Safran tackles the climate challenge

JUNE 2023

SAFRAN

VISION

Close-up view of a dye penetrant inspection of a landing gear wheel, a type of non-destructive test.

SUSTAINABLY CONNECTING THE WORLD

Olivier Andriès,
Chief Executive Officer of Safran

Aviation is at a turning point in its history. World events of recent years have shown how mobility plays such a vital role in our lives, economically, socially and culturally. Mobility is a fundamental human need and one of our most precious freedoms. At the same time, we are fully aware of the climate challenge and of the transport industry's role in greenhouse gas emissions. It's easy to express the equation, less so to solve it. If we want to preserve our freedom to travel in the years and decades to come, the only possible solution is to decarbonize all aspects of mobility.

Contrary to many preconceived notions, aviation is one of the sectors most committed to this goal and one of the most advanced. From generation to generation, airplanes in service worldwide have continued to improve their energy efficiency and, as a consequence, have reduced their greenhouse gas emissions.

Today, this deep-seated trend continues to gain pace and be more structured. Through the Air Transport Action Group (ATAG), the diverse members of the global aviation industry recently pledged to achieve net-zero carbon emissions by 2050. To meet this new and highly ambitious objective, our industry must leverage all the tools at its disposal. This means developing innovative aircraft concepts and architectures, especially concerning propulsion systems, enhancing the efficiency of airport and flight operations, and pushing for the widespread introduction of sustainable aviation fuels (SAF).

At Safran, we have long been committed to this energy transition. Tackling climate change is a top priority for our organization, on a par with flight safety. This commitment is largely reflected in our corporate purpose, approved during the 2020 Annual General Meeting of Shareholders. When I was appointed CEO of Safran in early 2021, one of my first actions was to increase the objectives of our low-carbon plan so we could set an example in terms of decarbonizing our production processes. Our revised aim is to reduce CO_2 emissions by 30% between 2018 and 2025.

Through our products, Safran plays a pivotal role in meeting the challenge of reducing aircraft emissions. Our research and innovation efforts are largely focused on achieving a drastic reduction in our environmental footprint. We do this by delivering innovative and competitive products to support a low-carbon aviation industry, based on a multipronged approach: develop ultra-efficient turbofan engines for the next generation of single-aisle commercial jets; work on new types of hybrid and all-electric propulsion for smaller aircraft; optimize the management of non-propulsive energy (electrical actuation, e-taxiing, etc.); come up with new designs and materials to reduce equipment weight; and explore all paths to allow the widespread use of sustainable aviation fuels, whether biofuels, synthetic hydrocarbons or liquid hydrogen.

It's a tremendous challenge, but I'm firmly convinced that it's within our reach. Not only is it a goal shared by our entire industry and by public authorities, but above all we have all the talent needed. Our employees across the board are both motivated and passionate about meeting the greatest challenge facing aviation today.

All of us at Safran are very proud to carry on the pioneering role played by our company in the revolutions that have shaped aviation over the years.

Contents

TAKING STOCK

Close-up look at a high-pressure compressor disk for an aircraft engine.

Aviation's impact on our climate

Before we delve into the ways to reduce aviation's carbon footprint, let's take a look at the underlying concepts.

When talking about climate policy, we generally define net-zero carbon emissions as a balanced state within a given scope where the amount of carbon dioxide (CO_2) generated by human activity is equal to the amount withdrawn from the atmosphere by natural absorption, coupled with carbon capture actions. Since the difference between the amount of CO_2 emitted and withdrawn equals zero, we also refer to this state as "zero net emissions".

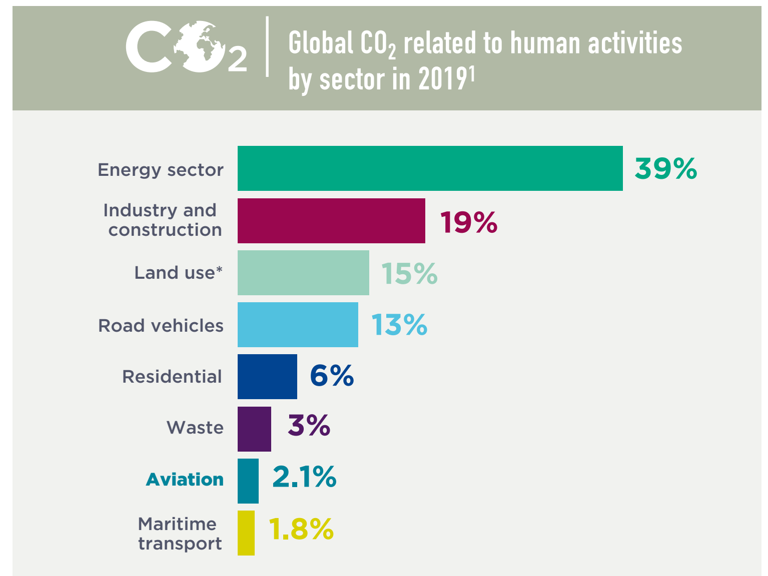
For companies, the quest for net-zero carbon emissions entails the application of technologies and processes that reduce emissions as much as possible during production, along with the direct or indirect funding of actions to negate emissions, such as planting trees, capture and storage, etc.

THE DIFFERENT TYPES OF GREENHOUSE GASES

In excess of 95% of the greenhouse gases (GHG) due to aviation is generated by the fuel aircraft burn over their lifetime. The majority is emitted in the form of carbon dioxide (CO_2), the main greenhouse gas caused by human activity. We have a clear understanding of the amount of this gas emitted by aircraft, since it's directly proportional to the weight of the fuel burned. According to ATAG, aviation emitted more than 900 million metric tons of CO_2 worldwide in 2019, or 2.1% of all CO_2 emitted by human activities (as in 2018). Reducing this amount is a top priority for the entire industry, which is focused on improving the energy efficiency of airframes and engines, while also optimizing operations.

Aircraft also generate other emissions that contribute to climate warming – the so-called "non-CO_2 effects" – but the amounts and proportions are much more difficult to quantify.

For example, engines emit water vapor which, depending on weather conditions at altitude, can form condensation trails, or contrails, and can resemble high-altitude clouds. These phenomena may cause some significant warming, but they only last a few hours. Their formation and warming power depend on complex atmospheric factors, which makes it hard to accurately estimate their climate impact.



Aircraft engines also emit oxides of nitrogen (NOx), as well as fine particles and soot. International aviation regulations stipulate limits to these emissions, which damage human health and contribute to global warming. NOx may destroy methane, a powerful greenhouse gas, but it also creates ozone, which contributes to warming. Fine particles and soot may influence the formation of contrails or contrail cirrus, but these effects are still poorly understood.

In other words, the contribution of non-CO_2 effects to global warming is still very difficult to quantify, and is highly uncertain. The international scientific community currently estimates the total contribution of aviation at 3.5%[2] of global warming due to all human activities. Safran is fully committed to understanding these phenomena so as to better guide its research & technology efforts and identify the required technological solutions.

A better understanding of how contrails form could help define operational measures for flight paths to minimize their appearance.

AIRCRAFT MANUFACTURE

According to the United States Federal Aviation Administration (FAA), in 2017 the average age of airplanes withdrawn from service was 23.3 years. Given this period of intensive operation, their production and dismantling at end-of-life accounts for less than 5% of emissions during their lifetime. This percentage is significantly less than for sectors such as the automotive industry, where these activities account for up to 30% of total emissions[3].

THE AIRPORT ECOSYSTEM

Over and above the airplanes themselves, the sector's environmental footprint must include the entire operational ecosystem. Once again, making an accurate estimation is difficult because of the number and complexity of parameters involved and the diverse conditions across the world. The European chapter of Airport Council International (ACI) nonetheless pegs airport operations at 2 to 5% of the sector's emissions. Then there's the production and shipping of jet fuel, which increases emissions due to aircraft operations by about 20% – in the same ballpark as for the gas and diesel fuels used in land vehicles.

[1] Source: IEA. [2] Source: D.Lee et.al 2020 [3] Source: Mercedes study
*Land use of ULUCF: Land use, land-use change, and forestry.

An entire sector steps up

Given the systemic challenge of climate change, making aviation carbon-neutral requires all players in the sector to step up, from airlines and airport operators to aircraft and equipment manufacturers, not to mention national, regional and international regulatory authorities.

Since commercial aviation really began to take off in the early 1950s, fuel consumption per passenger-kilometer has been reduced by 80%. From 2009-2017 alone, average fuel consumption decreased 17%, or more than 2% a year. However, this improvement is offset by the long-term growth in air traffic, driven by emerging countries. Without firm actions by the entire sector, total emissions from aviation will continue to grow - and that is unsustainable.

2050 OBJECTIVES: DEFINED AND SHARED

For several years, aviation regulatory and trade organizations have made bold public pledges to fight climate change. In October 2022, for example, the International Civil Aviation Organization (ICAO, an arm of the United Nations) made a commitment on behalf of its member states to achieve net-zero emissions from all flights by 2050.

Private companies in this sector — airlines, aircraft, engine and equipment manufacturers, airports — are represented by the Air Transport Action Group (ATAG). In 2008, they made a pledge to halve the global fleet's net emissions by 2050, compared with 2005. In October 2021, ATAG set a new target: net-zero carbon emissions by 2050, in line with the Paris Climate Agreement to contain global temperature rise to no more than 1.5°C.[4] In October 2022, this goal of carbon-neutral aviation by 2050 was ratified by the ICAO.

In Europe, public authorities and industry have aligned through the Clean Aviation research partnership to set a neutral carbon target for the aviation sector by 2050 (also ratified by the ICAO).

MARKET INCENTIVES

Several measures based on quotas for CO_2 emissions use incentives to encourage the aviation sector to reduce emissions. For example, Europe set up the Emissions Trading System (ETS) in 2005, and the aviation sector joined it in 2012. In addition, there's the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which mandates offsets for the rise in emissions from international flights, while awaiting various low-carbon technologies to prove their maturity. CORSIA was signed within the ICAO in 2016 and took effect on international air traffic in January 2021, but not for domestic flights. Safran believes it is very important to give this scheme a chance by not combining these measures with others, and also to make sure that offset programs meet strict sustainability criteria.

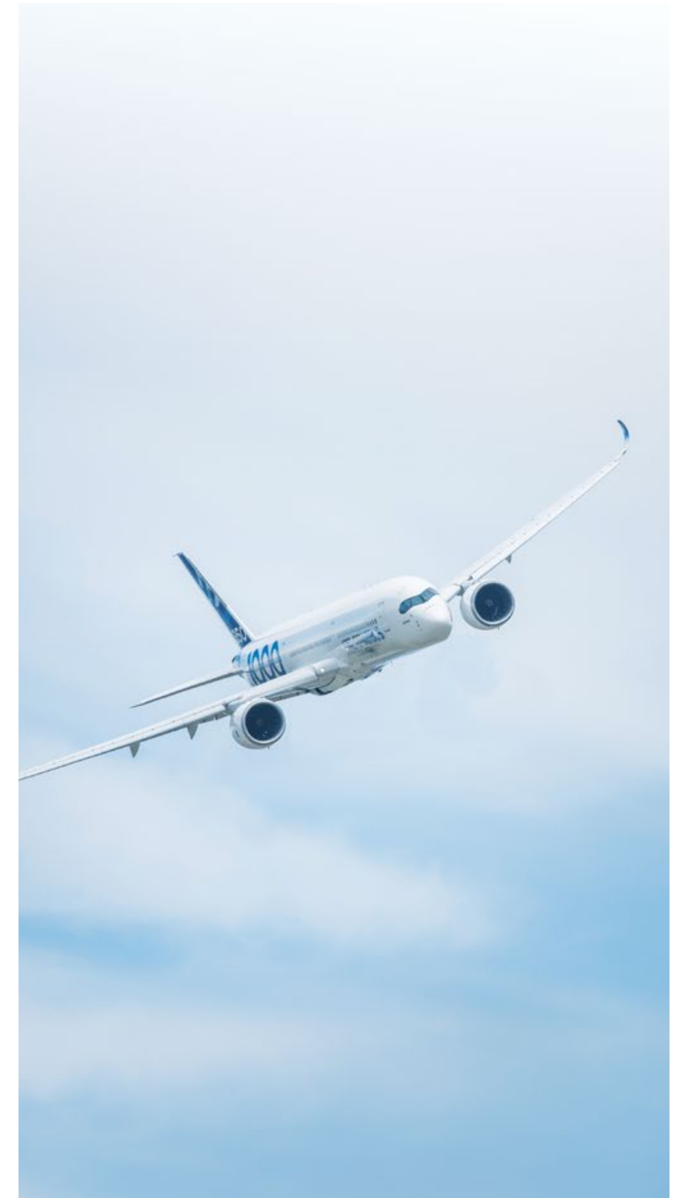
SUPPORT FROM PUBLIC AUTHORITES A NECESSITY

Given the requisite investments and the many different actors involved, the transition to decarbonized aviation will not happen without the support of public authorities. This is vital to implement fair and effective regulations concerning CO_2 emissions from air transport, especially in Europe. Industry players like Safran will have a role, but the extensive challenges involved mean that governments have to participate in the required research. Public support will also be decisive in the development of a widespread production and distribution system for low-carbon fuels, via budgetary measures and a regulatory framework that offers incentives.

CLEAN AVIATION

CLEAN AVIATION: A MODEL OF PUBLIC-PRIVATE PARTNERSHIP

Clean Aviation is a research and innovation program launched by the European Commission in 2021. It builds on the work of Clean Sky 1 (2008–14) and Clean Sky 2 (launched in 2014), in which Safran played an active role. Clean Aviation, which has a budget of €4 billion for 2021–27, brings together the expertise of national research centers, universities and industry to foster the emergence of disruptive technologies and enable the European aviation sector to achieve carbon neutrality by 2050. Safran is involved in seven of the 20 R&T projects selected by Clean Aviation in 2022. The OFELIA project, led by Safran Aircraft Engines, will work on the breakthrough Open Fan architecture at the heart of the RISE program.



4.5 billion airplane trips in 2019

119 countries have volunteered to join the CORSIA scheme

[4] By about 2100, in relation to temperatures in the pre-industrial era.

The path to decarbonization advocated by Safran

Given the forecast growth in global air traffic, the aviation industry has set an extremely ambitious target of achieving net-zero carbon emissions by 2050.

Meeting this goal will require a step change in the pace of decarbonization. In other words, we will have to duplicate the environmental progress of the civil aviation industry over the period 1950-2020 – but twice as fast!
Safran is a full-fledged participant in this global effort and shares the firm conviction that we can rise to the challenge. However, it will be a difficult transition, demanding a strategy supported by the entire sector, together with consistent public policies across the globe, and the activation of multiple levers to achieve the desired results.

AN ARRAY OF INDUSTRY ACTIONS

Safran believes that the objective of net-zero carbon emissions can be met by 2050 through a multipronged approach: technological innovation and aircraft replacement (from 35% to 40% of the effort required); the introduction of sustainable aviation fuels (about 50%); and the balance by optimizing traffic and infrastructures and by using offsets for residual emissions.

THE IMPACT OF COVID-19

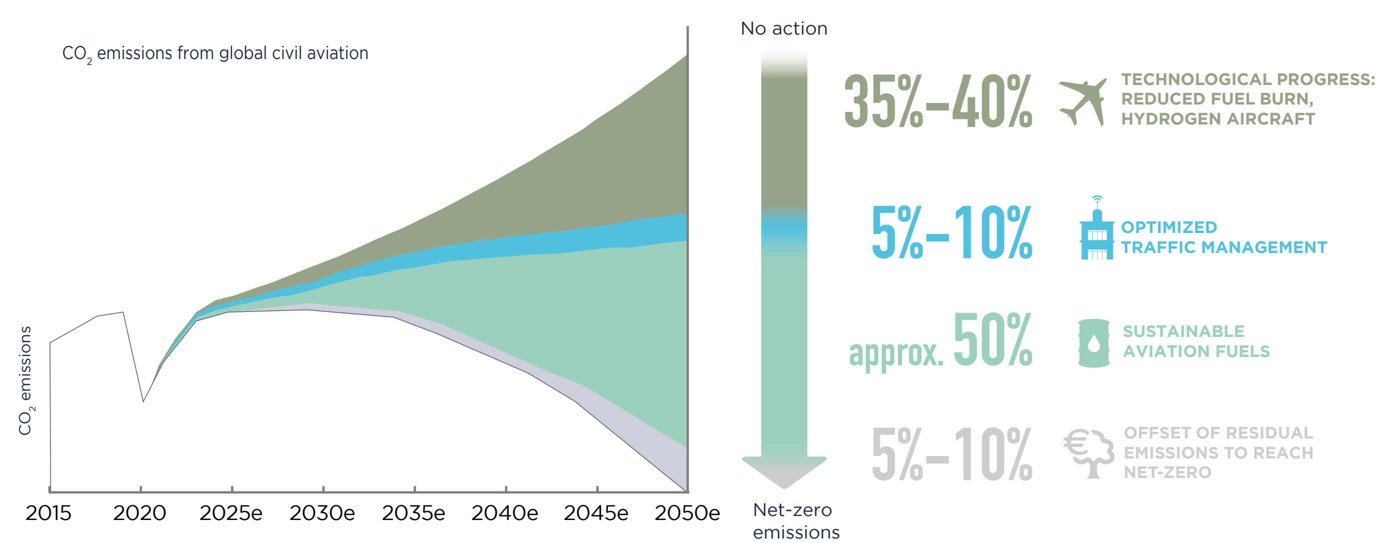
The air transport industry was hard hit by the global health crisis, resulting in an unprecedented drop in traffic in 2020 and 2021, and consequently in CO_2 emissions. Today, traffic volumes are almost back to their 2019 level and the environmental challenges associated with air traffic remain the same: reconcile air traffic growth with ambitious targets to reduce greenhouse gas emissions.

SAFRAN'S ROLE IN THE FRENCH INDUSTRY SUPPORT PLAN

Despite the crisis, Safran has made the responsible decision to sustain its unprecedented environmental efforts.

From 2020 to 2022, Safran benefited from France's national stimulus plan for the aerospace industry, coordinated by CORAC, the French civil aviation research council, with a budget of €1.5 billion for the period. The Group now benefits from the support of the aeronautics component of the France 2030 investment plan for 2022–24. These plans target an objective shared by Safran: make France a leader in clean aviation by developing disruptive technologies and continuing to work on reducing fuel consumption, electrifying aircraft and supporting the transition to carbon-neutral fuels.

AN AMBITIOUS COMMITMENT TO REACH NET-ZERO CARBON EMISSIONS BY 2050



IMMEDIATE GAINS BY INTRODUCING NEW AIRPLANES

Long-term air traffic growth forecasts remain strong, despite the short-term impact of Covid. Safran estimates that 38,200 new aircraft will be delivered in the next 20 years, which will almost completely replace current fleets. This fleet renewal with more efficient planes is a short-term decarbonization lever that airlines have continued to act on, despite the economic difficulties of recent years. For example, the two narrowbody leaders — the Airbus A320neo (service entry in 2016) and Boeing 737 MAX (2017) — are both powered by LEAP engines designed by Safran as part of the joint venture with GE Aerospace, CFM International. The LEAP delivers 15% lower fuel consumption than the CFM56 engines powering the previous generation of these popular twinjets.

According to Safran's estimates, the gradual introduction of latest-generation jetliners — the A320neo, 737 MAX, 787, A350 and 777X — will automatically reduce CO_2 emissions per passenger-mile by 1% to 2% per year over the next 15 years. Fleet renewal will partly offset traffic growth and complement other decarbonization levers, such as the use of sustainable fuels and improved operations, pending the introduction of more disruptive aircraft in the mid-2030s.

Despite the impact of Covid-19, the global civil aircraft fleet should nearly double by 2040, growing from about 23,000 today to more than **40,000** in 2040.

THE AVIATION INDUSTRY HAS LONG FOCUSED ON ENVIRONMENTAL AND ENERGY EFFICIENCY.

However, meeting the target for 2050 demands expanded and simultaneous efforts, starting now, in two major areas:

- developing ultra energy-efficient aircraft, spanning propulsion, systems & equipment, weight, etc.
- developing low-carbon fuels: biofuels, synthetic fuels and hydrogen.

DEVELOP ULTRA-EFFICIENT AIRCRAFT

A 3D-woven composite fan blade on a turbofan engine powering a single-aisle commercial jet.

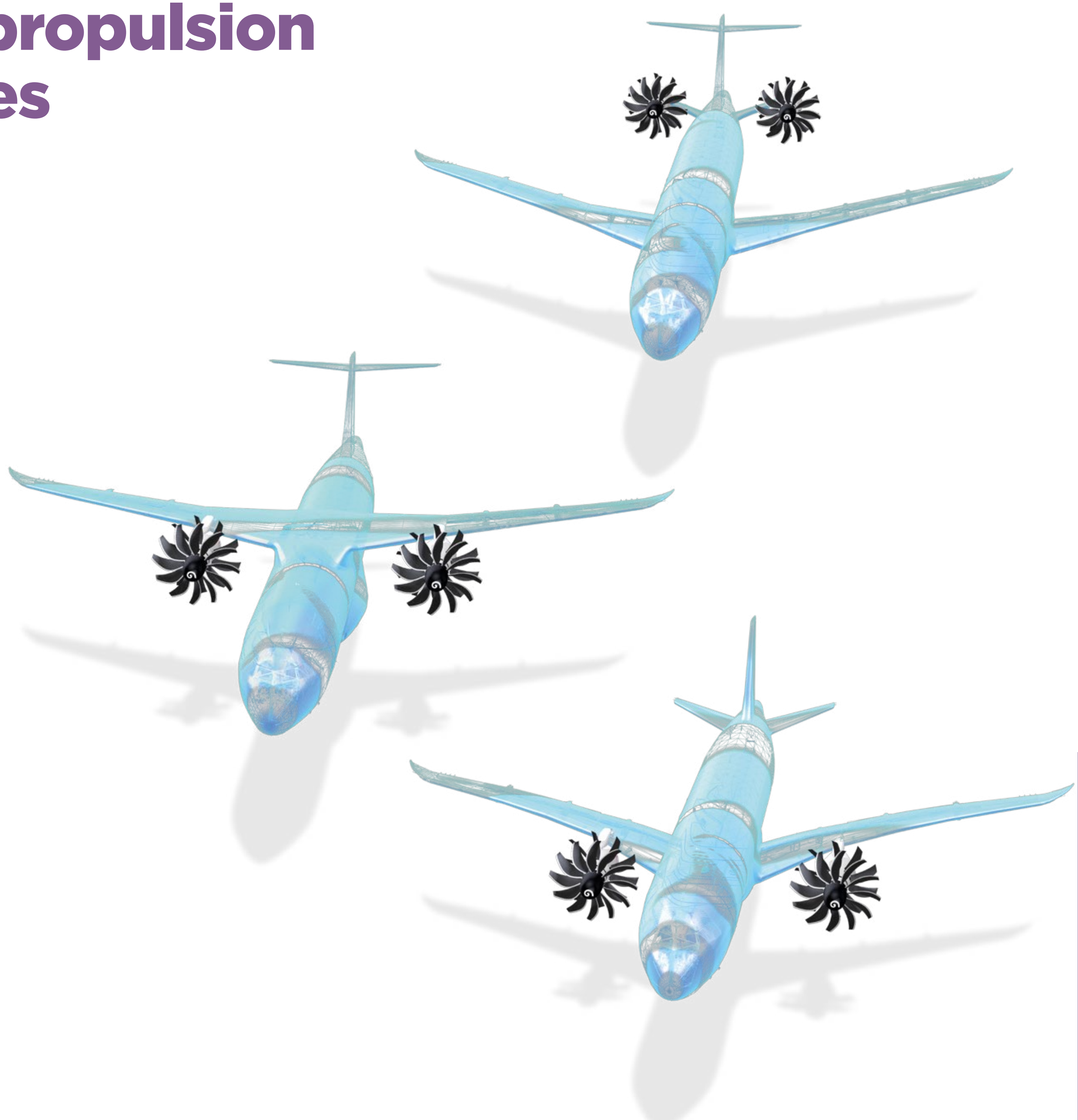
LEVER 1

Disruptive propulsion architectures

Safran is already working on various architectures that feature disruptive technologies and other breakthroughs to achieve net-zero carbon emissions.

Safran's technology strategy is designed to give aircraft manufacturers the technologies needed to introduce a new generation of aircraft by the mid-2030s that will reduce fuel consumption by up to 30% compared with current fleets. That means twice the usual pace of progress with the introduction of a new airplane.
According to Safran, a large part of this improvement is enabled by new engine architectures, along with reduced aircraft weight and more efficient energy use, especially by electrifying the plane's systems.

Up to a 30% decrease in fuel consumption
for the new generation of aircraft from 2035



Concepts rendering not representative of any future aircraft configuration.

ULTRA-EFFICIENT THERMAL PROPULSION

- Conventional thermal (gas turbine) engines will continue to be the only way of powering large, long-range aircraft for the next several decades. However, that doesn't mean that these long-range jets will continue to emit large quantities of CO_2.
- It's possible to drastically improve the energy efficiency of conventional turbofan engines, in particular by increasing their size and bypass ratio to augment the secondary airflow from the fan, which generates thrust without directly involving combustion.
- However, the structure and aerodynamic design of tomorrow's aircraft will still have to be extensively modified. Airframers are actively working on design studies and disruptive aircraft concepts to integrate innovative propulsion systems proposed by engine-makers. Safran's role is to support aircraft manufacturers in this quest.
- Above all, these conventional, but ultra-optimized thermal engines could use low-carbon or even carbon-neutral fuels (see pages 24-25). Their basic operating principle would be similar, whether they burn jet fuel, or other types of fuel, including liquid hydrogen.

OPEN ROTOR: A PROVEN EXAMPLE

Can we significantly reduce the consumption of conventional jet engines? With the Open Rotor, Safran proved that it was possible. Safran developed this concept through the European research program Clean Sky and carried out ground tests of the first full-scale demonstrator in 2017. It showed fuel savings of up to 15%, thanks to its innovative architecture without a nacelle, plus the use of twin counter-rotating fans and the use of advanced technologies. Despite its unshrouded design, the Open Rotor doesn't produce any more noise than the current LEAP engine. The results generated by this demonstrator will be used by Safran to develop the enabling technologies for its future engines.

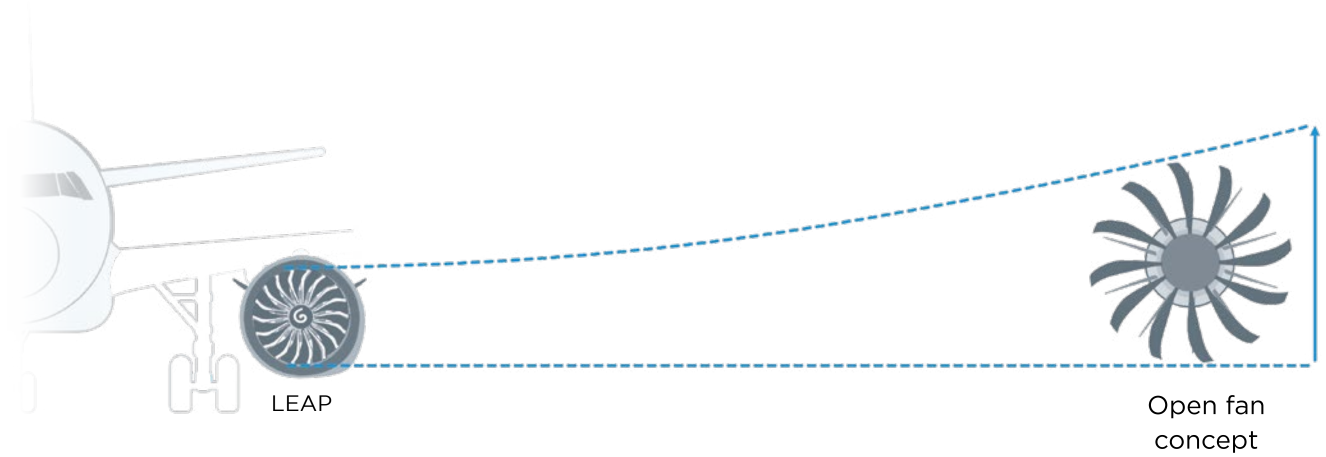
RISE: A TECHNOLOGY DEVELOPMENT PROGRAM FOR A NEW GENERATION OF SUSTAINABLE AIRCRAFT ENGINES

Together with its partner GE, Safran announced, on June 14, 2021 that it was launching an ambitious program to develop the technology for an upcoming generation of aircraft engines designed to burn 20% less fuel than the new-generation LEAP engine and be 100% compatible with sustainable aviation fuels as well as hydrogen. By combining these two major advances, planes powered by the future engine will be able to slash CO_2 emissions by more than 80%.

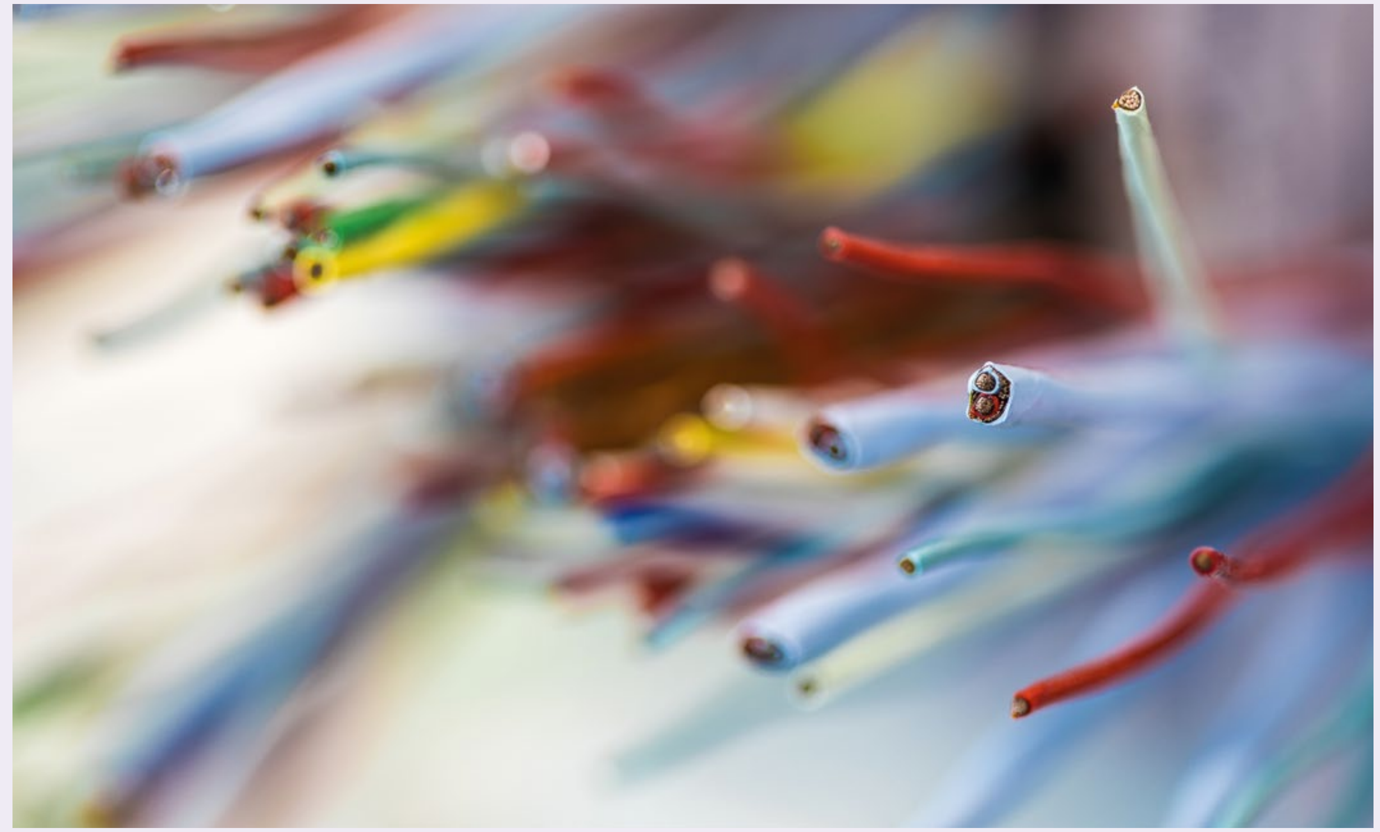
As part of the new program, dubbed RISE (Revolutionary Innovation for Sustainable Engines), Safran will develop the disruptive technologies required for the new sustainable engine, which could enter service on next-generation aircraft towards the middle of the next decade. With an unducted fan architecture and a fan diameter twice that of the current LEAP, the new engine will deliver maximum propulsion efficiency. It will also integrate a wealth of state-of-the-art technologies, from new materials such as alloys and composites offering very high-temperature resistance and substantially reduced weight, to hybrid electric layouts – a first for a commercial aircraft engine – and innovative production processes such as additive manufacturing, which requires fewer raw materials and allows for the creation of lighter parts.

Through the RISE program, Safran and GE are investing in a unique array of disruptive technologies to develop a state-of-the-art engine that will power the decarbonized commercial aircraft of the future.

A partnership with Airbus plans to build a demonstrator to test the “open fan” engine architecture on an Airbus A380 by the middle of the decade.



CFM International, the 50/50 joint venture between GE and Safran that was founded almost 50 years ago, is a textbook case of a successful transatlantic partnership



WILL PROPULSION GO ELECTRIC?

Developments in battery energy density in the short and medium term will limit electric or highly hybridized propulsion to short-distance, low-capacity flights: training aircraft, small shuttles, regional aircraft in the medium term and new aircraft dedicated to VTOL or STOL urban/suburban air transport. Coupled with this, the hybridization of propulsion systems on future aircraft and helicopters will help meet the ambitious targets for reduced fuel burn. Safran is a leader in all-electric and hybrid architectures, developing a range of products for the electrical power chain — motors, turbogenerators, energy management systems — and working with innovative battery companies. In 2022, Safran signed several agreements to equip CAE’s Piper Archer aircraft, VoltAero’s Cassio 330 hybrid-electric prototype and Diamond Aircraft’s eDA40 electric aircraft with its ENGINeUS™ electric motors. Safran is working with Aura Aero on the architecture and electric propulsion system for the Intégrale trainer and the ERA regional aircraft. In September 2022, the Group also opened a new electrical engineering center of excellence in Créteil, France, and invested in Cranfield Aerospace to collaborate on a hydrogen fuel cell electric-propulsion aircraft project.

In the market for medium and long-haul jets, which generate a large majority of greenhouse gas emissions, Safran believes that thermal propulsion will remain predominant until about 2050. Of course, this type of system could be optimized, for instance by providing electrical assistance to engines. But we will have to wait for major breakthroughs in terms of battery energy density and high-voltage power management to have any hope of replacing thermal engines by electrical or hybrid-electric propulsion systems.

DID YOU KNOW?

For a given mass, jet fuel provides **60** times more energy than current battery technology

Reduce weight... and streamline operations!

Tomorrow's low-carbon aircraft will have to go on a diet, and also incorporate electrical systems optimized for lower power consumption. Safran provides a broad portfolio of aircraft systems and equipment to meet these challenges.

HIGH-PERFORMANCE MATERIALS

▬ The need to reduce aircraft weight means greater use of composite materials, which combine high strength with low weight.

▬ Safran's engines and equipment, whether nacelles, landing gear, brakes or even cabin interiors, are subject to heavy loads and sometimes very high temperatures. To develop the high-performance solutions needed, Safran has set up dedicated research entities in these key areas. For instance, Safran Composites for organic matrix composites, and Safran Ceramics for higher-temperature ceramic matrix composites, both integrated into the Group's Research & Technology Center, Safran Tech.

▬ Other priority areas of research include new metallic alloys and higher performance coatings.

ADDITIVE MANUFACTURING COMES INTO ITS OWN

▬ Like the 3D printers now well known to the general public, industry has its own additive manufacturing (AM) machines that use a digital model to build up parts in successive layers from a raw material (metallic or ceramic powder, polymers, etc.). Safran has already certified parts based on this new process, especially for the LEAP turbofan and Arrano turboshaft engines. Additive manufacturing also paves the way for the design and fabrication of highly innovative products that would be impossible to make with conventional processes. AM is both fast and flexible, but it offers other advantages as well: certain engine parts made this way are 25% lighter, while the weight of some hydraulic parts can be reduced by more than 50%. In turn, this reduces fuel consumption and improves our carbon footprint. Additive manufacturing is applied in an increasing number of industries, changing the landscape for both production and repairs. Safran has made the investments needed to accelerate the development of this technology, in preparation for its widespread use. In particular, it has created the Safran Additive Manufacturing Campus in Le Haillan (Bordeaux region) to group all related activities: R&T, design and production.

ADDITIVE MANUFACTURING: A HOST OF ADVANTAGES FOR ENGINES

Using just the required amount of **raw materials**

Innovative designs

Between **10 and 50% less** time and industrial costs

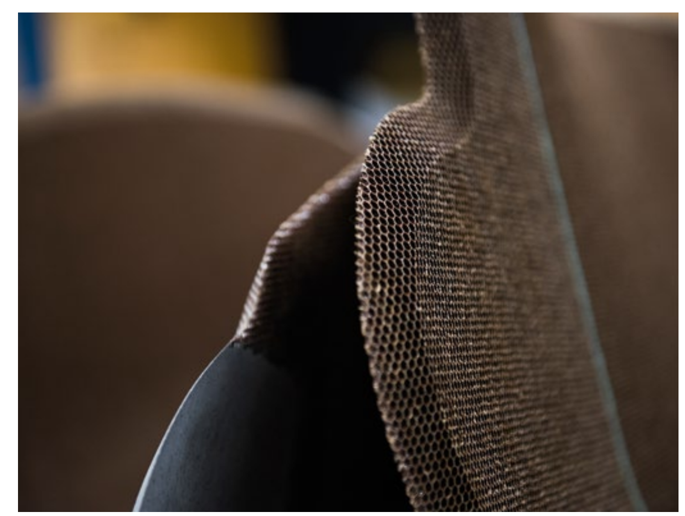
Faster design/production

A single component can replace up to **50 single pieces**

Weight reduced **15% to over 50%**

RETHINKING CABIN LAYOUTS

▬ Safran is ideally positioned to offer cabin components that reduce overall weight: seats, partitions, luggage bins, galleys, lavatories, in-flight entertainment systems and much more. The technological synergies between Safran Cabin and Safran Seats mean that products can be very highly integrated, based on lighter state-of-the-art materials such as organic matrix composites. These innovative developments also enhance airlines' operational efficiency, including optimized management of consumables, reduced waste and improved wastewater management.



ELECTRIFYING AIRCRAFT FUNCTIONS

Safran is also a leader in the drive to develop "more electric" aircraft. Through Safran Electrical & Power, it spans all aircraft electrical systems, and can integrate these different technologies to reduce overall weight.

Over the last dozen years, more and more non-propulsive functions on aircraft have been electrified thanks to the complementary areas of expertise offered by Safran's companies. These entities develop systems and equipment that combine economy and reliability with higher performance. Safran is involved in all aircraft electrical systems, from power generation via the engines and auxiliary power units (APU) to avionics, brakes, in-flight entertainment and many other electrical functions. The Group has established global leadership in many of these areas, including wiring and interconnect systems, actuators and power generation, distribution and management. For example, Safran pioneered the electric brake used on the Boeing 787 and the electrical thrust reverser actuation system for the C919, replacing the traditional hydraulic, pneumatic or mechanical systems for lighter weight and higher reliability. Safran has also developed an electrification solution for the nosewheel steering and landing gear extension/retraction functions.

Safran is also studying the use of auxiliary power units (APU), now mainly used on the ground to power various systems, to contribute to the airplane's energy efficiency in flight by powering more functions during certain flight phases. This initiative is already well under way with the eAPU, a new power generator better adapted to the needs of more electrified or all-electric aircraft. Tomorrow's systems could be higher-performance evolutions of current technologies (turbo-generators for example) to meet short-term needs, or revolutionary advances for the longer term (such as hydrogen fuel cells). As a secondary energy source, APUs could lighten the load on the main engines, and thus help decarbonize commercial aviation.

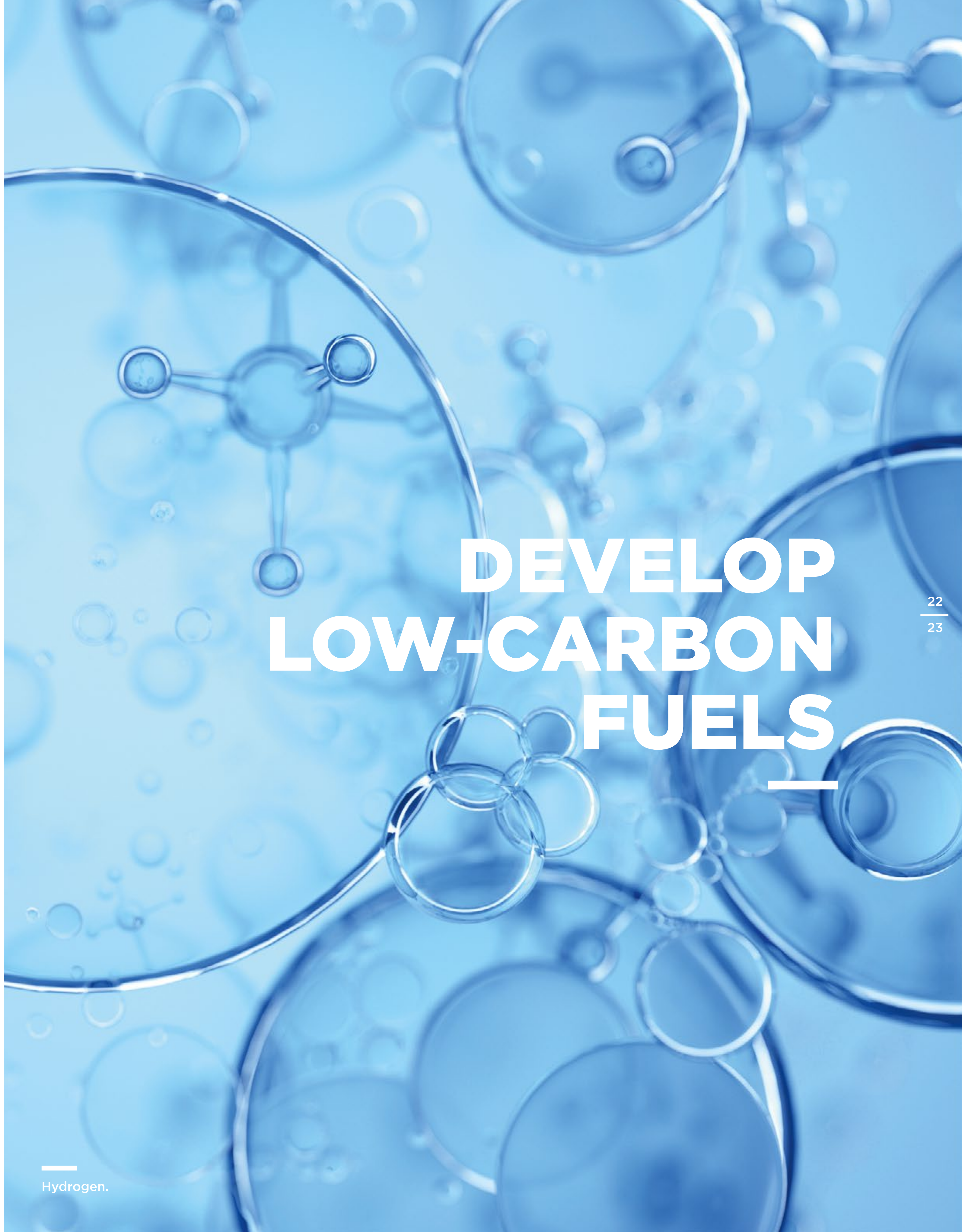
REDUCING CO_2 DURING TAXIING

The e-Taxi electric taxiing system developed by Safran Landing Systems runs off the auxiliary power unit (APU) and will enable aircraft to taxi without starting their main engines. Planes with this solution will save up to 4% fuel and drastically reduce the CO_2 and NOx emissions associated with ground operations by 61% and 51% respectively. E-Taxi will also reduce noise pollution around airports and delays due to the availability of pushback tractors.

IMPROVING OPERATIONS

In a complementary approach to reduce fuel consumption even before the next generation of airplanes takes to the skies, various stakeholders (airports, air traffic control, manufacturers, authorities) are teaming up to make operations more efficient. Aiming at up to a 10% decrease in CO_2 emissions, this approach spans a wide range of potential measures: better air traffic and airport management, definition of flight paths, adaptation of cruise speed, or even the use of formation flights – unprecedented in civil aviation. One possible improvement depends on reducing air traffic congestion around major hubs: with less waiting time and smoother traffic flows, airlines could reduce the speed of their airplanes without paying a sales penalty in terms of longer flights.

Safran is of course contributing to these efforts, most notably through its Cassiopée flight data analysis service, which supplies key information to airlines and other operators. Based on in-flight data, Cassiopée makes it possible to optimize maintenance operations and fuel consumption. With planes fitted with increasingly connected equipment, intelligence and sensors, this advanced data processing will drive significant improvements in the future.



DEVELOP LOW-CARBON FUELS

Hydrogen.

New production streams to be developed

Another way of immediately reducing the environmental impact of aircraft is to replace conventional jet fuels by fuels that emit less CO_2. But we have to start the replacement process right now if the industry is to meet its climate commitments.

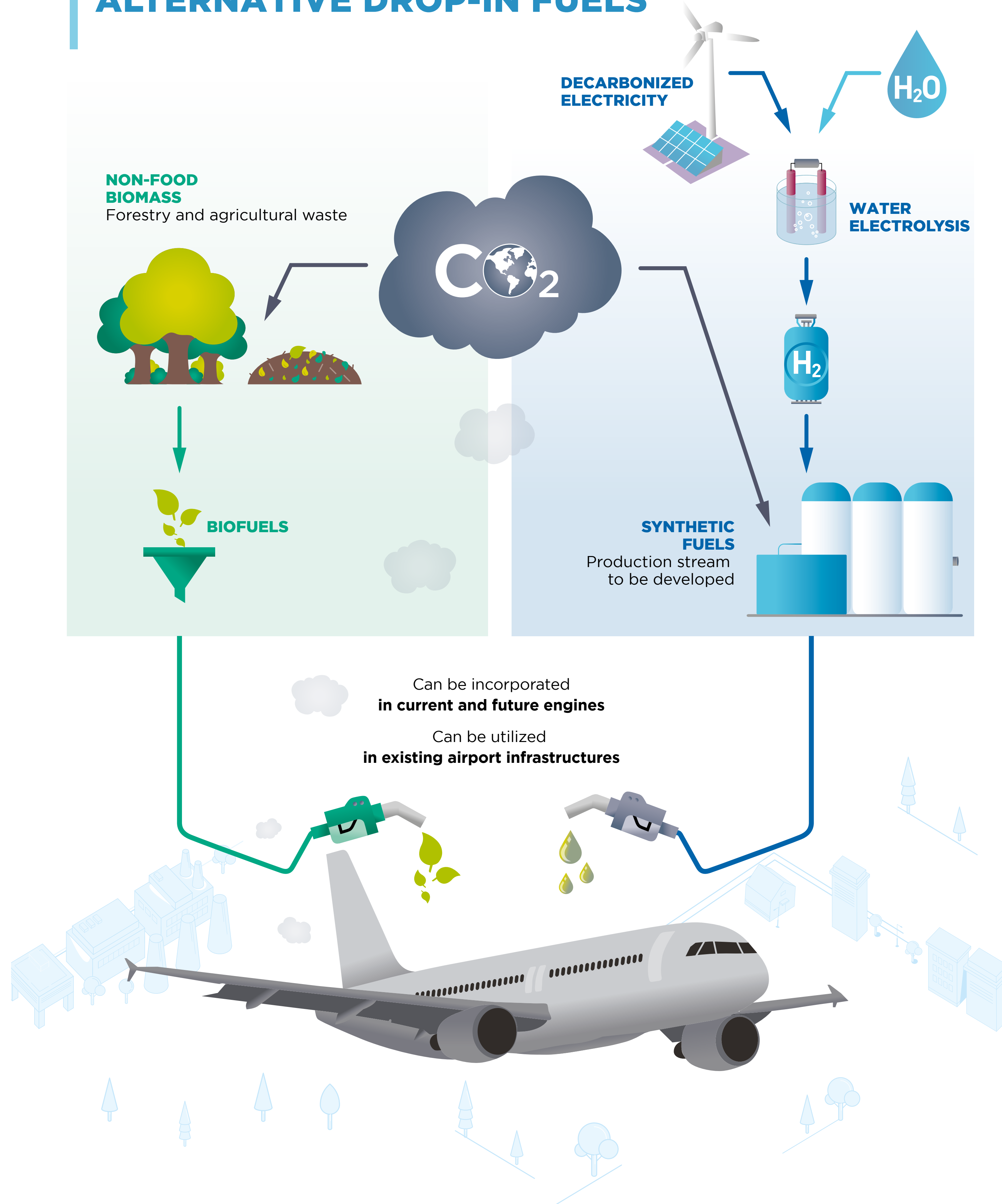
The emergence of low-carbon fuels depends not only on technological progress, but also on economic and political measures. These fuels have to come from renewable, easily accessible, financially competitive and socially acceptable sources, such as biomass-based fuels that do not compete with food crops. Despite the challenges to be met, Safran sees this solution as a decisive way of decarbonizing aviation, concurrently with optimized thermal engine architectures.

DROP-IN FUELS: CHANGING THE FUEL, NOT THE PLANE

From a technological standpoint, the most immediately accessible solution is drop-in fuels, which could be used with today's aircraft by mixing it with conventional jet fuel, without having to modify the plane, its operation or airport infrastructure. Current technologies already allow the use of up to 50% biofuels (from biomass). However, their feasibility is still limited by the lack of a large-scale production system to make them available in sufficient quantity and at competitive cost for airlines. Today, biofuels only account for about 0.1% of the total worldwide. In France and Europe, the modest target is 2% by 2025 and 6% by 2030. This will be raised to 20% in 2035, 34% in 2040 and 42% in 2040, with an ultimate goal of 70% by 2050.

As a manufacturer of engines and fuel system components, Safran is focusing on maximizing the usability of biofuels by overcoming the current technical threshold of 50% biofuels mixed with jet fuel. This involves defining fuel formulations compatible with current technologies, but also adapting engine and fuel system materials and technologies to ensure optimum performance, whatever the chemical composition of the fuel used. To push the envelope even further, Safran has teamed with TotalEnergies in a drive to achieve full compatibility for both current and future engines. Initial test flights using 100% biofuel have been carried out on CFM LEAP-powered Airbus A320neo and Boeing 737 MAX planes, as well as on several types of helicopter (Bell, Airbus Helicopters, etc.).

ALTERNATIVE DROP-IN FUELS



POWER-TO-LIQUID: TOWARDS A NEUTRAL EMISSIONS FUEL?

Another highly promising drop-in option would use synthetic fuels. Instead of refining increasingly scarce fossil fuels, which also emit CO_2, this technology produces a liquid fuel using low-carbon electricity (power-to-liquid). This offers a new way of producing hydrocarbons from hydrogen in water and captured carbon from the atmosphere. Power-to-liquid is a promising path to make a totally CO_2 neutral fuel (it emits only the carbon that was previously captured in the environment), provided of course that the electricity needed for production is generated by carbon-free sources (solar, wind, nuclear, etc.), and that the source of the CO_2 used as a raw material is carefully controlled.

Small, highly experimental refineries of this type already exist. But they harbor real potential, provided there is sufficient investment in research and the development of industrial-scale production. Starting in about 2030, power-to-liquid could well emerge as an effective response to meet the large-scale needs of a decarbonized aviation industry.

Safran is already working on ultra-optimized future-generation engines that could run on up to

100% sustainable aviation fuels (SAF)

HYDROGEN FUELS: CARBON-FREE FLIGHT

In its search for jet fuel replacements, Safran is also investigating the direct use of hydrogen in engines. This is a particularly attractive solution because the only theoretical product of hydrogen combustion is water. However, this would still require a major leap in technology.

Using hydrogen in fuel cells, as in vehicles, is another beneficial path, but for the moment this solution is limited to small aircraft: a system generating the 10 to 20 MW needed to power an A320-class airplane would still be much too heavy. So for this type of application, we would have to focus on using hydrogen as a fuel for a gas turbine. But, once again, this entails tremendous challenges in terms of the aircraft design and the entire fuel system, since it requires the storage of liquid hydrogen, meaning very low temperatures (-253°C, as for launch vehicles using this cryogenic fuel). At the same time, there are specific restrictions related to the use of hydrogen (volume and volatility), and a complete supply chain would have to be developed to meet these special conditions, also using green energy sources to provide the hydrogen. Furthermore, hydrogen combustion raises further questions in terms of operability, mechanical resistance and limiting NOx releases.

These concepts are currently being studied by the French Civil Aviation Research Council, CORAC. Through Europe's Clean Aviation research program. Safran is supporting its customers and actively working on these concepts based on a gradual investment policy keyed to the maturation of the enabling technologies. They would likely first be applied to regional aircraft, then subsequently to larger, longer-range aircraft in the single-aisle jet class. Safran has already initiated several joint research programs in this area: with Airbus and the French aerospace research agency ONERA on the availability of "green" hydrogen; and also on the impact of the specific contrails produced by these new fuels, since burning hydrogen naturally produces more water vapor than jet fuel. In addition, Safran is conducting research into high-power-density fuel cells, which offer propulsion potential for smaller aircraft (commuters, and eventually small regional aircraft). In 2022, Airbus and CFM International signed a partnership agreement to collaborate on a hydrogen-powered demonstrator program that will fly by the middle of this decade. Safran Aircraft Engines is also a partner in Clean Aviation's HYDEA project, coordinated by Avio Aero, to develop key technologies for the design of a hydrogen engine.

SAFRAN BELIEVES IN SYNTHETIC FUELS

In early 2022, Safran invested in German startup Ineratec, which is developing synthetic fuel production units.

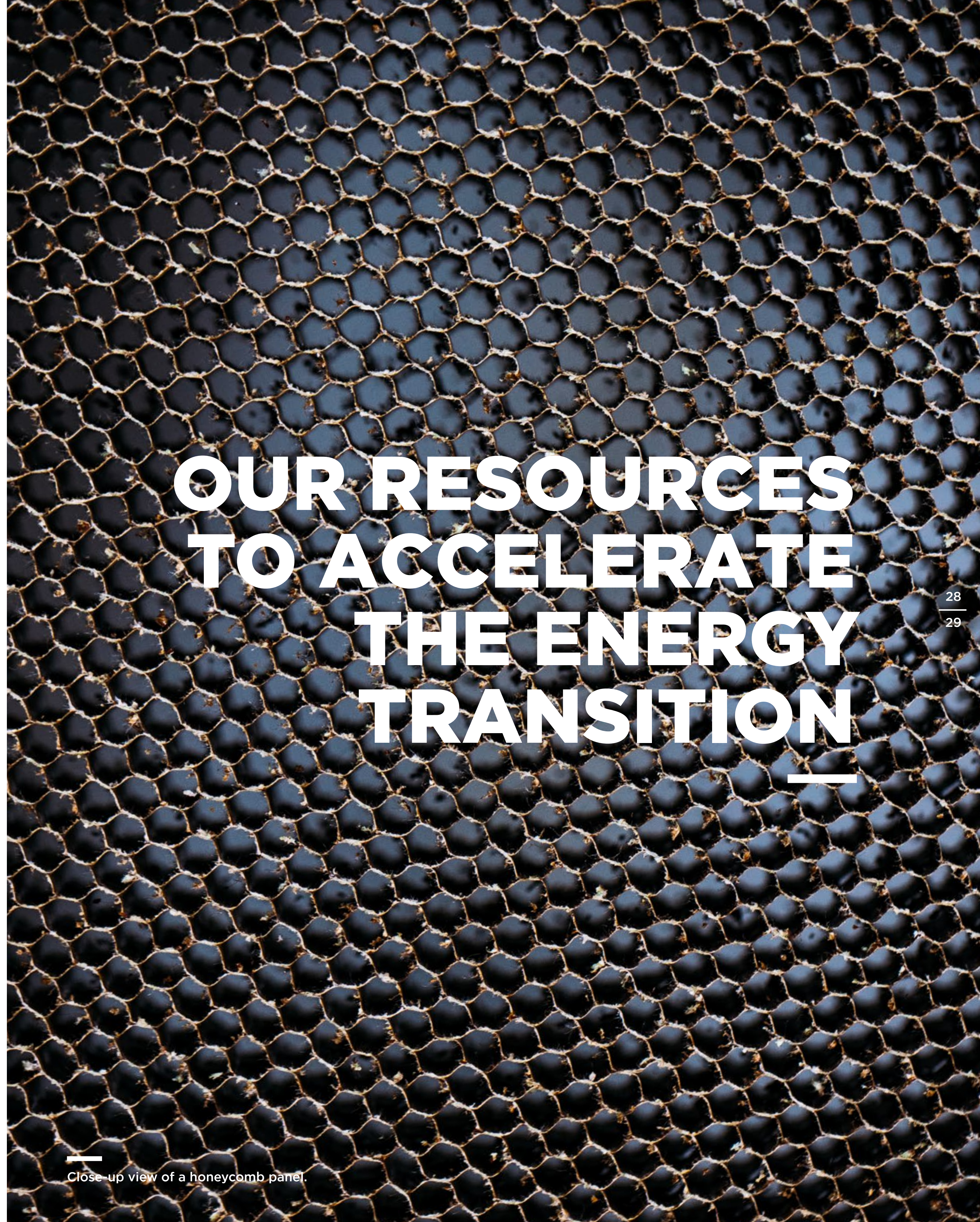
A QUESTION OF PRICE...

Over and above the technological challenges, the use of low-carbon fuels has mainly been hindered by their availability and price – at best two to three times higher than jet fuel for the moment. The large-scale development of these fuels will require an array of incentives to encourage the use of sustainable biomass in aviation, along with massive investments in infrastructure to increase production capacity and, for hydrogen, to develop the complete supply chain needed. Whatever happens, it's likely that these fuels will continue to be more expensive than jet fuel, which makes the enabling technologies needed to drastically reduce consumption all the more critical.

All these factors have informed Safran's strategy, based on the firm conviction that aviation net-zero carbon emissions can only be achieved by simultaneously targeting two objectives: optimized engines to significantly reduce fuel consumption; and low or zero-carbon fuels made available as quickly as possible, and considerably scaling up production to meet global needs.

$1 TRILLION+

The projected investment to foster the emergence of a production system for sustainable aviation fuels



OUR RESOURCES TO ACCELERATE THE ENERGY TRANSITION

Close-up view of a honeycomb panel.

A Research & Technology strategy focused on these challenges

To meet its commitment to achieve a carbon-neutral fleet by 2050, industry will need to radically innovate with its technologies and processes. Safran is playing its part with an unprecedented Research & Technology plan.

Thanks to Safran's broad positioning across a wide range of aircraft systems and equipment, in particular all energy systems, the technological advances introduced by the Group in its products are playing a major role in the decarbonization of air transport. Safran works with stakeholders across the sector — airlines, manufacturers, airports, airworthiness authorities, passengers — to affirm its leadership in the transition and be a key driver of change. To this end, we've bolstered our R&T effort, with sustained self-funded investments associated with the national aviation support plan under CORAC and the France 2030 investment plan.

A LOW-CARBON ROADMAP

About 75% of this self-funded R&T activity is focused on developing new technologies designed to reduce its products' environmental footprint, whether directly or indirectly. Safran's R&T roadmap covers four main areas: propulsion, aircraft electrification, materials and weight reduction, and sustainable aviation fuels (SAF).

Safran has expanded its research into these fuels to improve its understanding of alternative drop-in fuels and develop the technology building blocks needed for their widespread use. At the same time, the Group is exploring more disruptive solutions based on fuels that would require radical changes in aircraft architecture, including cryogenic fuels such as methane and liquid hydrogen.

Safran is counting on its vast in-house design capabilities to take a proactive role through developing innovative solutions for its customers to support the development of their next-generation aircraft – even the most radical.

SAFRAN R&T AT A GLANCE

3,000 employees, including 1,200 doctoral researchers

Ranked first for patent applications in France by INPI for second year in a row

R&T budget of 4.2 billions for 2022–25 devoted to environmental efficiency

75% of self-funded work dedicated to environmental aspects

Eco-design and co-innovation

Right from the design stage, Safran integrates reduced environmental impact in its products across their entire lifecycle. Safran applies an open innovation policy based on multiple partnerships to go beyond conventional thinking.

The Group applies ecodesign for its products to limit their potential impacts over their life cycle, such as resource depletion or ecotoxicity, and plans ahead for regulatory and customer requirements. Safran applies several approaches to ecodesign, drawing on an internal ecodesign standard, which ensures compliance with the requirements of ISO 14001, and the Technology Readiness Level (TRL) standard, which includes requirements and methods for ensuring that ecodesign is incorporated as the technology matures. At the 2022 International Conference on EcoBalance, Safran won the Best Business Practice Award for the quality of its TRL standard. Safran is also actively involved in the European Clean Sky 2 project, with a series of ecodesign demonstrator projects.

TOWARDS A CIRCULAR ECONOMY

The same environmental focus applies to Safran's aftersales services, especially maintenance, repair and overhaul, or MRO. Year after year, Safran's experts develop new repair and maintenance techniques to fully restore performance, extend part life and avoid replacements. Reflecting the precepts of the circular economy, Safran favors the reuse of pre-owned parts. For example, CFM Materials, a joint venture between GE and Safran Aircraft Engines specialized in used serviceable CFM56 parts, offers MRO shops worldwide a wide range of spare parts with guaranteed quality and traceability.

DID YOU KNOW?

92% of total aircraft weight
This is the recovery rate achieved by Tarmac Aerosave when recycling aircraft.

Safran teamed with Airbus and Suez to create Tarmac Aerosave in 2007. Today, Tarmac Aerosave sets the European standard for the storage, maintenance and recycling of aircraft (built by Airbus, Boeing, ATR and others) and engines. Tarmac Aerosave is the only transition center in the world to manage the entire aircraft lifecycle at its three sites in Europe: Tarbes and Toulouse in France and Teruel in Spain. Since 2007, some 1,000 aircraft have been returned to service and 350 have been recycled, with a recovery rate of over 92% of each plane's total weight.

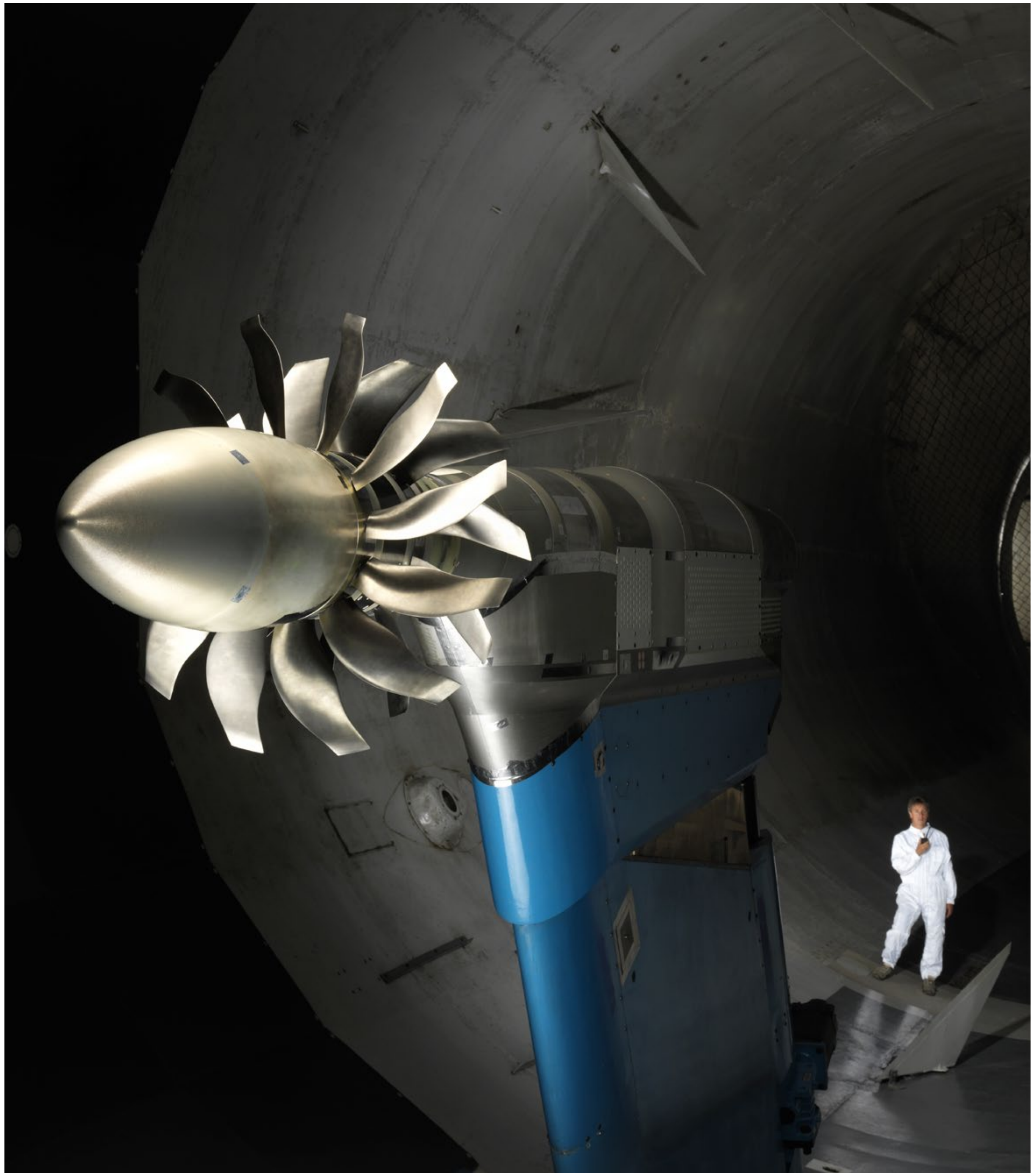
AN EXTENSIVE COLLABORATION POLICY

Within the scope of its co-innovation policy, Safran has established a growing number of scientific and industry partnerships focused on ecology and the energy transition. For instance, Safran works with the Saint-Exupéry Technology Research Institute, which is studying more electric aircraft, and also teams up with advanced research institutions such as ONERA (French aerospace research), CEA (French Alternative Energies and Atomic Energy Commission), CNRS (French national scientific research agency) and the Georgia Institute of Technology. Safran is also one of the founding members and leaders in Europe's Clean Sky research program, primarily dedicated to reducing CO_2 emissions, alongside other major European players, as well as in the Clean Aviation program, which will come on line in 2021.

In 2017, Safran signed a technological cooperation agreement with Alstom to pool their skills and expertise in electric propulsion, while also bringing innovative small businesses and universities into this endeavor. Another example of an industry partnership is with the major automotive supplier Valeo, enabling Safran to enrich its analysis of the industrial processes needed to mass produce electric motors; according to some scenarios, production rates will have to be increased ten-fold in the future compared with rates for current aircraft engines. Safran has also signed a strategic agreement with French electricity utility EDF to jointly improve battery performance and better understand what impact electric airplanes will have on airport infrastructures.

TOWARDS A SYNTHETIC JET FUEL PRODUCTION SYSTEM IN FRANCE

Safran is participating in the Engie-led KerEAUzen project to create a production system for synthetic jet fuel using electricity generated by renewable sources, water and CO_2.
This synthetic fuel would be a competitive alternative, complementary to conventional fuel, which could be used in existing aircraft and infrastructures.



SUPPORT FOR INNOVATIVE STARTUPS

Safran's strategy for aviation innovation and transformation is supported by its venture capital arm, Safran Corporate Ventures. This entity monitors about a hundred companies in Europe, North America and Asia that are actively involved in batteries and electrification, sustainable fuels, CO_2 capture and hydrogen propulsion. Capitalized at €80 million, Safran Corporate Ventures has already invested in 17 companies since its launch in 2015. It supports several projects that reflect Safran's vision of decarbonized aviation:

- **Turbotech:** a French startup founded by four former Safran employees, which is developing a turbogenerator for light aircraft or VTOLs under 650 kg, slated for service entry in 2024,
- **Electric Power Systems (EPS):** an American company in which Safran Ventures has invested along with AEI Horizon X (formerly part of Boeing). It markets highly innovative high-performance battery systems, already chosen for several state-of-the-art light aircraft programs,
- **Prodways Group:** a specialist in additive manufacturing for industry, which offers plastic and metal 3D-printed parts,
- **Cranfield Aerospace:** a market leader in the design and development of new aircraft concepts and the integration of advanced technologies. The company is working on its Fresson project, a concept that paves the way for commercial flights with hydrogen-electric propulsion.
- **Ineratec:** this startup provides modular chemical plants to convert green hydrogen, made using renewable electricity and biomass CO_2 or captured CO_2, into carbon-neutral fuels like e-methane, e-diesel and e-kerosene.
- **Sintermat:** a French startup with expertise in the spark plasma sintering (SPS) process, which is used to produce parts from powders of various kinds.

A Safran-wide low carbon plan

Over and above more sustainable products and services, Safran has pledged to reduce CO_2 emissions from its offices, production facilities, suppliers and logistics operations. The low-carbon plan, adopted in late 2019 and strengthened in 2021, aims to reduce emissions in line with the objectives of the Paris Climate Agreement.

In 2018, Safran launched a low-carbon project that ties together the efforts by each company, based on shared targets and indicators. It covers the Group's 200 facilities worldwide that employ more than 50 people. The targeted reductions concern three types of emissions (known as "scopes") as generally defined in environmental management terms. Scope 1 covers direct emissions from offices and factories, generated for instance by heating systems, but also, in Safran's case, by fuel burned in test stands. Scope 2 concerns "indirect" emissions, related to the facility's procured heat and electricity. Safran has raised its ambitions and now aims to reduce CO_2 emissions by 30% for scopes 1 and 2. This is just a first step on the Group's path toward net-zero carbon emissions by 2050. Scope 3 covers all "external" indirect emissions related to the operations of subcontractors and suppliers, logistics, purchasing of expendable supplies, waste management and employee commuting.

ACCELERATING SAFRAN'S ENERGY TRANSITION

To reduce greenhouse gas emissions under scopes 1 and 2, Safran's strategy is based on three main levers:
- Reduce energy consumption.
- Reduce the use of fossil fuels by on-site production of electricity and heat.
- Source renewable energy, including engine fuel.

This long-term strategy is already starting to deliver concrete results, especially via the following actions:

- An energy contract in Mexico to purchase power from solar plants.
- Projects for on-site production and consumption of electricity from solar and wind sources in France and Belgium, for example.
- In 2022, Safran pledged to equip 17 of its large French sites with photovoltaic solar panels, mainly on parking lot shade structures, to produce part of the electricity it requires. These projects represent almost 50 MWp and will cover an average of 15% of each site's consumption. In Morocco, a 1.7 MWp photovoltaic plant came on stream at the Safran Nacelles facility in Casablanca in December 2022, which will cover more than 20% of the site's consumption.
- Replacement of gas and oil-fired heating plants by more sustainable solutions, such as an urban heating network in Le Havre, a heat pump in Saclay, biomass in Bordes, biogas in Tarnos and a geothermal system in Vélizy.
- The development of additive manufacturing, a fast-growing process that only consumes the exact amount of raw material needed for the end part, thereby minimizing machining scrap and using all-electric energy, which reduces CO_2 emissions.
- The Safran Electronics & Defense plant in Valence, now being built, was eco-designed and expects annual savings of 500 metric tons of CO_2.
- Engine test stands used over 10% sustainable fuels by the end of 2021 and will use at least 35% by 2025.

Safran also introduced internal carbon pricing in 2020 for investment projects and supplier selection to encourage decisions in favor of lower emissions solutions.

In July 2022, the Group began mobilizing its 400 largest suppliers in terms of emissions to commit to action plans in line with the Paris Climate Agreement by 2025. Carbon maturity and internal carbon pricing are now part of the supplier selection process.

SAFRAN'S OBJECTIVES

Safran has set the following target for reducing CO_2 emissions by its production facilities, by 2025*:

-50%

Compatible with the stated aim of limiting global warming to no more than 1.5° C by the end of the century

*In relation to CO_2 in 2018

CO_2

150

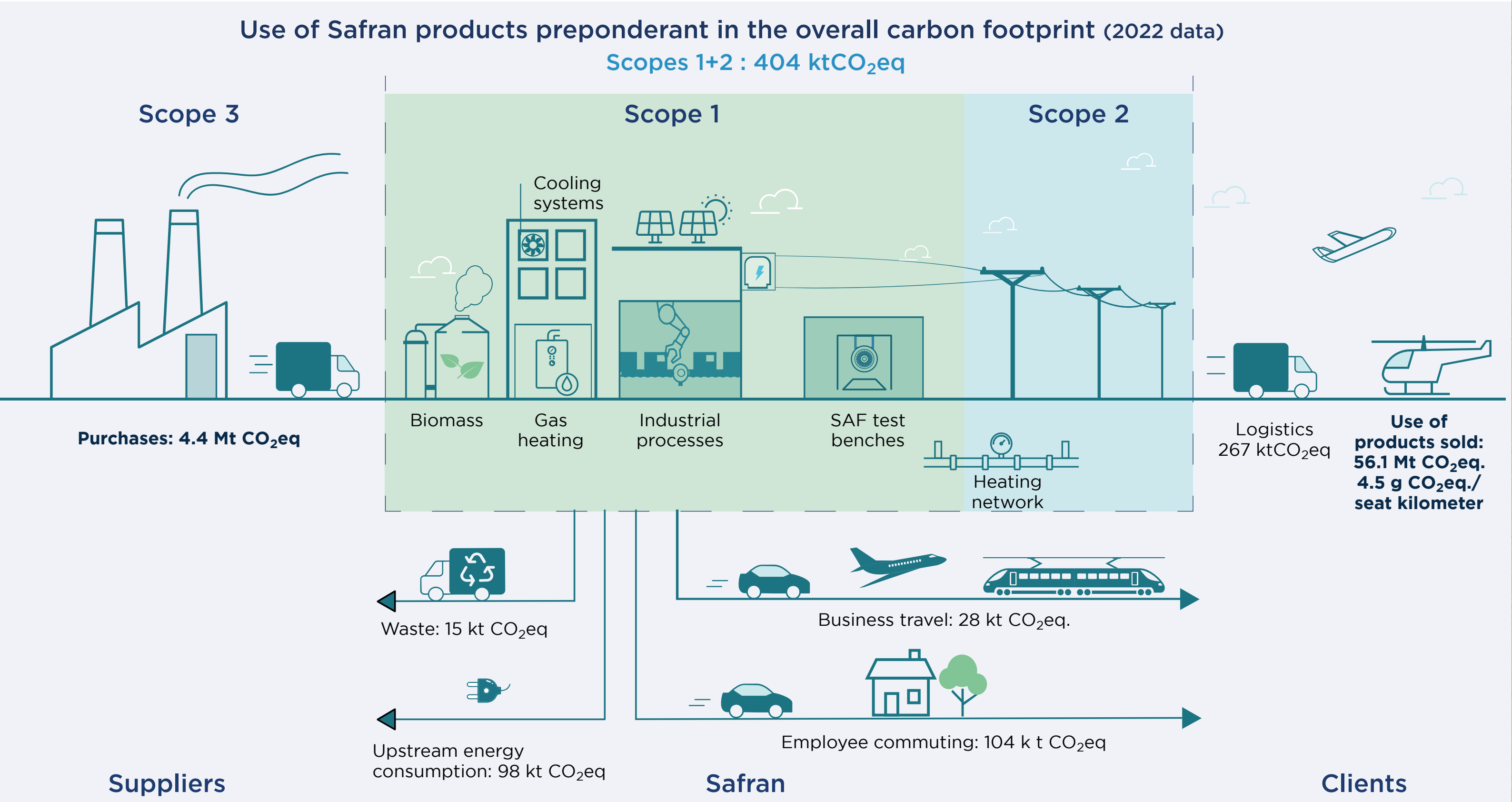
The number of indicators needed to measure and track Safran's carbon footprint

SAFRAN'S CLIMATE STRATEGY

Safran intends to lead the way in the decarbonization of the aviation sector, through a climate strategy with two focuses:

Reducing emissions from operations, including upstream supplier operations;

Reducing emissions from the use of its products.



DECARBONIZATION OBJECTIVES ALIGNED WITH THE PARIS AGREEMENT

In January 2023, the Science-Based Targets initiative (SBTi) validated Safran's greenhouse gas emissions reduction targets. Safran is one of the first aerospace companies in the world to obtain SBTi validation, certifying that its greenhouse gas emission reduction targets are compatible with meeting the objectives of the Paris Agreement.

Its greenhouse gas emissions reduction targets, validated by the SBTi, cover direct (Scope 1) and indirect (Scope 2) emissions from the energy consumption of the Group's operations, as well as emissions related to the use of its products (Scope 3).

	Greenhouse gas emissions targets	2018 data (reference year) in kt CO_2eq[(1)]
Scopes 1&2*	**30% reduction by 2025 and 50.4% reduction by 2030 vs. 2018,** in line with a 1.5°C scenario	579
Scope 3** Use of products sold	**42.5% reduction** in Scope 3 emissions from product use per seat kilometer **by 2035 vs. 2018***** **75%** of R&T focused on the environmental performance of products	**113,800 5.9 gCO_2/ seat kilometer**
Scope 3** Purchases of goods and services	Mobilize our **400** main suppliers on meeting the commitments under the Paris Agreement (emissions trajectory compatible with keeping global warming below 2°C, or even 1.5°C)	**4,961**
Scope 3** Business travel and employee commuting	**50% reduction by 2030 vs. 2018,** in line with a 1.5°C scenario	**187**

*Direct (Scope 1) and indirect (Scope 2) emissions related to energy consumption from Safran's operations.
**Indirect emissions.
***The target covers both emissions directly related to product use and emissions indirectly related to product use.

(1) Audited data. See sections 5.3.3.2, 5.3.3.3 and 5.3.3.4 of the Universal Registration Document.

POWERED BY TRUST

Safran is an international high-technology group, operating in the aviation (propulsion, equipment and interiors), defense and space markets. Its core purpose is to contribute to a safer, more sustainable world, where air transport is more environmentally friendly, comfortable and accessible. Safran has a global presence, with 83,800 employees and sales of 19 billion euros in 2022, and holds, alone or in partnership, world or regional leadership positions in its core markets. Safran undertakes research and development programs to maintain the environmental priorities of its R&T and Innovation roadmap. Safran is listed on the Euronext Paris stock exchange and is part of the CAC 40 and Euro Stoxx 50 indices.

For more information:

www.safran-group.com

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