

# Cutting-edge technologies for clean energy and climate protection

**Bright Green**  
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# 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.

**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.

**84% 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 CO<sub>2</sub> emissions. In 2008, the Group's cogeneration units **enabled the avoidance of 575,000 tons of carbon dioxide emissions** that would otherwise have been discharged into the atmosphere.

## **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<sub>x</sub>) 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<sub>x</sub>) 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 CO<sub>2</sub> emissions in the years to come.

## Removal of Sulfur from hydrocarbon, main current use of Hydrogen

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.

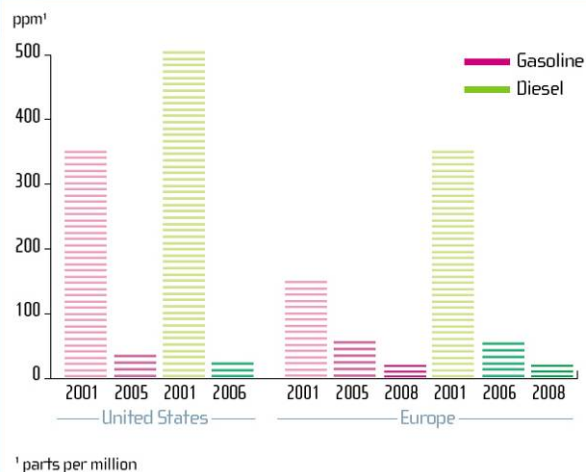
This de-sulfurization of hydrocarbons is necessary to reduce the level of sulfur oxides emissions into the atmosphere. In fact, sulfur oxides can cause serious respiratory problems in humans. They are not only responsible for the emergence of smog in certain built-up areas but also for acid rain, which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

Hydrogen is supplied by Air Liquide to refineries all over the world to avoid discharging **770,000 tons of sulfur oxides per year** into the atmosphere. In comparison, France discharges 450,000 tons every year.

Group 2008 H<sub>2</sub> revenue: **€1.2 billion**.

Production in 2008: **7 billion cubic meters** of hydrogen.

### SULFUR CONTENT REGULATIONS



# Hydrogen Energy clean energy of tomorrow



*Let's imagine sustainable energy that is clean to produce and to use, and vehicles that don't generate any pollution or noise.*

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, especially as **a clean means of transportation**. Mass-produced hydrogen powered vehicles are expected to appear on the market by 2015.

**The Air Liquide's subsidiary, Axane, develops a large variety of fuel cells.**

**The energy cartridge**, developed by the Group 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.

Many applications are proposed, including **fuel cells, internal combustion engines and small urban vehicles**. 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**.

Today, Air Liquide group has developed nearly **50 hydrogen filling stations worldwide**.



Fuel cell



Energy Cartridge



A hydrogen filling station and a fuel cell car

# Hydrogen Energy

## Air Liquide demonstration projects



As the world leader in gases for industry, health and the environment, 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 officially launched following the authorization of the European Commission in October 2008.

This highly innovative program will be based on both the Group and the project partners (manufacturers, small and medium sized firms, French public research laboratories). The total global investment in research and technology amounts to 200 million euros.



Air Liquide is leading the **European HyChain Minitrans Project**, a full-scale test in four European regions of 50 hydrogen powered vehicles supplied with hydrogen via reusable cylinders.

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 Canada signed an important contract for 20 hydrogen powered buses for the **BC Transit Vancouver 2010 Winter Olympics**.



Compressed Hydrogen

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>

# Oxycombustion a solution for Carbon Capture and Storage



## Oxycombustion to improve energy efficiency

Many industrial processes (glass industry, metallurgy, steel, etc. ) use combustion process to heat their charges of glass, aluminum or steel. Traditionally, these manufacturers use fuel (oil, natural gas , etc.) and air (21% oxygen and 78% nitrogen).

In the 80s, glassmakers were concerned about NO<sub>x</sub> 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.**  
Higher temperatures are possible when nitrogen is not used, and this reduces fuel consumption. Less fuel consumed means less CO<sub>2</sub> emitted.
- **NO<sub>x</sub> 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.

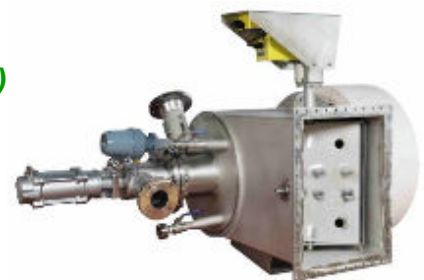
To concentrate CO<sub>2</sub>, Air Liquide researchers develop special burners for use with oxygen.

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.

The expertise acquired in oxycombustion for the glass and steel industries is now being applied to clean energy production.

Oxycombustion technology is now being implemented at a power plant to capture and store CO<sub>2</sub>. R&D engineers are developing equipment to enrich flue gas in CO<sub>2</sub>.

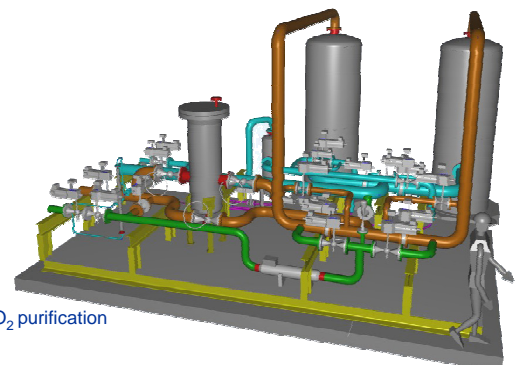
Finally, CO<sub>2</sub> is purified in a Cryogenic Purification Unit (CPU), ready for compression, transportation and sequestration.



REOXAL burner for clean power production



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



CO<sub>2</sub> purification



# Oxycombustion

## Air Liquide demonstration projects



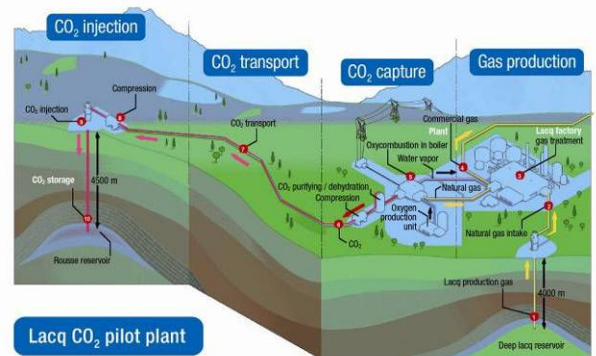
### Reducing CO<sub>2</sub> emissions

Air Liquide is engaged in numerous pilot projects in Europe, North America and Asia Pacific that are testing oxygen-based processes for reducing CO<sub>2</sub> emissions.

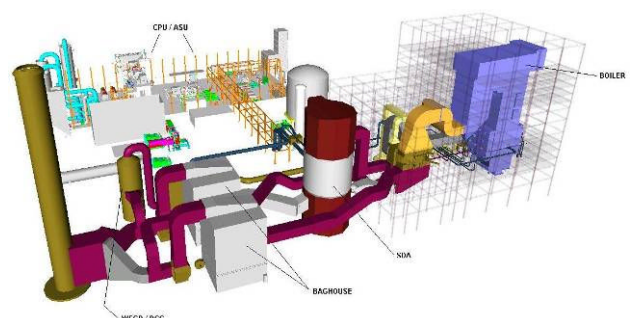
- Within the European project ULCOS, Air Liquide Group has developed, built and tested a **pilot equipment for separating CO<sub>2</sub> from blast furnace gases**. The first successful industrial validation of Air Liquide's expertise was in Luleå, (Sweden) in April 2008, on the site of MEFOS (Metallurgical Research Institute).
- In Europe, Air Liquide and Total are partners in the Lacq demonstration project in France, demonstrating the feasibility of **capturing and storing CO<sub>2</sub> from a 30 MWth gas-fired boiler in a depleted natural gas field**. Air Liquide has provided **proprietary burners, oxygen from an on-site unit, and CO<sub>2</sub> purification technology**. **Start-up in 2009.**
- 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 CO<sub>2</sub> capture and underground storage. Air Liquide is supplying **oxygen and a CO<sub>2</sub> compression and purification unit**. **Start-up in 2011.**
- In North America, Air Liquide, Babcock & Wilcox and Batelle are joining efforts to develop and implement the oxycombustion process at a pulverized coal plant to be built in Black Hills (Wyoming). Air Liquide will supply **oxygen and the CO<sub>2</sub> purification unit for the 100 MWe plant**. This will be the first **commercial-scale carbon capture and storage (CCS) oxycombustion demonstrator** in the world. Service **start-up in 2015.**



PSA (Pressure Swing Adsorption) CO<sub>2</sub>



Callide A Power Station to be converted to oxycombustion



Oxy-coal power equipment

# Photovoltaic offer an environmental friendly solution



Photovoltaic installations are expected to contribute approximately 5% of the worldwide electricity generation by 2020. 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:** more than half 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.

In 2006, Air Liquide launched **ALUX**, a dedicated advanced molecule range, offering turn-key solutions (gas, equipment and related services).

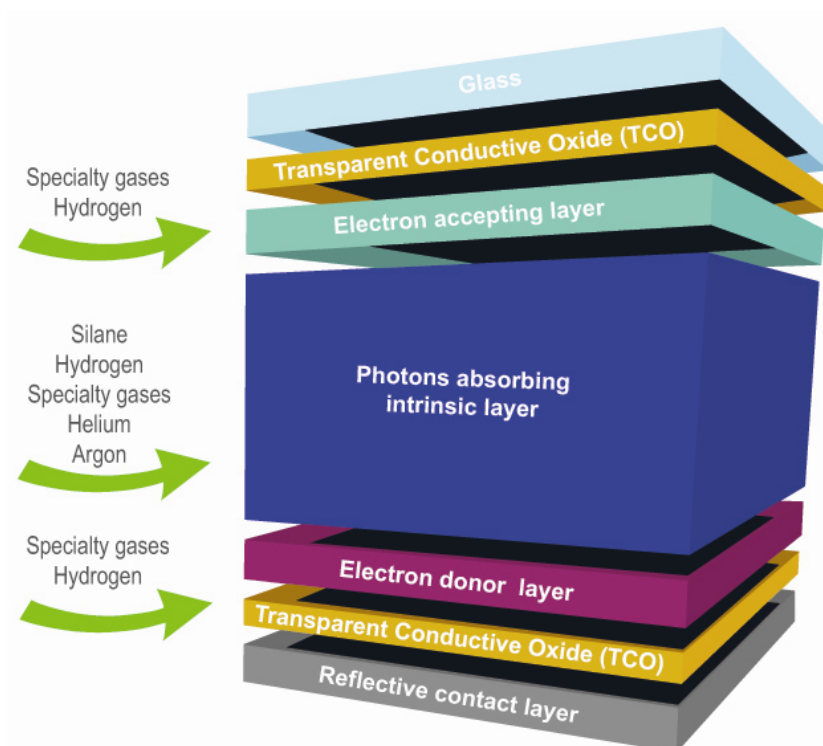
Air Liquide is a partner of large-scale photovoltaic production sites in Singapore, China and Germany, where it supplies specialty gases, carrier gases and services to the key players in the photovoltaic industry.

The Group leverages its expertise to actively contribute to reducing the final cost per watt of electricity produced by solar systems, **making solar energy more competitive with traditional fossil fuels.** Air Liquide has launched R&D activities **aimed at meeting this objective, a key challenge for the photovoltaic industry.**



StockPhoto

The Group supports its customers as they diversify geographically and technologically.



Standard amorphous silicon thin film solar cell

## *What are the main drivers?*

- Global CO<sub>2</sub> emissions are constantly increasing
- Limited fossil fuel resources
- Global warming
- As part of its policy targeting the reduction of greenhouse gases, the European Union requires that the proportion of biogenic motor fuels in the global fuel volume be increased to 5.75% by the year 2010.

## *Benefits of biofuels*

With its Engineering subsidiary **Lurgi**, Air Liquide uses biomass made up of plant residues to develop the production of the so-called green fuels that do not compete with the food supply. Air Liquide developed a multi-step technology that converts biomass like waste wood or straw, into valuable biomass-to-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.

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. **Over the last 10 years, the energy consumption per tonne of oxygen produced has declined by 1% per year on average.**



# Air Liquide in the Nordic countries



- 2008 revenue: around €200 million
- Around 500 employees
- 75,000 customers
- 350 distributors

Air Liquide is present in Denmark, Norway, Sweden and Finland. In the Nordic zone, the four subsidiaries share common resources. Air Liquide Denmark A/S has been ISO 9001 certified since 1992 and ISO 14001 certified since 2006.

Air Liquide supplies gas related equipment and nitrogen as well as silane and ammonia to a solar cell manufacturer, REC Scan Cell AS, in Narvik, Norway.

Air Liquide Denmark delivers high quality hydrogen, produced with renewable energy sources, to the hydrogen filling station in Copenhagen.



# 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, healthcare and to preserve environment.
- **410,000 individual shareholders who hold 38% of the capital. 35% non-French institutional investors, 26% 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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