



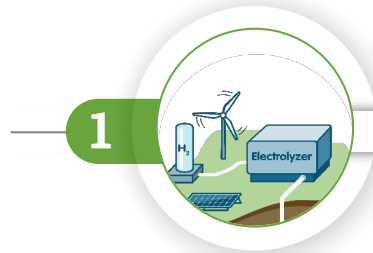
Hydrogen Energy

Ongoing work at Air Liquide
to address Hydrogen for
Aviation key challenges

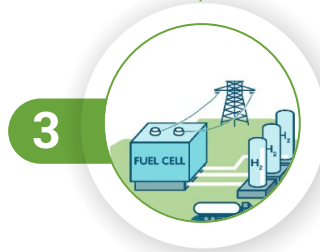
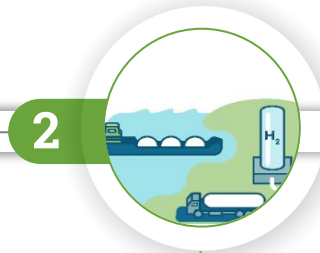
The seven roles for hydrogen in the energy transition

Enable the renewable energy system

Enable **large-scale renewables integration** and **power generation**

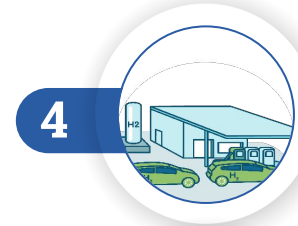


Distribute energy across sectors and regions



Act as a **buffer** to increase system resilience

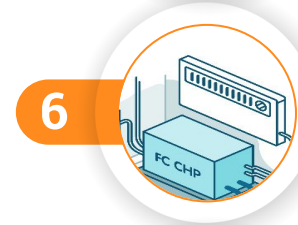
Decarbonize end uses



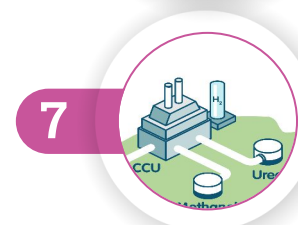
For **transport**



For **industry energy usage**



For **building heat & power**



As **feedstock**, using carbon capture

Key H2 supply chains

Primary production

Steam methane reformer + Carbon capture



Large electrolyser



Liquid supply chain

2.1 Large liquefier



2.2 Logistic tools



2.3 Liquid trailers & tanks



2.4 Liquid hydrogen maritime



Liquid Station and LH₂ Bunkering

- Aviation



- Maritime



- Ground



Gas supply chain

Filling Center



Gas transport



Logistic tools



Next Gen composite storage



Pipeline

Gaseous Station

Light duty (cars) station
Heavy duty (bus, train) station



Safety and Regulation, Code and Standards

Digital

Air Liquide already started to invest



Power to Gas
Denmark
1 Electrolyzer



Mobility for Consumers
Paris, Brussels and Rotterdam
7 HRS



Power-to-Hydrogen
Normandy
200 MW Electrolyzer



Mobility for Heavy-Duty
Fos-sur-Mer
1 HRS
8 trucks + 3 bus



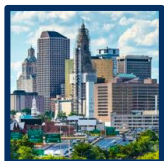
Mobility for Heavy-Duty
Rotterdam
25 HRS
1,000 trucks



Mobility for Consumers
Germany
36 HRS



Mobility for Professionals
US+EUROPE
9 HRS



Mobility for Consumers
US North-East
12 HRS
+ Supply chain



Mobility for Consumers
California
4 HRS



Power to Gas
Bécancour
20 MW Electrolyzer
PEM Technology



Liquid Hydrogen
Nevada
30 tonnes/day



Mobility for Consumers
Dubai
1 HRS



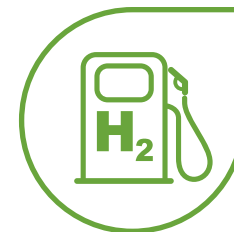
Mobility for Consumers
South Korea
9 HRS



Mobility for Consumers
Japan
13 HRS



Mobility for Consumers
China
30+ HRS



More than
185 Hydrogen
Refueling Stations
(HRS) assembled
and delivered by
Air Liquide in the
world

More than 80 HRS supplied
with Air Liquide hydrogen

ALIAD: 12 M€ invested
in five start-ups

1.2 M tonnes per year
2.2 B € sales
1,850 km H2 pipelines
47 large H2/CO plants
40+ electrolyzers in operation



30 tons of liquid Hydrogen per day (10 000 tons per year)

Already in operation in Nevada to serve fuel cell vehicles in California



Air Liquide's ambitions in hydrogen

Before 2035



Capex

+~€8bn

By 2030^(a)



Electrolysis

3GW

(a) Including 1 GW decided still under construction

Walking the talk we are **scaling-up**



World's largest
membrane-based
electrolyzer

Jan. 2021, Bécancour, Canada:
(20 MW)

In France, H2V Normandy project
(200 MW in 2025)

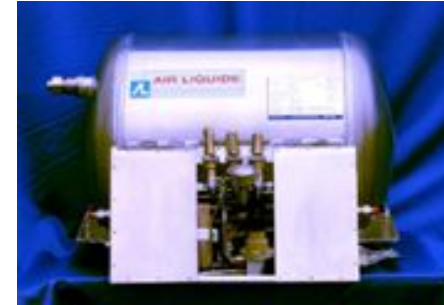
LH2 for mobility applications

Hydrogen mobility markets ready to scale up



LH2 tank developments for mobility

In the 2000s for the automotive industry



Ongoing developments

- For the aviation:

Heaven project

(Air Liquide, Pipistrel, H2FLY, DLR, EKPO)



- For the Heavy Duty trucks:

Technical collaboration with Faurecia

First LH2 station to support Daimler Truck AG Fuel Cell truck prototype tests

From GH2 to LH2

Air Liquide and Faurecia announce a Development Agreement to boost Hydrogen for Heavy-Duty vehicle

News | Tuesday, October 12, 2021



announce a Development Agreement to boost Hydrogen for Heavy-Duty vehicles



Airbus, a partner and leader in aviation



2035-2040

Airbus, Air Liquide and VINCI Airports announce a partnership to promote the use of hydrogen and accelerate the decarbonization of the aviation sector

News | Tuesday, September 21, 2021



Airbus, Air Liquide et VINCI Airports annoncent un partenariat pour développer l'usage de l'hydrogène et accélérer la décarbonation du secteur aérien

2025-2030



Onboard LH2 storage

Renewable hydrogen: the great ambition of Energy Observer & Air Liquide

2020-2025



Air Liquide supports Daimler Truck AG with Liquid Hydrogen for heavy-duty long-haul fuel-cell Truck prototype tests

Air Liquide Clean transportation Energies Logistics

Air Liquide supports Daimler Truck AG with Liquid Hydrogen for heavy-duty long-haul fuel-cell Truck prototype tests

News | Monday, May 17, 2021

Propulsion with H2 : 10 years of R&D at Air Liquide



2013-2019

350b gaseous H2 tank

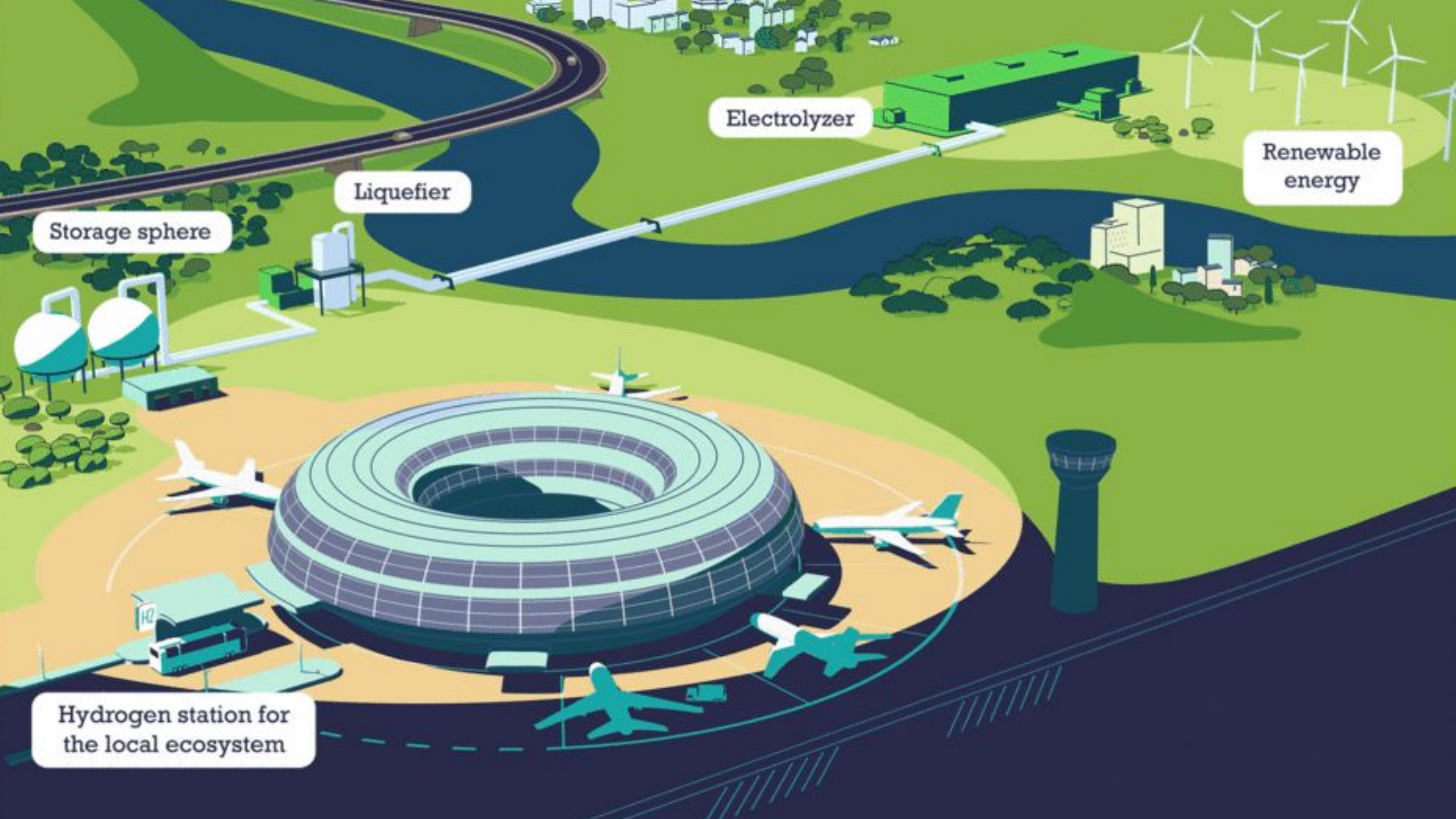


2019-2023

LH2 permit to fly



**Airborne tank on a vibration
test bench
225 liters of liquid H2 to fly
early 2023**



Electrolyzer

Renewable energy

Liquefier

Storage sphere

Hydrogen station for the local ecosystem

Liquid Hydrogen infrastructures on a large airport

 **ARRIVALS**

DEPARTURES 

10,000 LH₂- powered aircrafts by 2050
100-300 airports to be equipped
5 to 10 million tons LH₂ per year



150 H₂-aircraft take-off per day
150t LH₂/day; 400MW
(ex: Frankfurt)



10 to 20 mobile refuelers
specific LH₂ trailer



1 trailer for 10 aircrafts
15-20 min refueling

Conclusions

After more than 50 years of usage in space, Hydrogen is now used for mobility

- Heavy duty/trucks and maritime already ongoing
- Huge investments in progress on the whole supply chain
- Strong CO2 neutrality commitment
- Volume will bring cost down

Liquid H2 for aviation will benefit from synergies with ground mobilities

H2 for aircrafts can significantly reduce the environmental impact of aviation

- Several flight demonstrators in progress
- Regulations and policy needed