Hydrogen
gets things moving

Air Liquide

Hydrogen
Clean energy

Hydrogen (H_2) is element number one in the periodic table, and for a good reason: In our universe, no other element is as plentiful as hydrogen.

On Earth, hydrogen always exists in chemical compounds such as water, hydrocarbons and other organic compounds, from which it can be extracted using energy. Hydrogen is a very light gas, which quickly mixes with the surrounding air.

Used in the fuel cell, hydrogen combines with oxygen from the air to produce electricity, with water as the only byproduct. Hydrogen can be produced from a various range of energy sources, in particular from renewable ones. Hydrogen thus has great potential to provide clean energy and to substitute fossil fuels.

Air Liquide is actively involved in setting up a hydrogen industry and allowing the widespread use of hydrogen as a clean energy. As the world leader in gases, technologies and services for Industry and Health, Air Liquide has built up unique expertise in managing the entire hydrogen chain, covering not only production, distribution, and high-pressure storage but also hydrogen refuelling stations.

The world of energy is in the midst of deep change and hydrogen is one of the solutions that offer a response to the challenges of clean transportation: reducing greenhouse gases, pollution in our cities and dependency on oil-based fuels.

The transport sector is responsible for a large share of carbon dioxide and particle emissions. Reducing vehicles' carbon footprint is crucial to make our cities a better place to live in.

Hydrogen from renewable sources

BLUE HYDROGEN
Clean energy solutions

50%

BLUE HYDROGEN FOR ENERGY APPLICATIONS

BY **2020**

AS A COMMITMENT BY AIR LIQUIDE

The missing link of the energy transition

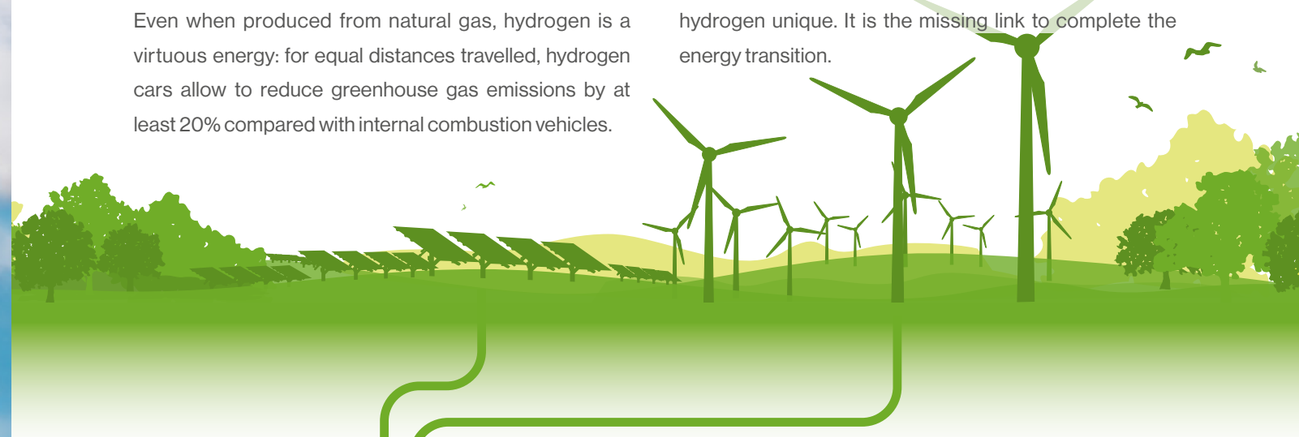
With Blue Hydrogen, Air Liquide is firmly moving towards a gradual decarbonization of its hydrogen production dedicated to energy applications. In practical terms, Air Liquide has made a commitment to produce at least 50% of the hydrogen required for these applications through carbon-free processes by 2020, combining:

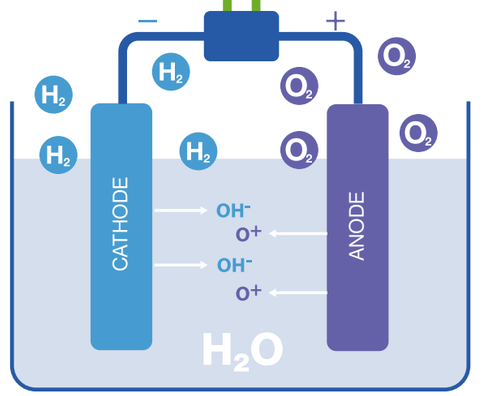
- biogas reforming,
- the use of renewable energies during water electrolysis,
- the use of technologies for the capture and upgrading of carbon emitted during the process of producing hydrogen from natural gas.

Even when produced from natural gas, hydrogen is a virtuous energy: for equal distances travelled, hydrogen cars allow to reduce greenhouse gas emissions by at least 20% compared with internal combustion vehicles.

Hydrogen extracted by electrolysis is completely emission-free if the electricity used originates from renewable sources, such as wind, solar energy or water power.

Hydrogen can be used as a storage medium for sustainably generated electricity. Hydrogen can carry large amounts of energy for a long period of time to be reconverted using fuel cells when required. It is thus able to offset network instabilities. At the same time hydrogen can also provide clean fuel to power vehicles, or energy for other applications where electicity is needed. The potential to build a bridge between energy, transport and industry is what makes hydrogen unique. It is the missing link to complete the energy transition.





Water electrolysis

During electrolysis, water is split into its components hydrogen and oxygen. The electrical energy used is converted into chemical energy and stored in the form of hydrogen.

Emission-free mobility with a range you are used to

500 A RANGE OF MORE THAN KILOMETRES
SIMILAR TO TODAY´S CONVENTIONAL VEHICLES

3 TO 5 MINUTES
REFUELLING TIME

Hydrogen
A proven solution

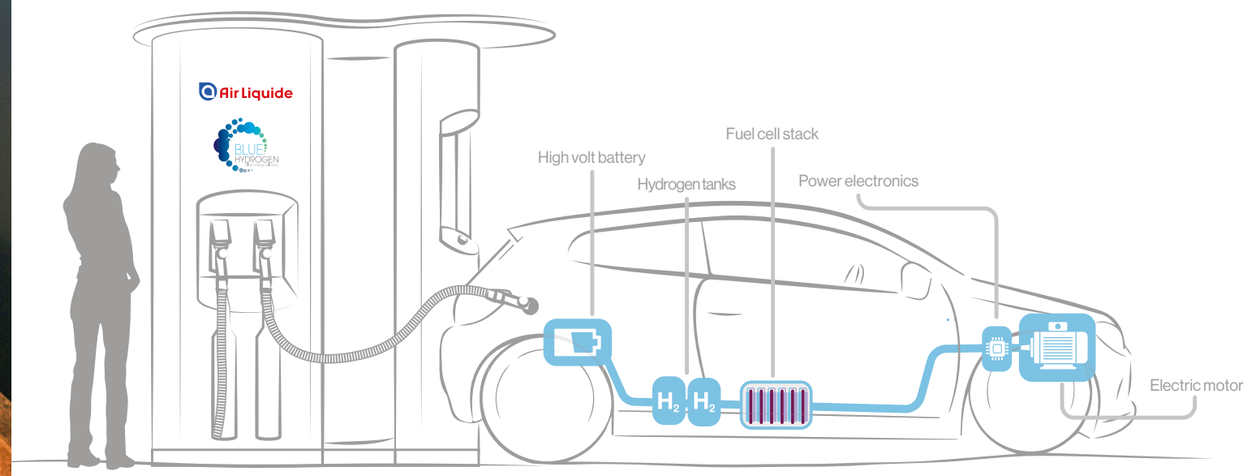
Fuel Cell Electric Vehicles (FCEV) offer emission-free mobility with a range we are used to.

The construction of a fuel cell is similar to that of a car battery. Every cell contains two plate-shaped electrodes (anode and cathode) with a polymer electrolyte membrane (PEM) separated from each other by an electrolyte. This electrolyte can conduct ions but it is gas-opaque.

The catalyst materials (normally platinum) are located on the electrodes and ensure that the gaseous hydrogen supplied releases ions as charge carriers. The hydrogen molecules decompose into hydrogen atoms at the anode which in turn become positively charged hydrogen ions by releasing electrons. The free electrons flow to the cathode via a conductor and can now be used as electricity that powers the electric motor.

To release the required energy to power a car, several cells are arranged in a ‘stack’.

The hydrogen tanks consist of a plastic core that is insulated by a carbon fibre composite. The tanks are designed for a high operating pressure. Before filling up, the tightness of the connection between the vehicle and the pump is checked – only then gaseous hydrogen does flow into the tank. The connector coupling has been standardized worldwide since 2007.



Hydrogen Focus: Infrastructure for Germany

In Germany, Air Liquide has been a member of the Clean Energy Partnership (CEP) since 2011. With its "50 Refuelling Stations" programme, funded by the German Federal Ministry of Transport and Digital Infrastructure (BMVI) within the framework of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP), CEP initiated the construction and operation of a nationwide H_2 refuelling infrastructure for passenger cars. Air Liquide contributed ten stations.

Today, the CEP partners – Air Liquide, Audi, BMW, Daimler, H2 MOBILITY, Honda, Hyundai, Linde, OMV, Shell, Total, Toyota and Westfalen – are working on the market establishment and systems compatibility of hydrogen and fuel-cell mobility, in the interests of a sustainable energy shift. The industry partnership is opening itself to new modes of transport, accelerating interconnection between sectors, and developing business models for H_2 production using renewable energy.

In 2014, Air Liquide joined forces together with its partners Daimler, Linde, OMV, Shell and Total and founded the joint venture H2 MOBILITY Deutschland GmbH & Co. KG. Its mission: establishing a nationwide hydrogen infrastructure to supply cars with fuel-cell drives in Germany. Or in other words: building a mobile future of rapid refuelling, long ranges, clean and quiet mobility.

The six shareholders are pushing for the swifter introduction of national and international standards, and thus making a major contribution to decoupling mobility from CO_2 emissions. In order to dovetail progress as closely as possible with the automotive industry, BMW, Honda, Hyundai, Toyota and Volkswagen are on board as associated partners.

H2 MOBILITY will expand the existing network of hydrogen stations in Germany to up to 400. First interim goal is to operate 100 H_2 stations in metropolitan areas and along the connecting arterial roads and motorways by 2019. This will be followed by another 300 as the vehicle numbers are ramped up.

The hydrogen stations are preferably integrated into existing conventional service stations. Their design is compact and mainly relies on standard components for the fuel pumps, the hydrogen storage, and the compression.

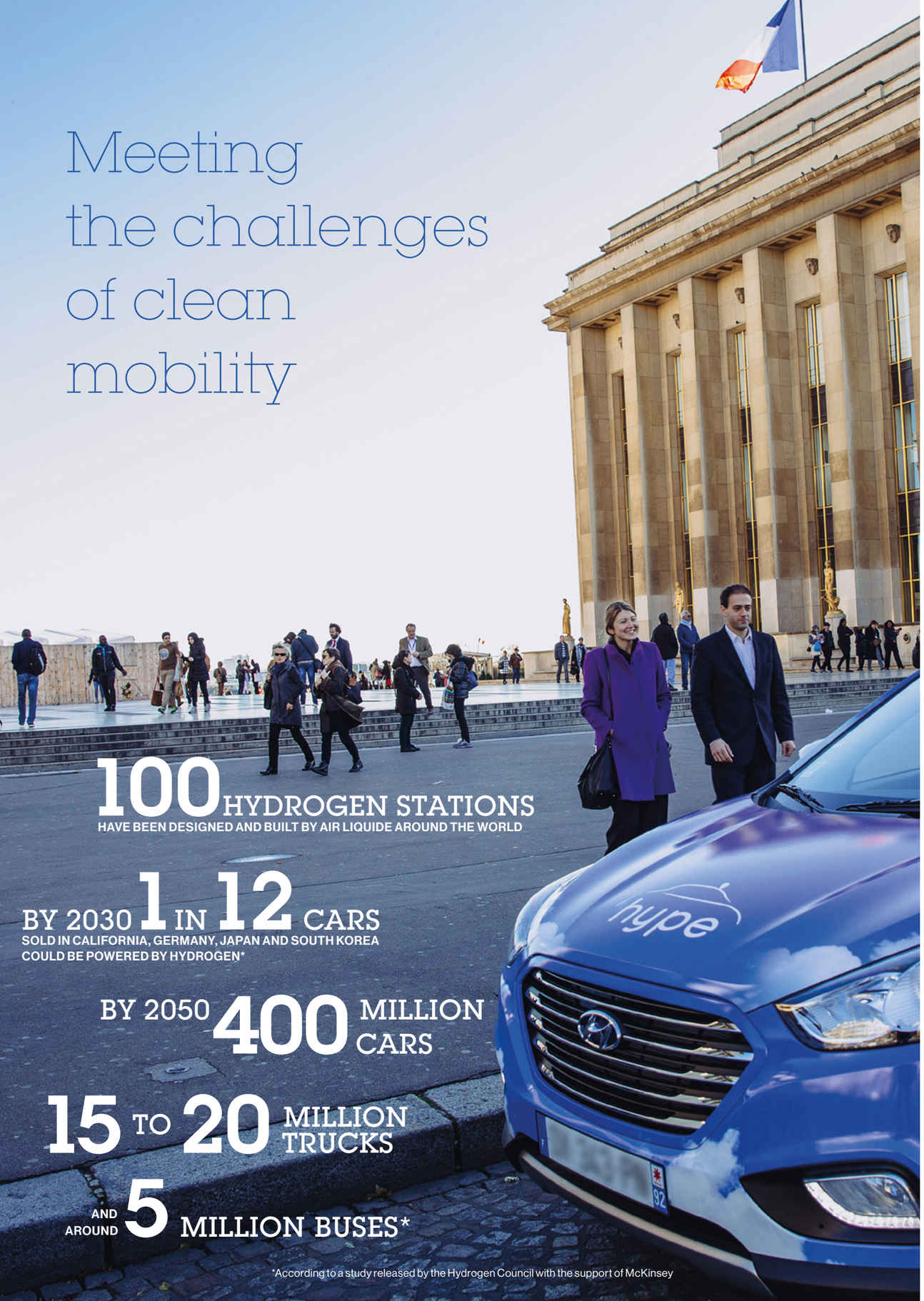
H2 MOBILITY receives funding from the German Federal Ministry of Transport and Digital Infrastructure (BMVI) as part of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) as well as from the European Commission in the Hydrogen Mobility Europe project, which receives funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU, grant agreement no. 671438). The FCH JU is supported by the European Union Framework Programme for Research and Innovation (Horizon 2020), Hydrogen Europe and the Hydrogen Europe Research Association.

Clean Energy Partnership CEP

H_2 MOBILITY FUELLING HYDROGEN

Sponsored by

Meeting the challenges of clean mobility



Hydrogen
The international roll-out

Even beyond Germany, Air Liquide is actively involved in setting up a hydrogen industry and developing alternative energy solutions for clean mobility, allowing the widespread use of hydrogen as a clean energy.

In France, Air Liquide opened a hydrogen station in Saint Lô (Manche) in January 2015. In December 2015, another one was inaugurated in Grenoble as part of the HyWay project. On the occasion of COP 21 in December 2015, Air Liquide installed the first H_2 station in the heart of Paris at Pont de l'Alma, in partnership with the STEP start-up (Société du Taxi Électrique Parisien of which Air Liquide is a minority shareholder) and supported this start-up in the launch of its hydrogen taxi fleet "Hype", the world's first hydrogen taxi fleet. Today, the fleet counts 100 H_2 vehicles which can also refuel at the stations installed by Air Liquide next to Paris-Orly airport (December 2017) and in Les-Loges-en-Josas near Versailles (March 2018). STEP plans to deploy 600 taxis by 2020.

In the Netherlands, Air Liquide opened its first hydrogen refuelling station in Rotterdam in September 2014. In Belgium, Air Liquide launched a first public station in Zaventem, near Brussels, in April 2016, marking the first use of hydrogen as a clean energy in the country.

In Denmark, Air Liquide operates a network of five H_2 stations through the Copenhagen Hydrogen Network (CHN), its wholly owned subsidiary. These five stations – three in Copenhagen, one in Aalborg and one in Vejle – joined two stations already in service, located in Copenhagen and in Holstebro.

In Japan, the government sees hydrogen as a major energy with great promise for the future of the automotive industry. There are already 100 H_2 stations in the country and the government intends to triple this figure in the coming years. A new joint venture of 11 companies called "Japan H2 Mobility", including Air Liquide Japan, was launched in March 2018. Japan H2 Mobility is committed to deploy 80 additional hydrogen stations nationwide by 2021. Air Liquide will install and operate 20 of them.

In November 2014, Air Liquide announced plans to develop and supply a fully-integrated hydrogen refuelling infrastructure with 12 stations in the Northeast of the US in collaboration with Toyota. Since December 2016, Air Liquide has also been operating its first station in California (Anaheim), as part of a State of California programme designed to support the deployment and use of FCEVs, with about 50 H_2 stations planned in California.

Hydrogen Council

The Hydrogen Council brings together 39 industry, energy and transportation sector companies, including 24 leading multinationals and 15 "supporting members". All are determined to position hydrogen as one of the key solutions for the energy transition.

More information: www.hydrogencouncil.com

Air Liquide H_2 stations
A worldwide presence

ANAHEIM, CALIFORNIA

HIRSCHBERG, GERMANY

KOBE, JAPAN

BAD RAPPENAU, GERMANY

ORLY, FRANCE


ZAVENTEM, BELGIUM


LIMBURG, GERMANY


ROTTERDAM, NETHERLANDS

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Air Liquide

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