H₂ Energy
At the heart of the energy transition

Dave Edwards
Director and Advocate for Hydrogen Energy
Air Liquide

1. The world leader in gases, technologies and services for Industry and Health.

Present in 80 countries.

Approximately 65,000 employees.

More than 3.5 million customers and patients.

292 millions euros of innovation expenses, almost 60% of these expenses are related to the improving of the environmental footprint, air quality and healthcare.

Around 300 patents per year.

2017 Revenue: €20.3 billion.
2017 Net profit: €2.2 billion.
Air Liquide - Hydrogen Energy

100 hydrogen stations designed and installed in the world.

A hydrogen station can recharge vehicles in less than 5 minutes.

A hydrogen car can ride more than 600 km with one charging.

ZERO

Zero CO₂ emission.
Zero particle.
Zero noise pollution.

Hydrogen produced by Air Liquide in 2016 for the refinery and petrochemical markets:
14 billion m³.
The current production could allow to recharge around 10 million hydrogen Fuel Cell Electric Vehicles.

Revenue from hydrogen for refineries and petrochemical markets in 2016:
€2 billion.
Hydrogen – today’s industrial pathway

Fossil Fuel Sources

Natural Gas Pipeline

Reformation

H₂

Traditional Markets
Refining
Fertilizers
Hydrogen – the pathway with renewables

Bio Methane Sources

Natural Gas Pipeline

Renewable Power Sources

Electric Grid

Reformation

Water Electrolysis

Transportation Fuel

On & Off Grid Power + Storage

Traditional Markets

Pipelines & New Storage Technologies

Hydrogen – the pathway with renewables

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Traditional Markets

Pipelines & New Storage Technologies
Hydrogen – today’s industrial pathway

- Fossil Fuel Sources
- Natural Gas Pipeline
- Reformation
- H₂
- Traditional Markets
- Refining
- Fertilizers
40 years of global investment in hydrogen

- > 14 bn m³/yr
- > 1,850 km H₂ pipeline
- > 46 large H₂/CO plants
- > 2 bn € sales

year 2015
Air Liquide to build first world scale liquid hydrogen production plant dedicated to the supply of Hydrogen energy markets

Air Liquide will build the first world scale liquid hydrogen production unit dedicated to the hydrogen energy markets, located in the Western U.S., and has signed a long-term agreement with FirstElement Fuel Inc (FEF), a leader in retail hydrogen infrastructure in the U.S., to supply hydrogen to FEF’s retail liquid hydrogen fueling stations in California. These new commitments will serve the growing needs of the hydrogen mobility market in California and help enable and complement the deployment of hydrogen fuel cell electric vehicles and support the hydrogen merchant market across the state.
Liquid Hydrogen - Production

- **Capacity**: 30 tons per day
- **Production**: Steam methane reforming

**Key Figures**
- Location: Western U.S.
- Construction to begin early 2019
- Operations & delivery by 2021
- $150 million USD investment

Air Liquide’s Western U.S. RLH\textsubscript{2} Investment

- 1ST
- @scale renewable liquid hydrogen dedicated to the H\textsubscript{2} E markets
- $150 MM anticipated investment
Liquid Hydrogen - Production

Air Liquide selects Hydrogenics for 20MW electrolyzer for hydrogen production; largest PEM electrolyzer in world

26 February 2019

Air Liquide will build in Canada the largest PEM (Proton-Exchange Membrane) electrolyzer in the world with a 20 megawatts (MW) capacity for the production of low-carbon hydrogen (the facility will use hydropower).

Air Liquide will install a 20 MW electrolyzer that increases by 50% the current capacity of its hydrogen facility located in Bécancour, Québec. The facility is expected to be in commercial operation by the end of 2020, with an output of just under 3,000 tons of hydrogen annually.
Station Characteristics

- **Vehicles & User**
  - 4-5 kg/fill
  - 3-5 minutes per fill
  - H70

- **Station Usage**
  - 100+ vehicles/day/position
  - 1-4 fueling positions/station
  - 1 nozzle/fueling position

- **Capacity**
  - Today: 300 kg per day
  - Future: may exceed 1000 kg per day
Delivery Options

- Gaseous supply chain (300-450 bar)
- Onsite gaseous production
- Liquid supply chain
From Today’s Distribution Model...

Production & Liquefaction

H2 Liquid Production

LH2 storage

Transport

LH2 storage

Vaporization to GH2

Hub

LH2 storage

Vaporization to GH2

Transport

Hydrogen Stations

Station Network
...To Tomorrow’s Distribution Model

Production & Liquefaction

- H2 Liquid Production
- Transport
- LH2 storage
- Vaporization to GH2
- Future stations
- LH2 storage
- Hydrogen Stations
Gaseous Hydrogen - Transport & Storage

- Industry standard trailer: 300 kg of H₂, 2400 psi
- Air Liquide tube trailer: 440 kg of H₂, 6500 psi
- Underground Hydrogen Cavern
  - Beaumont, TX
  - Nearly one mile wide and 230 ft deep
  - Enough hydrogen to back-up a SMR for 30 days
**Liquid Hydrogen - Transport & Storage**

**Onsite Liquid Storage**
15,000 gallons is the typical storage = 4 tons

**Liquid Delivery Tanker**
13,000 gallons in the typical tanker = 3.5 tons

**NASA Sphere**
Built in the 1960’s containing 850,000 gallons = 230 tons
Liquid Hydrogen - Liquefaction

- **Onsite Liquefaction**
  - 1 - 3 tons per day

- **Typical Industrial Liquefier**
  - 10 - 30 tons per day

- **Future Liquefier**
  - 100+ tons per day
Looking beyond...

**PRESS RELEASE**
Paris, February 25, 2019

Air Liquide invests in the world’s largest membrane-based electrolyzer to develop its carbon-free hydrogen production

**PRESS RELEASE**
November 26, 2018

Air Liquide to build first world scale liquid hydrogen production plant dedicated to the supply of Hydrogen energy markets

**PRESS RELEASE**
January 24, 2019

Air Liquide makes a strategic investment in the production of decarbonated hydrogen by electrolysis
Thank you

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