

GENERATING
A CLEANER
FUTURE

Air Products Introduction for the Liquid Hydrogen Knowledge Community

Presented in “1e bijeenkomst van de LH2-
kenniscommunity” (04/02/2025)

at Ministry of Climate Policy and Green Growth

by
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AIR
PRODUCTS 

Who is Air Products?



Our **Higher** Purpose

Bringing people together to **collaborate** and **innovate** solutions to the world's most significant energy and environmental sustainability challenges

We need to collaborate **today** to plan for **tomorrow**



Total Safety Philosophy

Maintaining a safe workplace is a **fundamental and moral responsibility.**



We take the approach that all accidents are preventable. The only acceptable goal is **zero** accidents and incidents. We will strive toward that goal in **every location, every day.**

Air Products at-a-glance

23,000 employees

83 years of industry leadership

50+ countries

750+ production facilities

110+ hydrogen production facilities in operation today

9,000+ tones of hydrogen per day production

109+ TWh of hydrogen per year production

and

65 Years safely operating hydrogen molecules



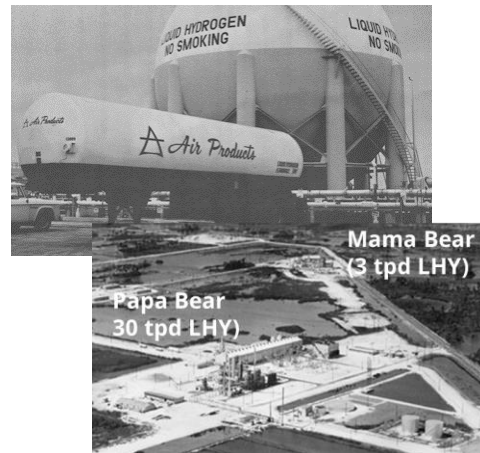
The world's largest
hydrogen supplier,
and a global leader
in the industrial gas
industry

When it comes to hydrogen, Air Products has been answering the call for more than 60 years.

1950s

Played a supporting role in the United States' space race

- Supplies hydrogen to the U.S. Air Force and later NASA
- Helped start space race by supplying liquid hydrogen



1980s

Taking part in the movement to prevent acid rain

- Becomes the leading global supplier of refinery hydrogen to desulfurize pollutants that cause acid rain



2000s

Pioneering hydrogen energy for mobility

- Started developing hydrogen refuelling solutions for vehicles reaching 1,000,000 in 2012



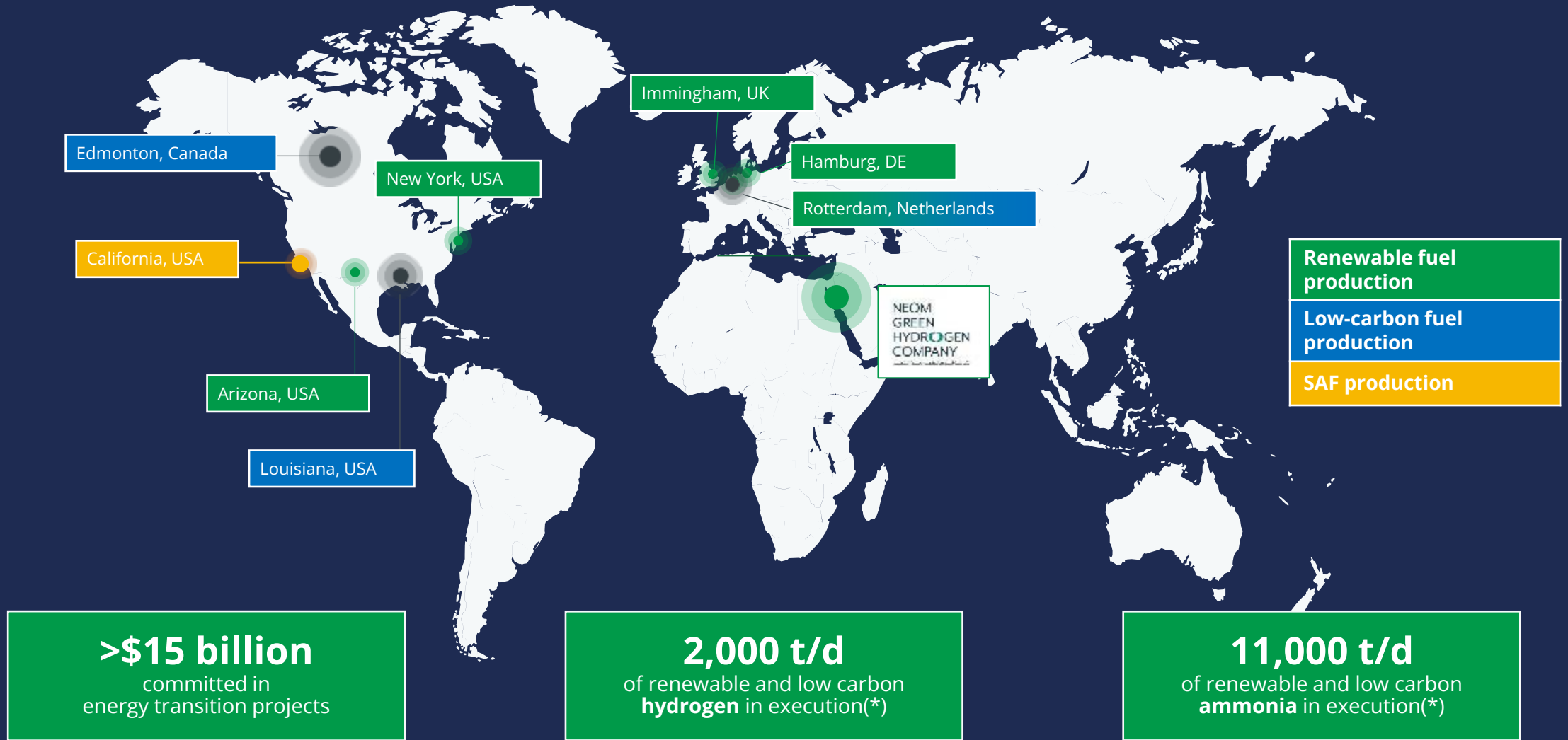
2020s

Leveraging hydrogen innovation and technology to meet the world's demand for a sustainable future

- Developed global hydrogen strategy to answer Energy Transition challenge

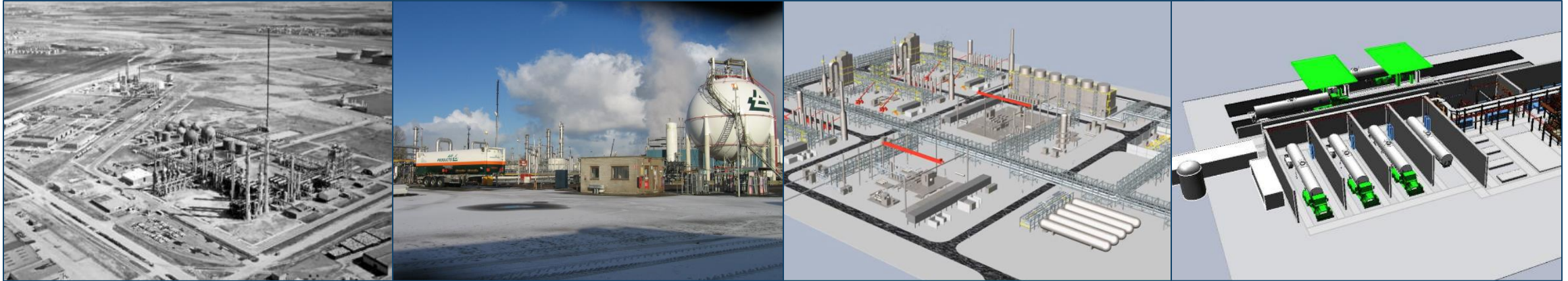


Air Products is globally shaping a renewable and low-carbon fuel supply chain



(*) co-location of projects allow synthesis/dissociation between the 2 fuels

Our presence in Rotterdam



70^s

Established first hydrogen franchise in Europe with subsequent growth from local refineries to remove sulfur from oil.

88 : FIRST EU LIQUID H₂ PLANT

Hydrogen liquefaction plant built to supply European Space Program

RENEWABLE HYDROGEN FACILITY

Air Products and Gunvor Energy Rotterdam (GER) have signed a development agreement for a renewable energy import facility in Rotterdam.

NEW LIQUID H₂ FILLING

Started construction of a second hydrogen liquefaction plant in Rotterdam.

Renewable hydrogen imports

From NEOM to Rotterdam



NEOM
GREEN
HYDROGEN
COMPANY

شركة نيوم للهيدروجين الأخضر



NEOM Green Hydrogen Company project is at the forefront of market development

It is world's largest green hydrogen facility, **300 km²**



Leveraging expertise from **4** major leading technology partners



We are the exclusive off-taker of NEOM Green Hydrogen Company project

The first fully funded world-scale renewable hydrogen and ammonia facility

4 GW of renewable power

produced by 2.4 GW of solar PV panels
and 1.6 GW of wind turbines

2.2 GW

electrolysis package to generate
hydrogen from water

Up to 600 tonnes

of renewable hydrogen
produced per day

Up to 1.2 Mio tons

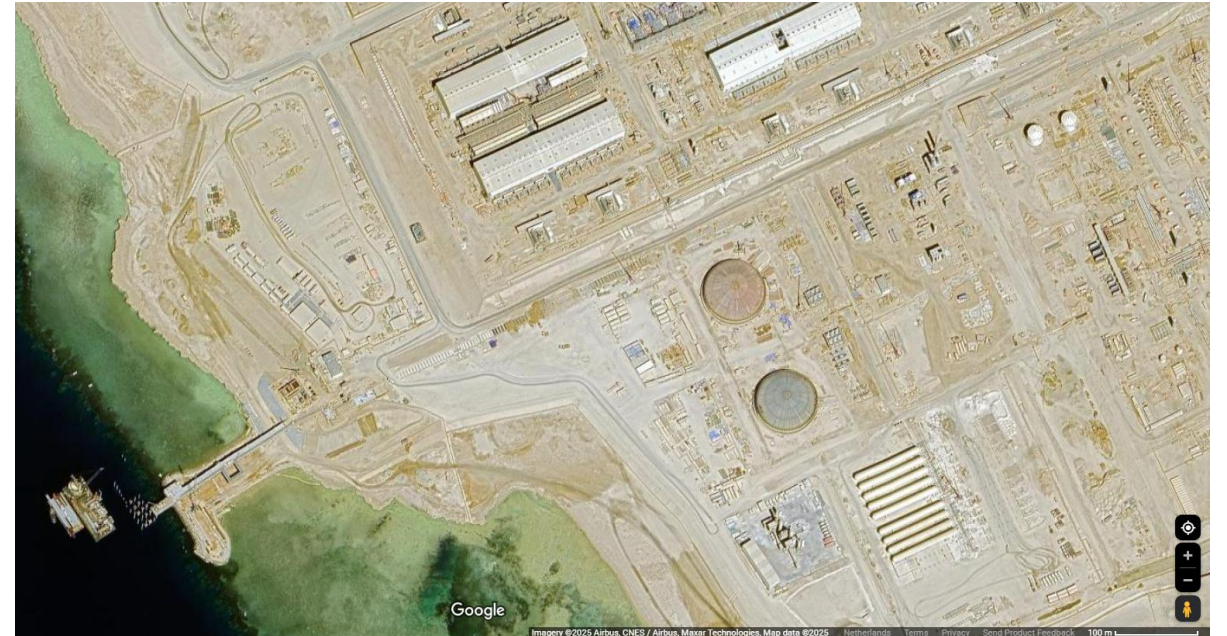
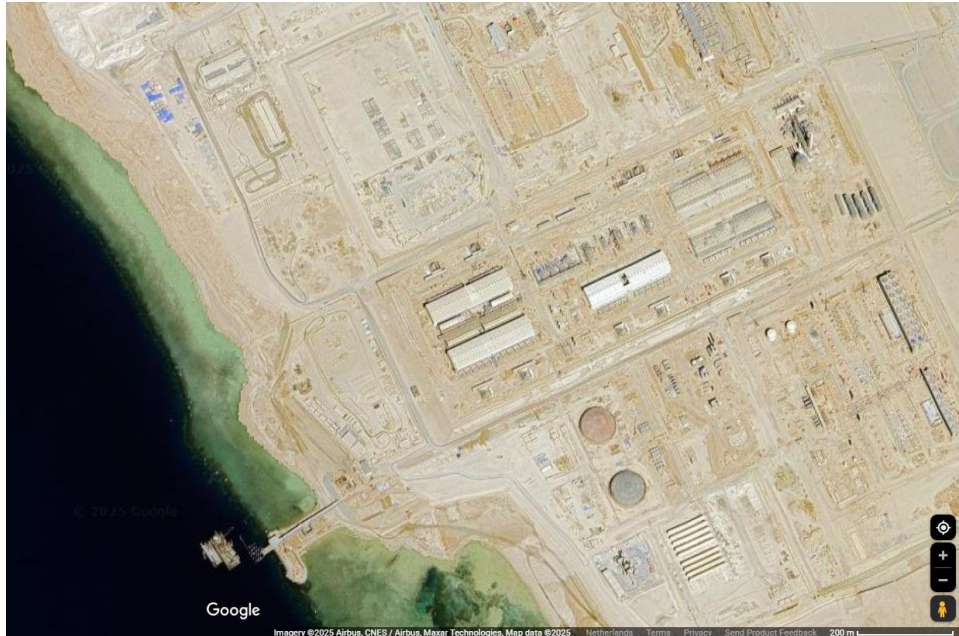
renewable ammonia
exported annually
from end 2026

Dedicated jetty

for the direct transfer
of renewable ammonia
to tanker ships



NEOM plant is 60% ready



Immingham (UK)

Hamburg (GER)

Rotterdam (NL)



Exporting **green hydrogen** to global markets at scale

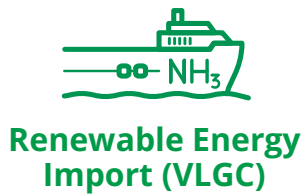


NEOM
GREEN
HYDROGEN
COMPANY

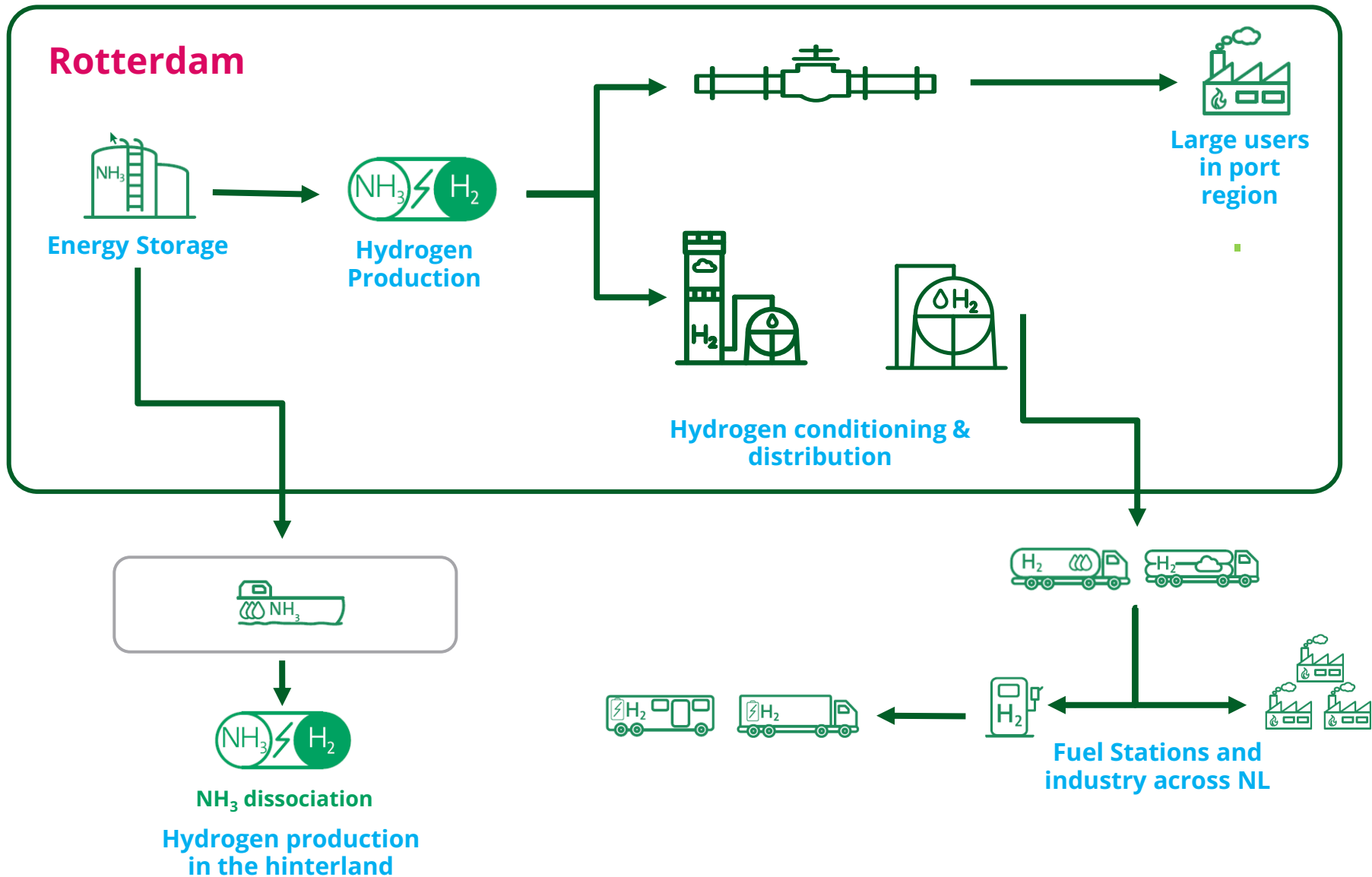
شركة نيوم للهيدروجين الأخضر

How to transport hydrogen from NEOM?





Renewable Energy Import (VLGC)



Port-to-port, liquid ammonia is most favorable for moving hydrogen over long distances.

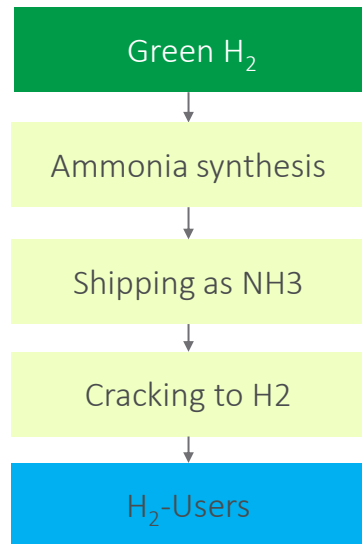
	Ammonia	LHY	LOHC	Solids (Metal Hydride)
H ₂ carrying capacity (wt %)	17%	100%	6%	1-15%
H ₂ carrying capacity (kg/m ³)	118	71	48-60	150
Energy efficiency	90%	73%	72-78%	<80%
Boiloff management	Low	High	N/A	N/A
Dead weight on return trip	Low	Low	High	High
Carrier losses	Low	High	Medium	Medium
Difficulty of material handling	Medium	Medium	Low	Medium-High
Overall technology readiness	High	Low-Medium	Medium	Low

For transport by sea, Ammonia is preferred.

World has an Ammonia shipping network in place.

Ammonia via ship

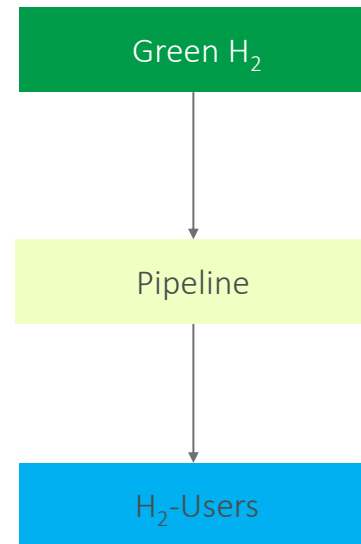
Maturity: High



- + Infrastructure in place and known technology i.e. bunkering, pumps etc.. Ships already in use
- Toxic but with known handling procedures Capital intensive

H₂ Pipeline

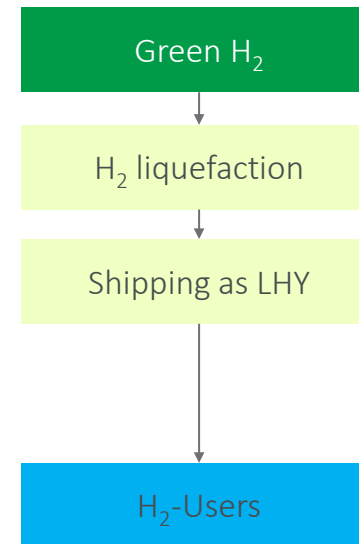
Maturity: High



- + Best for meeting large H₂ demand in one location (e.g., steel)
- Capital intensive and significant time for construction internationally Not considered for long distance transportation

LHY via ship

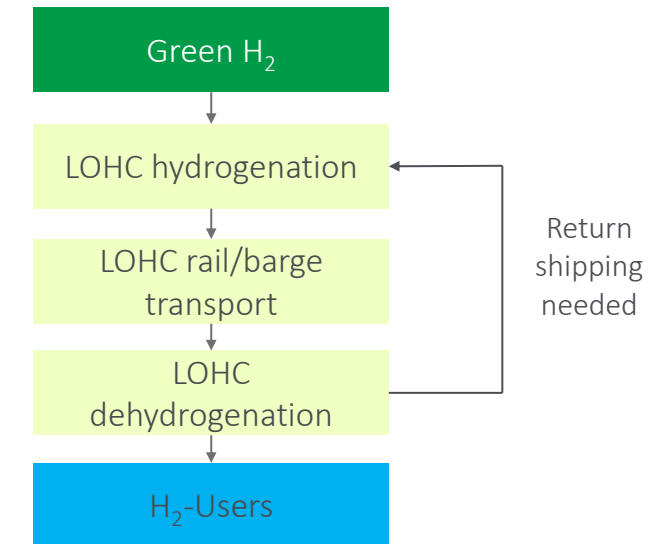
Maturity: Low



- + Known technology
- Limited international shipping industry and no infrastructure in place Energy required for boil off recovery Explosion safe zones around large scale storage as large

LOHC / Solid H₂ carrier

Maturity: Medium

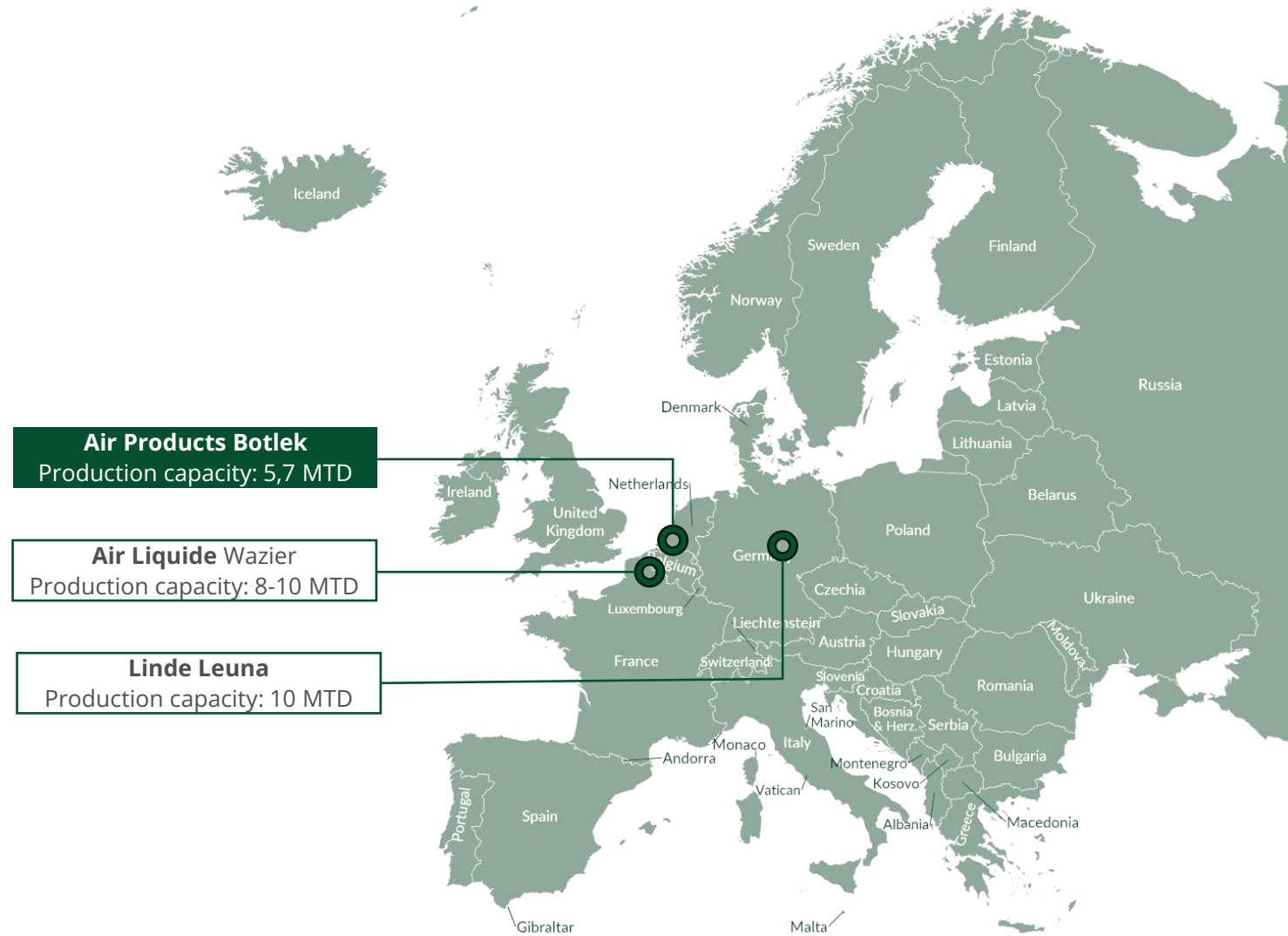


- Reverse logistics required for dehydrogenated LOHC Some technologies are toxic
- Solid handling can be problematic and slow compared to liquid handling Low TRL vs other solutions

Liquefaction in Rotterdam (NL)



LHY Sources in Europe



09/21/2022 | ROTTERDAM, THE NETHERLANDS

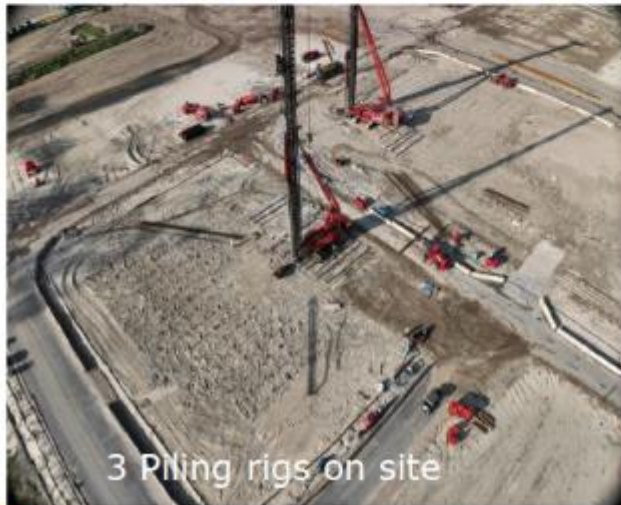
Air Products to Start Construction of Second Liquid Hydrogen Plant in Rotterdam

New plant brings additional liquid hydrogen capacity to Europe

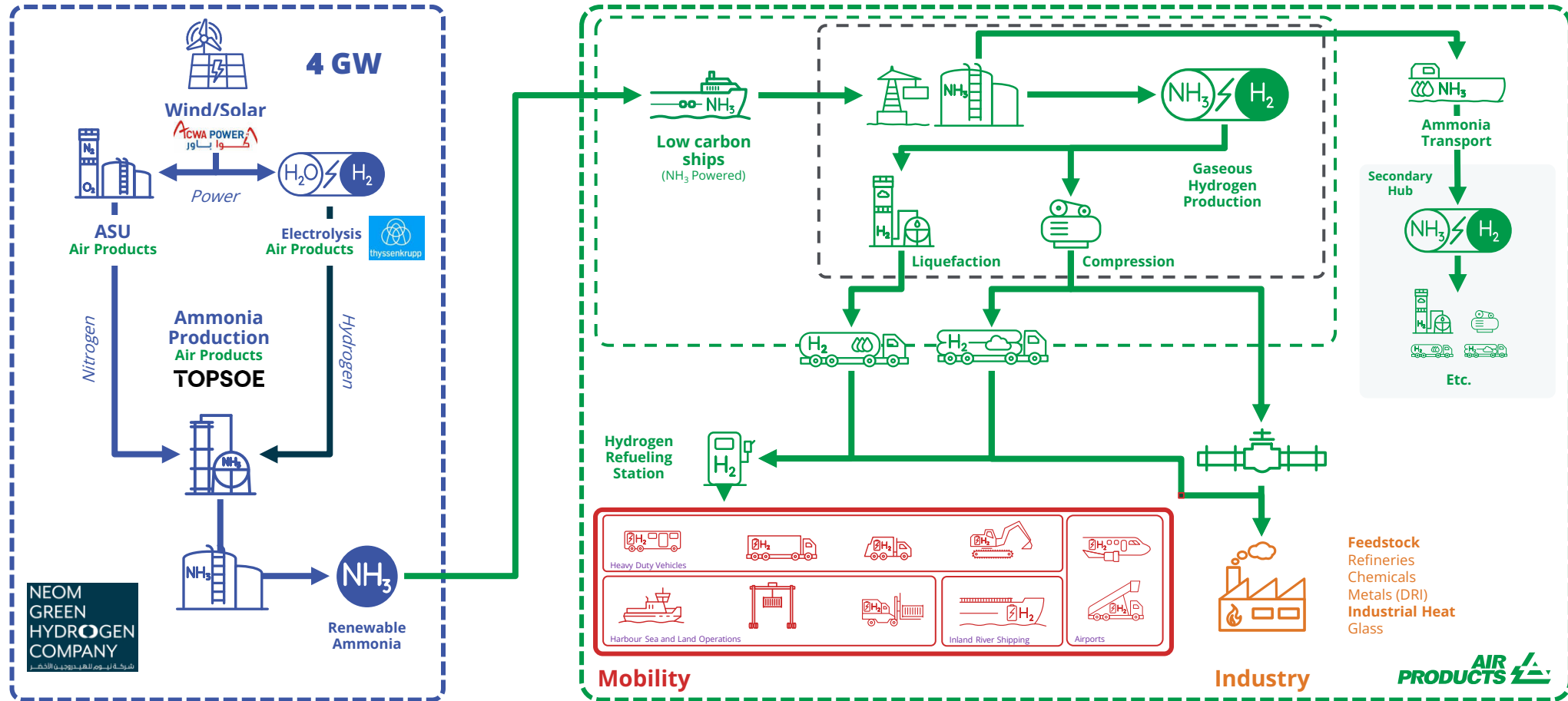
This new source is in addition to the company's existing liquid hydrogen plant in Botlek, the Netherlands.

Once operational, the plant will double Europe's total current liquid hydrogen capacity.

Air Products liquefier is under construction!



Air Products is the exclusive off-taker from NGHC for the next 30 years



Liquid Hydrogen (LHY) Applications

Liquid to Industry

Liquid to Mobility



From LHY Storage and Plant to various industries



Modes of Transport of Liquid Hydrogen



Liquid hydrogen is the answer to large bulk demand

Liquefaction process gives hydrogen **3x** more density than in gaseous form at 300bar



Reduce footprint

With cryogenic storage tanks and cryogenic pumps when required



Minimise power demand

With Cryogenic compression of liquid & gaseous hydrogen through Air Products CHC technology



Simplify hydrogen logistics

By larger delivered volumes >3t and fewer vehicles' movements in and out customer sites



Delivering liquid hydrogen to various industries

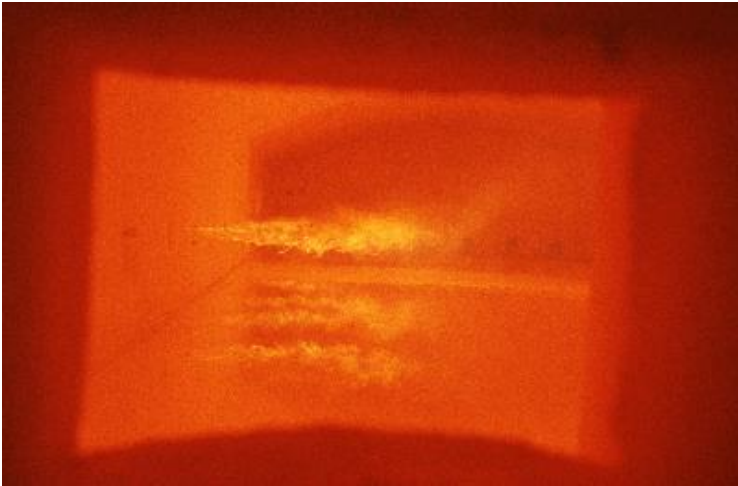
Space Industry



Semiconductor Industry



But as well LHY for testing and demonstrations in industrial applications



Hydrogen for combustion replacing natural gas in specific furnaces



Engineered solutions to meet specific requirements
Example 33Mt H₂ over 5 days & peak flow rate : +15 kNm³/h



Optimised supply chain with deliveries reduced by 90%

Hydrogen for mobility... the beginning (from 1957)



Meeting challenges of public transport captive fleets operation

Modular proprietary technology for Liquid Hydrogen Storage and compression to provide hydrogen as gaseous fuel at 350bar

Key features

Phase 1 capacity

>1,500kg/fuelling window

Phase 2 capacity

>3,000kg/fuelling window

Bus fuelling time

<7min

Total footprint

22m x 22m

Fuel availability

>99%



Liquid hydrogen to support trucks refuelling stations



High Pressure CHC technology

provides high flow fuelling capability for HRS to meet 10-15min 700bar fuelling time



Subcooled Liquid Hydrogen

for improved fuelling performance with longer range and faster fuelling



Warrant renewable fuel

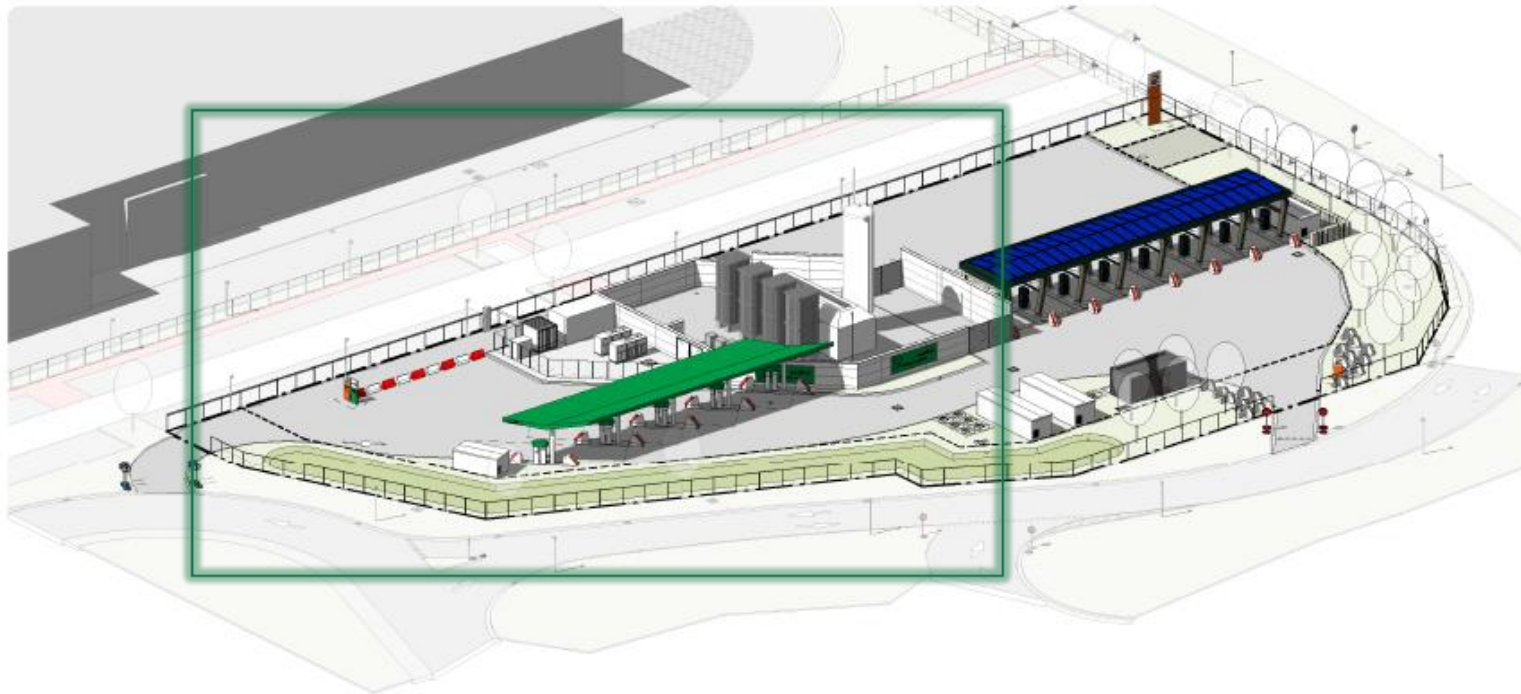
to the end customers through a certified scheme meeting the latest European Directives



DAIMLER TRUCK



Multi Modal Liquid Hydrogen Refuelling Station @ Ghent



Multi modal HRS Solution

- Capacity hydrogen storage tank ~ 4.9T
- 4 truck lanes
- Dual pressure dispensers H70/H35
- Plot/layout scalable for future growth: *space and measures prepared for capacity uptake & integration sLH2 technology*
- Focus on Heavy Duty Vehicles
- Alignment with AFIR
- Build-Own-Operate business concept

Liquid Hydrogen is an opportunity for maritime decarbonisation

Certified as a Renewable Fuel from Non-Biological Origin (**RFNBO**) it can support operators journey to meet EU maritime regulations

Liquid H₂ containers swap

To minimise port infrastructure and facilitate implementation



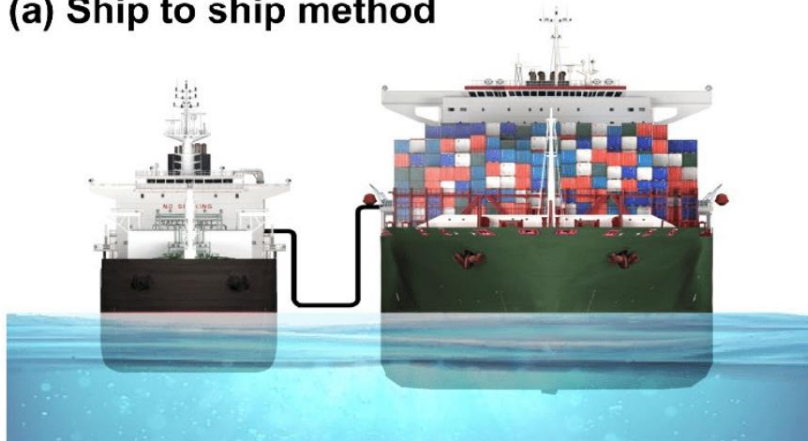
Onboard H₂ storage bunkering

To simplify refuelling operations and supply larger volumes

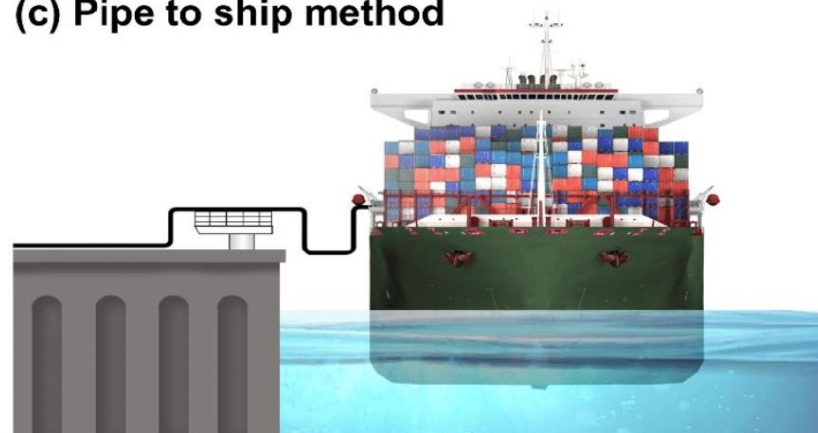


Bunkering options to fuel a ship

(a) Ship to ship method



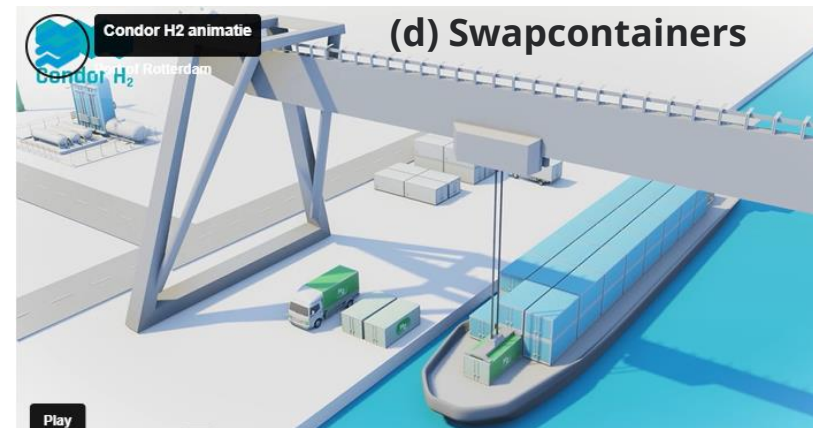
(c) Pipe to ship method



(b) Truck to ship method



(d) Swapcontainers

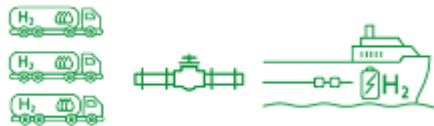


We adapt our product development to the decarbonisation needs of maritime sector

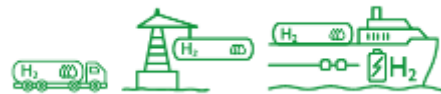


LIQUID HYDROGEN

We can facilitate **shore to ship bunkering** in many different ports using equipment and procedures to keep bunkering time at a minimum.



Air Products can fill and distribute **liquid hydrogen containers** at many locations worldwide.



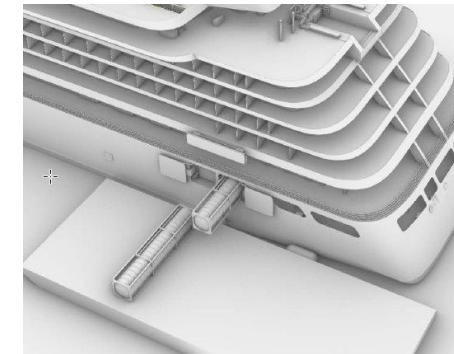
Below Deck Storage



On Deck Storage



Swappable Containers



Liquid Hydrogen in Aviation

Airbus, London Gatwick, easyJet and Air Products expand hydrogen capability and infrastructure with the target of getting a hydrogen powered aircraft in the sky by 2035.

Under Airbus' Hydrogen Hubs at Airports framework, the scope of work covers liquid hydrogen supply and storage at the airport, refuelling and ground handling of hydrogen aircraft and others.

Early hydrogen-powered aircraft will initially focus on short to medium haul routes.



Air Products objective through this knowledge community

- **Remind the *appropriate and necessary safety culture and experienced approach*** needed when handling liquid hydrogen
- **Share insights** from the liquid hydrogen experiences
- **Engage with key stakeholders** and value chain of liquid hydrogen in the Netherlands
- **Inform policy makers** for the technology and market of liquid hydrogen
- **Help shaping the necessary regulatory framework** for a sustainable and safe uptake of liquid hydrogen in the Netherlands

Thank you

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