

# ON AIR

No. **05**  
NOVEMBER  
2017

The magazine of the Air Liquide Group



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### FROM THE EDITORIAL TEAM

# A new milestone for the ON AIR magazine

**Air Liquide is transforming, and it shows!** On the heels of its new visual identity, Air Liquide is now renewing its magazine, ON AIR, by opening it up to all its stakeholders across the world to share its expertise and experiences more widely.

In this fifth issue, Air Liquide takes you on an exciting space adventure to discover the key role gases play in every step of space exploration (see page 8).

Back on earth, your first stop will be at a wastewater treatment plant, to learn how oxygen can help solve challenges related to water (see page 16). Next, you'll head to Dubai, where Air Liquide just opened a hydrogen station for its customer, AI Futtaim. Hydrogen's key role in the energy transition has not escaped our guest, the researcher Kevin Sivula. He was recently awarded for his innovative work in producing this gas using water and solar energy (see

page 36). Plus, a tour in the cab of an Airgas driver, equipped with an onboard safety system, and a visit to Antarctica, where the Air Liquide Foundation is funding a ground-breaking project: the creation of an ice core sanctuary to preserve memory of past climate changes (see page 34).

**BON VOYAGE!**  
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### ONAIR - The magazine of the Air Liquide Group

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## OPINION COLUMN

# Open Innovation, a key to transforming customer experience



### **Benoît Potier**

Chairman and CEO of the Air Liquide Group



Follow Benoît Potier on LinkedIn  
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Experience teaches us that innovation is always first and foremost a matter of people, connections and analogies, before being a question of pure technology. We've all found ourselves in those unique moments made for creativity and the emergence of new ideas—be it during an off-site staff meeting, or when traveling to a new place. It's not always clear how or why those dynamics occur, but we can no longer leave it up to chance to stumble upon such creative environments. From policymakers, scientists and sales

representatives, within the smallest start-ups or largest industrial groups, we must all be actively looking to create the conditions necessary for people's ideas and knowledge to connect—both within organizations and across entire ecosystems. This is the driving goal of Open Innovation.

In the industrial sector, fostering innovation has become a priority for companies striving to be market leaders. Gone are the days when a firm could retain control over its entire R&D efforts.

# “Experience teaches us that innovation is always first and foremost a matter of people, connections and analogies, before being a question of pure technology.”



Gone, too, is the frantic competition to simply obtain more and more patents. The recent revolution in information and communication technology has helped open up our world, where established innovation models are being disrupted and development times drastically reduced.

Regardless of the sector or the size of a company, innovation now thrives in an open ecosystem, developing hand-in-hand with customers, and relying on partnerships with start-ups, small- and medium-sized businesses, universities and research centers around the world. This new way of implementing Open Innovation applies not only to core business projects, but also to the so-called “new markets.” The goal is always the same: **early detection of the best solutions to transform customer experience, and deploy them with agility.**

While Open Innovation requires entry into different global innovation ecosystems to conquer new markets, one of the most crucial conditions of success remains **the ability to work together.** By organizing people around a network—where competences are better spread and shared, both locally and internationally—**we accelerate the development processes through sharing knowledge and risks while always moving closer to end users.** It is also an opportunity to attract new talent. If large companies want to stay on top, it has become indispensable for them to dive into the world and ways touted by start-ups. Granted, redefining one’s activity to fit our all-digital world requires considerable upfront investment, both financially and intellectually.

But favoring Open Innovation means believing that a more human way of working together is conducive to the best entrepreneurial spirit. It means always keeping up-to-date with the latest technological and societal changes. The goal, in the end, is to ensure the loyalty of existing customers while also attracting new ones.

In line with this approach, Air Liquide’s plant of the future project, Connect, which brings together ten start-ups and a large number of SMEs, was launched at the beginning of 2017. More recently, our company joined the Techstars Paris incubator, which connects large firms and start-ups. This opportunity to accelerate innovation in the fields of artificial intelligence, data, the Internet of Things, cybersecurity and smart mobility enables each of the participating start-ups to benefit from the industrial and technological experience of the big corporations that have worldwide reach. For the multinationals, **the experience helps enrich customer experience by taking into account the latest practices.**

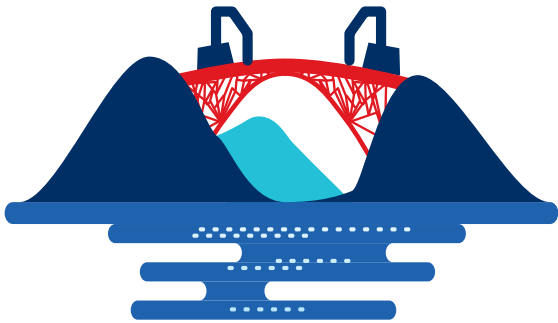
As we can see, this new innovation model offers enormous potential, which extends well beyond just technological advances. It is both a source for improving customer experience and increasing efficiency across a company, **placing people and their expectations squarely at the heart of the innovation process.**

Ultimately, Open Innovation is aimed at putting into place the conditions for a veritable paradigm shift—at every level of a company and across all of society.

*Posted on September 8, 2017*

# ONAIR 360

Industry of the future, e-health, the energy transition and the environment, digital transformation: these are all major topics on which Air Liquide works with its expertise and vision. **Overview of developments in 2017.**



## The immersive experience

### Additive manufacturing: a bridge to the future

Unveiled on June 11, 2015, the MX3D Bridge is a world first. The goal of this project, created by the Dutch designers at Joris Laarman Lab, is to build a stainless-steel passage in Amsterdam's historic downtown district using an innovative additive manufacturing process. Operating in real time and without any human intervention, a robotic arc welding machine will build the bridge out of metal using 3D printing technology. This impressive technological feat is a sign of the profound transformation the industrial manufacturing sector will undergo in the future. Air Liquide is working with the teams in several fields of expertise, including the supply of gas, know-how in arc welding, and Research and Development. Experience the construction of the bridge on the website [airliquide.com](http://airliquide.com).

## The mindset

### “Voice of Customer”: Listening ever more closely to our customers’ needs #CX

In the framework of its company program NEOS, Air Liquide is deploying “Voice of Customer,” a project which will in time compile customer feedback from all business lines throughout the world by inviting customers to fill out an online relationship survey. Feedback is made available in real time so teams can analyze it and implement all necessary actions to improve the customer experience. The next step: to measure the immediate impressions of customers at different key moments in the customer journey. This program represents a development in terms of precision and responsiveness, for a more personalized customer experience and contributing to company performance.

## The trend

### A new profession: Data Scientist

Making sense of numbers to add value—such is the role of a data scientist. These experts are well versed in both business and science, allowing them to contextualize and interpret data. They are highly sought after by companies. At Air Liquide, Data Scientists work in close collaboration with the company's operational marketing, sales, industrial, and IT teams. Their role consists of applying data science to all of these areas of expertise to detect, test, and optimize innovative solutions and tailor the Group's offers to better match customer needs.



The map

## The odyssey of Energy Observer: the first energy self-sufficient vessel

Energy Observer, the first seagoing vessel powered by hydrogen and renewable energies (sun and wind), will carry out a world tour, through the most challenging conditions, using only natural resources. Inaugurated on July 6 in Paris, the ship will travel to 50 countries and make 101 stops over a six-year period, without emitting any greenhouse gases or fine particles. Air Liquide has been involved in the development of hydrogen, particularly for mobility, for over twenty years. The Group supports this human, technological, and educational project, which demonstrates the key role of hydrogen in the energy transition.

The number

# 54%

This is the percentage of sales associates who report closing a sale following an interaction on social media. In Belgium, the Netherlands, and Luxembourg, Air Liquide sales teams have been undergoing training in social selling for the past year. The goal is to highlight their expertise and increase their visibility among customers and prospects by sharing content related to their business via a dedicated platform. Following the success of this initiative, similar approaches have started to appear throughout the Group's entities.

The safety good practice

## Detecting leaks with fiber optic cables

Known for its ability to transport a large amount of data at the speed of light, optical fiber is also used in the fields of safety and quality control. In fact, the technology can detect gas leaks in underground pipelines. This discovery is the result of the FOLD project<sup>(1)</sup>, carried out by the Group in 2015 and 2016 in collaboration with Total, Engie, GRTgaz, and Ineris. Fiber optic cables were installed near a 30-meter-long, 40 centimeter wide pipeline, buried 80 centimeters below ground. The teams noted that a leak triggered a change in temperature that altered the backscattering of light from the optical fiber and/or emitted a sound. A quick and effective alarm system for companies, partners, and customers operating pipelines.

(1) Fiber Optik Leak Detection

The inauguration

# Oxygen House

This year, Air Liquide opened its first Oxygen House in Senegal. As the base for its Access Oxygen program, this facility provides medical oxygen to small suburban and rural healthcare centers. Due to the lack of an adapted offer, these structures previously had no access to medical oxygen, despite the essential role of this product in the treatment of respiratory and heart diseases. Access Oxygen is part of the Group's innovation laboratory, the i-Lab's Inclusive Business approach. Working in conjunction with healthcare and operational teams in Senegal, it aims to provide solutions that are adapted to developing economies.

—  
**For more information, visit the i-Lab's website.**

# EXPLORER



EXPLORATEUR

EXPLORADOR

ENTDECKEN

ESPLORATORE

EXPLORADOR

エクスプローラー

ODKRYWCA

探索者

ОБОЗРЕНИЕ

## SPACE

The exploration of  
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## WATER TREATMENT

Oxygen and  
the water challenge

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# THE EXPLORATION OF SPACE CONTINUES

For over 50 years, Air Liquide has taken part in a great adventure: the exploration of space. Thanks to its unique expertise in cryogenics (extreme cold) and gas engineering, Air Liquide plays a decisive role at every key stage of the exploration of space: from the design of space launchers to the launch itself, from satellites to orbital systems. Air Liquide also provides its know-how to contribute to the field of renewable energy (from production to storage), and life support systems in space. Lift off!



# AIR LIQUIDE PRESENT AT EVERY STAGE

From the design of space launchers to space exploration and the optimization of installations on the launch pad, the Group provides its expertise.

## 1. Upstream: the design of launchers

With its entity Air Liquide advanced Technologies, Air Liquide designs the cryogenic tanks of launchers and integrates them into the rocket. As a partner of the space community, every day, the Group works on the development and optimization of this equipment, particularly in the areas of insulation and the management of fluids. As a result, Air Liquide has been involved in every development of the Ariane launcher since its creation in 1973.

## 2. On the ground: at the launch site

At the rocket launch sites of Kourou in French Guiana, Cape Canaveral in the US, Tanegashima in Japan, and Xichang and Wenchang in China, Air Liquide has tested, carried out, and optimized the installations and connections of launch sites' cryogenic transfer lines since the 1980s. For every launch, the Group's teams produce and supply the launchers' propulsion and inerting fluids: liquid hydrogen, liquid oxygen, helium and nitrogen.

## 3. Around Earth: in satellites and orbital systems

In the field of orbital cryogenics, the technological solutions developed by Air Liquide meet a wide range of needs: conservation of biological samples examined on the International Space Station, observation of thermal radiation in the universe with the Herschel and Planck satellites, and cooling of the infrared sensors of Earth-observation and meteorological satellites. Air Liquide also develops components for the electric propulsion of satellites that will be used by a quarter of geostationary satellites by 2022.

## 4. And beyond: space exploration

Air Liquide is taking part in mankind's quest to establish a human presence in space by producing and storing energy, purifying air, and by producing fuel to enable space vehicles to return to Earth, among other things. The technological building blocks required to undertake this journey have already been developed in part on Earth. Next step, adapting them for use in space.

# AROUND A LAUNCH

Design and production of cryogenic tanks and equipment, production of industrial gases that act as a propellant (rocket fuel), operational support and provision of services associated with the launch site: thanks to its know-how in cryogenics and gas applications, Air Liquide is involved in every major stage of the life of a launcher from design to lift off, on ground and on board.



ARIANE 5 IN FIGURES	
<b>420,000</b> liters of liquid oxygen and	<b>750</b> tons: approximately 1/10 of the Eiffel Tower.
<b>800,000</b> liters of liquid hydrogen used per launch.	<b>10</b> million liters of liquid oxygen and hydrogen are delivered every year to Kourou by Air Liquide Spatial Guyane.
<b>80</b> consecutive successful launches for Ariane 5 over a period of 14 years.	

## CHRONOLOGY OF A LAUNCH

1

**Lift off**  
Ignition of the cryogenic main stage (EPC) and then of the two solid propellant boosters (EAP) that surround it to propel the rocket out of the Earth's atmosphere. Pyrotechnic systems later detach the EAPs from the rocket.

## WHAT AIR LIQUIDE DOES

### Production and supply of propulsion fluids

In French Guiana, Air Liquide supplies the propulsion and implementation fluids (liquid oxygen and hydrogen) of the Ariane, Vega and Soyuz launchers. For example, in the case of Ariane 5, these fluids are supplied in semi-mobile tanks positioned near the launch base. Developed specifically for their content, these tanks are connected to the launcher through highly insulated pipes.

### Supply of launch pad and mast distribution systems

The launch pad is an enormous mobile metal structure that, on its own, weighs 850 tons. It is equipped with an umbilical mast, which stands at a height of 58 meters and houses the installations necessary to feed and control the launcher: Air Liquide supplies and operates all of the distribution systems that supply liquid oxygen and hydrogen to the cryogenic main stage (EPC). The mast also supports the two cryogenic arms needed to fill and empty the ESC-A (cryogenic upper stage 'A').



2

### Separation of the nose cone

Once out of the Earth's atmosphere, the rocket's nose cover is released. The engine continues to power the rocket. The nose cone and the tanks then come away, releasing the ESC-A (cryogenic upper stage 'A').

3

### Separation of the upper stage and satellite

Propulsion continues for approximately 15 minutes before stopping. The rocket - or more specifically, the 'payload'<sup>(1)</sup> - freed from the elements that surround it, continues its ballistic flight before deploying its two satellites in a geostationary orbit.

### Production and supply of helium, compressed air and nitrogen

Gaseous helium is used to inert the transfer lines, particularly the liquid oxygen and hydrogen lines of Ariane 5. In its liquid state, helium is used to maintain the pressure of the EPC tanks, which contain liquid hydrogen and oxygen, as they are emptied. Compressed air is used for different parts of the launcher (nose cone, EAP, etc.). Finally, nitrogen is supplied in its gaseous state, at 250 bar, through a pipeline that supplies the launch zone.

### Supervision and maintenance of the oxygen and hydrogen tanks

On behalf of Arianespace and the French National Space Agency (CNES), Air Liquide Spatial Guyane and Air Liquide advanced Technologies ensure the supervision and complete maintenance of the cryogenic equipment, EPC and ESC-A tanks as well as all of the tubes that connect the launcher, the arms and the pipelines to the installations on the ground. Highly-insulated pipes under vacuum are used to transfer cryogenic fluids at a very low temperature during the filling of Ariane 5's cryogenic tanks.

(1) The section of the spacecraft that is designed to fulfill the goals of the mission. The payload of a rocket is the man-made satellite or the space probe that it has to place in orbit.

# AIR LIQUIDE IN ORBIT

Today, the technology developed by Air Liquide can be found in the biggest international space projects sent into orbit: satellites, telescopes, the International Space Station, etc.

## THE ISS

“Happy birthday, MELFI!”<sup>(1)</sup> These are the words of French astronaut Thomas Pesquet to celebrate the tenth anniversary of the cryorefrigerator, during his stay on the International Space Station in December 2016. Air Liquide designed and developed MELFI, a turbo space fridge, for the ESA so that biological and scientific samples can be stored at a temperature of up to -95°C before being brought down to Earth for analysis. There are three MELFI units on the ISS. “They are essential for the smooth running of our biological experiments (...). For example, without MELFI, we would not be able to carry out research on the human body,” notes the astronaut.

*(1) The Minus Eighty degree Laboratory Freezer for the ISS.*



EARTH

ISS

MOON

## ON EARTH

In 1962, Air Liquide advanced Business & Technologies' current site in Sassenage (France) was created to develop industrial cryogenics, including for the space industry. A test center was subsequently created to carry out full-scale trials under simulated space conditions on the tanks built on site. This center then evolved to support other activities and customers. “A single site to test, check, qualify and manufacture equipment for the needs of the space industry is unique,” explains Bertrand Baratte, Space Business Unit Director at Air Liquide advanced Technologies. Today, the Sassenage site has around 700 employees, including around 180 who work directly or indirectly for the space industry. The tanks of each generation of the Ariane launcher were tested at this site.

## THE MOON

“Energy and its storage are part of the main challenges to be overcome before humans can establish themselves sustainably on the Moon,” explains Pierre Crespi, Head of Innovation at Air Liquide advanced Technologies in Sassenage. This is why Air Liquide joined forces with the European Space Agency (ESA) and the German aerospace center (DLR) under the LUNA project, which seeks to establish a ‘lunar village’. The first test missions are scheduled to take place in the 2020s. “The aim is to test water extraction on the ESA’s site to produce hydrogen directly in situ and to use it as an energy vector before carrying out experiments on the Moon at a later date,” explains Frank de Winne, Head of the ESA Astronaut Center in Cologne, Germany. This is the purpose of the laboratory, Lunar Analogues, which is scheduled to open in mid-2018. Under conditions close to those found on the Moon, different types of materials and production processes will be tested, “starting with a hydrogen fuel cell that will be supplied by Air Liquide for the project,” explains Pierre Crespi.

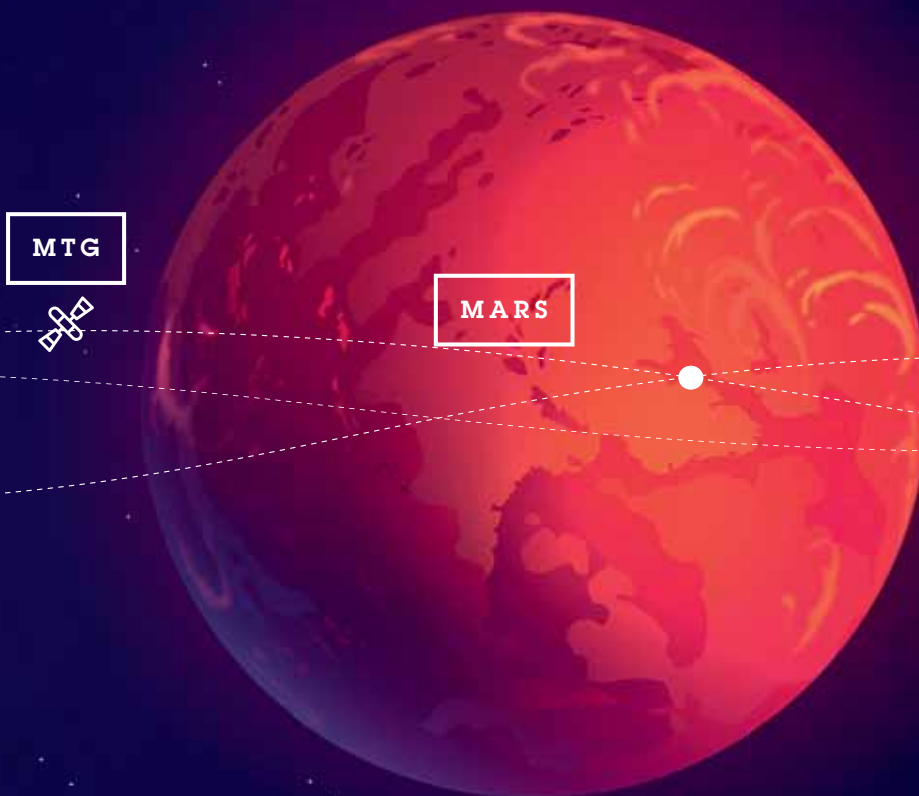
## MARS

“The Moon is just the first step. The goal is, of course, Mars,” insists Frank de Winne, at the ESA. “We also aim to send the first human to the red planet by the end of the century,” he says hopefully. Between now and then, several steps will have to be taken. After Curiosity, Air Liquide, will take part in the ExoMars mission in 2020, in partnership with the ESA and the Russian Space Agency Roscosmos. This mission will involve sending a rover to the red planet to analyze the composition of its subsoil. Air Liquide recently delivered a range of equipment, including microvalves that were specially developed for this mission and that will be mounted on ‘Moma’, the Mars Organic Molecule Analyzer, one of ExoMars’ main instruments.



### The next steps of space exploration

- 2018**  
Observation of the Earth from MTG satellites (MeteoSat Third Generation)
- 2020**  
ESA Mars Exploration Mission (ExoMars)
- 2021**  
Observation of the Earth from the Infrared Atmospheric Sounding Interferometer - New Generation (IASI-NG)
- 2030**  
Man returns to the Moon
- 2045**  
Man walks on Mars



#### SATELLITES AND ORBITAL SYSTEMS

##### MTG AND IASI-NG

Air Liquide will install pulsed gas coolers in MTG (MeteoSat Third Generation) meteorological and climatic data observation satellites and the Infrared Atmospheric Sounding Interferometer - New Generation (IASI-NG).

##### HERSCHEL AND PLANCK

Thanks to its technology which uses pulsed gas to provide refrigeration ('Pulse Tube'), Air Liquide has successfully carried out experiments for MELFI and the Herschel and Planck satellites while developing a dilution cooler capable of reaching -273°C with the CNRS (French National Center for Scientific

Research) and the CNES. Designed to cool one of the scientific observation instruments of the two satellites, this equipment guarantees the reliability and quality of the measurements collected thanks to its high stability in terms of temperature, without emitting vibrations or unwanted magnetic fields. It is one of the universe's coldest objects.

# FUTURE PROJECTS

From Earth to space, and from space to Earth: a 'continuum'.

This is how Air Liquide sees the space industry, which will continue to make enormous strides both in the sky and on Earth. We take a look at the challenges and prospects of an adventure that began 50 years ago and has never stopped developing.

(1) The European Organization for Nuclear Research.

(2) International Thermonuclear Experimental Reactor - ITER is a civil nuclear fusion research reactor project located in Cadarache (Bouches-du-Rhône, France).

(3) A homogeneous substance used on its own or in combination with other substances and designed to provide energy.

**"Air Liquide has been a part of the European program, Ariane, since 1973,"** recalls Dominique Boutelier, the Head of Air Liquide Spatial Guyane. This site has about 50 employees who are involved in each launch, just like the Sassenage teams in France responsible for the cryogenic tanks. Jean-Marc Astorg, Director of Launch Vehicles at the CNES agrees: "Without the

expertise of Air Liquide, Ariane would not have succeeded."

**Launchers, fluids, services, satellites:** today, the space business involves over 300 Air Liquide employees around the world. It is an area of major innovation for the Group, as noted by Pierre Crespi, Head of Innovation at Air Liquide advanced Technologies in Sassenage. Suzanne Roy, Vice President, Fusion, Aerospace, Space at Air Liquide adds: "The engineering, production and operational skills developed at our site are essential and a source of innovation in several high-tech industrial fields. I'm referring to scientific cryogenics for CERN<sup>(1)</sup> and ITER<sup>(2)</sup>, fuel cells and hydrogen that will be used by the aviation sector in the future and that are already being used by the car industry. In fact, it is a loop! Existing Earth-based technology is adapted for space and eventually brought back down for use on Earth. Sometimes, the loop may begin with a space application but the principle remains the same."

**Regarding the space sector,** the goal set by Bertrand Baratte, Space Business Unit Director at Air Liquide advanced Technologies, is ambitious: "we have to show clients that we can provide a global and comprehensive offer that draws on all of the Group's areas of



Space is an industry of major innovation for the Air Liquide group.

“For the ESA, it is essential to have partners like Air Liquide that bring us their expertise and enthusiasm.”

**FRANK DE WINNE**

Head of the Astronaut Center  
at the European Space Agency.



expertise.” He continues: “This offer begins with the separation of molecules (oxygen, hydrogen, helium) on Earth and extends to its use in different applications: launchers, satellites, electric propulsion (xenon, argon), cooling technology (cryo-coolers), cryogenic systems for future space tugs and even the creation of propellant<sup>(3)</sup> production stations in orbit.”

**In a fast-moving sector**, space is in the process of becoming a market like any other and in which there is more competition due to the emergence of new players. This is particularly the case with the entrepreneur, Elon Musk, and his launcher, Space X. The industry has its sights set on seeing man return to the Moon by 2030 at the earliest (see page 12). And Mars? “Everyone is talking about Mars!” Suzanne Roy and Bertrand Baratte exclaim simultaneously. “But if we want to get there by 2030, we have to position ourselves now, build technology roadmaps...” The reader will have understood that this is a journey in which Air Liquide wants to play an active role. And that journey begins today.



Today, over 300 Air Liquide employees around the world carry out work directly for space projects.

## AND TOMORROW

### ARIANE 6

Air Liquide acts as an advisor to the CNES, supports Ariane Group Project Managers, carries out thermal and functional studies on the two cryogenic stages, and qualifies and manufactures the functional equipment for the cryogenic tanks. It is therefore one of the

main partners of the Ariane 6 program, both on board and on the ground, and, above all, the design authority on all matters related to cryogenics. Ariane 6, equipped with two or four boosters and with a payload of 5 or 10.5 tons, will be more versatile than the current version. Its maiden flight is scheduled to take place in 2020.

# WATER TREATMENT



**Aerial view**  
of a wastewater  
treatment plant,  
including the  
clarifier tank.



# OXYGEN

— AND THE —

# WATER CHALLENGE

With freshwater a scarce resource, and pollution by wastewater posing an increasing threat to public health and the environment, the world urgently needs even more reliable and competitive water treatment technology. Air Liquide has grasped the scale of the challenge and is providing innovative solutions for it.



**O**

nly 64% of people have access to clean drinking water worldwide. Other worrying data: 80% of all wastewater flows back into the planet's ecosystem untreated<sup>(1)</sup>. Ensuring

proper treatment for wastewater is therefore one of the top priorities for the future of humanity. As such, many countries have recognized the importance of lessening damage to the environment and are legislating—and spending—accordingly. In China, for instance, the government is mid-way through a gigantic spending plan totaling around \$330 billion to fight water pollution<sup>(2)</sup> (see page 22).

Yet the issue is complicated even further by the fact that the diversity of pollutants found in wastewater is increasing: nitrates from fertilizers, nanoparticles from plastics, and micropollutants (drug residues, cosmetics, etc.) are increasingly present.

**THE WASTEWATER TREATMENT PROCESS IN SEWAGE PLANTS**

Both at industrial treatment plants and municipal sewage works, wastewater treatment generally involves three stages. In primary treatment, used water and sewage are held in a clarifier tank so that solids can settle on the bottom and be removed while lighter materials float and are skimmed off. The water then goes into secondary treatment, where water-borne microorganisms are used to break down biological matter. Finally, water undergoes tertiary treatment before it is released into the ecosystem. This stage can involve advanced oxidation processes or activated carbon adsorption<sup>(3)</sup>.

**HOW AIR LIQUIDE IS IMPROVING WATER TREATMENT**

Oxygen is required during secondary treatment so that microorganisms can breathe and metabolize biological mat-

ter. Currently, most plants inject air into their biological basins. So replacing air (composed of only 21% oxygen) with pure oxygen increases the effectiveness of the basins and their treatment capacity is boosted by up to 50%. No need to expand basins or build new ones, thus limiting capital expenditure. What is more, foam on the surface of the water in treatment basins, generated by chemicals and air flow is reduced and unpleasant odors caused by insufficient oxygen are eliminated (see infographic).

In addition to significant investments in research and development, Air Liquide has a unique know-how of more than 20 years, with over 1,500 references worldwide at both industrial water treatment sites and municipal sewage works. Air Liquide is therefore ideally placed to improve the efficiency, capacity and performance of existing facilities and to help equip state-of-the-art new-builds. Air Liquide's wastewater treatment solutions can be found under the Nexelia brand, a comprehensive, all-in-one offer combining industrial gas supply, application equipment and process expertise.

Air Liquide is committed to providing its customers (industries and municipalities) with high-performance equipment, know-how in the design of installations as well as rigorous follow-up of gas deliveries.

**FUTURE DEVELOPMENTS**

Air Liquide's customers have the capacity to deliver data on gas injection systems, temperatures and oxygen concentration in biological treatment basins, and the amount of waste products in water as it enters and leaves the plant. This allows Air Liquide to analyse site performance and raise alerts if the computed statistics indicate the ...



80%

of all wastewater flows back into the planet's ecosystem untreated<sup>(4)</sup>.

... presence of a malfunction. This MRV approach (Monitoring, Recording, and Verifying) prefigures future developments in which Air Liquide will be able to use Big Data and the Internet of Things to offer even higher performance and efficiency.

The planet's population is set to rise from 7.5 billion today to 9 billion by 2050 while the amount of freshwater available remains the same. Thanks to its know-how and technologies, Air Liquide is helping industries and municipalities rise to the challenge.

# HOW DOES IT WORK?

## STEP 1

### Primary treatment

This step involves removing easily collectible and filterable materials (fats, oils, greases, sand, gravel, stones, etc.). The clarifier basin then allows the elimination of the majority of non-soluble particles.

(activated sludge). This basin needs a supply of oxygen to function properly.

## STEP 3

### Secondary treatment

The clarifier basin enables the sludge to be separated from the clean water. This step allows for sludge to be recovered before clean water is discharged into the environment.

the sludge used must be evacuated. It is first thickened, then dehydrated and dried before being discharged.

## STEP 4

### Finish

This step consists of removing low concentration residues which are not biodegradable.

## STEP 2

### Biological treatment

In the so-called aerated basin, used water is put in contact with the microorganisms

## STEP 4

### Elimination of sludge

In parallel with the wastewater treatment,

(1) *Water Quality and Wastewater on unwater.org (2017, Unesco).*

(2) *"China to spend \$330 billion to fight water pollution" on reuters.com.*

(3) *Surface phenomenon by which molecules of gases or liquids attach themselves to the solid surfaces of adsorbents.*

(4) *Water Quality and Wastewater on unwater.org (2017, Unesco).*



## CASE STUDY

# WITH OUR CLIENT RENO DE MEDICI

RENO DE MEDICI (RDM) IS ONE OF THE EUROPE'S LARGEST PRODUCERS OF CARDBOARD.

**Thanks to Air Liquide's Nexelia service offer, Reno de Medici was able to improve the efficiency of its wastewater infrastructure at its La Rochette site in the French Alps.**

The plant produces cardboard for pharmaceutical and food packaging, a water-intensive process which places high demands on treatment solutions. Due to its mountainous location, the plant suffers from space constraints, meaning that the only way to grow was to improve the efficiency of its existing treatment basins. Air Liquide was on board from the concept stage, helping RDM to design a customized solution for increasing the amount of oxygen in its aerated basins. The Group's experts then produced and installed two additional floating injectors. Oxygen is stored in liquid form and then, after a passage through a vaporizer, injected in gaseous form. This heater is currently powered by an immersion exchanger which uses the residual heat of the sludge to heat the oxygen prior to injection: a sophisticated energy-saving addition.

### A REMOTE FOLLOW-UP

Furthermore, the site was equipped with online sensors and 3G/4G-connected devices which allow Air Liquide to offer a full Measurement, Reporting and Verification (MRV) service. RDM shares the statistics with Air Liquide, which uses them to offer monthly distance analysis. "We also inspect the biological make-up of the basins annually," explains Guido Gilardi, Marketing Design Manager at Air Liquide France Industrie and the Air Liquide offer designer behind the project, who sums up the benefits of MRV as "our opportunity to continue improving the ratio of oxygen injected per pollutants removed."

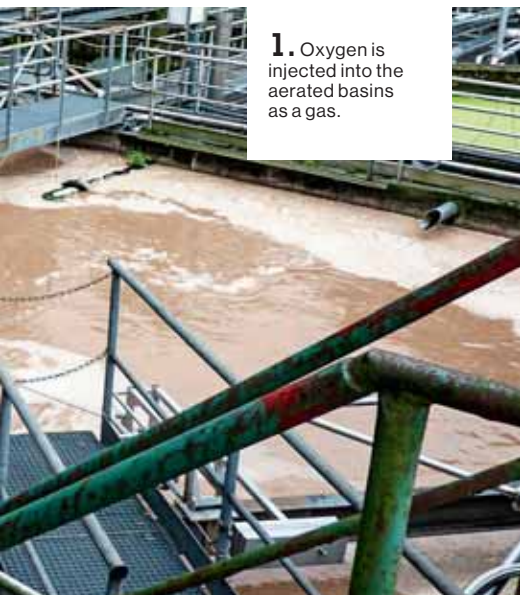


To find out more about our Nexelia solutions, visit [airliquide.com/industry/waste-water-management](http://airliquide.com/industry/waste-water-management)



“our opportunity to continue improving the ratio of oxygen injected per pollutants removed”

**GUIDO GILARDI**  
Marketing Design Manager at  
Air Liquide France Industrie



**1.** Oxygen is injected into the aerated basins as a gas.



**3.** Pollutants found in wastewater are diverse.



**2.** A full Measurement, Reporting and Verification service is essential.



**4.** The inspection of the biological make-up of the basins is useful for the proper functioning of the installation.

# CHINA: WATER AS A PRIORITY



Air Liquide provides effective solutions to help China **meet the important challenge of water treatment.**

## The pollution of lakes, rivers and groundwater is a growing concern.

"This has led authorities to make water treatment a matter of priority", explains Pascal Schvester, Air Liquide China's Marketing Director. "In terms of norms, China now has water treatment standards which are more stringent than those of the European Union," he stresses. "The challenge, of course, is to actually implement them." And this challenge is huge. China is looking to equip all the industrial parks and specifically production sites that often lack individual wastewater processing infrastructure. The most common industrial water treatment facility in Western Europe is attached to a single site with a consumption of 2 to 10 tons of oxygen per day. In China, that average is closer to 50, and facilities for whole industrial parks which require up to 300 tons daily are by no means unheard of.

## PROVIDING ADAPTED SOLUTIONS

"Not only does Air Liquide offer competitive and innovative technical solutions to meet these requirements, but it also builds relationships with engineering design offices and industrial parks demonstrating that it is more than a gas supplier; an efficient solutions provider with a global approach,"



# 2.5%

Only 2.5% of the planet's water is freshwater, much of it locked in glacier ice.

says Schvester, "which is why Air Liquide has opened up a uniquely equipped platform within the Shanghai Research and Technology Center, where these solutions can be tested in a variety of simulated treatment processes." It will accelerate technical progress and offer the opportunity to demonstrate Air Liquide's rich expertise and innovativeness to Chinese customers.

EXPÉRIENCES  
EXPERIENCIAS  
ERFAHRUNGEN  
ESPERIENZE  
EXPERIÊNCIAS  
エクスペリエンス  
DOŚWIADCZENIA  
经验  
Опыт

# EX PERI EN CES

**DIGITAL  
TRANSFORMATION**

One day  
with Xi Fang

P. 24

**SAFETY**

Airgas:  
Onboard safety

P. 26

**ELECTRONICS**

Air Liquide  
and smartphones

P. 27

**MOBILITY**

Cleaner  
mobility

P. 28

After the United States and France, Air Liquide inaugurated its first Remote Operations Center in China, as part of the Group's Smart Innovative Operations (SIO) program. Objective: to automate and centralize production units, optimize their performance and anticipate malfunctions.

# ONE DAY WITH... XI FANG

Senior Manager of the new Remote Operations Center

**Xi Fang's main mission is the coordination of the new Remote Operations Center based in Shanghai.**

Every day, she oversees the technical implementation of the project and cooperates directly with local site teams. She also helps employees to develop new skills.



**9:00 a.m.**

Xi Fang starts her day with the Real Time Operations Director. Together, they are preparing for the future of the Remote Operations Center. They check the project's overall progress, particularly the gradual migration of operations from sites to the center.



**11:00 a.m.**

From the control room, with the Industrial IT Supervisor, and the Real Time Operations Engineer, she oversees the quality of the remote connection for two pilot plants. Using multiple screens, the engineer continuously monitors data and ensures the industrial IT network is working properly at the plants.







## 2:30 p.m.

Building a quality Real Time Operations team is key, and existing plant personnel on sites are the preferred pool of talent to choose from. In a video call with the Managers of the two pilot plants, they discuss training plans and how employees will be able to develop skills and competencies. Once trained, they will be able to test and use new digital tools.



**“THE CENTER WILL ULTIMATELY EMPLOY 24 PEOPLE, DIVIDED INTO 4 TEAMS”**



## 5:30 p.m.

Last meeting for Xi Fang with the SIO Project Senior Manager, Digital Tools Project Managers, and the center’s engineers about the roll-out of new digital tools designed to enhance the work effectiveness of the Real Time Operations Engineers. For example PRISM, is a predictive maintenance tool, that detects and anticipates device and equipment failure. As for the Customer Portal, it will be used to share key information between customers and the Remote Operations Center in real time.



**Xi Fang joined Air Liquide in 2011 just after completing a Master’s degree in Cryogenic Engineering at Shanghai Jiao Tong University. After working as a Production Engineer for 14 months at an Air Separation Unit, she focused on production strategy optimization. In January 2016, Xi Fang became Senior Manager of the new Remote Operations Center, whose team is projected to triple by 2020.**

# AIRGAS: ONBOARD SAFETY

Airgas, Air Liquide's American subsidiary, oversees a fleet of over 5,000 trucks throughout the United States. To guarantee the safety of its drivers, optimize its deliveries, and provide a better customer experience, the company has installed onboard computers (OBC) on its trucks.

## Increased safety on the road

"The OBC saves and analyzes key data in real time, including road speed, accelerations, and brake power. I'm alerted in the event of any risky behavior, which improves my driving and therefore my safety."

## Simplified procedures

"The onboard IT system automatically completes route reports for me, which are required by US regulations. This saves me a lot of time and I can focus

on delivering a high quality service to my customers."

## Communication in real time

"Another advantage is that I can communicate with Airgas teams and stay informed in real time about any route changes, traffic, weather conditions... So, I'm more flexible and responsive during my route and I keep a nice connection with my colleagues!"

# "A valuable asset"

**LAMAR DAVIS**, Airgas truck driver



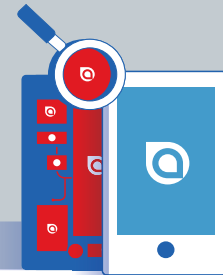
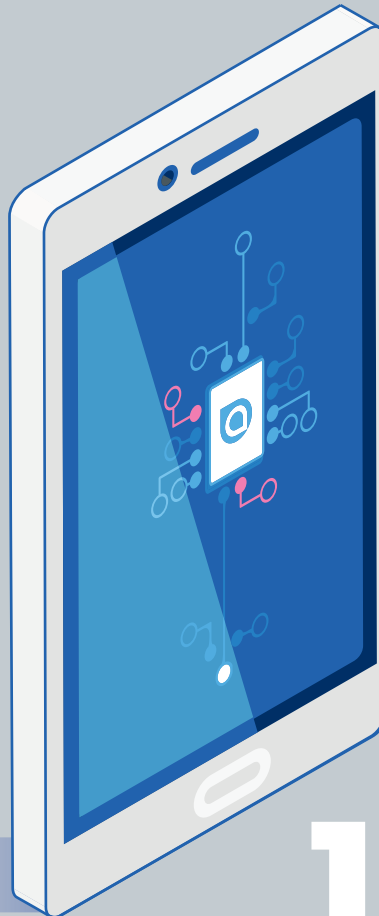
# AIR LIQUIDE AND SMART-PHONES

Smartphones are the result of several years of nanotechnology research. Even though they are invisible, gases and molecules play a key role in this digital transformation.

Air Liquide works with customers in the semiconductor industry and equipment manufacturers to select advanced materials that are best suited to the requirements of their processes and to design new materials if needed. The objective? A higher performance for smartphones in terms of features, connectivity and battery life.

# 14<sub>nm</sub>

Silicon transistors, a key part of microelectronics, can reach incredibly small sizes. In seven years, thanks to new advanced electronics materials developed by Air Liquide, the size of the smallest transistor in a semi-conductor has dropped from 65 nanometers to just 14 nanometers. Comparatively, a strand of human hair is around 50,000 nanometers thick. The result is lighter, faster smartphones that can support even more complex functionalities—all with a battery life of up to 12 hours.



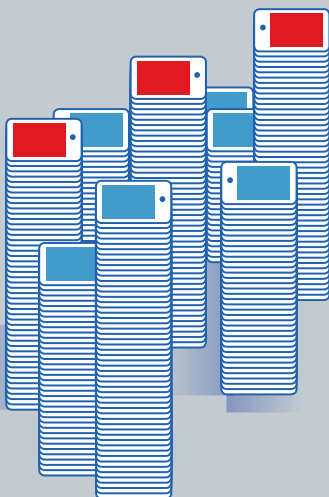
# 100%

**All latest generation smartphones have components, chips, and memories made with Air Liquide's advanced materials.**

They play a direct part in the production process, creating the first layers of nanotransistors. As part of the architecture of processors and memories, these advanced materials have become essential components for the electronics industry in just a few years.

# 1.3

**billion smartphones are sold throughout the world every year.**



**AND TOMORROW?** The experts are clear: **Moore's law**, which has governed the digital industry for over 50 years and states that the number of transistors—and therefore the power of hardware - doubles every two years, will soon be exceeded. The industry is struggling to keep up with this pace since the size of fine engraving has dived under the threshold of 90 nanometers. Make room for the **'More Than Moore'** approach: manufacturers are abandoning the race for miniaturization in favor of other levers such as new materials, circuit architecture or design methods.



**INTERVIEW**  
**OMAR AL-FUTTAIM,**  
CEO and Vice Chairman  
of the Al-Futtaim Group

# CLEANER MOBILITY

By the end of 2017, Air Liquide will have installed nearly 100 hydrogen stations around the world. In October, in Dubai, United Arab Emirates (UAE), Al-Futtaim Motors inaugurated the first hydrogen station of the Middle East designed in collaboration with Air Liquide. It aims to test hydrogen-powered vehicles in a hot climate, an important milestone for the development of clean mobility. Interview with Omar Al-Futtaim, CEO and Vice Chairman of the Al-Futtaim Group, on this promising initiative with major strategic and environmental stakes.

**Can you tell us what motivated you to launch the first hydrogen station in the Middle East?**

**Omar Al-Futtaim:** We are the exclusive Toyota retailer in the UAE, one of the leaders in hydrogen fuel cell vehicles. As such, our company's activities can positively impact the environmental issues in this region known for high vehicle ownership and fossil fuel consumption. Concerns about climate change, air quality and dependence on oil are a focus of the UAE Government. As hydrogen mobility continues to gain momentum, we also believe

while having a range of over 500 km and a quick recharging time.

**Can you describe the project?**

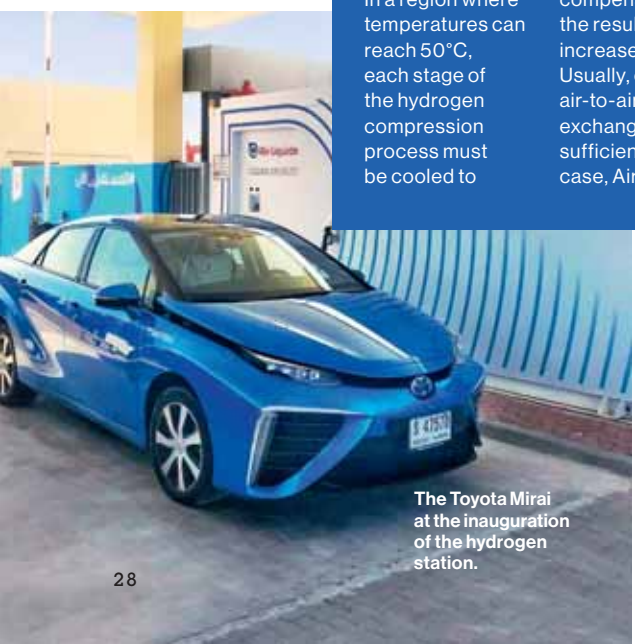
**O. A.-F.:** We launched this pilot project as a private initiative to study the logistics, scalability and feasibility and ultimately to demonstrate the potential of hydrogen use for forest transport in the UAE. To test the compatibility of hydrogen vehicles with the UAE's hot climate, we needed a hydrogen station. Air Liquide's shared commitment and expertise made it the ideal partner for this project. Driving and refueling demonstrations have been organized for government officials and private sector companies to generate interest in this technology.

**What do you aim to achieve with this project?**

**O. A.-F.:** Our ambition in the short term is to use this ground-breaking joint pilot program to illustrate that hydrogen technology is viable in the UAE, as well as to raise awareness about alternatives to fossil fuels. We strongly believe in hydrogen's potential to pave the way for a new paradigm for a sustainable and low-carbon society.

## A technology customized for high temperatures

In a region where temperatures can reach 50°C, each stage of the hydrogen compression process must be cooled to compensate for the resulting increase in heat. Usually, one air-to-air heat exchanger is sufficient, but in this case, Air Liquide redesigned the system with two water-to-air heat exchangers to limit the temperature increase.



The Toyota Mirai at the inauguration of the hydrogen station.

that hydrogen is one of the best solutions to reduce the carbon footprint. The advantage of hydrogen-powered fuel cell electric vehicles (FCEVs) is that they generate zero carbon dioxide emissions

ECOSYSTÈME

ECOSISTEMA

ÖKOSYSTEM

ECOSISTEMA

ECOSSISTEMA

エコシステム

EKOSYSTEM

生态系统

ЭКОСИСТЕМА

**HEALTHCARE**

Proximity  
care

P.30

**CLIMATE**

Ice Memory:  
Preserving the archives  
of the climate

P.33

**GUEST**

Producing hydrogen  
from water  
and solar energy

P.36

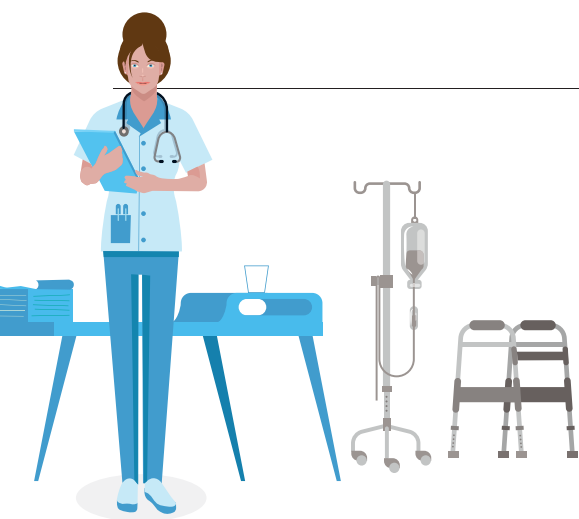
ECOSYSTEM

# PROXIMITY CARE

## Air Liquide near you!

Air Liquide's healthcare activity offers products and services all along the continuum of care, from hospitals to patients' homes. Healthcare professionals such as paramedics, retirement home staff, dermatologists, and dentists are also Air Liquide customers. These local care providers play a key role in patient care. Air Liquide maintains a close partnership with them by tailoring its offer to their specific needs in terms of mobility and responsiveness and is committed to effectively meeting their expectations as well as those of their patients. **Here are their testimonials.**





## “Improving patients’ quality of life.”

**ANA ORBEGOZO ARAMBURU**

Director of Matia Fundazioa Retirement Home, Spain

### What are the main challenges in your work?

In my job, the number-one challenge is to provide our patients with high-quality care to maintain their comfort and well-being in our retirement homes.

### What solutions are available to you?

Among the available treatments for patients in severe or chronic respiratory distress, the gold standard is oxygen therapy, which makes it possible to maintain the level of oxygen in the blood. In addition to providing treatment, we have to listen carefully to our patients and understand their situation.

### How would you define your cooperation with Air Liquide, in one word?

I would say ‘commitment.’ Air Liquide is a reliable and trustworthy partner that helps us meet our patients’ needs in the best way possible by providing equipment and technology that are adapted to our environment. I notice and appreciate how much technologies have evolved over the past 40 years, especially with respect to the weight of cylinders, which are becoming increasingly lighter. This makes cylinder transportation easier. The quality of the equipment used to administer medical gases has also improved.

## “Air Liquide is a strong and reliable partner.”

**FRANCESCO CATTANEO**

President of Croce Azzurra Onlus, Italy

### What are the main challenges in your work?

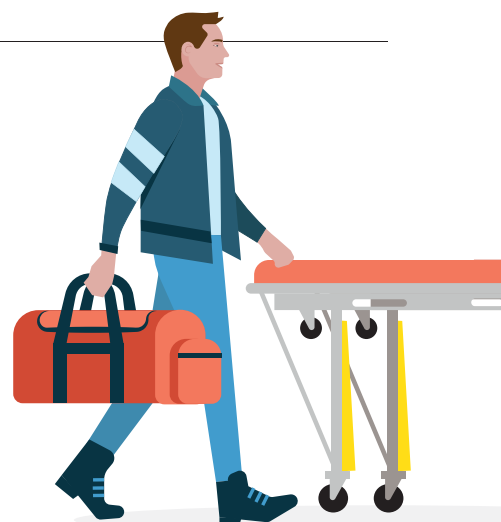
Croce Azzurra Onlus is a volunteer ambulance corps that provides both urgent and non-urgent 24/7 hospital transport services. We actively work to improve the quality of our services, especially by providing regular trainings, and we just received two certifications for health and safety at work.

### How does Air Liquide help you in your day-to-day work?

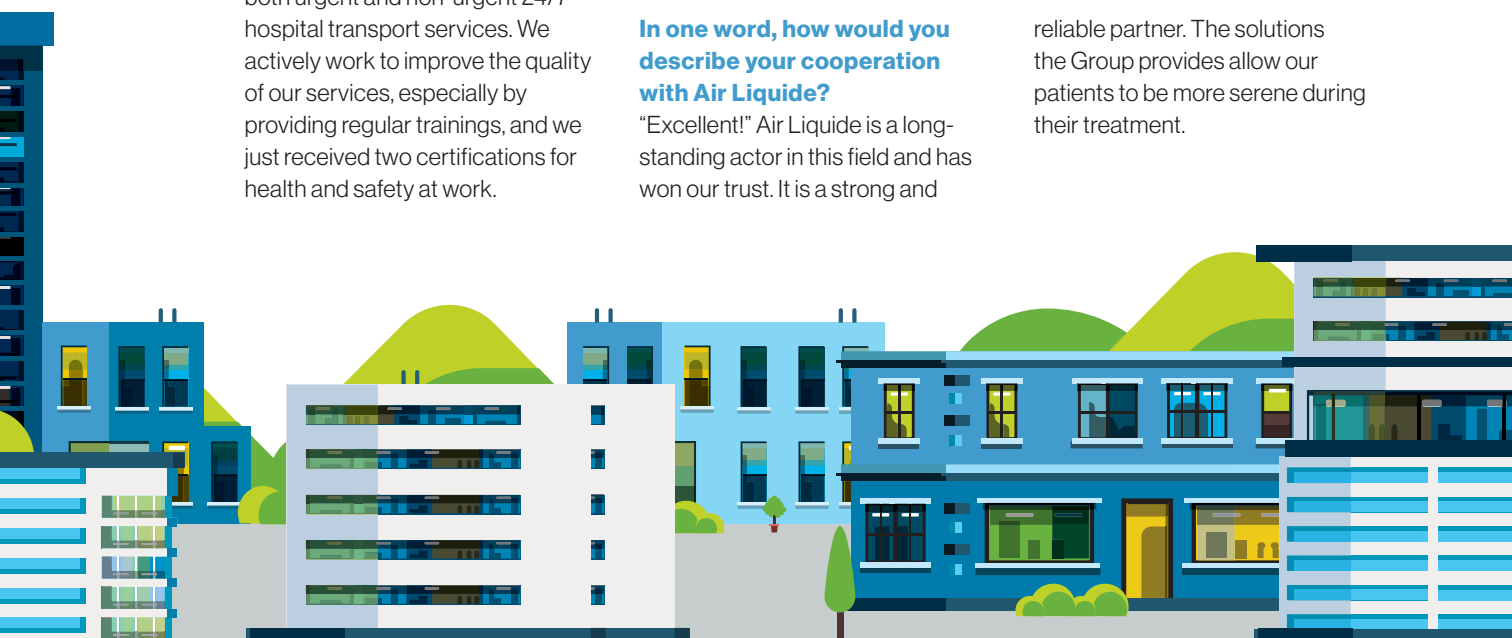
We are constantly looking for new solutions to help us become more effective. Two years ago, our volunteers were looking for ways to quickly visualize the levels of medical gas in our cylinders because they were losing a lot of time calculating it themselves and were sometimes wasting gas in the process. Air Liquide provided us with a technical solution that was adapted to suit our need for mobility.

### In one word, how would you describe your cooperation with Air Liquide?

“Excellent!” Air Liquide is a long-standing actor in this field and has won our trust. It is a strong and



reliable partner. The solutions the Group provides allow our patients to be more serene during their treatment.





# nipeurnidouleur.fr Air Liquide commits to fighting pain



**Every day, patients and healthcare professionals are confronted with pain. Faced with this reality and eager to provide concrete solutions, Air Liquide Healthcare in France (medical gases entity) launched an online documentary entitled Ni peur, ni douleur (“Neither fear, nor pain”) in October to coincide with the World Day Against Pain.**

The goal is to educate and inform patients, caregivers and the general public about pain and anxiety linked to painful treatments as well as existing solutions.

Available on the website [nipeurnidouleur.fr](http://nipeurnidouleur.fr), this web documentary offers a unique outlook. Through a compilation of portraits, testimonials of both patients and caregivers, the documentary is available to all audiences and is enriched each month with new content.


With this new platform, Air Liquide reinforces its expert role in healthcare and the treatment of induced pain. Make sure you don't miss out by following the #nipeurnidouleur hashtag on Twitter.



To access the website (in French only), see [www.nipeurnidouleur.fr](http://www.nipeurnidouleur.fr)







❄️ **All over the world**, the Air Liquide Foundation supports projects aiming to study and reduce the impact of climate change on our environment. One of these initiatives, the Ice Memory project, was launched in Antarctica in 2015 to create the first global ice archive sanctuary. The project consists of extracting samples from the world's glaciers, which serve as invaluable records of climatic change, and preserving them for future generations.

Ice Memory

# PRESERVING THE ARCHIVES OF THE CLIMATE



P

ut in place by an international team of glaciologists, the Ice Memory program aims to preserve the memory stored in glaciers endangered by climate change across the world. The goal is to store ice cores from these glaciers in Antarctica so future generations of researchers can continue to study this priceless raw material.

#### Saving the glacial heritage

Glaciers contain the chemical traces that tell the story of the climatic and environmental events that shaped the planet. However, global warming is causing glaciers to melt at an increasingly fast rate. The runoff water is leaking into the lower levels of the ground, distorting the data collected by glacier researchers. “We



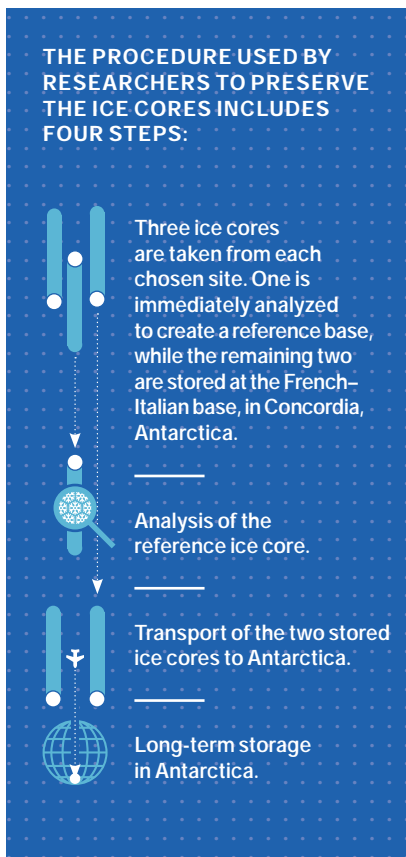
must act now—the sequence of geochemical information stored within the ice must be preserved,” says Jérôme Chappellaz, the co-founder of the Ice Memory project along with Carlo Barbante from Ca’Foscari University in Venice.



Drilling operations for the Ice Memory project started in France in 2016 on the Col du Dôme glacier in the Mont Blanc range and continued on Bolivia's Illimani glacier in 2017. The second expedition, which took place at over 6,300 meters above sea level, constituted a human and logistical challenge; the scientists had to carry nearly 4.5 tons of equipment and over 3 tons of ice cores representing 18,000 years of history! "As true mountaineers, the scientists had to work in very difficult conditions and take extra precautions to keep the ice cores free of contamination," says Susanne Adolphi, Project Sponsor at Air Liquide.

**An international project funded by sponsors**

Launched by a French-Italian team and sponsored by the Université Grenoble Alpes Foundation, Ice Memory is truly global in scope. In March 2017, the inaugural Ice Memory conference was attended by scientists from 12 countries and held in Paris under the patronage of UNESCO (United Nations Educational, Scientific



and Cultural Organization). The purpose was to establish a roadmap for this vast program.

Ice Memory is funded by scientific organizations and private sponsors. Donations from the Air Liquide Foundation primarily helped purchase the equipment and containers for the storage facility in Antarctica.

**12**  
nations  
were represented by scientists at the first symposium of Ice Memory.

"The Ice Memory project could not exist without our sponsors," said Anne-Catherine Ohlmann, Director of Fondation Université Grenoble Alpes and Project Coordinator, "because it doesn't qualify for funding schemes in France or Europe. These programs require fast results from the research, but the Ice Memory project is designed to be much more long term." ❄️

3 OTHER PROJECTS OF THE AIR LIQUIDE FOUNDATION FOR THE CLIMATE

**1 Understanding the potential of mangroves**

Mangroves, or 'swamp forests', are known carbon dioxide traps. But their exact ability to absorb carbon has not yet been measured. That is why the Foundation is supporting the French National Institute for Sustainable Development Research (IRD), which is conducting a full analysis of the carbon cycle of mangrove forests in three separate regions—New Caledonia, New Zealand, and Vietnam.

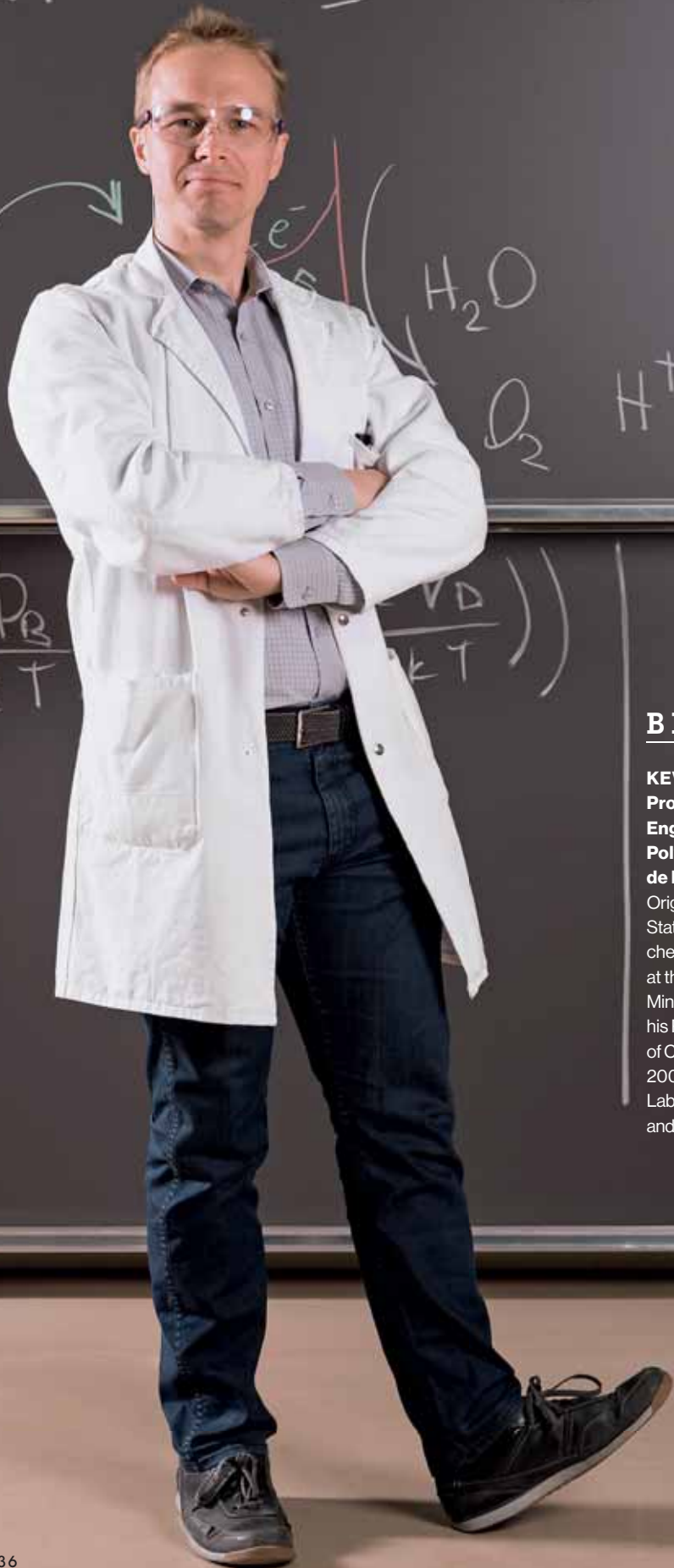
**2 Studying polar regions and underwater environments: Under the Pole I, II, and III**

The Foundation has supported the "Under the Pole" expeditions since the very first operation in 2010. This unique Arctic and Antarctic underwater exploration program has captured never-before-seen images of a world under threat from global warming and collected scientific data that is highly useful for studying these environments. The third expedition started on May 20, 2017 and will last for three years.

**3 Saving Gabon's forests**

80% of Gabon is covered by tropical forests, most of which are threatened by logging and palm oil plantations. These forests are havens for biodiversity and play a key role in reducing greenhouse gases by capturing and storing carbon dioxide. The Foundation is partnering with the non-governmental organization World Wildlife Fund to create a long-lasting system for measuring the amount of carbon stored in Gabon's forests. The purpose is to study their resilience to climate change and promote sustainable forest management.

GUEST



## BIOGRAPHY

**KEVIN SIVULA,**  
**Professor in Chemical**  
**Engineering at Ecole**  
**Polytechnique Fédérale**  
**de Lausanne (EPFL).**

Originally from the United States, Kevin Sivula studied chemical engineering at the University of Minnesota, then obtained his PhD at the University of California, Berkeley in 2007. He then joined the Laboratory for Photonics and Interfaces at École

Polytechnique Fédérale de Lausanne, where he developed a technique producing hydrogen using rust, water and solar energy. He currently leads the Laboratory for Molecular Engineering of Optoelectronic Nanomaterials, where he conducts research and teaches on solar energy conversion systems.

# "PRODUCING HYDR O GEN

from water  
+  
solar energy"



**Essential Small Molecules** such as oxygen, nitrogen, hydrogen, or carbon dioxide have been a core part

of Air Liquide's business since its creation. In 2016, the Group launched a contest called the 'Air Liquide Essential Molecules Challenge.' For its inaugural edition, the jury selected three winners, one of which was Kevin Sivula, a professor at the Ecole Polytechnique Fédérale de Lausanne (EPFL). Competing on the topic of 'Sunny H<sub>2</sub> in a bottle,' this American researcher was recognized for his work on using photoelectrocatalysis to produce hydrogen. Read on for details.

**You have been awarded for a project that involves producing hydrogen from water and solar energy using photoelectrocatalysis. Can you explain your work in a few words?**

**KEVIN SIVULA:** Making hydrogen from water and solar energy is not new. However, the process we developed is

## ESSENTIAL MOLECULES CHALLENGE IN FIGURES

# 130

SCIENTIFIC PROJECTS  
SUBMITTED

# 25

PARTICIPATING COUNTRIES

# 3

THEMES: 'SUNNY H<sub>2</sub> IN A BOTTLE',  
'SMALL MOLECULES  
IN MY POCKET',  
AND 'CO<sub>2</sub>, GIVE BACK YOUR O<sub>2</sub>'

# €50,000

GRANT FOR EACH AWARD

innovative and cost-effective. If I were to use an analogy, it would be photosynthesis, a process that harnesses sunlight to create energy in the form of carbohydrates. Sunlight, as a solar energy is used to oxidize water and reduce carbon dioxide, in order to synthesize organic substances (carbohydrates) by releasing oxygen. Our technology is therefore a type of artificial photosynthesis in which we use iron and copper oxide to reorganize water's chemical bonds and transform it into hydrogen and oxygen—all using solar energy.

**Your project was chosen from a wide selection of proposals. What made your research stand out?**

**K. S.:** The main advantage of this project is that it uses intrinsically stable materials like iron and copper oxide that are made from cheap and widely available raw materials. That's a key point. For a technology to have a significant societal impact, it must meet these two requirements.

...

## GAS ENCYCLOPEDIA

Comprehensive information on over 60 molecules, including argon, hydrogen, and methane, used in research, industrial, and health applications is available for free on Air Liquide's online Gas Encyclopedia ([encyclopedia.airliquide.com](http://encyclopedia.airliquide.com)).  
Add it to your favorites!

...

### Photoelectrocatalysis is an innovative but complex technology. What are the main challenges you face today?

**K. S.:** The implementation of this process is indeed very complex and there are still aspects of the process we don't yet fully understand, especially with respect to light absorption and catalytic processes. One of the challenges we face is capturing the energy at the right time. When a material absorbs light, it causes what is called an "excited" state, or a higher energy configuration. The difficulty is succeeding in capturing this state before it disappears. In the very stable materials (iron and copper oxide) that we use, the excited state doesn't last as long as we would like. We have to find a way to capture this powerful source of energy (excited state) before the material reverts to its stable state.

### Why is producing hydrogen from water and solar energy so important for the energy transition and the environment?

**K. S.:** Hydrogen is useful because it's easy to store on a large scale for a long period of time. It's also a renewable energy vector that doesn't pollute. Indeed, through its high-energy combustion process, hydrogen can provide either heat or electricity with no other residue but water. Today, most hydrogen is produced from natural gas. Photoelectrocatalysis produces hydrogen directly from light without any added energy and without generating CO<sub>2</sub>, making it a potential path forward in the transition to cleaner energies. I feel very privileged to work on a technology that could have such a significant impact on society.

### Is the research on hydrogen in the world encouraging?

**K. S.:** For 15 years, hydrogen has been the subject of a wide range of research. Whether it be production, storage, catalysis, or semi-conductors, no stone has been left unturned. This uptick in interest is without doubt due to the fact that many people now think this type of technology has become essential. Science is yet to contribute to developing an efficient and economically competitive solution.

### What drove you to participate in the 'Essential Molecules Challenge', and what have you taken away from this six-month collaboration with Air Liquide?

**K. S.:** My research topic fit well with the requirements and one of the challenge's themes. I had also reached a turning point in my research work and needed support to go beyond the preliminary stages of my project. My collaboration with Air Liquide made all the difference. It allowed me to focus on the technology's feasibility, and that's now coming along nicely. My goal is to build a demo by the end of 2018. This life-size model will allow me to simulate any constraints that might 'kill the idea.' I wouldn't have had the capacity or necessary resources without Air Liquide's support. The various technical discussions and feedback sessions I had with the company were extremely useful. I also had the opportunity to visit Air Liquide's R&D Center in Paris-Saclay, and I was very impressed by the teams' knowledge and resources.



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See the inauguration of the first hydrogen station in Dubai.



**On LinkedIn**  
Expert opinion columns  
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Discover the Ice Memory project on the Group's LinkedIn profile.



**On YouTube**  
Air Liquide in videos!  
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Discover Air Liquide's solutions, including Nexelia for the biological treatment of wastewater.  
[www.youtube.com/watch?v=gp5SQCE9YoA](http://www.youtube.com/watch?v=gp5SQCE9YoA)



**On the website [airliquide.com](http://airliquide.com)**  
Dynamic and immersive content about our innovations



Additive manufacturing: a stainless steel bridge designed by several robots!

[www.airliquide.com/connected-innovation/additive-manufacturing-bridge-future](http://www.airliquide.com/connected-innovation/additive-manufacturing-bridge-future)



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Our applications explained!  
April 12 • 👤



Did you know that liquid hydrogen is used as a propulsion fluid to launch the Ariane rockets ?



