AVIATION WEEK Intelligence NETWORK

Hydrogen Project Takes Root In European Industry

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To achieve viable economic performance, airports will need to be hydrogen hubs.
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ONE IN A SERIES

After Airbus unveiled plans in 2020 for hydrogen-powered aircraft to be in service in 2035, the entire European industry and some U.S. startups have followed suit.

As the airframer is engaging its supply chain, Paris' airports operator has selected partners for infrastructure equipment testing and the European Union Aviation Safety Agency (EASA) is gathering expertise on the subject.

- Hydrogen could be produced on-site at airports
- EASA mulls certifying ground-distribution network

Although the growing momentum has yet to translate into a product launch, a tectonic shift is underway.

Few industrial sectors have a 15-year vision, EASA Executive Director Patrick Ky said in a Paris Air Forum 2021 discussion in late June with Safran CEO Olivier Andries and Airbus CEO Guillaume Faury. "We started working on hydrogen before 2020, but we felt a need, when aviation was in a terrible situation, to clearly show the way and ask governments to help us maintain execution speed in research and development," Faury said about beginning the process. "We saw that the concept of a hydrogen aircraft in the aviation ecosystem was increasingly understood."

Hydrogen's main benefit is in the combustion process, since its emissions are decarbonized. Hydrogen could even make aviation the holy grail of transportation, combining low emissions with limited land use, in Faury's view.

To achieve a suitable energy density for aircraft, however, hydrogen must be used in its liquid form. Because hydrogen liquefies at -252C temperature, storage is especially challenging.

A key question for aviation as a global industry will be the availability of hydrogen—particularly hydrogen produced in an environmentally friendly way. "Will the new fuel be available globally or only in some regions?" Faury asked. "Until that question is answered, it strengthens the case for designing regional or short- to medium-haul aircraft. The [Airbus] A320 family will not be replaced in one shot.

"We are talking about existing technologies but new usage," Faury continued. "In the space industry, the environment is highly controlled. We must be able to have aircraft taking off every minute. . . . Today's conventional fuel is dangerous, too. It can burn and explode, but we learned how to handle it in the framework of commercial air transport."

Airbus is planning on five years of technology maturation, in 2020-24. "In 2025-27, we will prepare the program—finding financial partners and suppliers as well as putting production systems in place," Faury said. "Then, in 2027-28, we will launch the program, targeting entry into service in 2035."

Will hydrogen shape the supply chain? "Yes, we are talking to partners, asking questions such as: Are they willing to invest? Where are the skills? When do they want to enter the field?" Faury said.

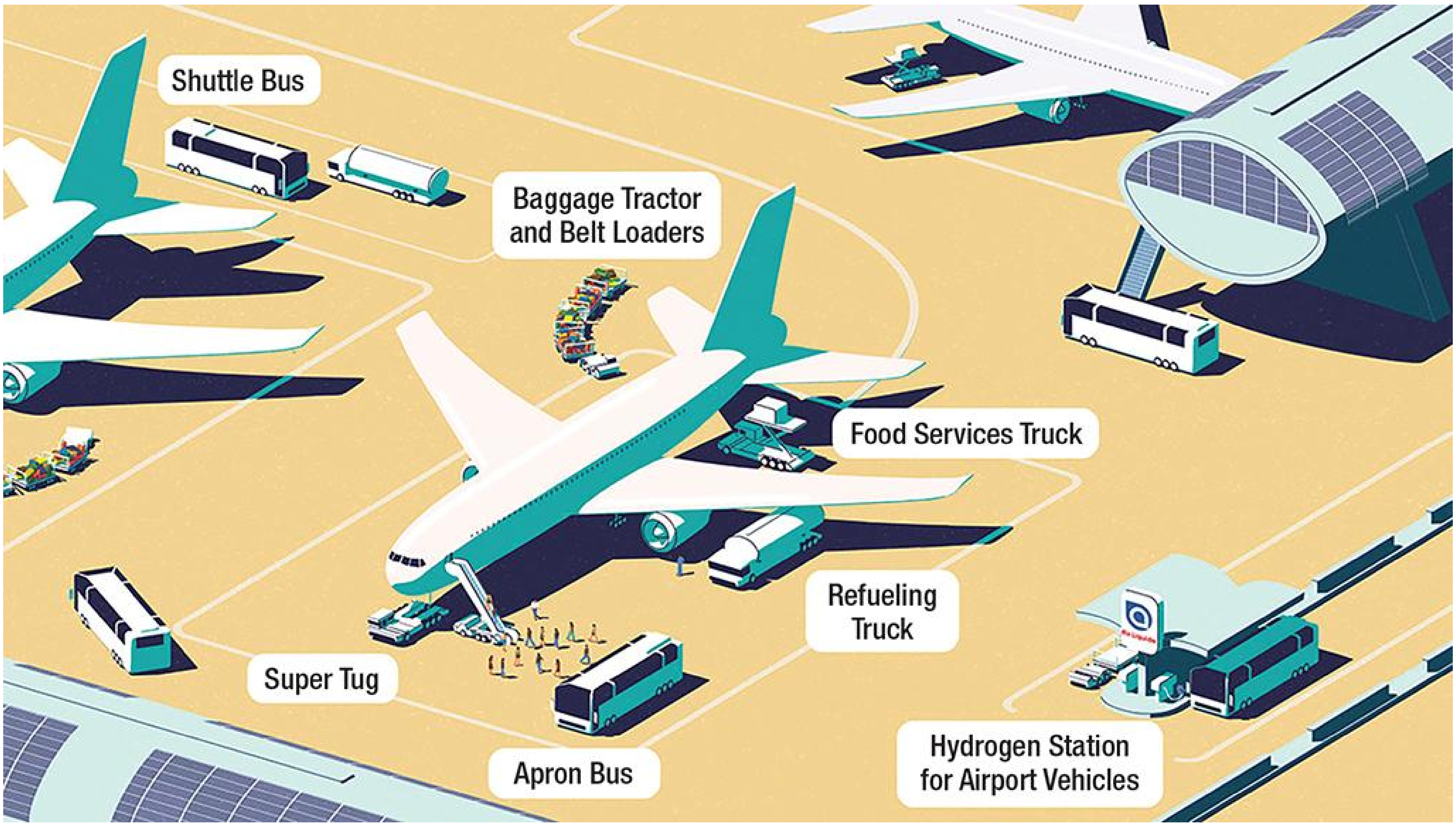
He sees speed as critical. "The cycles in aerospace and the certification level we are aiming for imply a great number of validations after functional and dysfunctional tests, safety analyses, ground operations trials and more," he said. "The entire ecosystem must be involved."

Ground testing of a small-scale hydrogen-propulsion system is planned for 2023 in Vernon, west of Paris. ArianeGroup's space launcher engine factory there can be described as Europe's competence center for hydrogen propulsion, Safran's Andries said. In Vernon, ArianeGroup and its shareholders, Airbus and Safran, have begun studying the system, including the liquid-hydrogen-distribution system on board the aircraft. The project, named Hyperion, is funded in part through a French government bailout plan for the aviation sector.

Meanwhile, Airbus has tasked its newly created zero-emission development centers in Bremen, Germany, and Nantes, France, with developing hydrogen tanks. The airframer has scheduled flight tests for 2025. The flying testbed will be an A380, finance daily *Les Echos* reports.

Airbus officials expect that near-term liquid-hydrogen tank structures for commercial aircraft applications will be metallic. "However, the potential performance opportunities associated with carbon-fiber-reinforced polymer composites are high," Airbus says.

At its headquarters in Cologne, Germany, EASA is well aware that it has yet to build proficiency in hydrogen-related matters. "We do not have technical expertise in hydrogen," Ky said. "But we should be able to support the industry, by acquiring the required skills and asking the right questions at the right time. We are creating a training program for our engineers, taking into account experience from the space sector, and factoring in different constraints. The user manual for a space launcher is different from that of an aircraft built to fly for 100,000 hr."



A number of ground vehicles could use hydrogen, strengthening its business case. Credit: Air Liquide

EASA has created a scientific committee that is reinforcing academic partnerships such as supporting theses that will help acquire technical expertise. "Hiring young people to work on those subjects is easy," Ky said. "They help the aviation dream live on."

Like Faury, Ky believes that timing is essential. "We must start work in terms of certification analysis. . . . Rulemaking on a global scale takes 4-5 years," he noted.

EASA sees its role as extending beyond aircraft. "At issue is technology, but moving to hydrogen is also a matter of the distribution chain," Ky said. "When it comes to refueling, the risks are different from those linked to Jet-A1 fuel. It is likely we will have to certify hydrogen distribution networks on the ground. Refueling time may have to be regulated, too. . . . We will have to talk to airport operators."

Any move to hydrogen will require early planning at the airport level, including the key issues of infrastructure as well as the business case. To achieve viable economic performance, airports will need to be hydrogen hubs, producing and using as much hydrogen as possible.

To test that concept, a consortium led by Paris airports operator Groupe ADP selected 11 companies for a comprehensive study, involving some on-site testing, on the use of hydrogen as an aviation fuel.

The plan is to broaden the research to encompass every foreseeable change that might be required at airports. In addition to ADP, the H2 Hub Airport project includes Airbus, Air France-KLM and the Ile-de-France region, with the support of the Choose Paris Region economic development organization. They plan to start testing some concepts in 2023.

The consortium selected the projects using three criteria. The primary one, accounting for 60% of the evaluation, was the offer itself: How is it contributing to the decarbonization of airport activities? And how innovative is it?

Another 30% is based on the organization of the project's team, especially its resources and expertise. The remaining 10% is left to jury members' own judgments of the overall project.

The 11 projects in the program were selected from 124 responses to a February call for expressions of interest. The call covered three areas: production, storage, transport and distribution of hydrogen; diversification of hydrogen uses; and recovery of hydrogen and other byproducts. The organizers received 45, 63 and 16 answers, respectively.

Absolut System, based near Grenoble, France, specializes in the development of cryogenic systems, most notably for research purposes, satellites and superconductivity. It has begun work with Airbus on the design of new superconducting systems for commercial aircraft.

Absolut System's expertise may also be useful in an airport environment. When hydrogen is used in its liquid form, one of the challenges is its propensity to vaporize. The company is working on two approaches to deal with that issue: using vaporized hydrogen and reliquefaction.

When liquid hydrogen is stored in a tank, part of it vaporizes. So Absolut System is studying how to recover cold gas, which is easier to handle than liquid hydrogen and could then be used in applications that rely on gaseous hydrogen such as aircraft tractors on the ground.

When vaporized in a limited volume, hydrogen can reach a 700-1,000-bar pressure by adapting the fill level. The conventional process calls for vaporizing to a low pressure level and then recompressing to 350-700 bar. That is the right level for ground applications.

"We find recompressing a waste of energy," Absolut System Chief Technology Officer Jerome Lacapere says. "We intend to use liquid hydrogen's intrinsic properties to self-pressurize to very high pressure." The idea is to let pressure increase naturally and then recover the gas at a very high pressure.

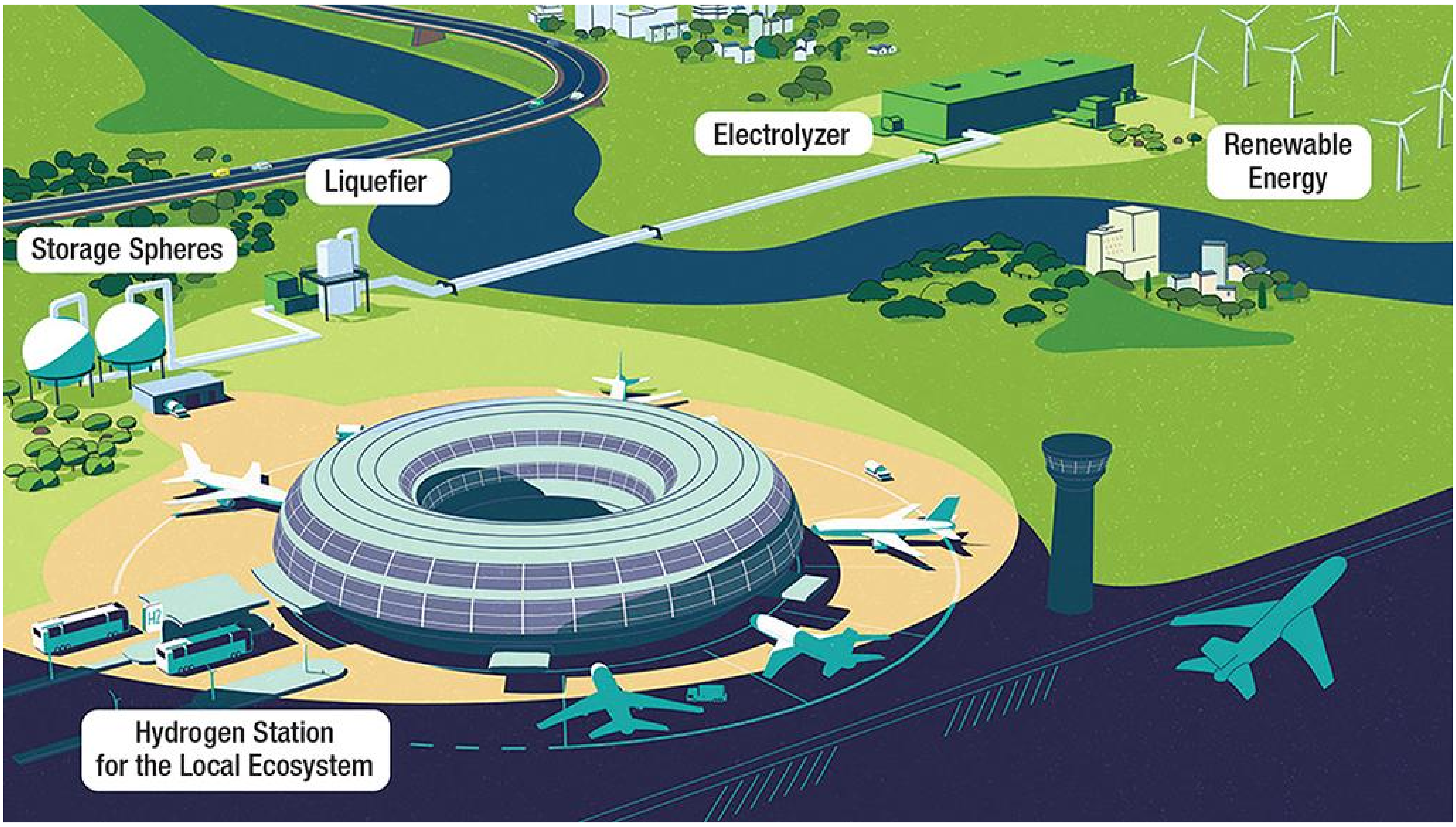
"We performed tests with helium and nitrogen," he says. To reach technology readiness level 6 (TRL 6)—indicating the technology is ready for product development—from the current TRL 4, trials will need to occur at a greater scale and with hydrogen.

Absolut System's second lead—also at TRL 4—may improve the aircraft-refueling process. Conventionally, the gas coming from natural vaporization in the refueling system would be recovered and used on the ground. This is what the company is planning on, but only at the start of the process when the quantity of vapor is too large to be used otherwise.

At some point, the vapor flow will decrease to a level at which it can be better harnessed, Absolut System engineers believe. They are designing a mobile liquefaction system that would reliquefy the gas, thus making the most of the liquid hydrogen brought to the aircraft's parking position. Under this concept, the second part of the refueling process would take place in a closed loop.

What's new is the size of the researched system. Similar technology is in use at a very large scale in industrial facilities as well as in miniaturized devices in satellites. Space launchers do not use it, however, because a monthly-or-so launch rate makes it relatively benign to waste a portion of the hydrogen.

Lacapere hopes to reach TRL 6 for both systems in two years. Funding on the order of €10 million ($12 million) is needed, thus the company's participation in the H2 Hub Airport project, he says, is crucial to getting that funding: "It gives us credibility, enables networking and provides us with data to size our systems in an airport's environment."



For the aviation sector, hydrogen is not only a matter of aircraft technology but also an infrastructure issue. Credit: Air Liquide

H2 Hub Airport officials say they selected Absolut System because the technology will enhance the hydrogen value chain at the airport by curbing natural losses.

Another original contribution to the H2 Hub Airport project may come from the local production of hydrogen from natural gas in a way that does not emit CO_2. Green energy supplier Sakowin, formed in 2017 in Frejus in southeast France, says it has solutions for the issues resulting from greater demand for green hydrogen. “To produce hydrogen, electrolysis is good but requires a huge amount of electric power, which looks unrealistic if you consider [that the] 2050 needs and would call for significant subsidies,” says Sakowin President Gerard Gatt. “And if you centralize production, you have to transport and store hydrogen, which prevents hydrogen from being competitive with oil-based energy. In addition, pressure on land surfaces becomes unbearable if photovoltaic farms and wind turbines sprawl.”

Natural gas—with reserves that are estimated will last hundreds of years—is the most efficient source for hydrogen, Gatt says. Natural gas is essentially made of methane (CH_4). Burning methane is an efficient way to use it, but combustion emits CO_2. Sakowin’s technique can extract hydrogen from methane without generating CO_2.

Pyrolysis with a high-energy plasma is already used for the decomposition of CH_4 to produce carbon, acetylene (C_2H_2) and other valuable industrial products. In those instances, hydrogen is a byproduct. High-energy plasma is suitable if the targeted product is high-quality carbon such as graphene. It is inefficient, however, if hydrogen production is the objective and carbon or acetylene is just a byproduct. The high-energy-plasma business model requires customers for the carbon or acetylene.

Sakowin’s technology uses low-energy plasma. “The energetic characteristics of the process are close to those of reforming, which makes it competitive with ‘gray’ hydrogen produced from fossil hydrocarbons,” Gatt says. As a bonus, carbon can be sold for various applications, typically battery electrodes and tires.

The compact reactor is contained in an 8-m^3 (300-$ft.^3$) cubicle, making the system modular by the combination of two or several cubicles. Production can be decentralized: Since it can be installed close to where hydrogen is consumed, the supply can be adapted to demand.

One 80-kW reactor can produce up to 1 metric ton of hydrogen per day. With on-site production, transportation is unnecessary and there is virtually no storage.

The process can also rely on biomethane, produced from organic sources.

TRL stands at 4, Gatt says. “We have a prototype running in a laboratory environment.” After more research and development is conducted, a product may be on the market in 2025, he says.

Sakowin’s idea may be a solution for complementary, low-cost production on-site, say H2 Hub Airport officials. It does not require water, and the facility’s footprint is small, they add.

Long Beach, California-based Ways2H, formed in 2019, is also offering a system for local production of hydrogen. The company's preferred source would be waste from aircraft and passengers, similar to municipal waste.

Ways2H's thermochemical conversion is an advanced version of the well-known gasification process, used in gas generators. Japan Blue Energy Co. (JBEC)—one of Ways2H's two shareholders with U.S. investor group Clean Energy Enterprises—has been developing it since the early 2000s. JBEC built four pilot reactors in Japan to improve the technology to the point at which it could be used in a product.

The latest variant has been operating successfully near Tokyo since 2018, says Ways2H CEO Jean-Louis Kindler. A more compact and transportable version has been designed based on those operations. Construction was completed in March, and it will soon be in working condition.

The concept is to crack organic matter into molecules such as methane, water vapor, carbon oxides and, above all, hydrogen, Kindler explains. "We push hydrogen content to 50% and more in volume," he says. "We then extract the hydrogen using a third-party gas-separation technology, such as a pressure swing adsorber."

A key feature of Ways2H's technology is its temperature management. "Our system can self-stabilize the reaction's temperature," Kindler says. Stabilization is critical because too high a temperature translates into dangerously high pressure, whereas too low a temperature results in the formation of tar. Stabilization by means other than the self-regulating process JBEC devised has proved difficult. In the first pilot reactor, tar and subsequent cleaning were an issue.

"We can handle a variety of feedstock—wood chips, municipal waste, sewage sludge or medical waste, for instance," Kindler says. The company is preparing the installation of a reactor in the Los Angeles area with production capacity for 40-50 kg (90-110 lb.) of hydrogen per day, using 1 metric ton of municipal waste.

The sort of waste available in airports is compatible with Ways2H's technology. Moreover, as the system heats up to 1,000C (1,832F), it can also operate as a sanitation device, destroying viruses and prions, Kindler says.

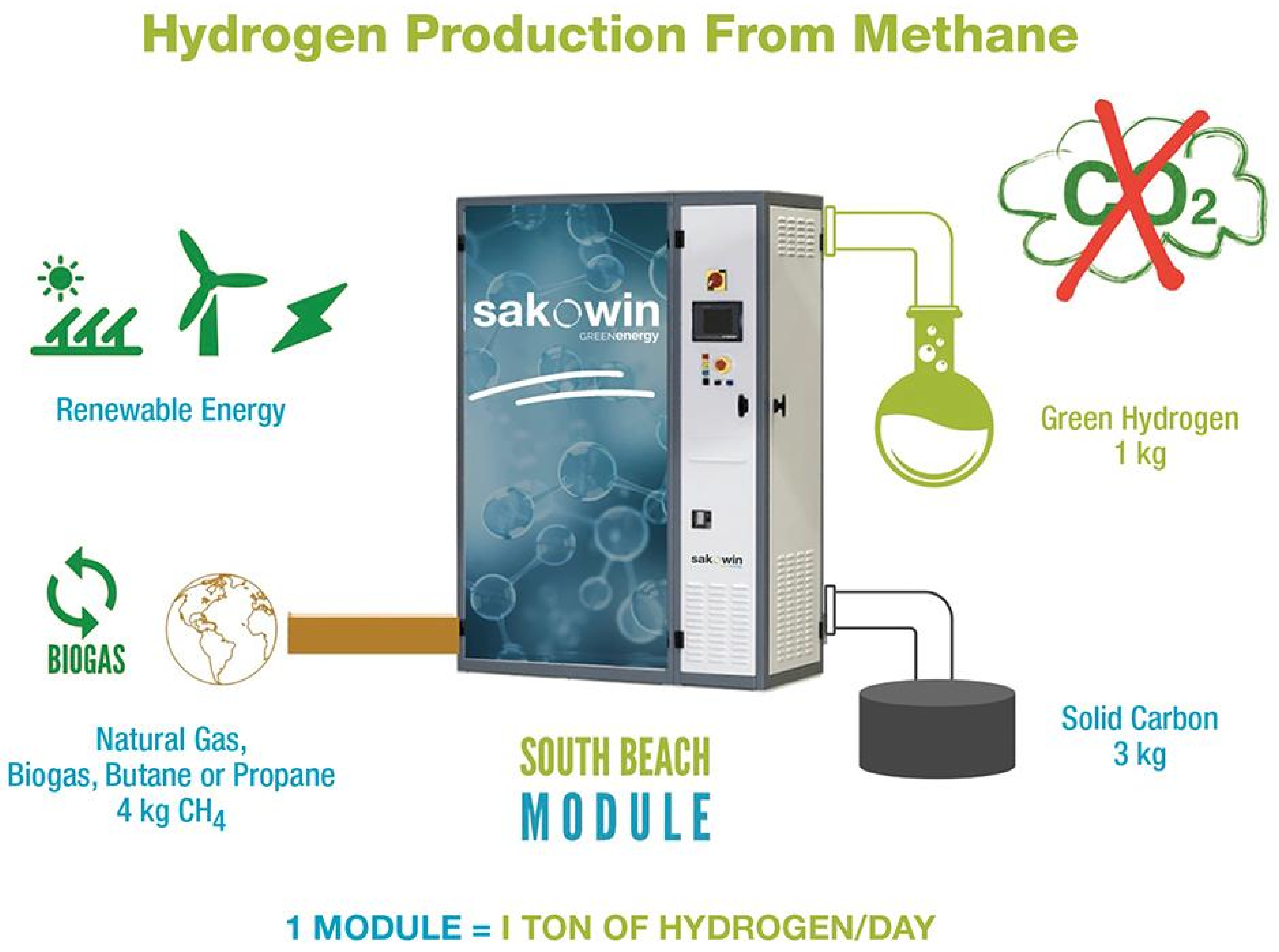
"An airport is ideal for the development of hydrogen infrastructure because it has a captive fleet of vehicles," he notes about the system's possible applications. The facility Ways2H plans to build at Paris Charles de Gaulle Airport will be able to process 24 tons of waste per day—the equivalent of what a town of 15,000 residents generates. One-and-a-half tons of hydrogen could be extracted, enough to fill the tanks of 300 hydrogen cars. "We will not have enough to fill aircraft tanks, but we could fuel ground operations," Kindler says.

He sees his company's offering as part of a decentralized scheme, a microgrid of waste processing and hydrogen production units. "You do not want to pay for transporting waste," he says. "We are advocating something that fits into a circular economy."

H2 Hub Airport project managers selected Ways2H in particular because of its circular, local-treatment approach and the prospect that it could deal with all sorts of waste, including plastics. A CO_2 capture system can be added, they note.

Air Liquide, a specialist in liquid hydrogen and oxygen for space launchers, is developing a liquid-hydrogen refueling truck. Design drivers include "high volume, high output and quick connection," the company says.

Its development is expected to be swift, from the current TRL 5. The truck may begin operations as soon as 2025 to feed the hydrogen stations deployed at the airport for ground vehicles. Air Liquide will adapt existing trucks to an airport's specifications. Synergy also can be expected with Absolut System, since Air Liquide is counting on condensing vapors.



Sakowin's concept uses natural gas, with its vast reserves, to produce hydrogen without emitting CO2. Credit: Sakowin

Other hydrogen-fueled ground-support equipment may be seen relatively soon on aprons. Their TRLs range from 6-9, depending on the type—ground power unit, aircraft tug, baggage tug or loader. A French-German consortium, including energy conglomerate Engie, is designing the systems and vehicles as well as defining their use and training drivers.

Among H2 Hub Airport's selections is U.S. startup Universal Hydrogen, which plans to modify regional aircraft to hydrogen propulsion using fuel cells and modular hydrogen capsules for storage and transportation. The H2 Hub Airport management team is interested in the capsules' intermodal capability; however, they are only at TRL 3-4.

The startup's fuel-cell partner Plug Power is another of the winners with its proposal for fuel-cell-powered ground-support vehicles.

The H2 Hub Airport project also includes a risk management element. French civil aviation authority DGAC has joined forces with the National Institute for Industrial Environment and Risk (the French acronym is Ineris) and the Gustave Eiffel University to form the Use-In H2 consortium. The three organizations are accustomed to working together, their representatives say.

Because hydrogen will be used for multiple applications at the airport, a number of safety and security concerns must be addressed and some big-picture aspects clarified early on.

If hydrogen use were intended to be "airside only," the issues would be limited. But then hydrogen would miss a potential target—passenger cars. "This is a central question, and if tackled early enough, we can find solutions," says Ineris Business Development Manager Emmanuel Lemazurier.

Another macro issue is the coexistence of Jet-A1, hydrogen, natural gas and electric vehicles on the same platform. Additionally, a tank filled with explosive materials should not be located next to a control tower.

Current issues with Jet-A1 fuel might also occur with hydrogen. The refueling process, for instance, could be disturbed by a catering truck tearing off a pipe. To prepare for that, a safety system can be designed to prevent massive leaks.

"Those engineers who develop new technologies are not necessarily aware of such issues," Lemazurier notes. Use-In H2 will support their work and ensure that the new designs include the necessary systems. The three organizations' risk analysis expertise can provide valuable advice to the designers.

"Symbolically, solving a problem during the design phase may cost €1, but it may cost €10 during the manufacturing phase and €100 at deployment," says Guillaume Roger, a scientific and international advisor at the DGAC's technical service.

DGAC, as an authority, will ultimately decide whether to green-light the new systems. But it sees its most important role as supporting the creation of the new ecosystem, Roger says.

The Use-In H2 consortium might also conduct environmental performance analyses, such as energy balances on a well-to-wheel basis, says Fabien Harel, a fuel cell specialist at the Gustave Eiffel University.

A more mysterious contribution is supposed to come from Geostock, a Vinci Group company specializing in gas and liquid storage in lined mining cavities. But the location of such cavities—typically salt caverns—remains uncertain, since the closest documented ones are hundreds of miles from the Paris area. Vinci would not comment.

Regardless, at TRL 2, its technology readiness is very low, H2 Hub Airport project officials estimate.

SUSTAINABILITY