

## SUSTAINABLE DEVELOPMENT AND THE SPACE BASE of CSG

**Aimée CIPPE<sup>a</sup>, Sandrine RICHARD<sup>b</sup>, Marie-José Gauthier<sup>b</sup>, Jérôme YVANEZ<sup>c</sup>, Jérémy HEDIN<sup>c</sup>, Whitney FLEURIVAL<sup>d</sup>, Joël EGALGI<sup>d</sup>, Teddy PEPPONNET<sup>e</sup>**

<sup>a</sup>CNES CSG, CNES, Kourou, French Guiana

<sup>b</sup>CNES CSG Space Service for French Guiana, CNES, Kourou, French Guiana

<sup>c</sup>CNES CSG Operations Sub-Directorate – Projects, Infrastructure and Operations Service, CNES, Kourou, French Guiana

<sup>d</sup>CNES CSG Operations Sub-Directorate – CSG New Generation Service, CNES, Kourou, French Guiana

<sup>e</sup>Space Transportation Systems, Infrastructure Department, ESA, Kourou, French Guiana

### Abstract

Human activities are directly affecting biodiversity, the planet's habitability and the well-being of populations. France has made climate and environmental issues national objectives, which it is also promoting at international level. CNES (French Space Agency) applies the legal and regulatory corpus<sup>1</sup> that sets out its objectives.

CNES has set out a strong commitment to corporate social and environmental responsibility (CSER) in its Contract of Objectives and Performance (COP) 2022-2025.

Through its projects and applications, its management practices and its commitment to an assertive environmental policy, CNES is contributing to the Sustainable Development Goals (SDGs) set out in the 2030 Agenda promoted by the United Nations.

At the Centre Spatial Guyanais (CSG), the Europe's Spaceport, a biodiversity reserve, the environment is a major issue that began in 2004 with the certification of CNES/CSG to the international ISO 14001 standard for the implementation of an Environmental Management System. This certification has been extended to the whole of CNES since 2011, and is fully integrated into the CNES Management System (SMC) based on "a process of continuous improvement in its quality and environmental performance, and enables it to remain compliant with environmental regulations".

CNES, which has a duty to set an example at the CSG, has been committed since 2018 alongside the European Space Agency (ESA), to reducing the Space Base's energy consumption by more than 10%. Through the CSG /"CSG New Generation" and "Flexible, Digital and Sustainable" projects co-financed by ESA:

- CNES has embarked on a major project to upgrade and optimize its air-conditioning network, with the aim of saving 6% energy per degree gained, using innovative technologies to better control consumption;
- By 2030, after the deployment of 2 self-consumption solar fields of 5MWp each and the introduction of two biomass cogeneration plants, the CSG should be powered by 90% renewable energies;
- The creation of photovoltaic fields (CPV) is carried out on selected sites to reduce the impact on the protected species present (site already in use or design meeting the ERC approach issued from the 2016 Law for the reconquest of biodiversity: avoid, reduce, compensate impacts);
- The production of green propellants will arrive at the CSG with the HYGUANE (HYdrogène GUyanais A Neutralité Environnementale) project, which will produce green hydrogen (photovoltaic field + electrolyser), and BIFROST (BioFuel for Rocket Operations in Space Transportation), which will produce biomethane to power the THEMIS demonstrator and the MAIA micro-launcher;
- CSG is rethinking its energy infrastructures, with a 20kVA (High Voltage) loop that aims to reduce from 3 to a single, more reliable loop distribution (buried cable to overhead link) that enables renewable energies to be connected (3 CPV + 1 more) and that operates by automatic self-healing to re-supply energy to the installations when a section or piece of equipment is inoperative on the loop (equipment eliminated automatically).

The result is a Space Base that is more reliable and more available, while at the same time respecting the environment by reducing its energy consumption and carbon footprint.

### 1- Introduction

French Guiana is an overseas region located on the north coast of South America, between Surinam and Brazil. It is the only overseas territory that is not an island.

It has a special status as an overseas department-region (DROM) and an outermost region of the European Union. It is subject to the provisions of French and European laws, with certain specificities due to its geographical location.

Its surface area of 83,846 km<sup>2</sup> is largely covered by tropical forest. Population density has risen from 2.9 in 2011 to 3.5 inhabitants per km<sup>2</sup> in 2021 (source: Insee).

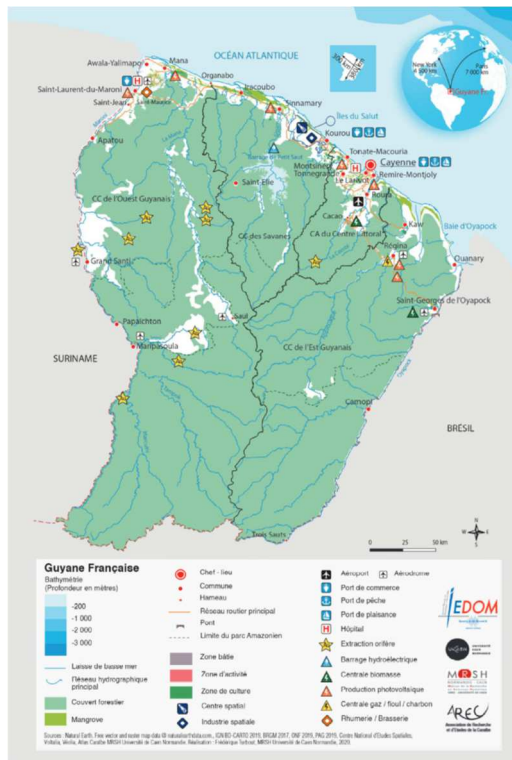


Figure 1 : Map of French Guiana (source IEDOM)

The region is experiencing significant demographic growth (on average +2.6%/year), which in turn means ever-greater energy needs, representing a major challenge for all local players.

Space activities in French Guiana are organized by a number of actors. The European Space Agency (ESA), which brings together 23 members states to decide on future strategies and space policies, and relies on national agencies for technical support.

Launch operators ARIANESPACE and AVIO, which market the Ar6 and VEGA-C launchers respectively. The production/operating industries ARIANEGROUP, REGULUS, EUROPROPULSION and AIR Liquide Spatial Guyane. The Centre National d’Études Spatiales (CNES), the French space agency, which owns the CSG site. It organizes and coordinates launches, as well as measures to protect people and the environment, and to ensure the safety of installations.

The Centre Spatial Guyanais (CSG), Europe’s spaceport, is located in French Guiana, between the towns of Kourou and Sinnamary. It covers an area of 660km<sup>2</sup> and comprises the Base de Lancement (BLA), two operational launch complexes with Ariane 6 and VEGA-C, and propellant manufacturing plants. Together, they consume up to 20% of the electricity produced in French Guiana. More than half of the base’s energy (60%) used to cool the buildings, while energy-intensive processes (solid and liquid propellant production) consume most of the remainder.

The annual electricity bill represents several million euros, with direct/indirect CO<sub>2</sub> emissions of over 130,000 tCO<sub>2</sub>eq/year (tons of CO<sub>2</sub> equivalent per year), mainly due to the “grey” electrons coming from the national grid.

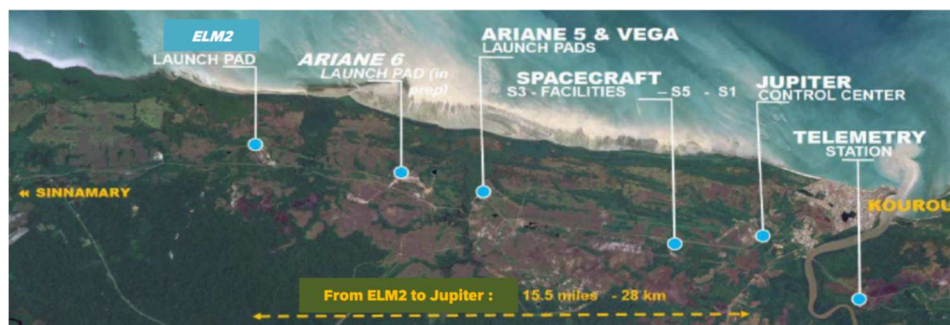


Figure 2: The CSG right-of-way between Kourou and Sinnamary

## 2- The Context

Human activities are not without consequences for the environment, directly affecting biodiversity, the planet's habitability and people's well-being. France has made climate and environmental issues national objectives that it is also promoting at international level. The Centre National d'Études Spatiales (CNES), the French space agency, applies the legal and regulatory corpus<sup>1</sup> that sets out its objectives. CNES has set out its ambitions in terms of corporate social responsibility (CSR) in its Contract of Objectives and Performance (COP) 2022-2025, which covers several key areas:

- \*development of the space sector (boosting economic growth, industrial competitiveness, emergence of a new space ecosystem),
- \*Strategic autonomy (maintaining and developing France's and Europe's strategic autonomy in the space sector,
- \*Scientific excellence (Maintaining the scientific excellence of the French space sector and boosting its international profile) and
- \*Sustainable development (Remaining at the forefront of sustainable development in the space industry).

Through its projects and applications, its management practices and its commitment to an assertive environmental policy, CNES has adopted a Corporate Social Responsibility (CSR) policy and is contributing to the Sustainable Development Goals (SDGs) set out in the 2030 Agenda promoted by the United Nation. CNES' main commitments :

- Responsible employer: CNES is committed to creating an inclusive and equitable working environment, favoring diversity and professional equality between women and men. It implements inclusive recruitment and lifelong training programs.
- Protective and sustainable space: CNES ensures the safety and sustainability of space operations, by controlling activities likely to present a risk to people, property, public health and the environment. It plays an active role in European initiatives on space traffic management.
- Creating shared value through space: CNES aims to foster competitiveness and sustainable growth in the French space ecosystem, by integrating professional integration clauses into its procurement contracts.
- Education and awareness-raising: CNES uses space as a lever for education and promotion of scientific and technical professions, raising stakeholders' awareness of CSR issues.
- Commitment to solidarity: CNES encourages its employees' commitment to solidarity and promotes actions to protect nature and combat climate change.

At the Centre Spatial Guyanais (Europe's Spaceport), a biodiversity reserve, the environment is a major issue that was affirmed in 2004 with the certification of CNES/CSG to the international ISO 14001 standard for the implementation of an Environmental Management System. This certification has been extended to the whole of CNES since 2011, and is fully integrated into the CNES management system (SMC). The principle of this standard is based on: "the process of continuous improvement to ensure that the organization controls the environmental impacts of its activity. It commits the organization to a process of continuous improvement in its environmental performance, and enables it to remain compliant with environmental regulations".

In this context, CNES/CSG is seeking to improve in terms of:

- purchasing,
- its energy consumption,
- production of low-carbon energy
- greenhouse gas emissions
- water consumption
- animal and plant biodiversity management
- waste and waste prevention

CNES, which has a duty to set an example at the Centre Spatial Guyanais (CSG), has been committed since 2018 alongside the European Space Agency (ESA), to reducing the space base's energy consumption by more than **10%**. This corresponds to 150,000 tonnes of CO<sub>2</sub> avoided over 25 years for each solar power plant.

According to the **BEGES** 2022 report (key figures), 77% of EDF's "energy" emissions come from electricity consumed at the CSG. The priority is to decarbonize CSG's electricity:

- Solar panel field projects
- **Electricité de Guyane (CSG):** emission factor corresponds to average Guianese electricity consumption mix: **0.957 kgCO<sub>2</sub>e/kWh**.

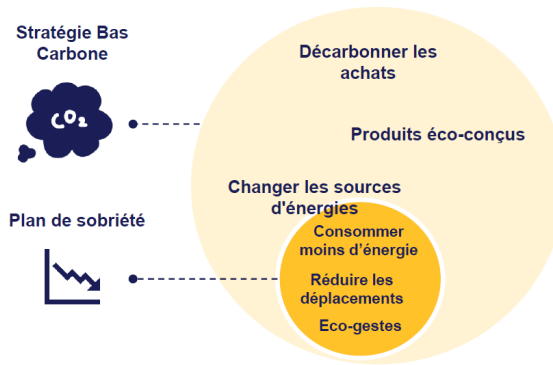


Figure 3 : Low-carbon strategy and energy sobriety plan

### 3 – The CSG power supply

The European spaceport is powered by two 90kVA power lines. This power is then brought down and distributed to the CSG site. The CSG network comprises 200 km of 20kVA distribution lines.

These 20kV lines supply various sites, including power generation facilities, solid and liquid propellant production sites, launcher complexes, launcher integration sites, satellite preparation facilities and the technical center.

Overall, the CSG consumes 103.5 GWh of electricity per year, representing an annual bill of €19 million (ec 2024).

The CSG network is directly affected by network failures or outages on the EDF grid. To avoid any impact on production and satellite preparation, and in particular during the few hours preceding a launch, the CSG network is backed up by diesel-powered generators. Every year, around 800 m<sup>3</sup> of diesel are burned to ensure continuity of operations and guarantee launch countdowns.

The European Spaceport is therefore directly independent of fossil fuels through the use of diesel generators, and indirectly by being powered by the EDF grid.

As a result, electricity demand represents around 90,000 tonnes of CO<sub>2</sub> equivalent (see Fig. 4), or more than three-quarters of the Spaceport's total carbon footprint.



Figure 4 : Carbon footprint emissions from power grid consumption

### 4 – The CSG's low-carbon trajectory

In 2018, CNES and ESA defined a strong doctrine to pave the way for a highly committed and ambitious trajectory to reduce CO<sub>2</sub> emissions from the entire European spaceport by around 90% by 2030.

This doctrine is based on four key pillars:

\* **Sobriety**: reduce energy waste and consume the minimum necessary by controlling electricity consumption through an optimized electrical management system (Smart Grid & EMS).

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\* **Energy efficiency:** Improving the efficiency of manufacturing and operating processes (building insulation, renovation, process supervision, etc.)

\* **Resilience and independence of the Guianese electricity grid:** introduction of renewable energies for self-consumption (solar fields)

\* **A revolution in propellant production:** replace fossil fuel processes with green processes while maintaining the same level of propellant characteristics and ensuring competitiveness.

Following brainstorming between CNES, ESA and all the industrial operators of Europe's Spaceport, a roadmap for a low-carbon trajectory has been drawn up and published as a guideline to be followed, implemented and monitored over the next 5 to 10 years, bearing in mind that this is a long-term objective.

This roadmap is based on two seasons:

- (i) the first focuses on greening the energy consumed by CSG operators (solar fields, smart grid, etc...)
- (ii) the second season is based on the decarbonization of launch propellants (Hydrogen & Methane).

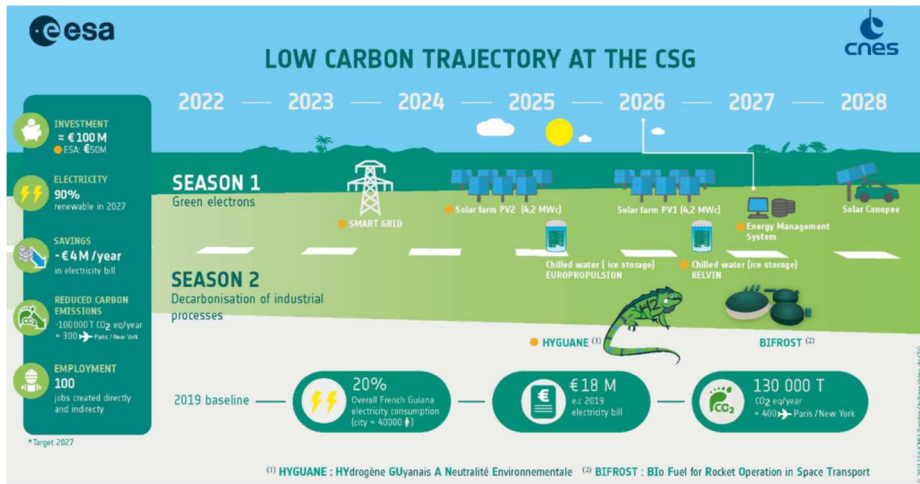


Figure 5 : Diagram of the low-carbon trajectory at CSG

#### 4.1 – Energy consumption reduction

Starting in 2019, through the CSG/ "CSG Nouvelle Génération" project and the 2023 CSG/ "Flexible, Digital and Sustainable" project co-financed with the European Space Agency (ESA): CNES has embarked on a major project to upgrade and optimize its air-conditioning network, with the aim of saving 6% energy per degree gained, using innovative technologies to better control energy consumption.

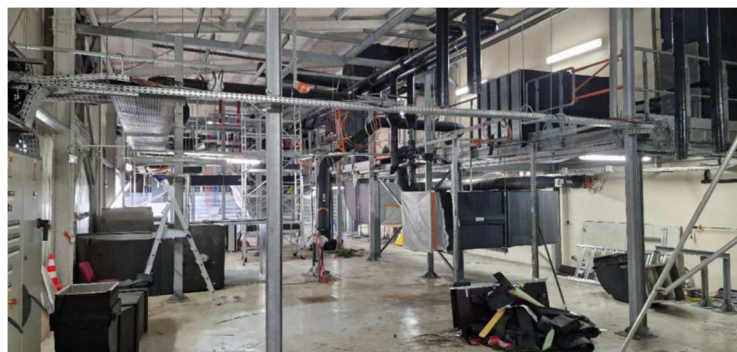


Photo 1 : Renovation of EPCU S5 air conditioning system

#### 4.2 – The smart grid (or 20kV loop)

The current grid is a star-shaped network. Its design does not allow it to accommodate production sites, let alone renewable energy. CNES has therefore decided to undertake work to create a 20kVA (High Voltage) electrical loop linking all CSG operators. Such a network is designed to supply renewable sources of electricity (2 CPVs). Its design is also more resilient to major outages, thanks to the installation of an automatic reconfiguration controller (automatic self-healing to re-supply the facilities with power).

Implementation work began in mid-2022 and the loop will be operational in 2025, after which the network will iteratively evolve towards a smart grid with the introduction of renewable energy generation, storage solutions and an energy management system. Full deployment is scheduled for the end of 2025.

#### 4.3 – Introducing renewable energy at CSG

Solar farms are particularly well-suited to our climate, which is generously sunny with over 2,200 hours of sunshine a year.

They are also relatively easy to set up and have low recurring costs, consisting mainly of annual cleaning of the solar panels.

To ensure independence from French Guiana's electricity grid, the CSG will introduce renewable energies by 2026, with the deployment of 2 self-consumption photovoltaic fields (CPV) of 4.2MWp each, one (CPV2) financed by France relance (FR2030) and the other (CPV1) by ESA via the CSG/NG project. The CSG will be powered by self-consuming renewable energies to meet 14% of its annual energy requirements.

The creation of photovoltaic fields (CPV) is carried out on selected sites aimed at reducing the impact on the protected species present (site already in use or design meeting the ERC approach resulting from the 2016 Law for the reconquest of biodiversity: avoid, reduce, compensate for impacts).

CPV2 will be located near the satellite preparation facilities (EPCU S5), while CPV1 is scheduled for 2026 and will be positioned near the solid propellant facilities, which are energy-intensive sites. The choice of photovoltaic panels includes their entire life cycle, from manufacture and recycling to yield and lifespan.



**Photo 2** : Drone photo of CPV2 photovoltaic field (FR2030)

#### 4.4 – Tertiary renovation program – CT 2032

In terms of eco-design and sustainable purchasing processes, the CNES Objectives and performance contract (COP) incorporates practices aimed at reducing the environmental impact of products right from the design stage, and giving preference to responsible suppliers. The building sector is an applied example of eco-design and energy performance, such as the technical center (CT) renovation program at the Guiana Space Center called CT2032, which implements national and regional directives by integrating methods for sustainability and energy efficiency, as well as purchasing processes that favor sustainable products and services.

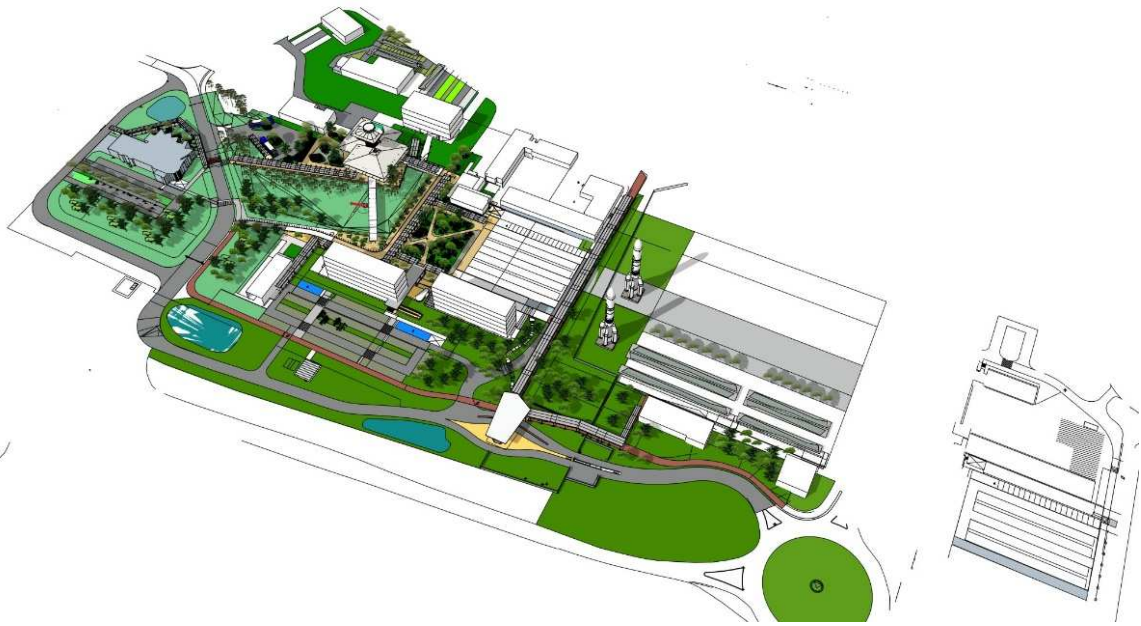
Over a 10-year period, the objectives of the CT2032 program include :

- \*Renovation of the CSG Technical Center (TC): tertiary buildings and roadways.
- \*Optimization of tertiary surfaces, energy and functional renovations
- \* Improving comfort, creating a “campus life”.
- \* Improving the attractiveness of CSG

To achieve this, the project includes the installation of shading devices, parking lot charging stations, centralized technical management to optimize and control the tertiary sector installations (air conditioning/energy/water) and monitor consumption.



**Figure 6.1 :** Illustration of CT renovation



**Figure 6.2 :** Illustration of CT renovation

As part of the CSG/NG project, the new Operational Center (CDO) will house all the systems involved in the launcher tracking and return mission, in a single building, the CDO-Building, which complies with the Amazonian Environmental Quality (QEA) doctrine defined by the Agency for ecological transition (ADEME) and applicable to equatorial regions. The "Loi sur l'eau" application for the CDO-Building to preserve aquatic environments was approved in Q3 2024.

The CDO-Building will be fitted with a wooden double skin to stop the direct effects of heat on the building. The thermoregulatory effect of the wood facade will reduce air-conditioning-related energy consumption by around 20%.

The office area is grouped together on one floor in a configuration optimized from the point of view of human interaction and space utilization.



**Figure 7 :** Illustration of CDO-Building

#### 4.5 – Ice Storage

The modernization of production infrastructures at CSG involves proposing adaptations to support launcher manufacturing and integration processes, with a view to “improving competitiveness” and reducing carbon footprint. It concerns facilities operated by Air Liquide Spatiale Guyane, Europropulsion, Regulus, Arianegroup-G and AVIO-G. The list of activities was drawn up jointly by ESA, CNES and the industrial operators on the basis of the following criteria:

- Societal challenge: carbon neutrality by 2030 for ZNIs (greening activities),
- Digital challenge: industry 4.0, automation, preventive maintenance (digitalization activities)
- Human challenge: the worker at the center of productivity (process optimization activities).

This competitive plan proposes a range of activities to refurbish buildings (insulation of roofs, gates, etc.) and electrical systems. The digitization of plants will be undertaken with the creation of a backbone network, equipment automation and data collection.

Air-conditioning optimization is a vast subject on which various improvements will be undertaken, as well as work on chilled water networks aimed at ice storage and thus contributing to the regulation of the 20 kVA loop.

Air conditioning, which is essential to the smooth operation of the base's industrial facilities, accounts for 60% of CSG's energy consumption.

Currently, CSG buildings are air-conditioned by blowing cooled air through a secondary chilled-water circuit. This water is produced by an exchanger connected to a “primary” circuit, where chillers generate the necessary cold. The aim is to optimize the power consumption of these chillers. Ice storage partially replaces this process.

At Europropulsion, air conditioning accounts for 85% of the electricity bill (€620,000/year) and CO<sub>2</sub> emissions (6,000 t CO<sub>2</sub>eq/year) in 2020. The ice storage system deployed by GTD, Entropie and Equans at the Europropulsion site is a concrete and innovative example.

Ice storage can partially replace this process. The idea is to produce large ice cubes during periods when electricity is cheaper and less carbon-intensive, either at night or when the CSG's solar installations generate surplus electricity. These ice cubes then serve as a source of cold during periods of high electrical demand, reducing the use of conventional.

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30% of electricity consumption will be “shifted” to off-peak hours for maximum savings and a reduced carbon footprint.

This competitive plan secures Guyanese production during the transition and responds to the evolution of ground infrastructures by introducing new digital and ecological technologies.

It is based on innovative principles, with investments shared between ESA and industrial partners, and guarantees a massive reduction in ESA's indirect CO<sub>2</sub> emissions.

### 5 – Decarbonizing CSG's industrial processes

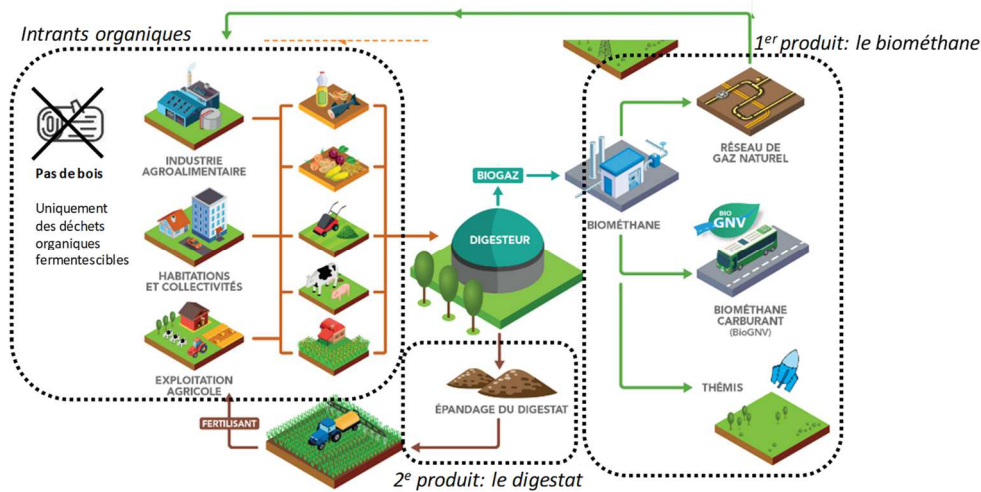
Renewable propellant production will arrive at the CSG with the following projects: 5.1) HYGUANE for HYdrogène GUyanais A Neutralité Environnementale, which will produce renewable hydrogen (photovoltaic field + electrolyser) and 5.2) BIFROST for BioFuel for Rocket Operations in Space Transportation, which will produce biomethane to power the THEMIS demonstrator and the MAIA micro-launcher.

### 5.1 BIFROST project (BioFuel for Rocket Operations in Space Transportation)

Liquid methane (LCH<sub>4</sub>) is becoming an attractive financial and technical solution for commercial launchers, with several well-known rocket companies choosing LCH<sub>4</sub>/LOX (liquid methane/liquid oxygen) for their future vehicles, such as Space X's Starship, Avio's Vega-E upper stage, etc... As a result, methane will play an important role in the propulsion of reusable rockets and "mini" launchers (such as the Themis reusable demonstrator) in the years to come.

Although LCH<sub>4</sub> has a lower specific impulse than liquid hydrogen (LH<sub>2</sub>), it is easier to store than LH<sub>2</sub> because of its higher boiling point. It is also easier to reuse than kerosene, as combustion leaves less residue in the rocket engine. What's more, there are many sustainable ways of producing methane, even if today it is mainly produced from fossil resources.

Faced with these developments, CNES is studying the future biofuel needs of CSG launchers and the possibility of producing biomethane locally as part of the BIFROST (BioFuel for rocket operations in the spaceport) project. Various industrial processes are being studied, such as methanization, which produces biomethane from the digestion of various types of waste by bacteria (see Fig. 8).



**Figure 8 : A virtuous cycle - methanization**

By way of example, the anaerobic digestion of organic matter will create an ecosystem where waste from different sectors will be used as inputs for the space sector, generating a profitable circular economy for waste management. Although this economy has yet to be created in French Guiana, this project is a tremendous opportunity to provide future innovative launchers with totally independent production of liquid propellant at CSG. BIFROST aims to create an industrial ecosystem that will benefit Guiana.

Methanation, a chemical process transforming CO<sub>2</sub> and H<sub>2</sub> into methane, is not ruled out at this stage.

### 5.2. HYGUANE Project (HYdrogène GUyAnais à Neutralité Environnementale)

Currently, the liquid hydrogen that powers the Ariane 6 launcher is produced using the methanol steam reforming (MSR) process. The overall process is shown in figure 9. As can be seen, methanol is produced in Trinidad and Tobago, then transported to the spaceport, where the methanol molecule is cracked by the MSR process. This process produces dihydrogen (H<sub>2</sub>), which is then liquefied, stored and filled into the cryogenic stages of launch vehicles. The whole process represents a direct and indirect carbon footprint of 30,000 teq CO<sub>2</sub> for a production rate of 9 Ariane 6 per year.

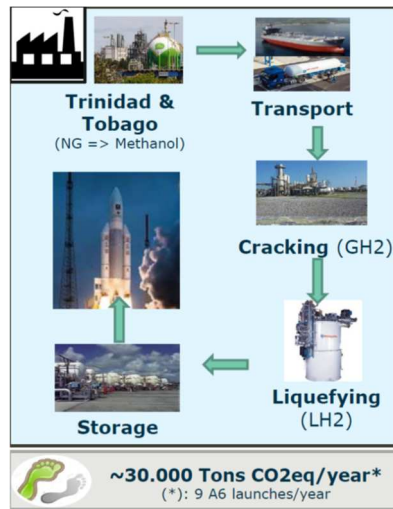


Figure 9 : H2 Methanol Steam reforming - CO2 emissions

HYGUANE is a pilot industrial project currently under development for the production and use of renewable hydrogen at the CSG and in French Guiana. On the one hand, HYGUANE aims to decarbonize the hydrogen used for Ariane launchers (resilience and independence), and on the other, it will develop an innovative green H2 ecosystem on Guiana's territory with the introduction of H2 heavy road transport (truck, coach and bus) for the citizens of CSG and Guiana (mobility use), the implementation of H2 fuel cells (stationary use) replacing diesel generators (to come on the ELM Diamant) and the development of a Hydrogen Competence Centre (HCC) hosting maintenance and training activities for H2 stationary and mobility uses.

As shown in figure 10, renewable, low-carbon hydrogen will be produced from a 1.25 MW electrolyzer powered by a 5 MW peak photovoltaic array (PV3 and PV3+). 235 tons of gaseous H2 will be produced each year, two-thirds of which will supply the Ariane 6 launcher (160 tonnes per year covering 25% of Ariane 6's annual requirements), 75 tonnes will supply mobile and stationary regional uses.

HYGUANE is also a territorial project, and CNES and ESA wanted to continue strengthening the specific relationship between the space sector and territorial players to initiate an H2 ecosystem based on the strengths of each. This specific relationship has prompted local players to become involved in the HYGUANE project.

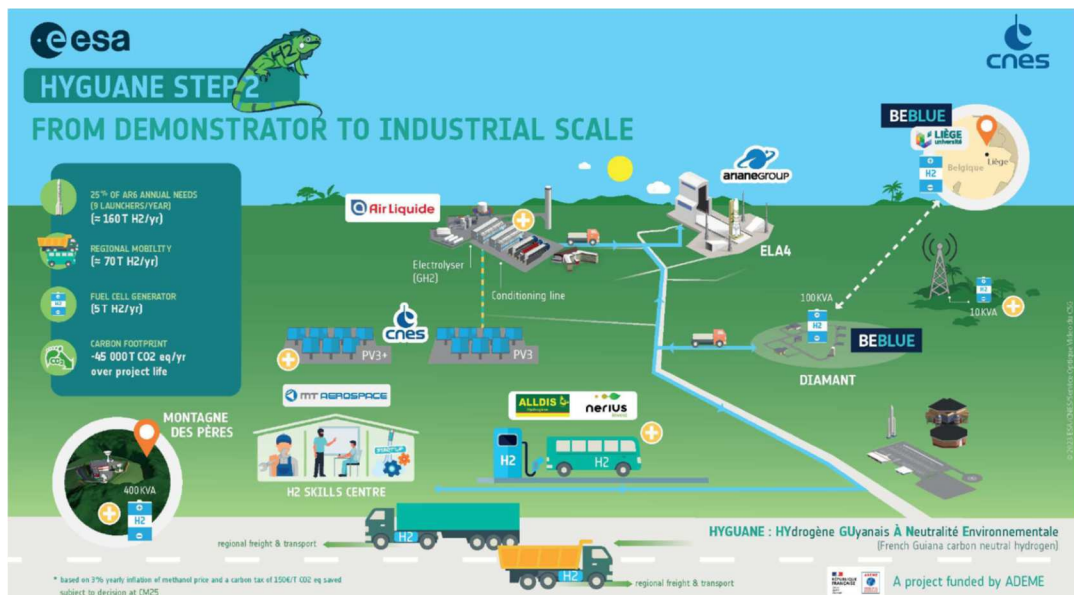


Figure 10 : HYGUANE project summary diagram

## 6 - Conclusion

To cut costs, limit industrial exposure to rising fossil fuel prices, relieve the national power grid and reduce the overall carbon footprint of Europe's Spaceport, the European Space Agency (ESA) and the Centre national d'études spatiales (CNES) have drawn up an ambitious roadmap for a low-carbon trajectory, involving the introduction of renewable energies (photovoltaic farms) to supply up to 90% of the electricity consumed by 2030. The transition will also make it possible to reduce the carbon footprint of industrial processes involving fossil materials, such as hydrogen production, by switching from a methanol reforming process to a water electrolysis process powered by renewable energies; also making it possible to develop territorial uses such as fuel cells or H2 buses for the citizens of French Guiana.

By achieving this, the Guiana Space Center will continue its drive to become a sustainable spaceport that respects the environment by reducing its energy consumption and carbon footprint.

## ACKNOWLEDGEMENT

The authors would like to thank the teams of CNES for their support and their hard work to make the CSG a competitive, performing and green launch base.

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