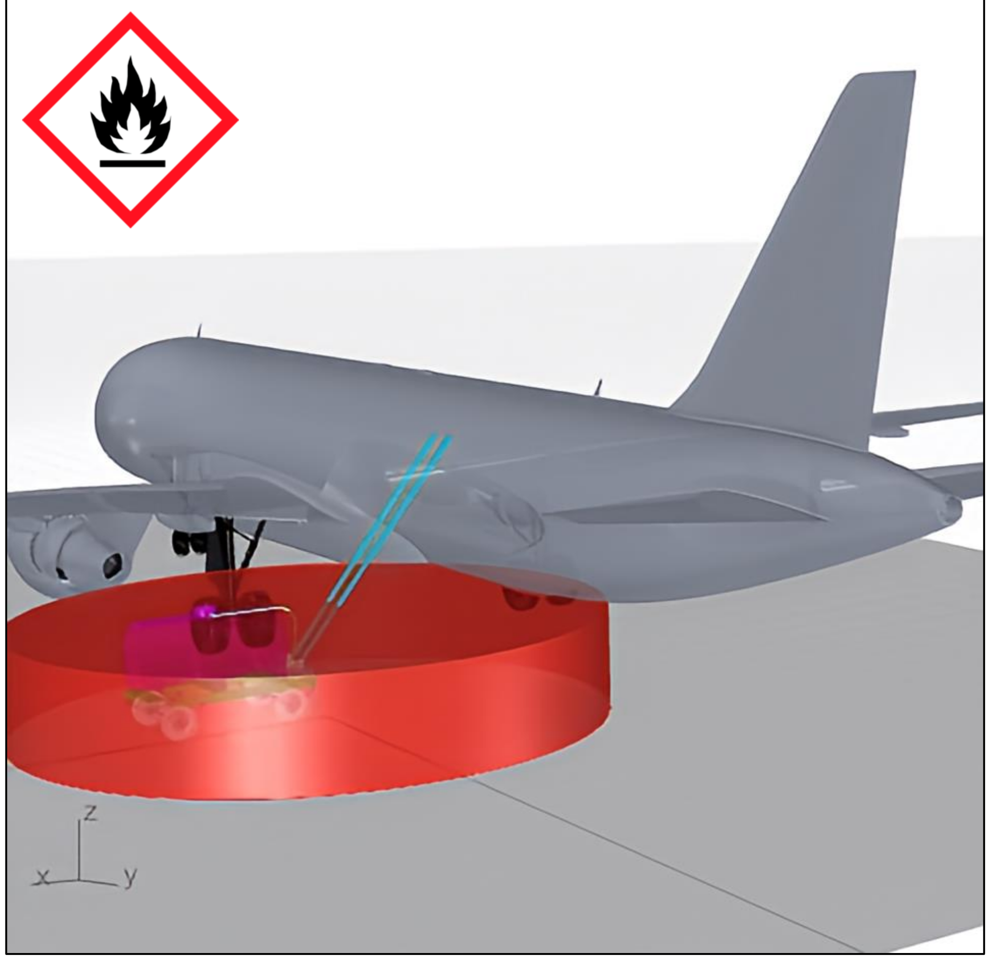

Temperature Profile



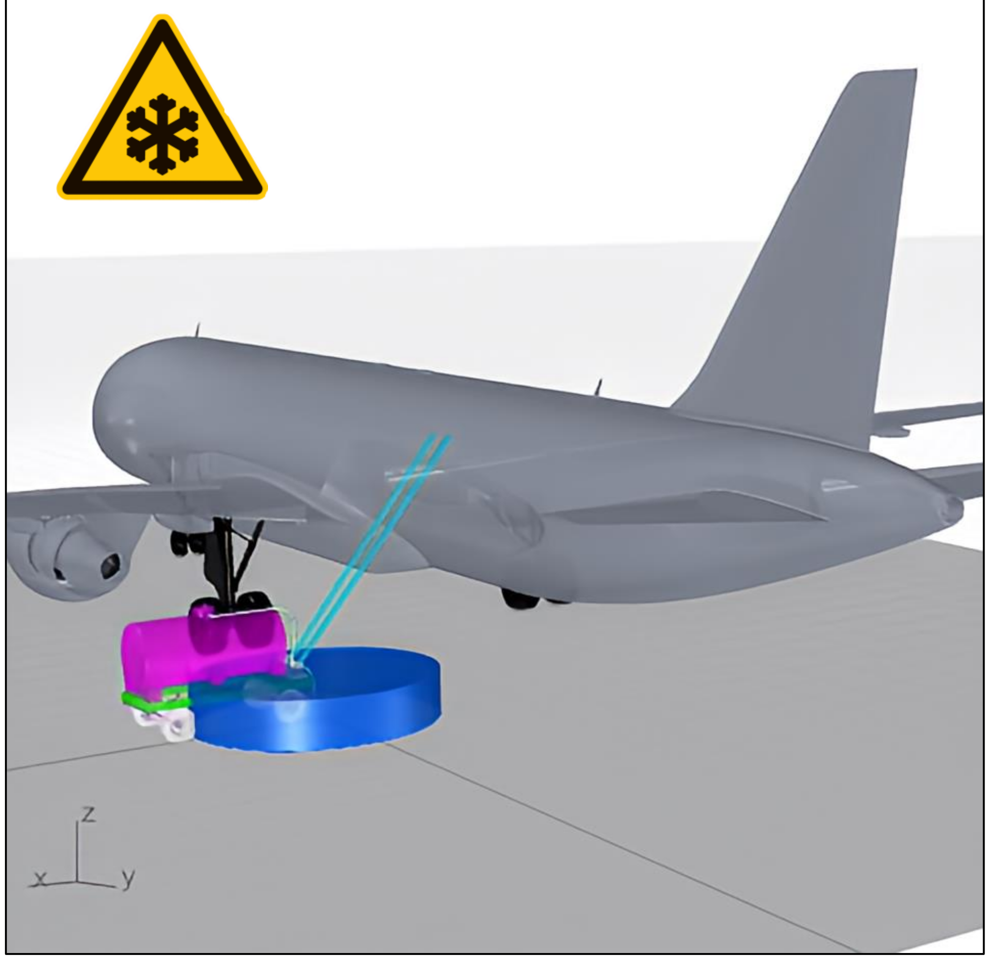

| Parameter | Einheit | Beschreibung | Wert |
|---|---|---|---|
| $\Delta t$ | s | Intervallschritt | 0.001 |
| $t$ | s | Gesamtzeit | 10 |
| $r_1$ | m | Austrittsradius | 0.075 |
| $T_E$ | K | Temperatur der Umgebungsluft | 288.15 |
| $h$ | - | Relative Luftfeuchtigkeit | 0.5 |
| $v_r$ | m $s^{-1}$ | Windgeschwindigkeit | 2 |
| $P$ | Pa | Umgebungsdruck | 101325 |

# Safety Area Example

**Explosive Atmosphere**




**Cryogenic Hazards**



# THANK YOU FOR YOUR ATTENTION!

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** Acting*