

Hydrogen, a new clean energy working for the environment



Air Liquide, technological partner of the
Challenge Bibendum 2010

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Air Liquide, technological partner of the Challenge Bibendum



10th edition of the Challenge Bibendum: once again Air Liquide is present alongside Michelin on the occasion of this global event for sustainable road mobility.

In 2010, for the first time in the history of the event, the Challenge Bibendum is being held in South America in Rio de Janeiro (Brazil) where it will celebrate its 10th anniversary from May 30 to June 2, under the high patronage of President Luiz Inácio Lula da Silva.

Dedicated to clean mobility, the Challenge Bibendum will host numerous vehicles this year including **around 10 vehicles** powered by a fuel cell and **hydrogen energy coming from the Air Liquide filling station.**

A technological partnership that covers various aspects:

- The installation of a **dual-pressure hydrogen station (350 and 700 bar) designed and developed by Air Liquide**, allowing hydrogen vehicles to be filled both during various trial phases at the test center and at rallies. The vehicles, equipped with the latest technologies, will aim to prove their abilities on the road in real driving conditions as well as to demonstrate their environmental performance.

- A **booth** in the exhibition area, the participation in the **Forum** and in 2 **round tables**:

How to achieve a 20% share in Road Transportation with Sustainable Biofuels by 2020?

Speech by **Dr. Thomas Wurzel, Vice President Market Groups, Lurgi (Air Liquide group)**

How to meet a relevant market share (15%) of Electric Vehicles by 2020?

Speech by **Eric Prades, Director Hydrogen Energy, Air Liquide**

Pierre Dufour, Senior Executive Vice-President of the Air Liquide Group will participate in the debate on **Alternative Energies** which will take place on Tuesday June 1st.

For Air Liquide, this event is also **an opportunity to raise citizens' awareness** in the use of **hydrogen as a clean and quiet new energy carrier** that will supply the cars of tomorrow, and to get to know better **Air Liquide's technologies for clean energy and environment preservation.**



Challenge Bibendum - Air Liquide hydrogen stations - Paris / France June 2006 - Shanghai / China November 2007

Hydrogen, clean energy of tomorrow



Let's imagine sustainable energy and vehicles that don't generate any pollution.

Air Liquide has over 40 years of experience across the entire hydrogen chain, from production (over 200 production units worldwide) to every application.

Today's society faces two major challenges: climate change and the growing demand for energy. Hydrogen energy is a genuine response to these challenges, in particular because it enables **clean transportation**. Hydrogen powered consumer vehicles are expected to appear on the market by 2015.

The Air Liquide's subsidiary, Axane, develops a large variety of fuel cells of various sizes and power levels.

The energy cartridge, developed by Air Liquide in one of the R&D centers in France, is a small, user friendly hydrogen cylinder. The cartridge is filled with hydrogen at high pressure (700 bar) while the outlet pressure of the gas is reduced to ensure safe use.

The applications of the energy cartridge are **fuel cells and small urban vehicles equipped with a fuel cell**. Its ergonomic packaging is well suited for **general public use**.

The hydrogen filling stations designed and developed by the Group can supply vehicles with hydrogen in **less than 5 minutes**.

Over forty Air Liquide hydrogen filling stations have been installed throughout the world to date.



Fuel cell



Energy Cartridge



A hydrogen filling station and a fuel cell car

Hydrogen Energy

Air Liquide demonstration projects



As the world leader, Air Liquide has a certain responsibility to increase access to this clean and renewable energy. The Group is actively pursuing a twofold strategy, continuing to channel its efforts into hydrogen research and innovation, and taking part in large international demonstration projects.



The Horizon Hydrogen Energy (H2E) Program coordinated by Air Liquide was launched in October 2008.

This highly innovative program is based on the expertise of both the Group and the project partners (manufacturers, small and medium sized firms, French public research laboratories). It aims at building sustainable and competitive hydrogen-energy solutions. The research and development will cover the full hydrogen energy value chain. The total global investment in research and technology amounts to 190 million euros.



Air Liquide is leading the **European HyChain Minitrans Project**, a full-scale test in four European regions.

In the United States, the Group has supplied five hydrogen filling stations for the **Driveway Project**, testing 100 hydrogen vehicles in several large cities like New York, Los Angeles and Washington DC.



Air Liquide hydrogen filling station– Whistler/Canada

Air Liquide Canada signed a contract for 20 hydrogen powered buses which were also used on the occasion of the **Vancouver 2010 Winter Olympics and Paralympics Games**.

Other Canadian programs include the **Vancouver and Montreal airports**, which are installing hydrogen stations to supply fuel-cell and internal combustion engine powered passenger and utility vehicles.



For the **French Balises Project**, the Group has equipped several Bouygues Telecom GSM telephone network stations on isolated sites near Toulouse - France.

For more information:
<http://www.hydrogen-planet.com>

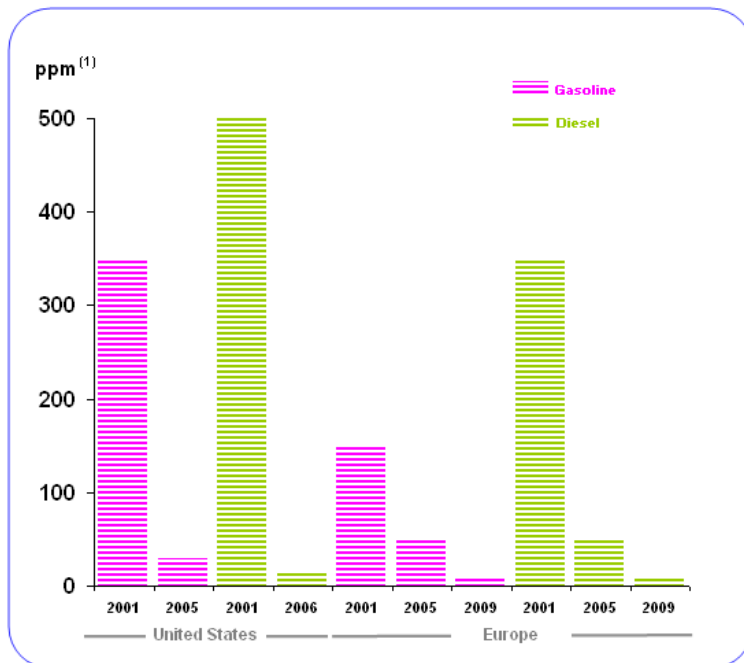
Removal of Sulfur from hydrocarbons, main current use of Hydrogen

Today, the most important current use of Hydrogen (nearly 2/3 of the quantity sold by the Group) is the de-sulfurisation of hydrocarbons to produce sulfur-free fuels.

This de-sulfurization of hydrocarbons is necessary to reduce the level of sulfur oxides emissions into the atmosphere and is mandatory under European and American regulations. Sulfur oxides can cause respiratory problems in humans. They are not only responsible for the emergence of smog in certain built-up areas but also for acid rain, which causes deforestation and the acidification of water. Sulfur also quickly deteriorates the performance of catalytic converters of vehicles.

Hydrogen supplied by Air Liquide to refineries all over the world avoided discharging **700,000 tonnes of sulfur oxides in 2009** into the atmosphere. In comparison, France discharges 450,000 tons every year.

Sulfur content regulation



Air Liquide, the world leader in gases for industry, health and the environment, committed to sustainable development



36% of Air Liquide's revenue comes from gas applications which preserve life and the environment.

More than 60% of Air Liquide's R&D budget is devoted to developing technologies designed to preserve the environment (energy savings, cleaner production, future energy development) and life.

85% of gas deliveries are made by pipelines or through on-site units. These pipelines, environmentally friendly and safe, span a network of over 8,500 kilometers worldwide.

18 cogeneration units replace steam and electricity production units that would have produced more CO₂ emissions. In 2009, the Group's cogeneration units **enabled the avoidance of 772,000 tonnes of CO₂** that would otherwise have been discharged into the atmosphere. They were about **14 % more efficient** than the separate production of electricity and steam.

Proposing alternative energy solutions

Air Liquide intends to play an active role in creating viable alternative energy solutions.



Understanding and anticipating environmental challenges

Using **oxygen for oxycombustion** in industrial furnaces reduces nitrous oxide (NO_x) emissions into the atmosphere and facilitates the capture of carbon dioxide. Hydrogen is indispensable for reducing the sulfur content of hydrocarbons and, consequently, the sulfur oxides (SO_x) emissions caused by their combustion.

Air Liquide is constantly increasing its involvement in areas such as cogeneration, second generation biofuels and hydrogen energy, which also offer significant potential for reducing CO₂ emissions in the years to come.

Oxycombustion a solution for Carbon Capture and Storage



Oxycombustion to improve energy efficiency

Many industrial processes (in the glass, metallurgy, steel and other industries) use the combustion process to heat raw materials (glass, aluminum, steel, etc.). Traditionally, these manufacturers use fuel (oil, natural gas, etc.) and air (21% oxygen and 78% nitrogen).

In the 80s, glassmakers were concerned about NOx being harmful to people and the environment due to the reaction of oxygen and nitrogen at high temperatures. The Air Liquide solution is to use oxygen during the combustion process, replacing the air.



Test combustion platform at Air Liquide R&D center in France

Oxycombustion presents two advantages:

- **higher energy performance.**

The absence of nitrogen makes it possible to heat raw materials without using as much fuel, which results in lower CO₂ emissions.

- **NOx reduction by factor 20.**

Oxycombustion for Carbon Capture & Storage (CCS)

Air Liquide is present across the CCS chain: the Group supplies the oxygen needed for oxycombustion. To concentrate CO₂, Air Liquide researchers develop special burners for use with oxygen.



REOXAL burner for clean power production

Oxy-burner properties are tested in a 2 MW pilot furnace at the Claude Delorme Research Center, France. A new oxycombustion platform of 5 MW was built in 2009 at the Delaware Research & Technology Center, USA.

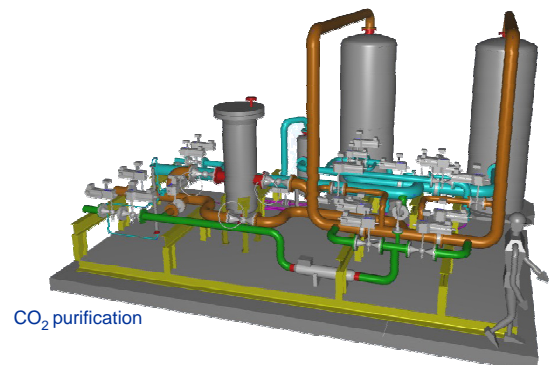


Test combustion platform at Air Liquide R&D center in USA

The expertise acquired in oxycombustion for the glass and steel industries, shown by over 800 patents in this field, is now being applied to clean energy production.

Oxycombustion technology is now being implemented at a power plants to capture and store CO₂. R&D engineers are developing equipment to enrich flue gas in CO₂.

Finally, CO₂ is purified, for example, in a Cryogenic Purification Unit (CPU), ready for compression, transportation and sequestration.



CO₂ purification

Oxycombustion

Air Liquide demonstration projects



Reducing CO₂ emissions

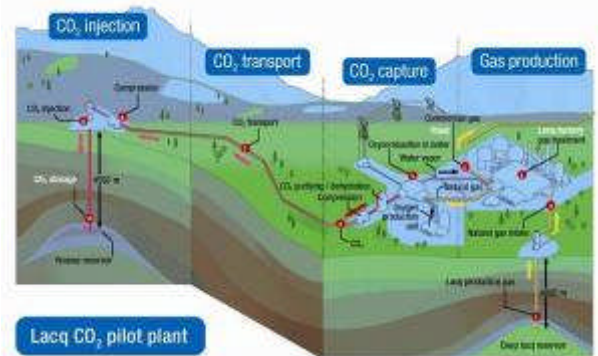
Air Liquide is engaged in numerous pilot projects in Europe, North America and Asia Pacific that are testing oxygen-based processes for reducing CO₂ emissions.

- Within the European project ULCOS, Air Liquide Group has developed, built and tested **a pilot equipment for separating CO₂ from blast furnace gases**. The first successful industrial validation of Air Liquide's expertise was in Luleå, (Sweden) in April 2008, on the site of MEFOS (Metallurgical Research Institute).



A pilot equipment for separating CO₂

- In **Europe**, Air Liquide and Total are partners in the Lacq demonstration project in France, demonstrating the feasibility of **capturing and storing CO₂** from a **30 MWth** gas-fired boiler in a depleted natural gas field. Air Liquide is providing **adapted oxygen burners, oxygen** from an on-site unit, and the **CO₂ drying process**. **Start-up in 2010.**



- In **Australia**, Air Liquide is the technological partner of the Callide Oxyfuel project. A **100 MWth** coal-fired boiler is being **retrofitted with oxy-combustion technology** for partial CO₂ capture and underground storage. Air Liquide is supplying **oxygen** and a **CO₂ compression and purification unit**. **Start-up in 2011.**



Callide A Power Station to be converted to oxycombustion

Photovoltaic offer an environmental friendly solution



Photovoltaic installations are expected to contribute approximately 5% of the worldwide electricity generation by 2020, providing greenhouse free energy to nearly 1 billion people.

The production of solar cells requires **large quantities of ultra-pure gases such as silane, hydrogen, nitrogen and other specialty gases.**

Air Liquide is the **leading supplier of gases and services to the photovoltaic industry:** major Poly-Silicon producers, eight of the top 10 crystalline-Si solar cell manufacturers, and over 40% of the thin film solar cell production “fabs” worldwide are today Air Liquide customers.

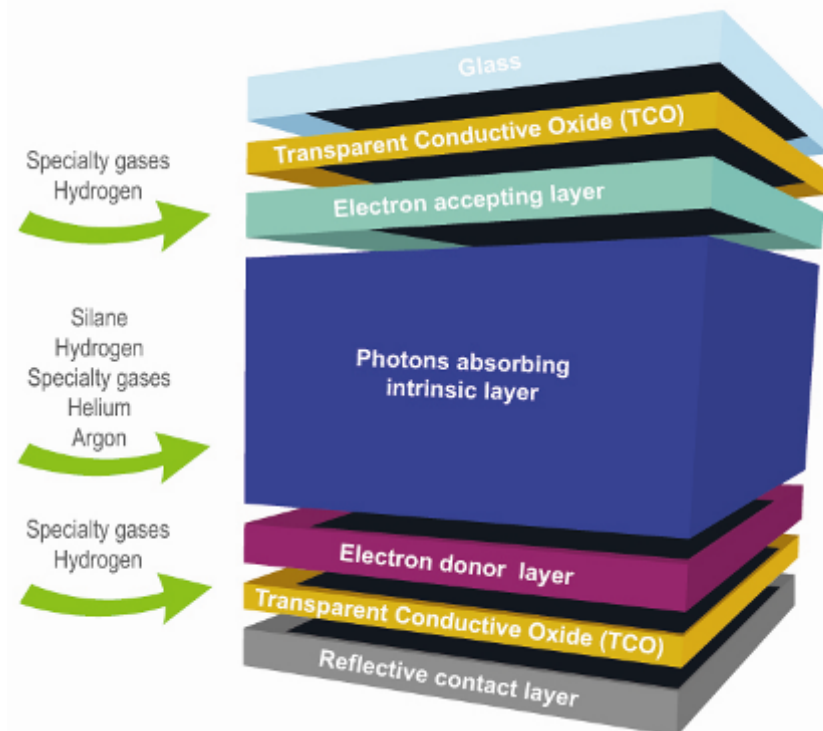
Air Liquide is indeed the partner of large-scale photovoltaic production sites in China, Japan, US and Europe, where it supplies specialty gases, carrier gases, liquid precursors and services to leading solar cell manufacturers.

The Group leverages its expertise to help its customers reduce their final solar cost per watt of electricity produced, **making solar energy more competitive** with traditional fossil fuels. To do so, Air Liquide has set-up dedicated R&D activities focused on developing next-generation molecules, aimed at increasing solar cells efficiency.



Air Liquide Solar

The Group also actively supports its customers, as they expand their production capacity globally, and as they introduce more advanced solar cells designs and technologies.



amorphous silicon thin film solar cell cross section

What are the main drivers?

- Global CO₂ emissions are constantly increasing
- Limited fossil fuel resources
- Global warming
- As part of its policy aimed at reducing greenhouse gas emissions, the European Union is requiring that renewable energy sources be increased to 10% of global fuel volume by 2020.

Benefits of second generation biofuels

With its Engineering subsidiary **Lurgi**, Air Liquide uses only the non-edible part of the plant to develop the production of the so-called green fuels.

Air Liquide developed a multi-step technology that converts biomass like waste wood or straw, into synthesis gas and then into liquid fuels.

Air Liquide participates in a major demonstration project in collaboration with the German Technical Center in **Karlsruhe** (Forschungszentrum) for fuel production from biomass.

Air Liquide is a partner in the 2nd generation biofuels project at **Bure-Saudron**, located on northeast France. The demonstration unit, which combines in a single facility all of the various second generation biofuel production elements, will be the first production unit of this kind in France.

The Group is also involved in a collaboration with the **University of Freiberg** for the high pressure gasification process of hydrocarbons.



Pyrolysis pilot unit at Karlsruhe (Germany)



Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft



Air Separation Unit (ASU)

For many years now, Air Liquide has made improving the efficiency of its production units a priority in its development plan.

Controlling and managing a technological process greatly improves its efficiency. Air Liquide teams develop process control systems which optimize the industrial efficiency of the Group facilities and of its customers. In industry, this concerns the management of oxy-fuel burners performance which increases the quality of glass or the recycled aluminium yield. When applied to gas production, process control enables Air Liquide to reduce energy consumption of its operational units.



For example, the energy efficiency of hydrogen units per m³ of CO₂ of gas produced by these units continued to improve in 2009, reaching almost 3% compared to 2004. This is the equivalent of **a decrease in CO₂ emissions of about 100,000 tonnes per year**, which corresponds to the average annual emissions of 50,000 cars.

The Air Liquide Group at a glance



- **The world leader in gases for industry, health and the environment.**
- Present in **75 countries**
- Over **42,300** 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. 36% 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 2009: **€12 billion**
- Net profit 2009: **€1.23 billion**

Air Liquide in Brazil

- About 1,500 employees
- More than 50,000 customers
- 2nd on national ranking in Brazil
- 23 commercial Branches
- 45 industrial sites:
 - 20 filling centers
 - 25 gas production centers

- Sales:

Industry 75%

aeronautics, automotive,
food & beverages, chemical,
defense, electronic, energy,
metallurgy, mining,
naval, paper and others

Health 25%

Medical gases and Homecare



For more information, please contact:

Air Liquide Brazil

Patricia Sakamiti

patricia.sakamiti@airliquide.com

☎ + 55 (11) 5509 8382

Corporate Communications

Corinne Estrade-Bordry

corinne.estrade-bordry@airliquide.com

☎ + 33 (0)1 40 62 51 31

Garance Bertrand

garance.bertrand@airliquide.com

☎ + 33 (0)1 40 62 59 62

www.airliquide.com