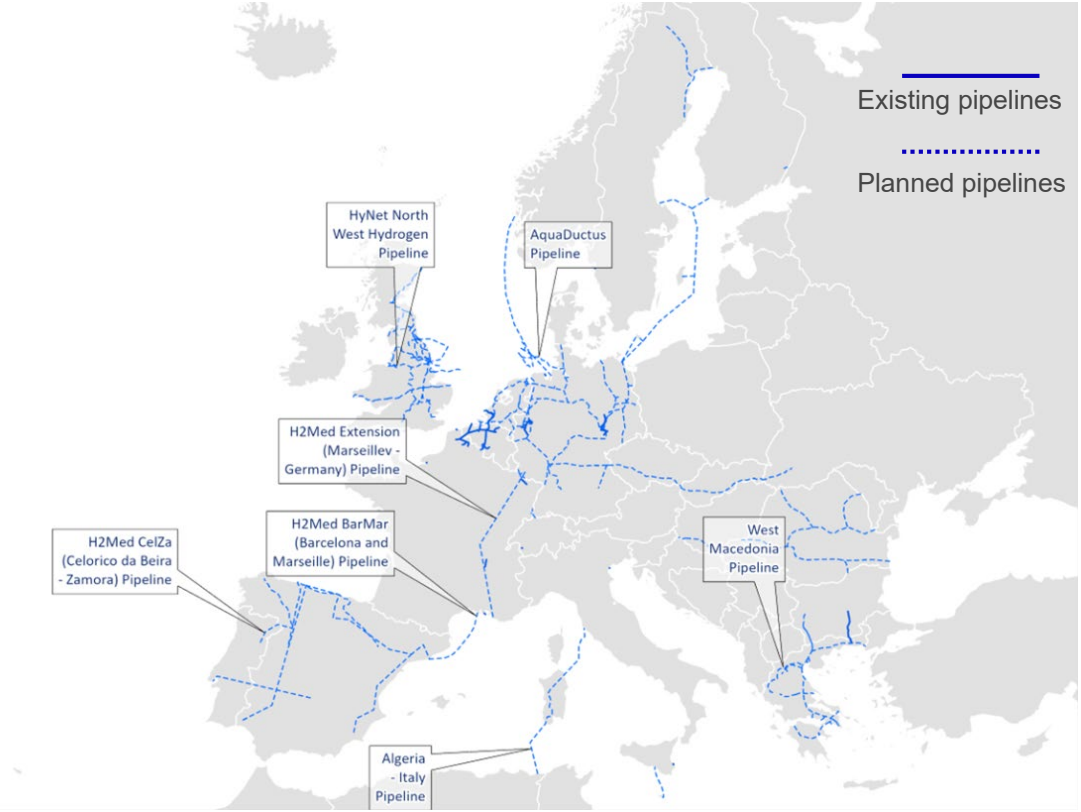
H_2- FROM PRODUCTION TO CONSUMPTION

Virtual Pipeline in the Retail Industry

Why is Hydrogen important?

Hydrogen Transfer by Pipelines



Source: Rystad Energy Hydrogen Solution

Existing Pipelines

- Natural Gas and H_2 are blended
- Regional: mayor industry sites are connected

Planned

- Supplying huge consumers
- Repurposing the existing NG infrastructure for H_2

Current Situation

- H_2 production and consumption need to be connected in addition to Pipelines

What is the Alternative? Virtual Pipelines! Why?

Source: US Department of Energy

- **7 Mayor H2 Hubs**
  - Local Production
  - Local Consumption
- **Remote Locations**
  - Pipelines are too expensive / hard to build

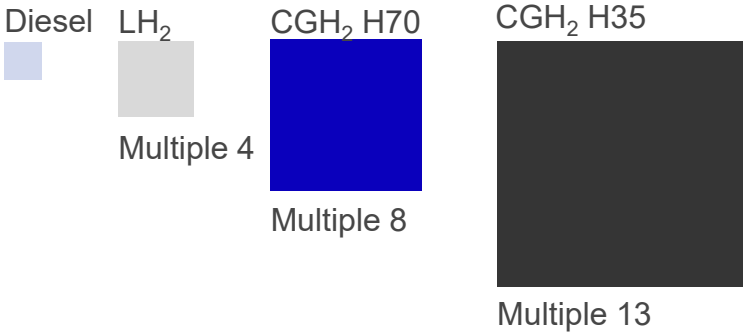
→ Connection by Virtual Pipelines necessary

H_2 Virtual Pipeline Options?

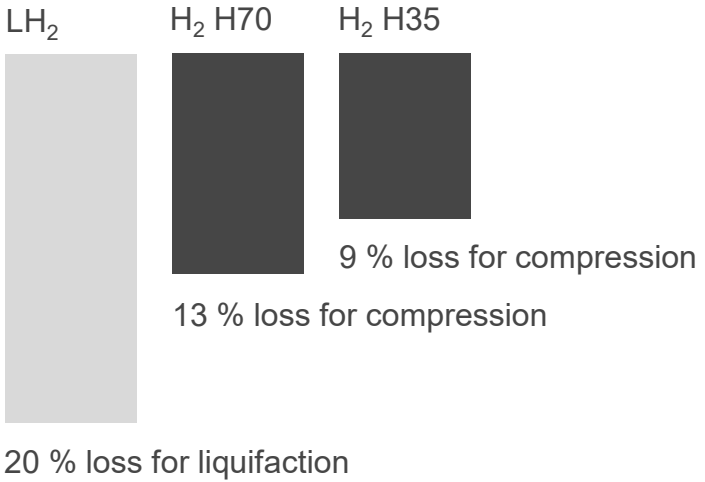
Definitions

- LH_2 = Liquid Hydrogen @ -253 °C
- (s)LH_2 = subcooled Liquid Hydrogen @ -255 °C
- CGH_2 = Compressed Gaseous Hydrogen
- Hydrogen Service Pressure Levels = H35 / 350 bar, H70 / 700 bar

Required Tank Volume – same Energy Content



Energy Consumption for Production



How cost and availability develop is today not predictable.

The Future. Just began

Compressed H2

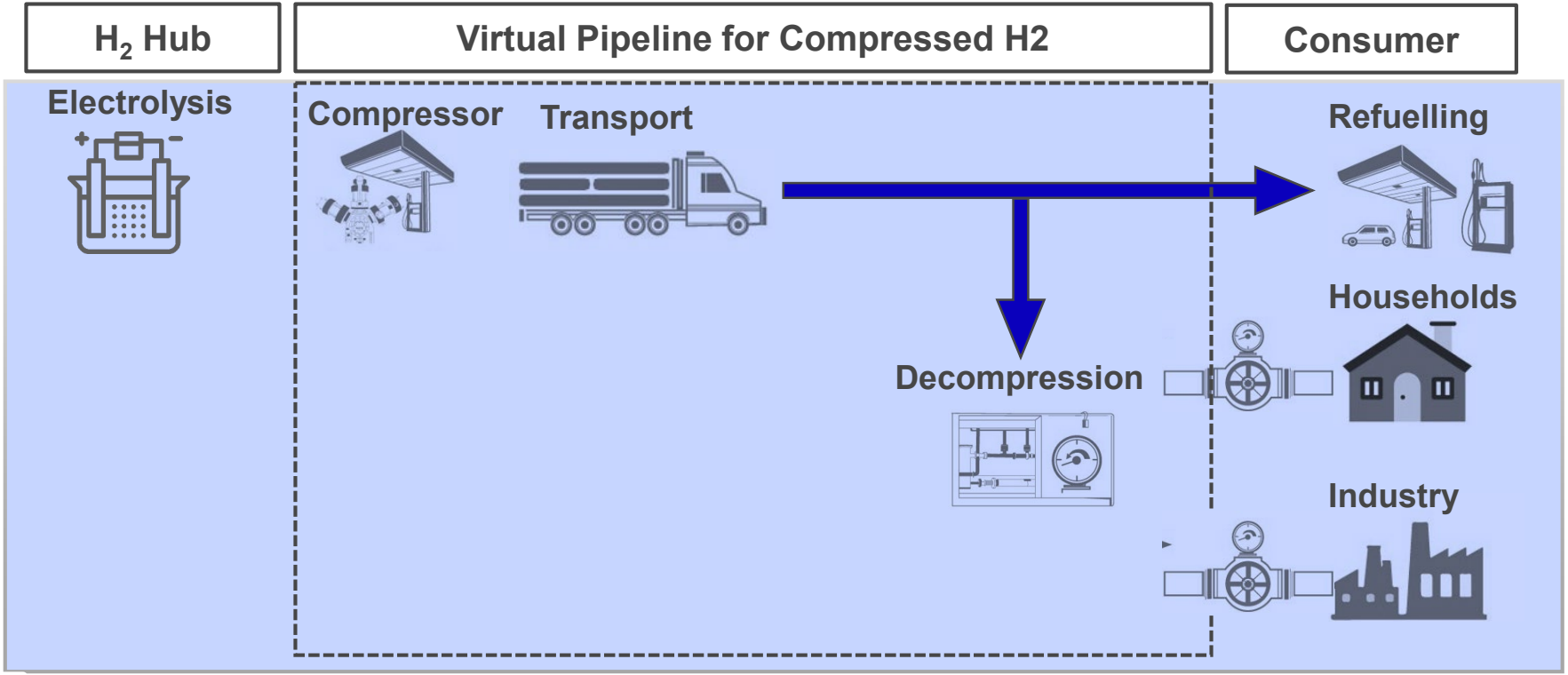
Up to 31 MWh / Trailer

Liquefied H2

Up to 150 m^3/h

What is a Virtual Pipeline? Principle and Definition CGH2

A virtual pipeline (VP) transfers gas via road, rail or ship to consumers without physical pipelines



Virtual Pipeline for Compressed Gaseous H_2 – CGH2

Virtual Pipeline for Compressed Gaseous H_2 – CGH2

CGH_2 refilling equipment

End of CGH_2 virtual pipeline

What are the challenges of CGH2?

Challenges with CGH2	Subsequence
High Pressures	High Forces → extensive testing
Material Compatibility	Embrittlement
Hydrogen Permeation	Product Loss
Leakage Prevention	Product Loss
Safety Concerns	Explosion hazard
Expansion	Overpressure hazard
Contamination Control	Contaminants can destroy fuel cells

Source: Quantum Fuels Type IV H2 Trailer

Equipment to transfer CGH2 from Production to Consumption

Tank Head Valves

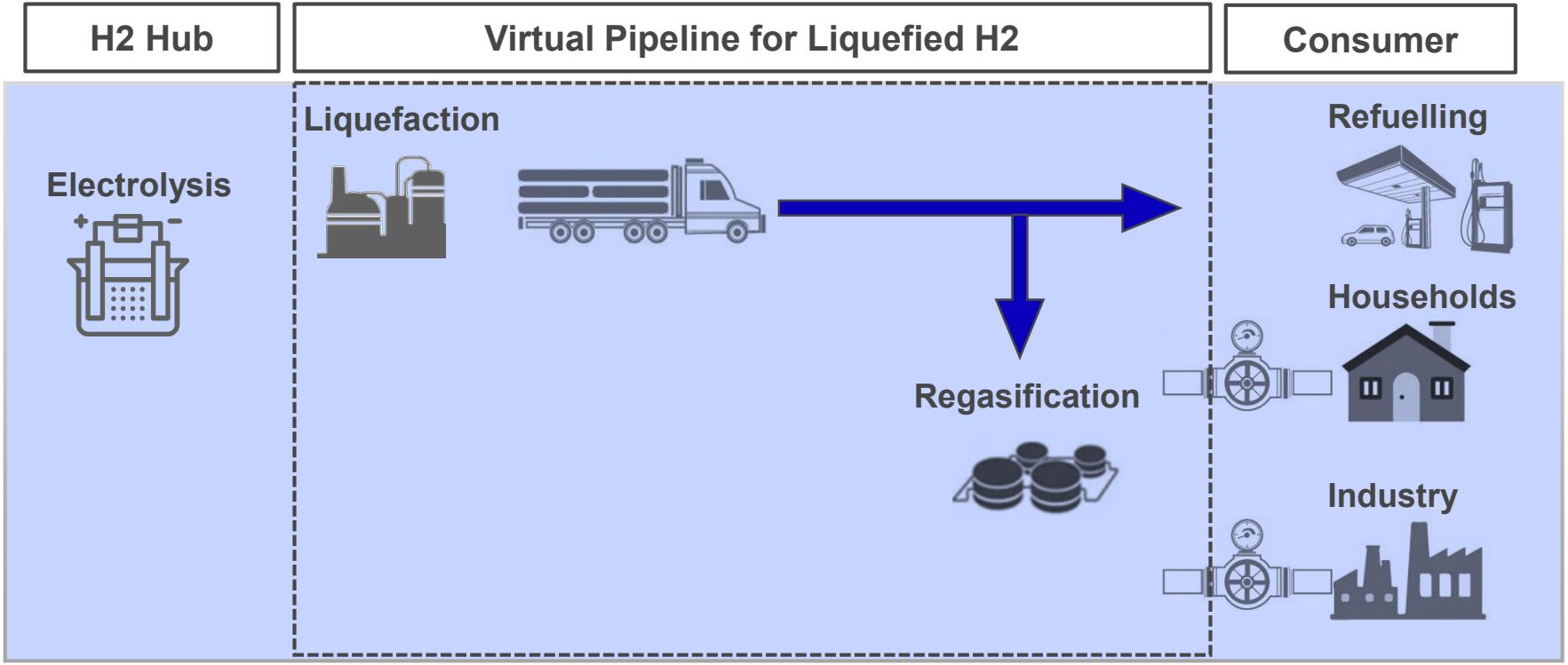
Ball Valves

Manifolds

Quick Couplers

What is a Virtual Pipeline? Principle and Definition LH2

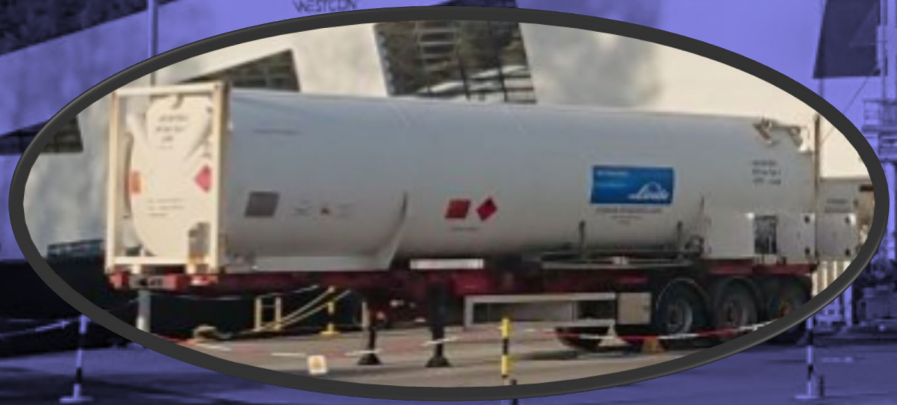
A virtual pipeline (VP) transfers gas via road, rail or ship to consumers without physical pipelines



Virtual Pipeline of Liquefied H2 – LH2

Virtual Pipeline of Liquefied H2 – LH2

End of LH2 virtual pipeline

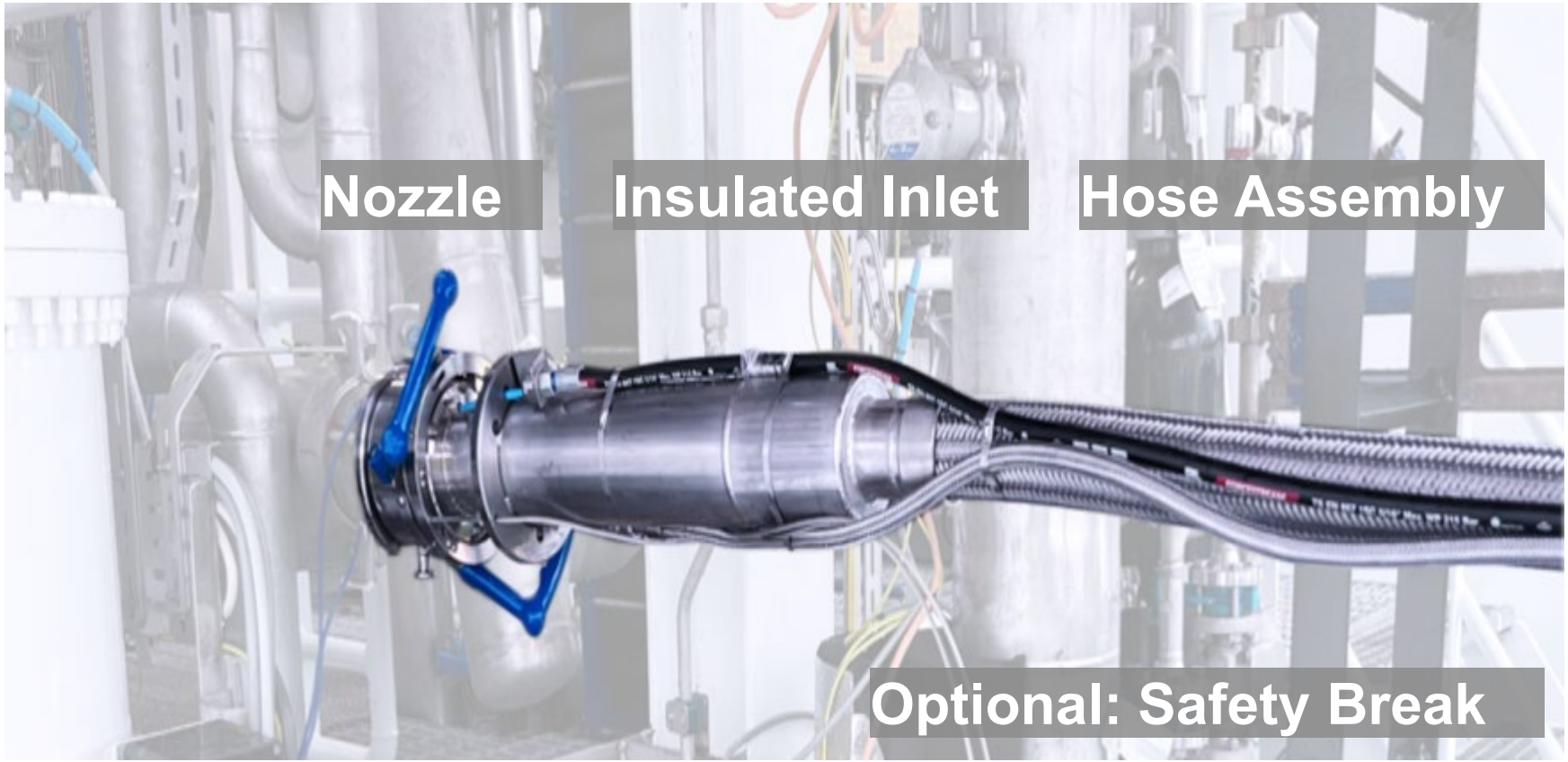


LH2 tank and refuelling equipment

What are the challenges of LH2?

Challenges with LH2	Subsequence
Low Temperature Operation	Isolation
Material Compatibility	Embrittlement Stiffness / Flexibility
Hydrogen Permeation	Product Loss
Leakage Prevention	Product Loss
Safety Concerns	Explosion Hazard
Thermal Expansion	Overpressure Hazard
Contamination Control	Purity degradation Loss of efficiency

Equipment to transfer LH2 from Producer to Consumer



(s)LH2 - Truck Refuelling Equipment

General information

- For the refuelling of vehicles like trucks
- Subsequent locking, purging and opening
- Manual and pneumatic (semi-automatic) version
- TÜV approved

Specification

- DN 20, 100 l/min (max 150 l/min)
- Filling time 12 minutes (range from 10 to 15 min)
- -253°C to +50°C
- Various connections to dispenser available
- Optional semi automatic version available

Ship Bunkering LH2 Quick Connector DN50

General information

- LH_2 transfer for various applications
- Multiple applications in field
- Intuitive handling

Specification

- Transfer rate 150 m^3/h
- -253°C to +50°C
- Max flow velocity 12 m/s

Invitation (All)

- Please come around to see the Equipment and to discuss Details
- Hall 5, Booth B02