
Hydrogen, a new clean energy



Innovation working for energy and the environment

Press kit
June 2009

Air Liquide and the *Observatoire des Innovations*



- The *Cité des Sciences et de l'Industrie* launched a periodically renewed exhibit in January 2007 called the **Observatoire des Innovations** (“*Innovation Observatory*”).
- For its first renewal, in January 2009 the **Observatoire des Innovations** inaugurated a new exhibit that puts a spotlight on the relationship between **innovation and sustainable development**. Visitors are invited to look at four sets of innovative responses to the challenges posed by massive population growth and global energy needs.
- Air Liquide is a partner of this *Observatoire des Innovations*, offering visitors to *La Cité des Sciences* a chance to experience **Hydrogen, a New Energy** through August 10, 2010.
- Innovation lies at the heart of development for Air Liquide, the world leader in gases for industry, health and the environment. **Born out of an innovation in 1902**, Air Liquide has continuously developed new technologies that work for customers and meet their needs. By participating in the *Observatoire des Innovations*, Air Liquide seeks to introduce the general public to hydrogen, an **environmentally friendly alternative energy**.
- The exhibition space that houses the *Observatoire des Innovations* attracts some **250, 000 - 300, 000 visitors a year**.

The “Hydrogen, a New Energy” display: objectives

Explain, educate, demonstrate

- In light of **growing energy needs** and **declining fossil fuel sources**, hydrogen is bound to become an increasingly important energy vector, because it is clean and can be produced from all primary sources of energy.

The objectives of the Air Liquide display:

- **Raise awareness and introduce** citizens to hydrogen, in conjunction with fuel cells, as an alternative energy vector
- **Explain and educate**, providing the general public with the basic building blocks needed to understand this breakthrough innovation
- **Demonstrate the feasibility** of this energy vector in the future via recent innovations in the areas of:
 - Hydrogen storage
 - Hydrogen distribution
 - Fuel cells

What's on display at "Hydrogen, a New Energy"

■ General introduction:

Jean-Louis Etienne, physician and explorer, in a video about how he has used fuel cell batteries for his expeditions. He also comments on the clean and silent virtues of this new energy.

■ The historical and scientific foundations: Where does it come from?

- The problem set: an environmental and energy challenge
- Historical milestones in the development of hydrogen and fuel cells
- Greenhouse gas emissions and global warming
- An innovative solution: hydrogen and fuel cells

See: A scale model that explains greenhouse gases

■ Techniques: How does it work?

- Hydrogen: multiple, inexhaustible sources
- Fuel cells: transforming hydrogen into energy efficiently
- Environmental performance of H₂ – Fuel Cell combination
- Hydrogen production
- Hydrogen uses in industry
- Environmental performance: comparison of emission levels of CO₂

See:

- *An interactive feature on how a fuel cell work*
- *A visual that compares the environmental impacts of cars with various modes of propulsion*

■ The prospects - For what future: What is it for?

- The uses of hydrogen energy
- Transporting and storing hydrogen
- Distributing hydrogen
- Hydrogen cars

See:

- *A scale model hydrogen car, the Nissan Xtrail FCV*
- *A video: Nissan Xtrail FCV getting a hydrogen refill at a Air Liquide filling station in Paris*
- *An interactive hands-on display that simulates a hydrogen fill-up on a car*
- *A hydrogen cartridge to fuel small vehicles*

Air Liquide and hydrogen: key figures



- **With more than 40 years** of experience in the hydrogen business, Air Liquide has extensive expertise at every stage along the hydrogen “chain”, from research to production and use.
- Production in 2008: **7 billion cubic meters** of hydrogen.
- **1 850 km** of pipeline (the world’s number 1 pipeline network).
- **50% increase** in global production capacity in the course of the last three years.
- Group revenue in hydrogen: **€1.2 billion in 2008**.
- **770 000 tonnes/year of sulfur dioxide emissions** are avoided by desulfurizing fossil fuels, which is equal to **two times the total of all emissions in a year for a country like France** (460 000 tonnes/year).
- **Nearly 40 hydrogen stations** in the world today.

Control of the entire Hydrogen chain

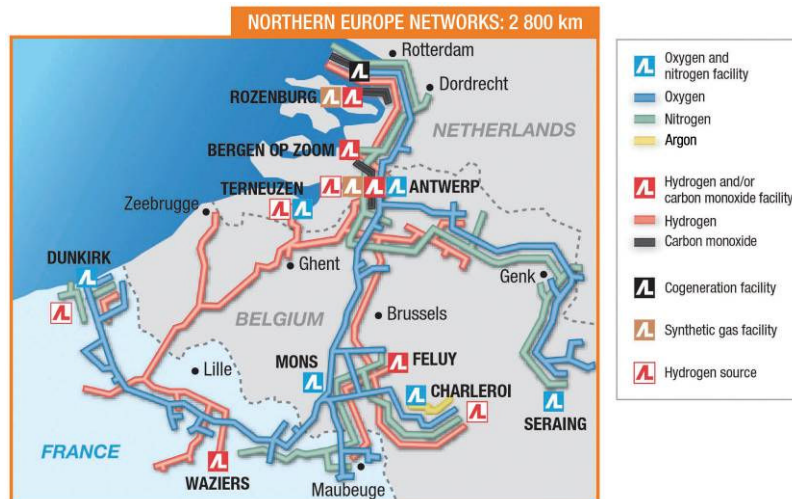
- **Production:** More than **200 production units worldwide, among which 50 with the greatest production capacity** (gaseous or liquid hydrogen)



Air Liquide designs and develops **tanks for storing and transporting liquid hydrogen at very low temperature** (- 253°C). With its subsidiary Cryospace, Air Liquide builds the hydrogen and liquid oxygen tanks used for Ariane, the European satellite launcher.

- **Distribution:** **1,850 km of pipeline (the greatest hydrogen network in the world) with 12 hydrogen networks worldwide**

Example: One of the group's gas pipeline networks in Northern Europe



- **Uses:** Air Liquide masters **every current industrial use of hydrogen** (glass manufacturing, semi-conductors, steel transformers, desulfurization, etc.).

- **The removal of sulfur from hydrocarbon, currently the main use of hydrogen**
 - The most significant current use of hydrogen (nearly 2/3 of the total amount sold by the Group) is in the **desulfurization of hydrocarbon** to produce **sulfur-free fuels**.
 - The desulfurization of hydrocarbon using hydrogen is needed to **reduce the amount of sulfur dioxide (SO_x) released into the atmosphere**. Sulfur dioxides can cause severe **respiratory problems** in humans. They are responsible not only for the **smog** that stagnates above some densely populated urban areas, but also for acid rain, which causes both deforestation and the acidification of water. Sulfur is also toxic for catalyzers, since it quickly deteriorates the performance of **catalytic converters** in cars.
 - The hydrogen supplied by Air Liquide to refineries all over the world prevents the release of **770,000 tonnes of sulfur dioxides/year** into the atmosphere, an amount that is equal to **twice the amount that is discharged each year by a country like France** (460,000 tonnes/year).

SULFUR CONTENT REGULATIONS



Hydrogen, working for the environment

■ Supplying clean stand alone energy

- Air Liquide develops **stationary fuel cell** and the equipment needed to put them into operation. With its subsidiary Axane, the group is part of the French project *Balises*, where it has **partnered with Bouygues Telecom by providing fuel cells** to enable **GSM telephone network stations** to function at five remote sites in France.
- Other projects of the same type are being carried out in Greece and Spain.
- Fuel cells make it possible to bring electricity to places where no power substation is present, without spoiling the landscape and without emitting noise, pollution or green house gases.

Axane, a subsidiary of the Air Liquide Group that was founded in May 2001, designs, develops, produces and sells hydrogen fuel cells.



Axane designs and produces **portable power generators that run on fuel cells**. These generators provide clean, quiet and vibration-free energy - for example, for **municipal service vehicles**.

They can also be used on movie sets, where silence is essential!

Hydrogen, a clean energy vector

- Leveraging its expert knowledge of all aspects of the hydrogen, Air Liquide is also working on the future use of **hydrogen which can also be used as a fuel in cars**, both for individuals and for city **bus fleets**.
- Air Liquide is particularly active in the following areas:
 - The **storage of hydrogen in cars**. Air Liquide is developing all types of storage facilities, with a particular focus on storage technologies for **gaseous hydrogen under high pressure** (up to 700 bar) and **liquid hydrogen at very low temperature** (-253°C). Air Liquide is also carrying out research programs focused on storing hydrogen in its chemical form (such as hydrides).
 - **The distribution of hydrogen**. To fuel cars that run on hydrogen, Air Liquide is developing **bi-pressure hydrogen distribution stations (350 or 700 bar)**. These stations can do a fill-up in less than 5 minutes while maintaining the same level of safety and offering the same degree of facility as traditional fuel.



Hydrogen, a clean energy vector

Nearly 40 hydrogen stations in the world

Air Liquide has already designed, built and rolled out a **growing number of hydrogen filling stations in the course of the last four years.**

Examples: in Madrid (abus fleet), Kawasaki, Luxembourg, Shanghai with a mobile station for the Michelin Challenge Bibendum, in Singapore, in South Korea... The Group is also developing hydrogen stations for European automakers.

In 2007, Air Liquide designed and installed **five hydrogen filling stations for General Motors in the United States.** In Canada, the group supplied three stations for **BC Transit**, servicing a captive fleet of 20 buses that will be used during the 2010 Olympic Games in Vancouver. Since 2008, thirteen stations are operational in North America.

The Group also supplies many universities that are developing hydrogen as an energy vector, such as Glamorgan (Wales) and Rome (Italy).



From June to November 2008, Air Liquide was the **official technological supplier for the Nissan Pan European Tour.** Accordingly, Air Liquide installed the service stations and supplied the hydrogen needed to carry out the shows organized by Nissan, around the fuel-cell operated XTrail car.

Hydrogen energy and fuel cells

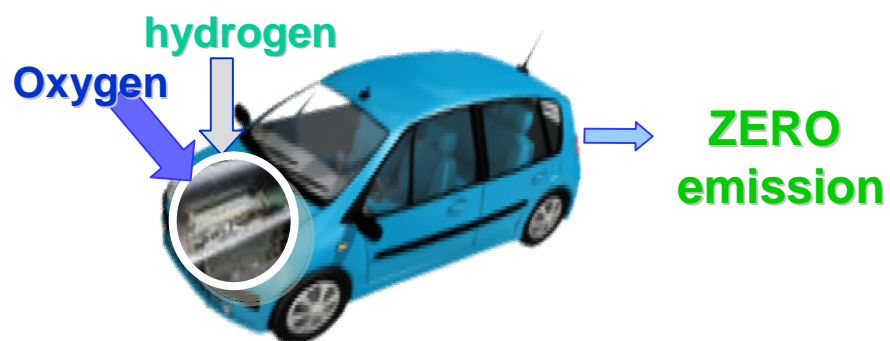
- **Longer term**, the Group is involved in work related to the **replacement of conventional fuels with hydrogen for individual cars.**
- **Hydrogen and fuel cells - how does it work?**
 - Beyond the use of hydrogen for directly fueling a **conventional internal combustion engine** (thermal), the **fuel cell** shows promises. Compared with the use of hydrogen in a thermal engine, it offers a higher output and a smaller tank.
 - The whole system, with an **hydrogen fuel cell and an electrical engine**, features numerous advantages:
 - Hydrogen stored in the car supplies the energy to fuel cell to produce electricity with only water as emission. Then, the electricity that is produced is transformed in mechanical energy to propel the car. This system does not generate any **local pollution**. In addition, if we look at **the global performance from well to wheel, energy produced by hydrogen in a fuel cell generates around 50% less CO₂ emissions** than an internal combustion engine with fossil fuel.
 - The system has a much higher efficiency than an internal combustion engine.

Efficiency

	From well to wheel
Hydrogen	29%
Gas (petrol)	17%

CO₂ emissions

	From well to wheel
Hydrogen	90 g/km
Gas (petrol)	190 g/km



Air Liquide and hydrogen energy: a twofold strategy

Pushing back the limits of technology

- To access these technological solutions of the future, it is necessary to overcome technological and societal obstacles:
 - With respect to the **storage of hydrogen onboard a car**: it is necessary to offer users sufficient driving range (of around 500 km at the very least). Two possibilities exist:
 - One involves compressing the hydrogen: at pressure of 700 bar, only 3 times the volume of hydrogen versus gasoline is required.
 - Another involves the use of liquid hydrogen at -253°C : in this case, only 2 times the volume of hydrogen versus gasoline is needed to cover the same number of kilometers.

To cover 500 km, you need:

40 liters of petrol
60 000 liters of H_2 at atmosphere pressure
200 liters of compressed H_2 at 350 bar
125 liters of compressed H_2 at 700 bar
75 liters of liquefied H_2 at -253°C



- With respect to the **fuel cell itself**: Axane, a subsidiary of Air Liquide, is working on the performance, cost and life time of a fuel cell.
 - The new technologies and breakthroughs in terms of industrialization have cut the cost of manufacturing fuel cell tenfold in just four years!
 - The Group is also searching for ways to extend the life of a fuel cell by doing reliability tests based on weather conditions, for example.
- The fuel cell is a **breakthrough innovation**: people will learn to do things differently. For this reason, Air Liquide participates in projects, initiatives and events whose goal is to **raise public awareness** of the use of alternative energies like hydrogen. The **Hychain project** provides a way of ascertaining the societal aspects of hydrogen-energy related to safety, training and public acceptance of an innovation.
- The **H2E program**, which entails a global investment in research and technology amounting to nearly **€200 million** over a period of 7 years, seeks to build a sustainable and competitive hydrogen-energy business. In the short term, this program will bring hydrogen-energy solutions to the marketplace and create the conditions needed to launch and sustain hydrogen vehicles around 2015.

Participating in demo programs

- In Europe, transportation is 95% dependent on fossil fuels and is responsible for 20% of total CO₂ emissions. **Europe decided to increase the share of substitution fuels to 20% in overall consumption by year 2020.** These include **hydrogen, a clean energy vector.**
- In addition to its **major R&D effort, Air Liquide participates in large-scale international demo projects** with automakers or as part of European or international projects: **Hychain-Minitrans, STORHY, Nesshy and others.**
The **H2E - Horizon Hydrogen Energy** program is supported by the French government and coordinated by the Air Liquide Group.
- These many full-scale projects, particularly in Europe and in North America, are pushing technology forward and **also promoting understanding of this new energy vector among a wide public audience.**

Air Liquide, general coordinator of the H2E program - Horizon Hydrogen Energy



- In late 2008, the European Commission authorized funding of €67.6 million granted by OSEO to finance the H2E (Horizon Hydrogen Energy) program coordinated by Air Liquide in the area of hydrogen and fuel cells.
- The H2E program, which represents a global investment in research and technology worth close to € 200 million over a period of 7 years, seeks to create a competitive and sustainable hydrogen-energy solution.
- Under this ambitious program, Air Liquide is coordinating the work of 20 partners with recognized expertise in the field of hydrogen energy. They include large manufacturing groups, SMEs and public research laboratories. Thanks to an intensified level of coordination, H2E will help to step up innovation around a shared industrial roadmap that is consistent with the European strategic vision.
- H2E will enable the development of a hydrogen energy business in markets for which hydrogen and fuel cell technology address a current need. These advanced markets will serve as the transition to future applications, such as hydrogen in transport, to which they will open the door around year 2015.
These markets, which offer the best conditions for jump-starting this business in the short term, are captive motor fleets, portable generators and emergency energy supply, for which the advantages of hydrogen energy (power supply quality, rapidity of refuel/charge, absence of emissions) are rapidly apparent.
- The aim of the H2E program is to ensure that hydrogen energy is competitive in the short term, by simultaneously rolling out a new hydrogen infrastructure specifically designed for these new uses, reducing the cost of fuel cells, and industrializing products.

The research and development effort will encompass each link in the chain, and will mainly focus on:

- The development of innovative technologies for the production of hydrogen out of renewable energies
- Hydrogen storage
- Industrializing fuel cells

This program will also contribute to the development of a suitable regulatory framework and will include a program of demos and educational efforts to enable a broad spectrum of the public to familiarize itself with this new vector of clean energy.

Air Liquide, general coordinator of the Hychain-Minitrans project



Hychain - the world's first deployment of small urban hybrid vehicles running on fuel cells, in four European regions.

■ The European Commission initiated the **Hychain-Minitrans project** in late 2006. With 24 partners coordinated by Air Liquide.

Objective: deploy around fifty small urban vehicles in four regions of the European Union, in real-life conditions, which run on electricity provided by a fuel cell that uses hydrogen: 13 utility vehicles, 3 mid-buses, 29 tricycles, 6 scooters and 8 wheelchairs. The main users are municipal service departments and some private or semi-private organizations such as retirement homes for the wheelchairs. **Budget:** €37.6 million (of which €17.2 million financed by the European Commission).

■ **The Rhône-Alpes Region in France** (and in particular the cities of Grenoble, Saint-Egrève and Sassenage part of Grenoble Alpes Métropole), **Emilia Romagna in Italy** (the city of Modena), **Castilla y León in Spain** (the cities of Soria and León), and **Nordrhein Westfalen in Germany** (Emscher Lippe region) are the 4 regions taking part in the Hychain-Minitrans project.



■ The project will be rolled out **over 5 years** and will include **2 phases**:

- ✓ 2006-2007: the manufacture of vehicles and development of the hydrogen distribution infrastructure
- ✓ 2008-2010: the experiment of vehicles under real-life conditions in the four regions, public education, information and feedback.

■ The **Hychain-Minitrans** project sets up **logistical platforms** adapted to user needs to facilitate the supply of vehicle's fuel cells in hydrogen. Besides, the substitution of the empty hydrogen cartridges by the full ones is very easy. Thanks to the technologies developed by Air Liquide, users can quickly, easily and safely change high pressure cartridges using a quick connection system.

■ Hychain also intends to **foster user acceptance** of this totally innovative technology, in particular by focusing on training and promoting the emergence of regulations that will apply to these environmentally friendly technologies in the future and by developing a new industrial field. Fueling a vehicle with hydrogen is a breakthrough innovation.

Hydrogen fact sheet

What is hydrogen?

■ The simplest atom

Hydrogen is the simplest atom in the universe. Its nucleus contains just a single particle: a proton. Around this nucleus, just one electron orbits.

An atom is made up of a nucleus, which contains protons (positively charged) and sometimes neutrons (no charge). Electrons circle around this nucleus (negatively charged). An atom has as many protons as electrons.

■ The oldest element

Scientists say that hydrogen was the first element to be formed on earth. It is also said that hydrogen gave birth to all of the other elements that make up matter.

■ The lightest gas

The hydrogen molecule is made up of two hydrogen atoms. It is sometimes called di-hydrogen (H₂). It is the lightest gas in the world: 1 liter weighs less than 90 milligrams. This is the gas we are referring to when we talk about its use as a vector of clean energy for tomorrow.



Molecule of di-hydrogen

By way of comparison:

1 liter of hydrogen weighs 90 milligrams = three postage stamps

*This is **16 times less** than 1 liter of oxygen, one of the gases we breathe in the air*

*It is **65 times less than** 1 liter of xenon, which is the heaviest gas. It is used for the headlights in our cars.*

Where is hydrogen found?

■ Elusive hydrogen!

Hydrogen is an extremely light gas...

So light, in fact, that it cannot be kept in our atmosphere: it rises and rises, indefinitely. It is even lighter than helium, which is used to fill balloons. Accordingly, it is impossible to find hydrogen in its gaseous form on earth. And yet ...

■ And yet, it is everywhere

The hydrogen atom is the most abundant in the universe...

We find it everywhere, but never alone. It is always associated with other atoms.

First of all, in water. Water molecules are composed of 1 oxygen atom and 2 hydrogen atoms. And water is abundant on our planet - it covers 70% of the earth's surface and constitutes 60% of our own bodies!

It is also found in hydrocarbon. As the name implies, hydrocarbon is made up of carbon and hydrogen.

Innovation and technology at the heart of Air Liquide's development



Innovation at Air Liquide:

- 200 to 250 innovations are patented each year (which is one new patent per business day)
- 2,640 active patents
- More than 224 million euros devoted to innovation in 2008
- More than 100 industrial partnerships and more than 120 collaborative projects with universities and research institutions
- Air Liquide's participation in the *Observatoire des Innovations* is part of a broader global approach that seeks to promote the awareness and the understanding of hydrogen, an alternative energy that respects the environment.

www.planet-hydrogen.com

The Air Liquide Group at a glance

- **The world leader in gases for industry, health and the environment.**
- Present in **75 countries**
- Over **43,000** employees
- **8 Research & Development centers, 5 Engineering centers**, more than 200 patents annually
- Innovative solutions for **1 million customers** in a broad range of industrial sectors and healthcare: gases are indispensable in everyday life
- **410,000 individual shareholders who hold 38% of the capital. 35 % of not French institutional investors, 26 % of French institutional investors.** A relationship with shareholders built on **trust and transparency** for more than 100 years.
- A commitment to **sustainable development**: responsibility to the shareholder, safety and preservation of the environment, social and ethical commitment, innovation and technological progress
- Revenue in 2008: **€13.1 billion**
- Net profit 2008: **€1.22 billion**



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