

2021 IN REVIEW

LAB CRIGEN

LAB CYLERGIE

LABORELEC

LAB SINGAPORE

RESEARCH & INNOVATION



EDITOS



Olivier Sala
Group Vice President
Research & Innovation



As part of ENGIE Research & Innovation, ENGIE Lab CRIGEN, ENGIE Lab Cylergie, ENGIE Laborelec and ENGIE Lab Singapore focus on green gases, electrical power technologies, new energy services for customers and emerging technologies.

IN ORDER TO ACCELERATE THE TRANSITION TOWARDS A CARBON-NEUTRAL WORLD, NEW TECHNOLOGIES WILL HAVE TO BE IMPLEMENTED. OUR OPERATIONAL EXCELLENCE IS ALSO AN AREA WHERE IMPROVEMENTS CAN BE MADE.

In this context, Research and Innovation is key to providing a competitive advantage for our Global Business Units.

As part of ENGIE Research & Innovation, ENGIE Lab CRIGEN, ENGIE Lab Cylergie, ENGIE Laborelec and ENGIE Lab Singapore focus on green gases, electrical power technologies, new energy services for customers and emerging technologies. They lead operational R&D projects and expertise, develop pilots and implement innovative offers to boost and speed up the energy transition.

The research projects that have been developed focus on ENGIE's strategic priorities and critical issues:

- Develop, test, optimize, de-risk and industrialize cutting-edge biogas and hydrogen technologies, enabling ENGIE to achieve the target of 100% green gas in 2045;
- Accelerate development in renewables. Our R&D enables us to develop the technologies that will be at the heart of the energy transition in the future and provides our operating entities with cutting-edge expertise;
- Develop our expertise in infrastructure, such as urban heating and cooling, networks and decentralized energy production projects;
- Make it possible to achieve our customers' energy transition objectives, cities, communities and industries, by offering them innovative low-carbon solutions;
- Improve our Global Business Units' operational performance through the use of digital tools and disruptive technologies;
- Build new revenue streams, by identifying technological breakthroughs that will enable ENGIE to develop new businesses and new markets.

This booklet presents an overview of our 2021 successes.

I warmly thank our researchers, who are fully committed to the energy transition!

I wish you a pleasant reading experience!

COVER: **Gaëlle Dubourg**,
Liquefaction Lab, ENGIE Lab CRIGEN



Adeline Duterque,
Managing Director,
ENGIE Lab CRIGEN



ENGIE Lab CRIGEN, ENGIE's Corporate R&D Center devoted to green gases, new energy uses and emerging technologies developed innovative solutions in 2021 to accelerate the greening of the Group's infrastructures, to assist our B-to-B clients in their move to zero carbon and to create sustainable growth drivers and design sustainable competitive advantages.



Martial Archenault,
Managing Director,
ENGIE Lab Cylergie



ENGIE Lab Cylergie, entirely devoted to energy solutions, converts technologies emerging from ENGIE Labs and research partners into innovative energy services.



Loïc VILLOCEL,
Managing Director,
ENGIE Lab Singapore



In 2021 ENGIE Lab Singapore redefined its priorities around District Cooling and Green Datacentres in order to meet the Group's ambitious objectives on the matter in Asia Pacific. We reinforced our anchorage in the regional ecosystem (new grant with the Singaporean Government) and started to operate and valorise our testing facility (REIDS SPORE) with a strong health and safety culture.



Michaël Marique,
CEO ENGIE Laborelec



A source of great pride for me is that, even during the pandemic, ENGIE Laborelec teams have continued to develop opportunities for the Group, testing innovative solutions to maintain ENGIE's competitive edge and strengthen our unique contribution in supporting the operational excellence of our customers and partners.

KEY FIGURES



REVENUES

35,6 M€

ENGIE Lab CRIGEN

71,5 M€

ENGIE Laborelec

2,34 M€

ENGIE Lab Cylergie

2 M€

ENGIE Lab Singapore



EMPLOYEES

180

ENGIE Lab CRIGEN

358

ENGIE Laborelec

16

ENGIE Lab Cylergie

17

ENGIE Lab Singapore

NATIONALITIES

27

ENGIE Lab CRIGEN

26

ENGIE Laborelec

3

ENGIE Lab Cylergie

8

ENGIE Lab Singapore



R&D STAFF

63% MEN

ENGIE Lab CRIGEN

37% WOMEN

77% MEN

ENGIE Laborelec

23% WOMEN

65% MEN

ENGIE Lab Cylergie

35% WOMEN

65% MEN

ENGIE Lab Singapore

35% WOMEN



PATENTS

100

ENGIE Lab CRIGEN

10

ENGIE Laborelec

5

ENGIE Lab Cylergie

-

ENGIE Lab Singapore



MEMBERS OF STAFF HOLDING A PHD

51

ENGIE Lab CRIGEN

76

ENGIE Laborelec

5

ENGIE Lab Cylergie

6

ENGIE Lab Singapore

ONGOING PROJECTS

160

ENGIE Lab CRIGEN

320

ENGIE Laborelec

21

ENGIE Lab Cylergie

25

ENGIE Lab Singapore



SUMMARY

ENGIE Lab Cylergie: facilities

5 pilots reproducing Energy Solutions Business

ENGIE Lab CRIGEN: a unique European test facilities

6 floors experimental building, Stains (93)

GAYA green gas R&D platform, Saint-Fons (69)

Biogas liquefaction test bench, Montoir-de-Bretagne (44)

3,300 m² indoor test area

4,100 m² outdoor test area

ENGIE Lab Singapore: a unique testing facility with REIDS SPORE

The only testing facility of Singapore in real conditions and the only testing facility of ENGIE in tropical environment and in APAC region.

ENGIE Laborelec: facilities

25 specific testing facilities or laboratories, e.g.

- Solar energy
- Batteries and storage
- Materials technology
- Lighting technology
- Smart Homes
- Biomass
- Power networks
- Cybersecurity

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ENERGY SOLUTIONS GBU





Nora Guemar,
Head of Innovation
Research & Technology
at GBU Energy Solutions



The Global Business Unit Energy Solutions is striving for a growth of +8GW of installed capacity by 2025. This ambitious growth mainly focuses on heat and cooling networks as well as the decentralisation of our clients' industrial facilities, and aims to reach zero carbon status.

We are convinced that to achieve this growth and meet our clients' expectations, innovation, research and development play a major role. The issues are many: hydrogen for green transport and decentralised production, biomass and European regulations, as well as new technologies for producing heat and cold.

How can these technologies be integrated into our solutions? And with which business model? How can regulatory changes be integrated with our technological choices? These shows the scale of the challenges ahead.

The energy transition and the role that we play within the Group provides us with a fantastic playing field to invent tomorrow's world. So, let's analyse the technologies, develop innovative pilots and go full speed ahead together!



ENGIE LAB SINGAPORE

ENGIE Lab Singapore to double its Research and Innovation presence in Singapore

ENGIE Lab Singapore announced the next phase of growth in Singapore's research and innovation capabilities. Supported by the Singapore Economic Development Board (EDB), ENGIE will double its research team in Singapore over the next 3 years, and work closely with local universities in building up its competencies in the local ecosystem. ENGIE Lab Singapore will focus on developing local capabilities related to low-carbon cooling systems, the greening of data centres, and the integration of renewable energy into the local energy mix. The lab will develop a Center of Excellence on Tropical Climate Cooling and will, from Singapore, lead all ENGIE's Research and Innovation programs related to data centres, to enable the Group's vision and ambition to be a world leader in carbon-neutral data centres to be fulfilled. These strategic areas for the region, and globally for ENGIE, were identified through a comprehensive 6-month study and engagement of stakeholders from the government, research and business.

ENGIE Lab Singapore started in 2016 with the construction of its microgrid testing facility on Semakau Island to generate clean power from multiple sources and test energy-efficient industrial solutions in tropical conditions. This was launched under Nanyang Technological University's Renewable Energy Integration Department (REIDS) initiative, an R&D platform that provides a testbed for Singapore's ongoing energy research.

This expansion by ENGIE is the latest milestone in a long-running series of investments that ENGIE has made in Singapore, which hosts its regional operating hub for Southeast Asia. Over the last 5 years, ENGIE has successfully grown and expanded its energy service capabilities in Singapore to include advisory, research and venture building roles. ■



"The longstanding partnership with the Singapore Economic Development Board (EDB) has helped ENGIE Lab Singapore to grow from strength to strength. This new investment will continue to support the development of research, innovation, and business competencies in Singapore. We are excited to collaborate with key stakeholders to bridge the gap between R&D and business, accelerate the energy transition, and help our clients in their journey towards carbon neutrality", explained Loïc Villocel, Director of the ENGIE Lab Singapore."

"Thanks to stronger integration into the local ecosystem, ENGIE Lab Singapore will be able to develop key research capabilities, at the heart of ENGIE's research strategy", states Olivier Sala, ENGIE's Research and Innovation Vice President.

"ENGIE Lab Singapore's commitment to deepening sustainability-related research capabilities is in line with our efforts to create a conducive environment for businesses to meet their sustainability needs. We look forward to working with ENGIE, and other like-minded companies, in the push for sustainable, clean energy solutions that can be developed from Singapore for the region and beyond," said Dawn Lim, Vice President and Head, Commercial and Professional Services, Economic Development Board (EDB).

ENGIE Lab Singapore has been awarded a new contract for government grants of more than one million euros for a period of three years

LOÏC VILLOCEL, IN CONCRETE TERMS, HOW ARE YOU GOING TO USE THIS GRANT? WHAT WILL IT CHANGE FOR YOU AND YOUR TEAMS?

This new grant will allow us to move to a new scale as our team is expected to double within three years. It is not only about boosting the size of the team but also its maturity. One of the challenges is to include our actions in an increasingly global approach to our areas of expertise, by being recognized beyond Singapore, in the region and elsewhere, internally and externally. In order to recruit, we will rely on the local university ecosystem with which we have already signed partnerships and with whom Lab researchers have forged links through their own university career. Thanks to better anchoring in the local ecosystem, we will also have easier access to public subsidies. We will thus optimize our sources of income to find significant leverage effects to finance the ENGIE Group's research programs..

WHAT ARE YOUR AMBITIONS FOR THE NEXT THREE YEARS?

We are going to enter a phase of growth and develop new expertise on subjects that respond to strong challenges locally, both for the Singaporean government and for ENGIE, while having a potential impact of deployment in Asia-Pacific and globally. We have identified two new major topics: cooling and green data centers. These two themes constitute business priorities for the region, but also more generally for ENGIE. To identify these priorities, we carried out more than 70 internal and external interviews, bringing together stakeholders

Cooling data centers constitute business priorities for the region, but also more generally for ENGIE.

from both the State, research and business. By doing so, we wanted to adopt a long-term strategy that makes sense and resonates with the Group's commercial challenges. It has also enabled us to give even more meaning to our research and innovation work, giving it very concrete perspectives. To be more efficient, especially on these two themes, we will of course continue to develop historical expertise and existing assets, in particular our test platform (REIDS SPORE) commissioned at the end of 2020 which will allow the development of pilot projects under real conditions in order to better prepare the commercial deployment of different types of integrated offers.

WHAT ARE THE LINKS BETWEEN RESEARCH AND BUSINESS?

They are the key to success! The role of a research center like ours is to contribute to the commercial success of ENGIE in the region by developing expertise aligned with business needs and differentiating innovative solutions that can be integrated into commercial offers. Our new R&D priorities are now fully aligned with ENGIE's business priorities in the region. The impact of this research applied to business is already bearing fruit with two commercial



bids (Pfizer and NTUC FairPrice), won this year thanks to our support to business developers. ENGIE has great ambitions in the region, in particular around District Cooling, green data centers and integrated offers. And we now have the keys and an important card to play to help the business make a difference to competition.

WHY IS THE ECONOMIC DEVELOPMENT BOARD, A GOVERNMENT AGENCY, INVESTING ALONGSIDE YOU?

The Singapore Economic Development Board (EDB) has supported us from the very beginning. Five years ago it was the first to have awarded us a grant to help us set up the company. This help made it possible to finance our first phase of skills development around the decarbonisation of industry and smart grids, and to build our platform - called REIDS SPORE - to demonstrate innovative low-carbon solutions in real and tropical conditions. The fact that EDB has again invested in the Lab until 2024 is a testament to the credibility we have acquired in the local ecosystem and the desire of the Singaporean government to position itself as a world leader in innovation and new technologies. ■

Catherine MacGregor and Anne-Laure de Chammard visited ENGIE Lab Singapore

Heading for the AMEA zone: in November, Catherine MacGregor and Anne-Laure de Chammard met with local teams and clients in Singapore, and visited ENGIE Lab Singapore, which is dedicated to research and innovation.

During their trip to Singapore from 16 to 18 November, Catherine MacGregor and Anne-Laure de Chammard had many great opportunities to talk with the local teams: COP26 report, Group strategy and current news (including the sale of EQUANS), as well as the recently published Q3 financial results, which highlight the progress made in terms of implementing the strategy. This trip was also an opportunity to meet clients, including Pfizer and Iron Mountain representatives, and thus further strengthen ENGIE's role as a player and trailblazer in the region's energy transition. ENGIE South East Asia has just received the 2021 Sustainability Award in recognition of the Group's choice to install the first electric vehicle public charging infrastructure dealership in Singapore. Alongside its strategic partner ComfortDelGro, ENGIE is set to install more than 500 charging points throughout the country by 2022.



Catherine MacGregor and Anne-Laure de Chammard also went to visit the ENGIE Lab Singapore, which has just received a grant of more than one million euros from a Singapore government agency. Finally, Catherine MacGregor took part in this year's Bloomberg New Economy Forum, organised in Singapore. Joined by politicians and business representatives, she discussed key themes, such as the way technology can help mitigate global warming or how companies and governments can work together in order to build the world economy. ■

BIOGAS, BIOMETHANE & WASTE LAB

ENGIE Lab CRIGEN

★ ★ ★ EUROPEAN PROJECT

OLGA, a European collaborative project to decarbonize airports

CONTEXT

A new project was approved by the European Commission (EC), for the European Green Deal on green airports and ports as multimodal hubs for sustainable and smart mobility to help mitigate the environmental impact of the aviation sector.

NEWS

HOListic Green Airports (OLGA) started on 1st October 2021. It will develop innovative sustainable measures for reducing both airside and landside emissions, while improving energy efficiency, air quality, biodiversity, and waste management. The OLGA project brings together 57 partners and associated entities which form a diverse consortium gathering a high level of experience and expertise, ranging

from large and small airports, airlines and the aeronautic industry to public authorities, researchers and innovative small and medium enterprises focusing on environmental performance. The project is led by Groupe Aéroports de Paris (ADP) and 4 international airports, and their local stakeholders are involved in the project: Paris-Charles de Gaulle, Milan Malpensa (Italy), Zagreb (Croatia), and Cluj (Romania). With a total budget of 34 million euros, it is expected that the OLGA project will rapidly achieve quantifiable advances. The efforts and innovative measures of OLGA will lead to CO₂ reduction, air quality improvement, and biodiversity preservation, throughout the entire value chain of the aviation sector. The OLGA results will generate positive impacts at societal, environmental and

economic levels which will spread at local, national and EU scales.

WHAT ARE THE BENEFITS FOR ENGIE?

ENGIE represented through ENGIE Lab CRIGEN will be in charge of waste recovery towards gaseous fuels production. The objective is to demonstrate the feasibility to develop green gas production based on municipality and airport waste. This approach could then be replicated in other areas -and not only at airports - to study the specificities of their waste and resources. ENGIE GEM is working on Blockchain Traceability and sustainability of Sustainable Aviation Fuel and ENGIE Solutions is working on a prefeasibility study of a H₂ station for Heavy Duty Vehicle at Roissy-Charles de Gaulle Airport. In the short term, the OLGA project could contribute to the development of the biomethane production in Romania and in the medium term, this approach could be implemented to any environment. ■



HYDROGEN LAB

ENGIE Lab CRIGEN

NanoH2: industrialization of a solar-assisted electrolyzer

CONTEXT

In the case of a hydrogen refueling station or small hydrogen consumers, the production cost of decentralized production of hydrogen is still between 7€/kg and 12€/kg, depending on the capacity of the delivery point (from tens to a few hundred kg/day). This remains a key hurdle for the development of local hydrogen infrastructures. This situation is mainly due to (1) the electricity prices accessible to hundreds of kW installations and (2) CAPEX linked to the balance of plants where such installations exist and that do not benefit from cost reductions linked to upscaling. As such, business cases based on competitive decentralized production of hydrogen need disruptive technologies in order to be profitable. The technology developed in the NanoH2 project meets such business

needs and is estimated to be competitive compared to standard alkaline electrolysis at the considered scales, with a hydrogen production cost below 5€/kg, thanks to solar assistance.

NEWS

A pilot will be installed at ENGIE Lab CRIGEN's facilities in order to demonstrate the continuous production of hydrogen, taking advantage of solar illumination costs that decrease during the day. Specific efforts are made to optimize the pilot in terms of design, materials used and configuration and a small scale unit has been successfully tested in order to derisk the final technology. ■



MACBETH: testing and validating a biogas reformer connected to a commercial methanization unit able to produce 100kg/day of green hydrogen



CONTEXT

The MACBETH consortium will provide breakthrough technology for advanced downstream processing by combining catalytic synthesis with the corresponding separation units in a single, highly efficient catalytic membrane reactor (CMR) in order to produce hydrogen from biogas reforming. This technology is especially interesting for decentralized hydrogen production.

NEWS

Within the framework of the MACBETH project, the Hydrogen Lab will test a CMR biogas reforming unit on a biogas producing site for a duration of 8000h in 2023. In 2021, the biogas plant where the pilot will be tested was selected and in 2022 discussions will take place for works definition and planning in order to prepare the site for the delivery of the pilot in early 2023. ■



LIVING H₂: hydrogen fuel cell cogeneration to provide heat and power to ENGIE Lab CRIGEN offices

CONTEXT

Living H₂, which started in October 2019, is co-funded by ANR (French Research Agency) and the German BMBF. The project aims to develop and test a hydrogen-based fuel cell micro-CHP system to provide green electricity and heat to tertiary and residential buildings. The project brings together high-level industrial and academic partners from France and Germany: CEA Liten, InHouse a system developer, DBI a major German Gas Institute and Regensburg University. ENGIE Lab CRIGEN will install the system in the boiler room of its offices, and perform technical, economic and social studies.

NEWS

The installation of the mCHP system has been postponed to March 2022 due delays caused by COVID-19. The design and assembly of the system has been finalized by the manufacturer, as well as the

hydrogen odorization unit. A safety study regarding the installation within ENGIE Lab CRIGEN's boiler room and site preparation has been conducted.

The next key steps in 2022 will be the installation and commissioning of the mCHP planned in March 2022. The first characterization tests will be carried out from April to September, on a first generation PEMFC stack. A second and improved stack will be implemented in September, and a test in real conditions, in order to provide heat and power to ENGIE Lab CRIGEN's offices, with green hydrogen produced locally with a 50 kW electrolyzer, will take place during the 2022-2023 heating period.

WHAT ARE THE BENEFITS FOR ENGIE?

This project enables a first evaluation of a new hydrogen-based solution to provide green heat and power to residential and commercial market, to be carried out. This



project contributes to the development of hydrogen usages for GBU Energy Solutions within the building sector and contributes to reducing the cost of stationary fuel cells. ■

Hydrogen and e-fuels fuel cell Gensets: green decentralized power for datacenters, back-up and remote power

CONTEXT

Gensets are widely used for several applications as back-up power (datacenters, hospitals, telecoms, etc.) and remote temporary power (events, construction sites, etc.). The state-of-the-art technology is a diesel engine, and therefore they have high CO₂, pollution and noise emission levels. Fuel cells are a promising alternative to replace these diesel generators.

ENGIE Lab CRIGEN purchased a 20 kW hydrogen fuel cell genset system which will be delivered in March 2022. The integration of hydrogen gensets was further studied in 2021, mainly for Datacenters, as a power back-up power solution, or integrated into a larger smart energy system in order to provide high availability. In 2021, ENGIE Lab CRIGEN and ENGIE Laborelec carried out a preliminary feasibility study on an innovative fuel cell system, combining breakthrough technology. ENGIE Lab CRIGEN is also studying possibilities to use other green fuels, such as ammonia or methanol, to supply fuel cell gensets using innovative cracking technologies to convert these alternative fuels into pure and high-quality hydrogen. These alternatives would solve the issues of safety and footprint related to gaseous stored hydrogen.

NEWS

In 2021, the Hydrogen Lab conducted new tests on a 4 kW fuel cell coupled with Li-ion batteries. The tests have been used to improve our knowledge on the control strategies for such a hybrid system combining a fuel cell and a battery. A larger genset system (20 kW) from a leading European fuel cell manufacturer and had been installed mid-2021 within the ENGIE Lab CRIGEN H₂Factory. Tests have been scheduled in order to: (1) further identify the technical



requirements of fuel cell gensets for several key applications, such as zero-time back-up power for datacenters, within the new Green Datacenters Key Program led by ENGIE Lab Singapore, (2) demonstrate this technology in the field for temporary power in partnership with ENGIE Hydrogen BU, and (3) couple this fuel cell genset with an innovative reactor, that will generate pure H₂ from ammonia. Simulation studies with a simulation tool have also been conducted to further analyze the relevance of fuel cell back-up power Genset within a Datacenter configuration and to access the Total Cost of Ownership of such a green innovative solution.

WHAT'S IN IT FOR ENGIE?

Fuel cells may be considered as disruptive technology in the genset market as it can replace polluting diesel generators that are traditionally used for temporary and back-up power. The expertise developed by ENGIE Lab CRIGEN through its studies and tests will help BUs (ENGIE Solutions and Hydrogen BU) to develop specific offers for our customers. ■



LittleCithy: a Local Energy Community (LEC)

CONTEXT

In continuation of the GRHYD project in the usage of hydrogen in buildings in the Dunkirk Urban Community, a new project was launched to create a Local Energy Community in a new district under construction. This project included the techno-economic analysis of the integration of hydrogen solutions as energy solutions to promote low-carbon buildings and districts, in keeping with the new RE2020.

NEWS

Three energy architectures were studied to implement hydrogen in the district:

- _ Hydrogen Local Energy Community with electric distribution;
- _ Hydrogen Local Energy Community with hydrogen distribution;
- _ Hydrogen Local Energy Community with distribution by the heat network.

Each of these solutions enables the district's autonomy in energy to be optimized. Further calculations are needed to identify the most relevant ones. In the event of implementation of one of these solutions, the hydrogen will be produced locally within the district using local renewable electricity sources (PV panels or wind turbines).

WHAT ARE THE BENEFITS FOR ENGIE?

With decentralized renewable energy production methods becoming increasingly accessible, individuals are able to produce their own energy, limiting their needs for supply by utilities. For ENGIE, this project is an opportunity to embrace this long-term trend, providing not only energy solutions but global renewable energy solutions at a district scale, meeting the expectations of individuals on both environmental impacts and energy resiliency and autonomy. ■

ENVIRONMENT & SOCIETY LAB

ENGIE Lab CRIGEN

The LepiNoc project: light pollution studies on nocturnal lepidoptera

CONTEXT

The LepiNoc project's objective is to develop a collaborative protocol and associated device to collect data on night-time butterflies and contribute to increasing scientific knowledge.

Lepidopteras and nighttime butterflies make up about 5 000 species, i.e., 50% of wild pollinators in France and 95% of the butterfly species. They play a crucial part in the basic functioning of many ecosystems, mainly through pollination. However, they are exposed to anthropic pressure, such as farming intensification and urbanization. The purpose of this study is to better estimate the impact that these pressures have on insects.

The project was initiated by Noé, an environmental NGO, as a response to a call for projects from the French region, Île-de-France. Storengy SA and SAS are funding partners and provide pilot sites.

NEWS

The 2021 part of the project consists in a Proof of Concept for an automated image capture of nocturnal lepidoptera based on a light trap.

The aim of the project is to design a device that is simple, reliable and cheap. Once the prototype and associated protocol are validated, they will be deployed in mainland France as a participative science program. This kind of program enables large datasets to be collected on abundance and diversity.



WHAT ARE THE BENEFITS FOR ENGIE?

The LepiNoc project fits with our other works on light pollution and nighttime ecological continuities, along with other projects conducted with the Lighting Lab for Storengy or Equans.

The Lighting Lab for example is deploying a light diagnostic offer with their tool DYLA, which could be coupled with Environment & Society Lab tool LiFECO and ecological assessments based on the LepiNoc protocol.

The device developed within the LepiNoc project could contribute to business differentiation in public lighting offers, as nighttime ecological continuities and dark corridor studies are becoming more and more present in requirements of cities in their call for tenders. Finally, contributing to a participative science project is also beneficial to the pilot sites themselves as it provides an opportunity for collaborating with external local stakeholders and provides site employees with an opportunity to discover and protect nature at their workplace. ■

INUIT project: implementation of eco-innovation

CONTEXT

Eco-innovation is a new business approach which promotes sustainability throughout a product's entire life cycle of, while also boosting a company's performance and competitiveness. It can help companies access new and expanding markets, increase productivity, attract new investment into the business, increase profitability across the value chain, and help stay ahead of regulations and standards – notably those related to the environment.

Lowering the environmental impacts of public lighting has become a recurring expectation in the public lighting and services sectors and therefore, ENGIE's clients. The increasing development of LED lighting has allowed many improvements, however, there is still much room for improvement concerning LED lighting, in regards to its different modules (driver, LED, optical block). With the current market in favor of the replacement of high pressure sodium lights by LED lights, and the improvement of LED lighting, there is a very



good opportunity to develop eco-innovation in ENGIE's offerings.

ENGIE Lab CRIGEN Environment & Society, along with the ENGIE Laborelec's Lighting Competence Centre, has won a call for projects (INUIT) launched by ADEME, the French Agency for the ecological transition.

NEWS

Within the French ADEME INUIT project (2019-2022), the objective is to identify eco-innovation opportunities that help to reduce environmental impacts by

maximizing efficiency, reducing energy consumption, reusing critical and strategic materials, avoiding lighting, etc. We analyze the environmental and social impacts of each identified opportunity.

The project brings together competencies in environmental assessments, circular economy, biodiversity, lighting and sociology.

In 2022, we will promote this project so that the whole ENGIE group can optimize public lighting projects by offering a differentiating offer to our customers. We also want to offer our skills to other GBUs in order to develop new designs.

WHAT ARE THE BENEFITS FOR ENGIE?

The INUIT project is paving the way for ENGIE Lab CRIGEN to work on eco-innovation. Therefore, benefits are various. Firstly, it offers the opportunity to work on new designs to avoid environmental impacts and respect – or anticipate – environmental future laws. Secondly, it allows us to work with different stakeholders in the value chain, who can be levers to develop new projects, based on the synergies started with this project. Finally, eco-innovation is a way to obtain competitiveness for collectivities, who need to meet environmental constraints without having extra costs. ■

ENVIRONMENT & SOCIETY LAB

ENGIE Lab CRIGEN

CLAFooti: a simplified tool to measure the performance of products and services through Life Cycle Assessment (LCA)

CONTEXT

LCA is a standardized method aiming to quantify the potential environmental impacts of a system (product, process, service, organization, territory...), throughout its whole life cycle, following a multicriteria approach. Today regulations (particularly at a European level) are increasingly demanding assessment throughout the value chain and players are increasingly proactive in regards to environmental performance issues in the value chain, for example through:

- Performance contracts;
- The willingness of actors to reach carbon neutrality (local territories, industrial clients etc.);
- The development of sustainable procurement policies (e.g., PV chains);
- Customer communication and lobbying.

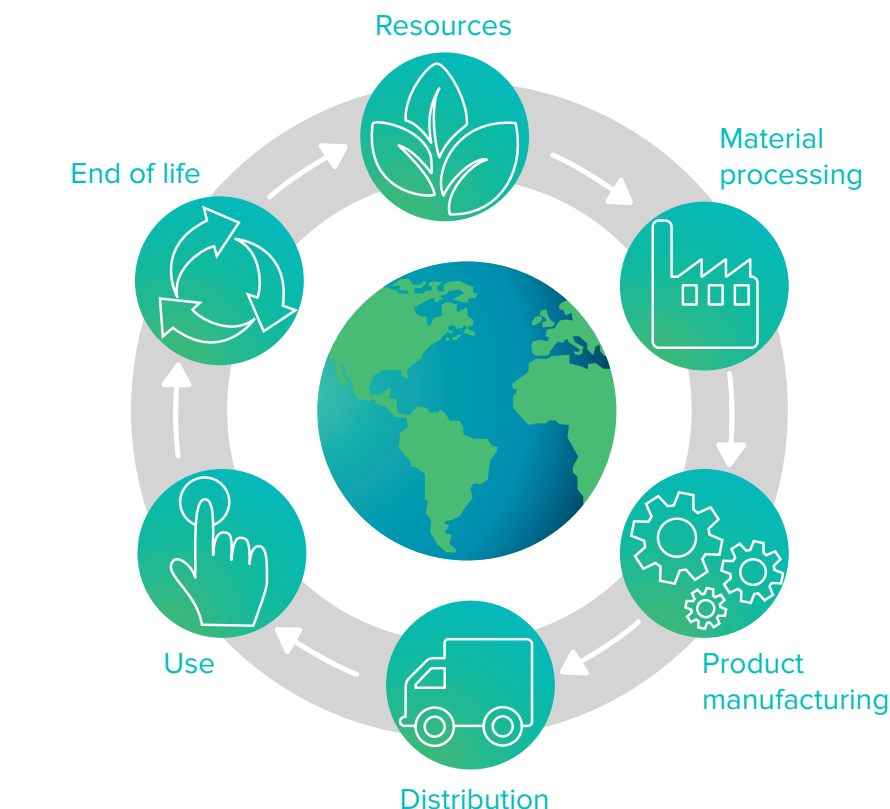
While the majority of expectations focus on GHG assessments, there are more and more requirements in regards to the assessment of other potential environmental impacts on human health and on ecosystems. There is, thus, a growing need by ENGIE's entities for performing LCA of their activities (with a particular focus on GHG assessments), and which can meet those expectations. Yet LCA requires a specific expertise and tools that are, so far, not available in all of the Group's entities.

NEWS

The Environment & Society Lab, together with the Computer Science & AI Lab, developed CLAFooti in 2021, in order to spread the life-cycle rationale within ENGIE and to allow its entities to perform LCA in a simplified way, but based on ENGIE Lab CRIGEN's long-standing expertise. The main aims of CLAFooti are to:

- Equip ENGIE's entities in order to meet their routine needs with regards to LCA, with models that are consistent at Group level and updated regularly by ENGIE Lab CRIGEN;
- Avoid the development of multiple "GHG calculators";
- Allow the Group to go beyond GHG assessments with a multi-impact assessment (water footprint, resource use, impacts due to atmospheric emissions, etc.).

CLAFooti consists in a web-interface and an API, directly linked to Simapro®, the tool used by LCA experts at ENGIE Lab CRIGEN,



so that the models developed by ENGIE Lab CRIGEN are directly accessible to the whole Group. The CLAFooti interface gives access to a simplified configured version of the LCA model, based on an in-depth study and an expert calculation model. Together with the interface, the user also has access to a detailed document including all modelling assumptions, and to a user guide. Results of the assessment are directly available on the interface, and allow:

- Comparison of relative environmental performances of several scenario for a given project;
- Comparison of the main contributing steps of the life cycle for each environmental impact category;
- An upload of the results in excel format that can be used for further calculations.

The first version of the tool will be available in 2022 for 2 sets of technologies: district heating systems and solar panels. More

technologies will be implemented during 2022 as well as new features such as the download of programmable logic controlled based on scenarii modeled by the user.

WHAT ARE THE BENEFITS FOR ENGIE?

CLAFooti allows non-experts to evaluate the environmental performance of their projects, quickly and with a standardized and recognized method and tools. It can support ENGIE's entities in the design of a project and demonstrate their environmental benefits in tender bids which can provide a competitive advantage to the Group. ■

FUTURE INDUSTRY LAB

ENGIE Lab CRIGEN

Developing the Smart Factory of the Future with Digital Twin

CONTEXT

Across its GBUs ENGIE is operating a wide variety of low carbon energy systems. Ensuring the overall effectiveness of this equipment is key to maintaining quality of service and operational profitability. To do so, Future Industry Lab has developed specific skills and expertise on industrial 4.0 technologies and associated use cases. Using Digital Twin, it is actively investigating multiple opportunities on condition-based and predictive maintenance strategies, augmented and mixed reality on behalf of GBUs.

NEWS

Digital Twin: in 2021, along with our partner PTC, substantial progress has been made in setting-up the full industrial IoT infrastructure required to use our simulation-based Digital Twin for monitoring on-site operations. Major technical challenges were overcome through our partnership with Fives Group (construction of a Digital Twin to speed-up the design and optimize the performance of a new industrial gas burner). Major communication campaigns were conducted in order to share the added value of our solutions, in particular press articles with our technological partner ANSYS, and the participation in the inauguration of ArcelorMittal's Digital Lab in Dunkirk with a demonstrator.

Augmented and mixed reality: in collaboration with SYNERGIZ, 2021 has seen the completion of the MIRORS project, our mixed reality solution that offers a brand new way to visualize and analyze 3D multi-physics data (throughout an industrial project's lifecycle, from design to operations and maintenance). Again, multiple communication campaigns were undertaken to enhance the value of the solution including participation to VivaTech and the ENGIE Innovation Trophies (MIRORS selected for final).

New maintenance strategies: In 2021 the Future Industry Lab has focused on on-site steam production and industrial steam networks, including biomass boilers. Based on failures prioritization, a technical and financial study was conducted on solutions to detect and quantify steam trap defaults. A first predictive maintenance project was launched on biomass boilers with some promising initial results on early detection of defaults using a machine learning approach.

WHAT ARE THE BENEFITS FOR ENGIE?

Through this Smart Factory Program, the Future Industry Lab is expecting to contribute to the improvement in the operational performance of the assets managed by ENGIE, from boosting energy yields to increasing asset availability and reduction of safety risks. ■



Decarbonization solutions for the Industry



CONTEXT

A key challenge for most of ENGIE's industrial customers is to secure options to decarbonize their energy usages. A major topic, in ENGIE's core activities, is to deliver low carbon steam, hot or chilled water, or low carbon energy (fuel or electricity) to the plants for thermal processes. The Future Industry Lab actively investigates such options, addressing technico-economic challenges, but also systemic consequences that may impact a customer's decision.

NEWS

In 2021, the Future Industry Lab made significant progress on the evaluation of low carbon options to generate industrial steam or hot water utilities.

In particular, scientific, technological and maturity assessments were made on: conversion of natural gas boilers for competitive

CO₂ capture, efficient electrification solutions (e.g. high temperature heat pumps, mechanical vapor recompression) through fatal heat upgrading, Solar Heat for Industrial Process (SHIP), hybrid solution to integrate bio-sourced gaseous fuels in natural gas boilers, and the integration of thermal storage solutions to increase the share of intermittent low carbon thermal energy. Several business cases have been proposed, in relation with business developers from several ENGIE Group entities.

Low carbon energy for thermal processes is another priority topic. Topics launched in 2020 have progressed significantly. The partnership with Centrale Supelec will help to better assess the adoption of hydrogen in industrial processes. Ammonia as a fuel has also been investigated regarding combustion properties and the mapping of the current maturity of technologies. The VERCANE project, supported by ADEME, in partnership with two glassmakers (Saverglass and Verescence), and a technological partner (Fives Group), is delivering potential roadmaps to decarbonize glass plants through an appropriate mix of electrification and integration of green gases (bio-sourced, hydrogen). The MACBETH project, supported by the European Commission, is preparing the deployment of a semi-industrial scale bench in ENGIE Lab CRIGEN for the end of 2022. This bench aims at demonstrating the ability of the H2Site technology to decarbonize the propane dehydrogenation process, which is a key process in the chemical industry.

WHAT ARE THE BENEFITS FOR ENGIE?

ENGIE is a leader of low carbon industrial utilities and low carbon commodities, in particular regarding wood chip boilers, and biomethane. The current R&I projects on decarbonization options will provide ENGIE with a larger portfolio and improve "customer intimacy", which is essential to reach ambitious decarbonization targets. The solutions investigated may provide answers to the many different specific contexts of our industrial customers, in order to deploy optimal options that fit our customers' roadmaps. ■

Excellence Center in Industry 4.0

CONTEXT

Most industrial sectors are now mobilized around achieving net zero carbon goals in the next few decades. In this context, ENGIE faces new technical challenges, and commercial offers often require the expertise brought by ENGIE Lab CRIGEN. The continuous capitalization of knowledge on the state-of-the-art in the field of decarbonization, as well as the ability of the team to investigate options thanks to digital modeling are appreciated by the operational business units and their customers.

NEWS

In 2021, Future Industry Lab has supported ENGIE's activity in Europe, the Americas and Asia on several topics. ENGIE Solutions asked for our expertise in order to investigate the best options to integrate bioresources in order to generate the energy required in the plasterboards process. ENGIE Impact asked the team to contribute to workshops for an end customer in the agri-food sector, bringing a cross-business vision on decarbonization options, based on mature or emerging technologies. Energy audits have been conducted focusing on the energy efficiency of processes in the field of durum wheat for ENGIE Solutions. Dedicated



Webinars have been set-up and presented to a large audience in the ENGIE Group on decarbonation options in the main chemical industry sectors, sponsored by the Global Business Unit Energy Solutions. Finally, several workshops have been organized at the ENGIE Lab CRIGEN facilities, for ENGIE end customers of, in order to promote the Group's ability to address the challenge of decarbonization of the industry. These workshops included large international customers like Procter&Gamble, the Renault Group, or Holcim.

WHAT ARE THE BENEFITS FOR ENGIE?

The Future Industry Lab develops and maintains a high level of expertise dedicated to the decarbonation of industrial sectors. The Group regularly mobilizes this expertise in customer journeys, in order to develop "customer intimacy", to identify technological options relevant in specific contexts, to solve problems in order to enable projects to move forward, and to provide global overviews to help decision-making. ■

GREEN GASES MOBILITY LAB

ENGIE Lab CRIGEN

Fill-Good: Compressed Natural Gas (CNG) refueling test bench

CONTEXT

Compressed Natural Gas (CNG) is delivered at a pressure of 200 bars in Natural Gas Vehicles (NGV). The increase of NGV share has meant that new compressor or refueling technologies have emerged on the market, making it necessary to test and assess their performances and safety in the related environment. Furthermore, the understanding of the thermodynamical behavior of the gas at such a pressure during delivery is key towards an improved vehicle range.

NEWS

Green Gases Mobility Lab and Future Industry Lab have developed a refueling test bench (Fill-Good) which enables to test several CNG dedicated items of equipment such as compressors, gas storage systems, fueling procedures and associated instrumentation (pressure sensor, flowmeter, temperature sensor...). One of the main advantages of this test bench is

the possibility to align the test of a natural gas compressor with the requirements of the French Natural Gas Vehicle Association specifications (AFGNV). In 2021, the Fill-Good test bench was used to qualify a reciprocal piston compressor (low flow at 5 Nm³/h) from Motor Jikov. This compressor aims to be used for domestic applications in vehicle refueling at night (passenger car refueling in a few hours). Through its connection to the Fill-Good test bench, it has been possible to highlight this compressor's good performance in terms of temperature compensation, which is a procedure aiming at maximizing the amount of gas within the vehicle tank. Several tests aiming at assessing the safety of the machine in case of electrical or gas shutdown have been successfully carried out and showed that the machine was robustness. Further use of this test bench will rely on the qualification of innovative solution for increasing vehicle mileage but will also serve as an experimental tool for calibration of a

model developed in 2021 by Green Gases Mobility Lab (CH4RGE model) which aims at simulating the operative behavior of different CNG stations.

WHAT ARE THE BENEFITS FOR ENGIE?

The development of this test bench enables ENGIE Lab CRIGEN's position to be strengthened in the green gas mobility R&D sector. The versatility in the use of this test bench for NGV-related technology testing or for the development of a new innovative refueling procedure is a major advantage towards removing the obstacles in growth of the CNG sector. ■



NANOTECHNOLOGIES, SENSORS & WIRELESS LAB

ENGIE Lab CRIGEN



CYGNUS: radiative cooling solutions for sustainable energy production

CONTEXT

Together with concerns about global warming, demand in cooling is about to skyrocket, potentially doubling by 2025. ENGIE Lab CRIGEN is proposing to explore the potential of state-of-the-art radiative cooling solutions for sustainable energy production.

Since 2019, ENGIE Lab CRIGEN has set up field-trials in various locations and climates, with the support of some interested parties, in order to provide more mature collected data and knowledge about radiative cooling technology.

NEWS

In 2020-2021, the Nanotechnologies, Sensors & Wireless Lab worked on new applications such as cool islands (cooled street furniture designed to respond to the effects of urban heat islands) in coordination with ENGIE Solutions and Climespace. The field test conducted in 2021 at La Défense on a cool island was successful and has given very promising results. To increase the observed performance of cool islands and make them more compact, the wooden canopy of the cooling island structure must be replaced by Skycool panels. One of the objectives of 2021 was therefore to redesign and manufacture new panels that maintain Skycool panel properties and meet the regulatory safety constraints of

furniture placed in an elevated position in a public place (wind resistance, resistance to accidental loads related to vandalism, etc.). The manufacture of 18 new panels is currently in progress. They will be assembled and tested in 2022.

In order to broaden the use cases of Skycool panels, another project was also started in 2021: replace glycol water circulating in the panels with other refrigerants such as CO₂ or propane. Early results indicate that Skycool panels need to be redesigned to withstand the high pressures required for these fluids. The next step will be to obtain more accurate values and to explore the opportunity to use water in a refrigeration cycle in order to produce net negative cooling with extremely high economical and climate change benefits.

In addition to its fluid cooling function, The Skycool panel4S highly reflective film can also be used as a mirror and thus be coupled with other systems such as photovoltaic or solar thermal panels to improve their harvest of sunlight and thus generate more electricity or heat. In 2020, a first analysis undertaken using Dymola software indicated that coupling Skycool panels with vertical bifacial modules oriented east/west shows a gain compared with classical systems tilted and oriented south/north. In 2021, to confirm the effective electric power gain, simulations were carried out in collaboration

with CEA/INES indicating that the lower the ground albedo, the greater the impact of Skycool panels on the electrical power gain, with 27% for a ground albedo of 0.5 (white paint) and 42% for 0.2 (asphalt, grass, concrete, etc.). So, simulations demonstrated the interest of coupling a vertical bifacial module and a Skycool panel with significant electric production gains. A techno-economic study has been performed with Dymola for a use case concerning a plastic manufacturing factory in Belgium. In 2022, a field test will be mounted on the roof of ENGIE Laborelec to validate the digital results.

WHAT ARE THE BENEFITS FOR ENGIE?

More than one fourth of the energy resources in developed countries are used for cooling and heating. Most standard refrigeration and air-conditioning equipment (such as wet towers or air heat-pumps) relies on heat exchange with the surrounding air, quickly reaching a weather-sensitive equilibrium that cannot be overcome at a low energy costs. The disruptive radiative Skycooling system technology that cools by sending out calories to space can be an alternative. This CAPEX-intensive approach enables a quick return on investment and provides a key solution for next generation cooling assets with high, long-term profitability. ■

DRONES & ROBOTS LAB

ENGIE Lab CRIGEN

Asset Information Model (AIM) at the heart of an asset-based strategy

CONTEXT

An Asset Information Model (AIM) is a model that compiles the data and information necessary to support asset management; it provides all the data and information related to, or required for operating an asset. An AIM allows the asset to be followed-up throughout its lifecycle: design, construction, disposal, decommissioning and demolition. Thus, AIM is similar to BIM but at asset level.

The objectives of asset management are to optimize costs, risk and performance throughout the asset's whole lifecycle, at portfolio, system, and individual asset levels. The Drones & Robots Lab is working on this topic in 2 separate areas: industry and thermal comfort.

NEWS

In 2021, the Drones & Robots Lab focused on offering new use cases linked to AIM (Asset Information Modelling). The team focused on several modules for the AIM4all project which links 3D modelling of assets to further asset management-focused data processing: asset inventory help, 2D and 3D map updates, automated detection in raw data and projection on 3D point cloud of points and objects of interest. To achieve this, developments have been made in improving the efficiency of QR codes detection and reading, scene-text detection and objects detection. The aim was to take the biggest possible advantage of raw data collected during scanning for automated tagging of all useful data for the different needs in information for the business areas.

In regards to industry, the Lab participated in the establishment of the first Storengy Digital Twin, currently under deployment at the Beynes storage site next to Paris. The contribution of the Drones & Robots Lab enabled quick and relevant scans of different environments: wellhead platforms and process equipment, tertiary buildings, boiler rooms, control cabinets. Scene-text and QR codes detection, as well as recognition, were undertaken on these assets. The link of this information to the Storengy Digital Twin is under progress. According to Storengy's lowest estimations, the benefit should be 3% on engineering OPEX per year.



The Drones & Robots Lab also worked with Energy Solutions GBU BLIT teams. AIM4all features helped them to tackle non-compliances during an equipment inventory phase on newly won contracts.

In regards to thermal comfort, 2021 success story is the thermal comfort assessment performed for the Mogador Theatre (Paris). As comfortable during a show is an important part of user experience, thermal comfort monitoring is of significant interest for Mogador teams. The results enabled uncomfortable zones to be identified and for them to be adjusted by mechanical and maintenance means. Attracted by the proposed results on thermal comfort and convinced of ENGIE's expertise, Mogador followed-up with the implementation of a predictive maintenance tool to optimize energy consumptions and thermal comfort depending on the schedule, the number of spectators and the weather conditions.

WHAT ARE THE BENEFITS FOR ENGIE?

The main benefits for ENGIE of the AIM4all project are:

- A gain in safety during operation by better knowledge and visualization of sites, by enabling 3D scanning for new types of complicated environments (boiler rooms and HVAC technical equipment, gas storage sites and industrial sites);

- An equipment inventory through the AIM model: scene-text detection into raw images and projection of points of interest (POI) in the 3D point cloud;
- Security and contract optimization thanks to more efficient asset management.

2022 developments will focus on the industrialization of the solution to make it available and user-friendly for ENGIE operational teams through a simple on-premise user interface. The features of the AIM4all industry will be expanded to cover Renewables GBU issues such as the monitoring of PV panel serial numbers for warranty follow-up and Networks GBU issues such as underground DHC network detection and location. The quantification and mapping of gas leakages are the next topics that Drones & Robots Lab will tackle. ■

Multi-purpose autonomous cleaning robot for public lighting market

CONTEXT

Compared to traditional public lighting, comprising sodium vapor light bulbs, fluorescent light bulbs or metal halide bulbs, which made it necessary to replace bulbs every year, LED lighting exceeds 100,000 hours, or the equivalent of over twenty years of operation.

During maintenance operations, traditional public lighting optical units were cleaned to maintain light quality. The use of LED technology in public lighting has significantly changed the maintenance model: there is no worry about spare parts and service continuity but the new challenge is to maintain a high level of light quality (intensity, color temperature, emission cone, etc.), which may be reduced by fouling due to pollution.

On demand of the Acceleration Task Force and Ineo, in 2020/2021 the Drones & Robots Lab worked on the development of technological components of a robotic solution that aims to clean public lightings' autonomously and proposes other features (inspection of mast integrity, light quality measurement, 3D mapping and automatic road measurement).

NEWS

In 2021, the Drones & Robots Lab provided an operational answer with a Proof-of-Concept (POC) for two public lighting systems installed by ENGIE Ineo on the outdoor experimental area of ENGIE Lab CRIGEN.

The Lighting Laboratory, the Computer and Artificial Intelligence Laboratory, the Acceleration Task Force and Ineo worked jointly on the development process and tests in order to find the best technical solution for operational needs.

The objectives of this R&D program is to propose an innovative robotic solution and a tool for the operational teams in order to save time and costs, increase safety and allow operational staff to develop new skills.

Three main technological components were developed:

- Detection/Recognition/Localization of public lighting with optical sensors and trained neural network as well as 3D lidar-aided localization;
- Lidar-aided autonomous navigation and precise visual positioning under optical unit;
- An autonomous cleaning system developed with a pneumatic mast, a closed-loop control robotic arm to apply a constant cleaning strength, a motorized brush and embedded sensors to visualize and measure distance/strength;
- This proof of concept provided a first estimate of the duration of operations;
- In addition, our laboratory worked on target robot sizing (taking into account wind, slope of road, height of pneumatic



mast, robotic arm offset, etc.) and some experiments of non-destructive measurement sensors that could be used to ensure the structural integrity of public lighting masts.

R&D program for 2022 will be to finalize development of the technological components, in particular:

- Integration of a robotic arm with seven degrees of freedom to give offset capacity and allow optical units with different shapes and sizes to be cleaned;
- Measurement of the efficiency of automatic cleaning with an ENGIE Laborelec (DyLA) light measurement system;
- Make the detection and autonomous navigation of public lighting fully operational for field tests with our partner, OUTSIGHT, specialized in lidar data pre-processing.

in order to make specifications for the pre-industrialized prototype.

The Drones & Robots Lab will also continue to develop other features like lidar-aided road sizing coupled with light quality measurements in collaboration with ENGIE Laborelec.

WHAT ARE THE BENEFITS FOR ENGIE?

The Drones & Robots Lab can provide a tool to meet operational needs and provide local authorities with innovative and differentiating offers.

An industrialized solution deployed in the field will have a significant impact on cost reduction in view of the market potential. ■



Asset Information Model (AIM) for O&M thermal and visual inspections

CONTEXT

The 2020 Solar Generation Index report is the largest industry-wide energy validation study. The report analyzed over 30% of the market's non-residential systems in the United States and found that on average, systems underperformed by 6.3% their initial estimates on a weather-adjusted basis. The report concluded that performance estimates are systemically over-estimated and that assets are often not yielding the expected returns.

Drones are continuously being used on solar farms to improve inspection operations, especially areas that are highly irradiated and create a host of issues for on-site teams. The use of drones allows solar farm teams to cut down inspection time by 70%, a significant reduction when compared to traditional methods.

NEWS

In 2021, a fixed-wing drone was used on two ENGIE Green photovoltaic sites (around 30MW) in order to validate their use for O&M thermal and visual inspections. The Raptor Maps platform was used for data-processing and results were comparable to data collected by traditional rotary-drone (multi-rotor). The main advantage of the fixed-wing solution is the time required to collect data: 25 minutes vs 6-7 hours. This solution is 15 times faster than a traditional tool.

This kind of drone, which is mainly used for construction work (topography, etc.), could also be very useful for ENGIE for large-scale plant scans. The rotary drone can also be used by operators in order to better identify and locate defective panels during maintenance rounds.

WHAT ARE THE BENEFITS FOR ENGIE?

The main benefits for ENGIE in using drones on photovoltaic sites are:

- Increased safety during operation by better knowledge and visualization of the location of defaults on site;
- Less risks for humans during inspections for default detection;
- According to the Drones & Robots Lab and also ENGIE Noram (2 different studies leading to the same conclusion), if drone competencies ENGIE for data collection are internalized within, drone inspection costs could be divided by 2 in comparison to a 100% outsourced solution.

2022 developments will focus on multi-site demonstrations and also autonomous ground inspection in order to collect data, as operators would do, but by using a robot in order to reduce risks for humans. Site digitalization (linked to AIM actions) would also be a key achievement of our 2022 roadmap. ■

FUTURE BUILDING LAB

ENGIE Lab CRIGEN



Evaluation of a predictive maintenance solution through the development of a specific test bench design

CONTEXT

Intelligence concerns all technical, administrative and management work during the life cycle of an asset, which aims at maintaining or restoring it to a state in which it can perform a required function. More and more energy production system manufacturers (boilers, heat pumps, micro CHPs, etc.) offer systems monitoring as an option. Some start-ups are also developing their non-onboard maintenance solutions based on external sensors with IoT to monitor a system in real-time. Many advertise “predictive maintenance” possibilities, but in reality there are no regulations or equipment dedicated to the standardization of predictive maintenance solutions to qualify or to compare it.

The Future Building & Cities Lab designed a test bench aimed at generating malfunction scenarios in order to objectively evaluate and compare predictive maintenance solutions developed by business units or manufacturers.

NEWS

The bench aims at evaluating a predictive maintenance system, onboard a generator or elements of an HVAC system or installed as an “external” sensor offer for residential and commercial applications. It was designed in 2020 and commissioned in September 2021. We have already supported ENGIE Lab Singapore, ENGIE Digital Agathe and GRDF in their development of custom-made solutions for air handling units or the evaluation of connected solutions for residential boilers. The tests allowed an understanding of how the various solutions to identify failure scenarios to be obtained and correlate the speed of detection with the real event.

WHAT ARE THE BENEFITS FOR ENGIE?

The predictive maintenance test bench will be a very useful tool to ensure selection and development of robust and flexible connected solutions linked to different kinds of assets (boiler rooms, auxiliary equipment, air handling units, CHPs, etc.) while targeting the different maintenance markets offered to the customers (individuals, social lords and local authorities). ■

Design the sector coupling

How can sector coupling help match production with consumption within a distribution network and unlock emissions reduction?

CONTEXT

Sector coupling means developing synergies between two separate energy sectors (e.g. electricity/gas) in order to provide greater flexibility to both coupled sectors, so that decarbonization can be achieved in a more cost-effective way. In the context of cities (traditionally negative load centers but nowadays migrating towards being prosumers thanks to local renewable-based energy generation), sector coupling can help match production with consumption within a distribution network. The wide array of combinations (storage/conversion technologies, etc.) makes sector coupling a complex multi-variable optimization problem, with the objective of minimizing design and operational costs (CAPEX/OPEX), given decarbonization targets and system-inherent boundary conditions and operational constraints.

NEWS

The question studied by our research was therefore how to design “sector coupling” (sizing of the system, coupling, controlling strategies, etc.) to develop future integrated offers. In a city/district context, we defined and evaluated different energy systems architectures and their synergies thanks to decentralized energy generation (local resources), energy conversion technologies (conversion from one vector to another) and energy storage. Several scenarios were evaluated with dedicated KPIs, both on the demand side (variation of energy intensity and energy use mix) and supply side (energy local energy community architectures with local renewable energy sources valued and pooled).

WHAT ARE THE BENEFITS FOR ENGIE?

According to our simulations, sector coupling enables the reduction of the electricity peaks and thus limits the constraints on the electricity grid. It brings flexibility thanks to the complementarity between electricity and other sectors (heat, gas). ■



HIVE wins Helsinki Energy Challenge

HIVE won award for the most effective solution to decarbonize heating networks.

CONTEXT

Helsinki is aiming to be one of the leading cities in the transition towards a sustainable future, with the goal of becoming carbon-neutral by 2035. To achieve this target, the city decided, in February 2020, to launch a competition to meet the challenge of decarbonizing its heating network by using as little biomass as possible.

NEWS

On Tuesday 16 March 2021, an international jury selected four winners, including the European team HIVE (Hyvä meaning "good" in Finnish), composed of ENGIE and its subsidiary Storengy, NEWHEAT, SAVOSOLAR, PLANENERGI and AEE INTEC. HIVE was recognized internally as well and was one of the finalist of the ENGIE Innovation Trophies 2021.

HIVE is proposing a solution for the city of Helsinki that calls for an end to burning of coal by 2028, no burning of any fossil fuels beyond 2035 and a reduction in the use of biomass by 50% of needs by 2024.

HIVE's energy plan for Helsinki, based on proven solutions, consists of a combination of seawater heat pumps, solar thermal energy, electric boilers and extensive heat storage. The mixed asset portfolio



of mature technologies further enhances the reliability of the system. The plan will reduce greenhouse gas emissions by 78%, in line with the Helsinki targets.

WHAT ARE THE BENEFITS FOR ENGIE?

HIVE is a proven methodology developed by a multidisciplinary and multi-BU team, accompanied by solid internal and external partners, around an innovative master plan, sharing several proven internal digital tools. HIVE provides ENGIE Business Units with a proven and replicable methodology, based

on the best-in-class expertise and state-of-the-art tools to decarbonize large DHC infrastructure.

The Helsinki Energy Challenge has given wide visibility to HIVE and a further competitive edge to ENGIE on the market of heat and cold decarbonization. HIVE has therefore built the bases of a model that is aligned with the market, European and international policies and ENGIE's strategy on decarbonization. It is replicable, flexible and contributes to the growth expected by our Group. ■

Field test of a new concept of a hybrid product for the commercial market

CONTEXT

The place of gas is challenged in the new and retrofit commercial market because of requirements by the new 2020 thermal regulation and the efficiency of alternative products such as electrical heat pumps. A hybrid product, a combination of a gas and electrical system using renewable energy, is an interesting solution. ENGIE Lab CRIGEN has identified the first hybrid product combining an electrical heat pump and a gas engine heat pump. This specificity of the product developed by Panasonic is to use the same refrigerant circuit for the electrical and gas heat pumps. ENGIE Lab CRIGEN has decided to test this new concept.

NEWS

The field test were launched in 2021. It is located in Roissy-en-Brie, closed to Paris,

in a large pharmacy (4000 m²). This setup is composed of two Panasonic gas engine heat pumps (71 kW cooling; 80 kW heating) and the new Panasonic hybrid concept. ENGIE Lab CRIGEN will monitor the data and analyze the results for two years. The goal is to decide if, at the end of the field test, this product can be promoted by a Business Unit. The first results have allowed the control system of the hybrid concept to be optimized. A first assessment will be carried out at the end of the winter season.

WHAT ARE THE BENEFITS FOR ENGIE?

Different studies show that full electrification is not reasonable because of electricity peaks and possible blackout. The Panasonic hybrid concept is the first hybrid system available for the commercial market. The benefit for ENGIE is an opportunity for the GBU Networks to secure gas connections. ■



ENGIE Lab CRIGEN supports the Group in the decarbonization of residential and tertiary buildings through forward-looking scenarios up to 2050

CONTEXT

The operation of existing buildings around the world accounts for 30% of global energy consumption and 39% of greenhouse gas emissions [IAE]. The reduction of this consumption and of greenhouse gas emissions is a global challenge in which ENGIE plays an important role as a leader in technologies for the energy and environmental transition. Through its various entities, the Group aims to reduce greenhouse gas emissions of its clients over the long-term in an increasingly favorable regulatory context (European Union Directives, the French «Energy Policy Guidelines» law and the 2021 climate resilience law). To achieve the objectives set by the public authorities and to propose scenarios that are consistent with our activities, the BU France BtoC, GRDF and the other entities of the Group rely on the expertise of the Lab to achieve the best possible results in the building sector.

NEWS

ENGIE Lab CRIGEN has for several years been developing expertise in the roadmap for zero carbon buildings and expertise encoded in a tool that has evolved over time. ENGIE Lab CRIGEN has in-depth knowledge of the buildings in France in the residential and tertiary sectors. From this database, the Lab has developed renovation scenarios that are best suited to reduce energy consumption and greenhouse gas emissions while keeping financial indicators under control.

To support the environmental transition of the residential and tertiary building sector in France, the Lab is developing an extension of the tool to build a forward-looking vision (2050). This work will allow the Group to position itself in the discussions with the public authorities on the future scenarios provided for in the PPE (multiannual energy plans in France) and the SNBC (National Low Carbon Strategy in France).

WHAT ARE THE BENEFITS FOR ENGIE?

This work provides the Group with information on building renovation strategies that make it possible to reduce energy consumption and greenhouse gas emissions by integrating an economic dimension into the project. In a forward-looking approach, it also enables us to define a roadmap for the future in which ENGIE will play a major role in the decarbonization of energy carriers through the integration of new gases. This approach enables ENGIE to position its offers on national markets, but also allows it to be one of the few expert companies and thus play a major role in public discussions on the subject. ■



Impact of building Demand-Side Management (DSM) on the electrical production

CONTEXT

Demand-Side Management (DSM) encompasses all the actions that modify building load in order to optimize the energy system, from production to consumption. Transient renewable production is growing, while electricity is expected to play an even more important role for building space-heating. Electricity production is sized on the maximum expected energy demand which, in Western Europe, occurs in winter and therefore space-heating plays a crucial role in this sizing. The electricity production that can match peak-demand is mainly carbon-intensive means, while fatal renewables are left running as much as possible. Knowing the type of production units that adapt to DSM events, especially in winter, is key in optimizing such events, especially in the context of hybridization of electricity and gas where local utilization of gas may be less decarbonized than the electrical production units that could adjust their output.

NEWS

ENGIE Lab CRIGEN and La Rochelle University have developed a model that



provides the types of production units that adapt their production to DSM events, from reductions of 30 minutes to 1 week. This model is a breakthrough because, being based on data calibration, it is lightweight, but at the same time it encompasses key physical constraints such as the conservation of hydroelectrical units, and it sources the imported/exported electricity to the countries that are actually affected by DSM events.

This model will be typically used to optimize

the behavior of hybrid systems in order to ensure that gas back-up is activated when its carbon emissions are lower than those of the electrical mix required for keeping the electrical heat pump running.

WHAT ARE THE BENEFITS FOR ENGIE?

Such work shows the relevance of combining gas and electricity in end-uses. Short-term advantages of such integration clearly include the CO₂ emission as long as this remains carbonized electrical production units, and it provides key elements on the role of gas infrastructures in the decarbonization pathway. As green gases are replacing natural gas, this limited resource will have to be optimized and hybrid systems are expected to play a key role as they avoid the oversizing of the electrical production and transmission systems while relying on local gas infrastructures to use green gas for peak demand, mostly in winter. This model is expected to help support and optimize the regulation of hybrid systems, but also all kinds of Demand-Side Management strategies. ■

LIGHTING & URBAN SOLUTIONS LAB

ENGIE Laborelec

Learning more about the impact of public lighting on biodiversity

ENGIE Laborelec is engaging in a comprehensive research program to investigate the impact of public lighting on biodiversity, taking bat activity as a reference. Measurements carried out in 2021 near Paris and Brussels provide food for thought about further research. Artificial lighting has a negative impact on nocturnal animal activity, which represents around 70% of all fauna activity. But current knowledge about the impact of various types of lighting is still limited. That's why ENGIE Laborelec's lighting competence center is engaging in a comprehensive measurement program to learn more about it. The research focuses on quantifying the presence of various species of bats in relation to the characteristics of the artificial lighting found in their habitats.

Bats are particularly appropriate for this type of research because the diversity of bat species is a good indicator of an area's biodiversity, including the presence of a variety of insects and the possibilities for nocturnal hunters such as owls and hawks to find prey.

PIONEERING MEASUREMENT CAMPAIGNS IN PARIS AND BRUSSELS

In 2021, ENGIE Laborelec carried out major measurement campaigns in suburban areas of Paris and Brussels. In both campaigns, ultrasonic detection was used, with geolocation, to record the signals emitted by bats. The recordings were subsequently analyzed to identify which types of bats were present at which locations. ENGIE Laborelec's car-mounted DYLA dynamic lighting assessment system was also used to measure the characteristics of the street lighting in the areas concerned, picking up every aspect of the lighting infrastructure, including location and height of each individual light point, the type of lamp, street-level light quality, and light coverage and intensity. These data were

then supplemented with spectrometric measurements to allow short wavelength light impact to be measured compared to other spectra.

IMPROVING PUBLIC LIGHTING IN THE INTEREST OF BIODIVERSITY

The work was presented in October at the international Lightfair conference as well as at other forums. *"The campaigns provided valuable insight into the lighting parameters impacting bat populations, and therefore impacting biodiversity too,"* says ENGIE Laborelec expert Agathe Pharel. *"In 2022, we're carrying out further analysis and working with international lighting and biodiversity experts to finetune our methodology."*

"We're also advising Brussels communes on how they could improve their public lighting infrastructure in the interests of biodiversity." A pilot project called 'bat light district' is already ongoing in the commune of Jette. ■



GREEN MOBILITY LAB

ENGIE Laborelec



Smart EV charging, a vision which becomes true

ENGIE Laborelec's SMATCH smart EV charging solution was a decisive element in the attribution of the concession by the city of Rotterdam towards Equans as well as for several B2B customers for ENGIE.

If in the past most of the customers required only to install few chargers with basic need of recharge, currently the needs are evolving towards a more complex energy management, which respects the local constraints (power limitations on the site, consumption of the building, renewable productions) while lowering down the cost of the energy for the recharge.

SUPPORTING THE BALANCE OF THE ELECTRICITY GRID

SMATCH smart charging optimizes the charging of electric vehicles, not only in function of the local energy constraints but also of the energy price and of the needs of energy operators (DSOs, TSOs), while respecting charging priorities and driver expectations. The platform has already proved its value at numerous business sites helping site managers to accomplish the need of recharge of the employees while respecting the power constraints of their sites. Now, the solution is going beyond. In 2021, ENGIE Laborelec helped EQUANS to win the concession to develop and operate a new network of public charging stations in Rotterdam and the surrounding region. A decisive factor in the selection of EQUANS was the fact that ENGIE Laborelec's SMATCH was shown as a possible solution to carefully balance demand across the network via the optimization of EVs recharge, meeting the distribution grid operator's requirements. A year earlier, ENGIE Laborelec had already demonstrated the solution's viability in a pilot setup in Rotterdam. In four months of operating a network of 58 connections (29 stations), 21% peak shaving was achieved, shifting 15% of the power consumption to less loaded time periods without impacting service to EV drivers.

BOOSTING PERFORMANCE AND FINETUNING SERVICE

"The more Renewables in the system the more flexibility we can store in EV batteries, and viceversa" - SMATCH business developer, Tommaso Difonzo, underlines importance of SMART Charging for both the mobility and energy markets - "Our mission is to put EV and the EV driver at the center of a bigger interconnected ecosystem which facilitates the spread of renewables and reduces the need for grid reinforcements, improving the sustainability and energy efficiency of the system." ■

ENERGY STORAGE LAB

ENGIE Laborelec

A comprehensive solution to maximize renewable power self-consumption

ENGIE Laborelec have deployed their reputed energy management system (EMS) to help port service provider Luik Natie maximize self-consumption of onsite renewable power production.

Luik Natie offers warehousing and related transport services on the left bank of the Scheldt in the port of Antwerp. Their facilities include a sizeable cold storage warehouse which, by its nature, is somewhat energy intensive. In pursuit of carbon neutrality in the medium to long term, Luik Natie called in ENGIE to equip their site with an appropriately sized PV installation and additional equipment, to permit maximum self-consumption of the renewable energy generated. Part of the challenge was to include in the equation the renewable energy produced by a 3-MW wind turbine installed at the site a few years ago.

DESIGNING THE PV INSTALLATION AND CHOOSING THE BEST STORAGE SOLUTION

ENGIE installed 1.2 MWp of PV capacity, deploying 3,800 solar panels on 6,000-m² of roof and called in ENGIE Laborelec to provide the EMS and develop a proposal for a power storage unit and how it would be integrated and connected at the site. Several battery storage solutions were benchmarked, evaluating criteria such as performance, safety, and ease of integration, before a 1.2-MWh (650 kW) lithium-ion Tesla Megapack battery, which can be charged to full capacity within two hours, was proposed.

REDUCING DEPENDENCE ON POWER FROM THE GRID

"Most importantly, we deployed our EMS, which we tuned to the situation to prioritize consumption of locally produced renewable energy from solar and wind, and store as much excess renewable energy as possible in the battery," says ENGIE Laborelec expert Matthijs Doclo. The project was commissioned successfully in September 2021, and ENGIE Laborelec is currently evaluating the first few months of operation as it continues to monitor battery performance and health. "We also envisage further fine-tuning the EMS algorithm to optimize peak shaving, using statistical forecasting to assess the expected power consumption, weather forecasting one day ahead to assess PV yield, and smart EV charging to help balance load," Doclo continues. "This means Luik Natie can significantly reduce their dependence on power from the grid." ■



ENGIE LAB CYLERGIE



Speeding up projects on heat pumps

CONTEXT

Heat pump integration plays a major role in achieving reduction of greenhouse gas emissions (GHC) and improving energy efficiency, the main levers towards carbon neutral transition in line with ENGIE's objectives. Heat pumps can upgrade low grade waste heat or from a renewable source to higher temperature levels, which is useful for heating systems in buildings, district networks or in industrial processes.

NEWS

In 2021, ENGIE Lab Cylergie started the development of new functionalities for the Cooling Plant tool so that it now includes the simulation of heating production plants using heat pumps. In parallel, to support the progressive expansion of heat pump projects and to increase know-how on the deployment of these technologies, ENGIE Lab Cylergie performed a review of heat pumps in operation within ENGIE. Several case studies were chosen to present the different heat pumps technologies, their application in industry and in district

heating along with an analysis of operating data and performance.

Furthermore, ENGIE Lab Cylergie is developing a Heat Pump Preselection tool, an MVP version, for decision-makers to compare the various available technologies on heat pump markets and to preselect a solution which best meets the needs of the client. This tool is needed to address the barriers of heat pump uptake: the complexity of integration, the low awareness of integration points, the different heat pump technologies, the suitability of heat pump technology and the economic potential compared to gas boilers. The tool uses "Heat integration" methodologies to optimally integrate heat pumps in industrial processes. In addition, the tool has a holistic guide with technical details and insights for technology selection (refrigerant, type of compressor) based on environmental, technical, safety and performance criteria.

ENGIE Lab Cylergie is participating in a new project, in collaboration with ENGIE Solutions BIL, Marketing and Operational Departments, that aims at standardizing a thermodynamic heating production offer to meet the potential growth of heat pump market for residential, commercial and tertiary sectors. It targets air to water heat

pumps as a solution to provide heating and hot water for the aforementioned sectors.

WHAT ARE THE BENEFITS FOR ENGIE?

The expertise and tools developed on heat pumps allow ENGIE Lab Cylergie to be engaged in building innovation and in the deployment of higher value-added heat pump offers in DHC, the industrial sector and in residential or tertiary sectors in order to accelerate the transition to zero carbon. ■

Prevent industrial risk of biomass combustion: dioxin emissions

CONTEXT

Biomass is the leading source of renewable energy in France and is the main resource in terms of energy conversion for heat production. Within the framework of the thermal energy fund, for example, 70% of the energy production systems financed are biomass. However, in order to avoid increasing the pressure on forest resources and to avoid destabilizing other uses of wood, this expansion is based mainly on the use of by-products or even waste wood. These products contain varying amounts of additives or pollutants that can lead to changes in the composition of flue gas and ash.

NEWS

Through feedback on a few rare industrial cases at ENGIE, or during laboratory tests conducted by LERMAB, dioxin emissions exceeding regulatory thresholds have been identified. During tests in a pilot boiler, it became clear that dioxin emissions could occur even with the use of very good quality wood if the boiler had previously been operated with contaminated fuels. It seems that dioxins can be stored in the boiler or that the presence of certain pollutants in the deposited ashes can generate dioxins.

In order to carry out further investigations, ENGIE R&I has decided to participate to the support of a research project, called APEDIOX, partially funded by ADEME. This project started in 2021 will end in 2023 with practical deliverables dedicated to biomass plant operators.

This project aims to improve the overall operation of biomass boilers in order to further reduce environmental impacts, both in terms of gas emissions and ash quality. Thus, the main objectives and expected results are as follows:

- Characterize dioxin formation-destruction zones and the quality of deposits and ash in the facilities;
- Evaluate the impact of operating conditions (stoppages, ignition, cleaning, etc.) on emissions and ash characteristics;
- Propose primary solutions to reduce emissions (dioxins, but also other pollutants such as unburned or NOx, for example) and to obtain recoverable ashes more easily;
- Determine and reduce the overall environmental impact of the facilities in terms of dioxins, both in the immediate field and in the ash.

The results will be valorized scientifically through publications, but also at the technical level through articles in specialized journals and participation in conferences. The aim is to gain a better understanding of the characteristics of ash at different levels, but also to propose technical solutions to reduce emissions and facilitate the recovery of the ash.

WHAT ARE THE BENEFITS FOR ENGIE?

The research partner of the project is LERMAB laboratory. ENGIE Lab Cylergie is the project coordinator.

Within ENGIE, ENGIE Lab Cylergie is working on this project with the agencies of the Energy Solutions Business Units that operate the biomass boiler plants. For technical support, we also consult the Performance Department. Regarding the characteristics of the wood, we work with our subsidiary SOVEN.

Semi-continuous dioxin measurements are subcontracted to the companies ENVEA and TECORA which work with the laboratory KaliAir. The analysis of ash and chlorine content in the biomass is performed by SOCOR Analyse Environmental (Cofrac accreditation). The analysis of the environmental impact via lichens is carried out by the company Air Lichens (lichen sampling standard NF X 43-904). ■



BM Conso: application of Artificial Intelligence in an essential task of business

CONTEXT

District Heating Networks are identified by ENGIE, especially through the activities and the objectives of GBU Energy Solutions, as a major solution for reducing greenhouse gases and in the transition to carbon neutrality. Indeed, DHN play a key role in integrating and pooling the resources of the various available energy sources such as fossil energy and renewables.

NEWS

Biomass is one of the most important renewable energies on heating networks. For example, in France, we operate 350 biomass sites spread throughout the country. Contrary to gas, or electricity, for a biomass plant the fuel is not a stream available on a dedicated network: a biomass boiler transform wood storage into heating energy. And this storage needs to be finely managed.

When the volume available for biomass storage is limited, it is necessary for logistical reasons to anticipate orders. The stock manager must order just the right amount of wood (especially before weekends). Some suppliers have supply time of 7 to 10 days, thus, it is necessary to anticipate heating requirements, and the related wood consumption, to reduce and avoid two main risks:

- Over-estimation of wood needs, in this case it is usually possible to cancel an order at the last moment (with penalties);
- Under-estimation of wood needs, in this case it is impossible to add an additional delivery (= a truck) at the last minute, the stock would be insufficient to cover the heating needs, which can lead to the shortage of wood stock.

The current procedure for forecasting deliveries is as follows: the manager makes a mid-week pre-order for the following week. To do this, he evaluates the energy production of the installation for the next 10 days, calculates the quantities of fuel needed and a delivery schedule, according to several parameters: expected outside temperature, stock level, already scheduled deliveries, average density and Lower Heating Value (LHV) of biomass, capacity of the site to accommodate trucks and so on. The manager usually takes a margin, even if it means cancelling orders the following days (trying to anticipate as much as possible...).

The most crucial point of this procedure is therefore the forecasting of biomass consumption. As previously explained, the difficulty in predicting can cause an under-estimation of wood needs, and a shortage of wood stock.

WHAT ARE THE BENEFITS FOR ENGIE?

In this case, operators prefer to avoid the complete shutdown of the biomass



boilers because their restart is sometimes laborious. So, the power of biomass boilers is restricted during the weekend, sometimes with a margin, and the remaining heating needs are generally provided by gas boilers. This control strategy can reduce the renewable energy coverage rate of the installation (and consequently increase CO₂ emissions).

The most crucial point of this procedure is therefore the forecasting of biomass consumption.

Combined with Artificial Intelligence Algorithm, BM Conso is a "predictive" decision-making tool for the substantial improvement of wood deliveries to biomass boilers. This computerized tool for managing the storage of biomass wood will make it possible to predict the needs per farm. In addition, its objectives are to propose to the manager of an installation equipped with at least one biomass boiler:

- A forecast of the plant's heating consumption for the next 10 days - calculated thanks to algorithms developed in collaboration with ENGIE Lab CRIGEN's Computer Science & AI Lab;

- A corresponding delivery schedule;
- A simple way to determine an optimal load rate of the biomass boiler for critical periods.

This tool is currently in deployment on pioneering sites in order to validate its performance.

Wood storage is actually energy storage, thus we expect that the approach can be reproduced for all sites with other kinds of energy storage. ■

ENGIE Lab Cylergie Services: a useful complement for research programs

CONTEXT

ENGIE Lab Cylergie Services team was created and developed to perform different functions:

- _ Provide operational support for the research program, both in the laboratory and on site (e.g. on the ENVERID technology assessment project);
- _ Maintain the budgetary balance of the GIE;
- _ Test innovative products or services developed by the research team, on a real site. The test sometimes includes the commercial aspects: we can evaluate the market value of the innovation, then correct, promote or abandon the solution.

NEWS

As an example, the “Healthy Building” offer was rapidly developed in 2020 in response to the Covid19 crisis, at the request of ENGIE Solutions and in collaboration with the Marketing Department. The offer was based on 3 innovative components: measuring, simulating, treating risk. Despite much communication, the offer did not spread quickly through ENGIE Solutions' branches.

However, ENGIE Lab Cylergie itself supported this offer in 2021 and could draw interesting conclusions.

64 requests have been directly reported to ENGIE Lab Cylergie who rolled out the offer in this way:

- _ 17 Technical support missions for the implementation of about 400 CO₂ sensors;
- _ 5 STD models of heating consumption for Energy contract management (middle & secondary schools);
- _ 25 consolidated sales of an Air Purifier and 9 studies of implementation of New ELENA;
- _ CFD Modeling for 3 prestigious sites.

This last item must be highlighted. In 2020, through its research Program, ENGIE Lab Cylergie had chosen and tested partners who could simulate through new CFD Environments the transport of

particles suspected of carrying the SarsCov2 virus. Research work also focused on the speed of modeling spaces. On this point the mesh technology of *Simulia 3DS* was clearly approved. In 2021, the innovative CFD solution supported by Dassault System resulted in significant orders for major sites operated by ENGIE Solutions: Paris Opera and European Parliament. In both cases, Dassault worked on the modeling of the sites and on the production of comprehensive videos. ENGIE Lab Cylergie sent the data from assessments, interpreted the modelling outputs, experimentally validated the models (in the case of the European Parliament), presented the modelling as proposals for work or change of conduct.

WHAT ARE THE BENEFITS FOR ENGIE?

These results only take into account ENGIE Lab Cylergie's direct work. The level of application in ENGIE Solutions probably exceeds these figures.

The installation and management of air cleaners does not correspond to the perception of added-value of ENGIE by our clients. Integrated metrology offerings make sense for agencies and their clients.

Nevertheless, it was shown that the added value of ENGIE solutions is clearly based on simulation and modelling, particularly the impact of health recommendations on heating consumption.

It has been shown that some customers can place orders for significant CFD modelling studies (100 k€) and that significant work can result from modeling.

When this research project was finished relayed by ENGIE Lab Cylergie Services, it was proven that the future of HVAC professions will integrate CFD.

ENGIE Lab Cylergie's model, research projects established due to operational and commercial needs with declared sponsors, projects possibly relayed by the business support activity, is exactly in line with the purpose of R&I. ■



CFD modeling of European parliament showing correct extraction of potential pollution in auditorium with lower performances in balconies.

ENGIE LAB CYLERGIE

A research program covering TRL 5 up to commercial solutions

CONTEXT

The Air Quality lab's production in 2021, funded by ENGIE R&I since 2018, was high. The advances are based on skills that have been in place for several years and on the dynamics created on health topics. This translates into diverse production, from prospective topics to on-site applications.

NEWS

The in-depth evaluation of an American technology, identified by ENGIE New Venture, was carried out. This technology is an innovative air treatment system that limits energy consumption while guaranteeing excellent air quality. It operates by treating air by adsorption (recirculation) instead of providing outside air, which is energy intensive to heat/refresh. This evaluation consisted in a two years study: a theoretical analysis in 2020 and a laboratory test in 2021. One of the objectives was to understand whether or not to rely on this technology for energy

efficiency. The conclusions of this test are mixed, except in special cases, an air handling unit equipped with an energy recovery unit on extracted air is preferable, for air quality and energy savings.

General evaluations of other alternative air treatment technologies (photocatalysis, ionization, ozonation, etc.) have been carried out with one objective: to summarize the results so that operational staff can have a clearer view and answer their customers' questions about air cleaners. Indeed, the questions on this subject were numerous and required a structured answer at a group level.

Several research topics have led to the creation of professional services carried out by "ENGIE Lab Cylergie Services" in 2021. The objective is to test the possibility of commercial deployment of the most technically accomplished issues. This is the case for microbiological air quality measurements by ATPmetry and CFD studies for operations (modeling of air flows in the

building). An ATP measurement service was carried out in a shopping center in the Paris region and a CFD study was carried out for the European Parliament in Strasbourg.

WHAT ARE THE BENEFITS FOR ENGIE?

The optimization of existing air treatment systems in buildings is a key topic for ENGIE Lab Cylergie. After amphitheaters, swimming pools and clean rooms, in 2021, a regulation solution adaptable to any type of building and able to integrate all available parameters (analog, digital, wireless sensors, data from the internet etc.) has been developed. This is a first step towards the decarbonized AHU under study in 2022. ■



Nathalie Roussel,
ENGIE Lab Cylergie



RENEWABLES

GBU



Jaideep Sandhu,
Head of Technology
Renewables

“ The Global Business Unit Renewables has set itself growth targets of achieving an installed capacity of 50GW by end 2025 and 80GW by end 2030. Furthermore, there is a strong focus to improve operational performance maximising value creation from the assets while ensuring top priority to health and safety. The early adoption of innovative technologies and business models, digitalisation, new methods and practices in plant O&M, and risk management are integral to the achievement of the targets of the GBU Renewables. The ENGIE Research & Innovation team and its R&D centers are our partners in this exciting journey of rapid growth and acceleration in performance optimisation.





SOLAR LAB

ENGIE Laborelec

Scaling up pioneering Agri-PV initiatives

ENGIE Laborelec is conducting research on scaling up pioneering initiatives for Agri-PV, solutions combining cultivation or pasture with photovoltaic production on the same piece of land.

The Agri-PV concept is gaining traction because it holds out the promise of using scarce land for two good causes at the same time: contributing to food security in times of climate change while producing power from renewables for the energy transition. Multiple Agri-PV techniques have been developed over the past few years, including using semi-translucent PV panels as cover for sensitive crops, and bifacial PV panels installed vertically in fields of crops or grazing animals.

OUTLINING A BUSINESS CASE FOR AGRI-PV WITH SEMI-TRANSLUCENT PANELS

ENGIE Laborelec is participating in research projects and pilot installations to investigate whether the solutions can be rolled out on an industrial scale. Near Eindhoven in the Netherlands, for example, the company is monitoring a farm where raspberries and strawberries are grown beneath non-

traditional PV panels that let a portion of the light pass through. Most raspberries and strawberries are cultivated under semi-translucent plastic covers to protect against hail, heavy rainfall, and excess sunlight. Replacing these covers with semi-translucent PV panels has the dual advantage of avoiding plastic waste and producing green energy.

In 2021, KU Leuven's Crop Biotechnics department took samples of the soft fruit grown in Eindhoven to analyze nutritional quality. ENGIE Laborelec Agri-PV expert James Macdonald is enthusiastic about the opportunities: *"We'll be combining the crop yield and quality assessment with our PV energy monitoring data to put together a business case for scaling up this kind of Agri-PV solution in the Benelux and other markets."*

PERFORMANCE AND IMPACT OF VERTICAL PV PANELS ON GRAZING LAND

The Camelia demonstrator plant in Laqueuille, in the Auvergne region, is one of several Agri-PV projects in France benefiting from ENGIE Laborelec's involvement. This ENGIE 100-kW pilot facility is equipped with bifacial PV panels installed vertically in a field where grazing cows work their magic: converting the local mix of grasses into dairy products.

The agronomic effects of this configuration



on aerial and underground microclimates and grass biomass growth are being monitored, along with the effects on soil fertility and carbon stocks. ENGIE Laborelec is also carefully evaluating the electricity production profile of this kind of non-standard open-field PV format, where panels are daily exposed to sunlight during two distinct time periods. ■



Sustainable albedo boosting for bifacial PV panels

ENGIE Laborelec is working with Chilean cement producer Cbb on a highly reflective lime-based substrate that can be applied to the ground beneath bifacial PV panels making use of the albedo effect to boost yield. The initial results are very promising.

Bifacial solar cells have been around for special applications since the 1970s, but they entered the mainstream in large PV plants only in the past few years. Since they were introduced, operators have been on the lookout to maximize yield from the panels' undersides, to take advantage of reflected direct and diffuse sunlight, and many solutions have been proposed.

EXISTING ALBEDO SOLUTIONS HAVE DOWNSIDES

ENGIE Laborelec tested several possibilities. Mixtures of salt and seashells gave an albedo factor, the ratio of incidental sunlight reflected by a surface, of up to 50%, while applying plastic film raised it to 60%. But these solutions tend to degrade quite quickly and lose their effect. Plastic film is also difficult to apply beneath existing installations and comes with an undesirable environmental footprint.

A CLEAN AND EASY TO APPLY MIX BOOSTS YIELD BY 15%

That's why ENGIE Laborelec has been working on a better and more sustainable solution, in collaboration with a Chilean cement producer. Cbb developed an environmentally safe lime-based liquid mix that can be applied very easily using a mobile pumping unit, producing a 2 to 3-cm substrate that needs just a day or two to dry. The solution was gradually perfected and validated through testing at ENGIE's El Aguila solar farm in northern Chile.

"With the final product, we were measuring albedo values as high as 70%, even after several weeks' exposure to the weather," according to ENGIE Laborelec expert Franco Clandestino. *"In an ideal case, this lime based substrate can boost a bifacial PV installation's yield by more than 10%."* ■

Successful recovery of PID-affected PV installations with a rapid ROI

Potential induced degradation, or PID, continues to impose a serious threat to the performance of every generation of PV plants. ENGIE Laborelec achieves impressive results with PID mitigation solutions tuned to the plant configuration.

PID can occur within weeks or even days of commissioning, with modules gradually losing up to 80% of their power generation capacity. What's more, latest generation modules designated as PID-free are still susceptible to the phenomenon, to the surprise of manufacturers. That's why ENGIE Laborelec continues to refine and improve its PID detection and remediation service. Visual inspection and measurement. We typically identify PID through a combination of visual inspection (looking for indicators of moisture ingress such as browning of the EVA in the cell centers, and back sheet cracking or chalking), and measurement (drone-assisted IR detection, IV-curve quantification, and operating data analysis). It's extremely important to detect

the problem at an early stage, or the degradation could become too extensive to completely recover from. Nevertheless, we achieved impressive recovery rates at a number of severely affected PV plants in 2021.

30% YIELD IMPROVEMENT

At a Compagnie National du Rhône 7 MW PV dual site installation in France, we found that a significant number of the modules suffered from severe PID. We applied a turnkey PID mitigation solution based on night-time float voltage control. ENGIE Laborelec expert Andreas Wabbes was delighted with the impressive results: *"We were able to achieve a 30% yield improvement on the affected modules, recovering them to more than 90% of their initial capacity for a return on investment in just 10 to 15 months."*

NO BACKING AWAY FROM COMPLEX CONFIGURATIONS

And we don't back away from the more complex situations. We successfully addressed PID degradation at an ENGIE



Green 10 MW PV plant in the Haute-Loire region of France. Because the system is symmetrically earthed, we had to devise a special solution where we deactivated the earthing at sunset and ran the PID recovery only during the night. It proved very successful, and we'll be implementing the same solution at four more plants. Meanwhile, we're participating in research projects to develop tools for PID monitoring exclusively based on PV operating data. ■

More reliable PV plant performance assessment

ENGIE Laborelec's PV HealthScan is a gamechanger for assessing and remediating underperformance in large PV installations. In 2021, our scan base has grown to 30 sites, representing more than 700 MWp.

The traditional way of assessing how well a PV installation performs is to calculate a performance ratio (PR) based on the plant's design parameters, and extrapolating irradiation data and PV yield from a representative time period. However, the method is not fully reliable because environmental parameters such as irradiation, temperature, soiling, and shadowing are highly uncertain, and the design parameters are not always well known. More importantly, it also fails to provide insight into when and where issues occur.

IDENTIFYING UNDERPERFORMANCE AT SUBSYSTEM LEVEL

That's why ENGIE Laborelec is pioneering a new way of addressing the problem using a patented innovative approach. This involves a statistical analysis of power output data from every individual inverter or subsystem over a given period. Assuming all the subsystems in the same plant are subject to identical meteorological conditions, an inverter's relative output compared to other inverters in the plant is an indicator of its performance.

Our algorithm first normalizes the data, then defines a virtual well-performing subsystem for each timestamp, and offsets each subsystem's performance against this reference. This results in a heatmap, highlighting underperforming subsystems in orange (> 2% lower output than the reference) or red (> 5% lower output).

BENCHMARKING PV PLANTS AGAINST EACH OTHER

Based on this analysis, we compile a health score spider chart, which indicates the plant's relative performance with respect to major and minor events, time between failures, health recovery time, downtimes, and production deviation. This allows PV fleet owners to quantify production losses, assess plant market value, prioritize maintenance, and provide valuable



return of experience when developing new assets. The benchmarking exercise will become an even more powerful tool over time as our database of audited plants grows.

REVEALING THE CAUSES OF UNDERPERFORMANCE

Interestingly, the heatmaps clearly indicate when and where problems occur, which allows us to carry out further analysis to reveal the causes of underperformance whether shading or soiling losses, tracker faults, DC side faults, issues with the inverter fan, earthing, cabling, or PID.

ENGIE Laborelec expert Quentin Van Nieuwenhoven confirms: *"The HealthScan method is not only more reliable than traditional methods, it also provides an excellent starting point to further investigate and ultimately remediate performance issues."* ■



Viability of robotized PV cleaning demonstrated

ENGIE Laborelec's highly efficient robotized PV cleaning solution is a game-changer for regular cleaning of single-axis tracking modules. Last year, its value was demonstrated in a semi-autonomous setting at the Trompezón plant in Mexico.

Panel soiling issues at PV plants have prompted operators to instigate cleaning programmes, mostly involving tractors with big brushes working along the rows of panels. While tractors can do a cleaning job quite quickly, they are extremely expensive. Most plants have only a couple of them available, because buying an extra one would require too much capital expenditure. Tractors manoeuvring also risks damaging PV modules, especially on rough terrain. And the abundant use of diesel fuel and water significantly increases the plant's carbon footprint.

SOLAR-POWERED DRY-CLEANING ROBOTS TRAVELLING ACROSS THE TRACKERS

ENGIE Laborelec's solution is much more flexible, safe, and sustainable. It uses robots travelling across the single-axis tracking modules, cleaning with dry brushes approved by PV panel manufacturers. Cleaning can take place with the panels in almost any position.

The electric robots are powered by solar energy, and the absence of water not only reduces the environmental footprint, but also eliminates the risk of inducing thermal shock on the modules.

Mounting and operating the robots is easy and can be learned quickly. As a result, in most cases cleaning can take place more frequently, which is essential because research indicates that yield diminishes significantly with just two or three weeks' exposure to dust or rain.

LARGELY OUTPERFORMING TRADITIONAL SOLUTIONS

In 2021, the solution was applied for the first time in a semi-automatic setting at the 158.6-MWp Trompezón PV plant in Aguascalientes, Mexico. A set of eight robots were deployed, allowing several trackers to be cleaned simultaneously. Work was organized in such a way that a team of operators could keep the cleaning going, unmounting a robot finishing its job on one tracker, and moving it to the next.

"We managed to have each robot clean 22.9 trackers per day on average," says ENGIE Laborelec expert Franco Clandestino. "This means that the robotic solution can be a viable, safe, and sustainable alternative to tractors, especially considering the much lower up-front cost." ■

WIND, HYDRO & MARINE LAB

ENGIE Laborelec



Orchestrating airborne wind energy, PV, and battery storage to maximize self-consumption

ENGIE Laborelec is participating in the Aquilon project at a Storengy gas storage facility in Germany. The project deploys innovative airborne wind energy technology, a PV installation, a redox-flow battery, and an energy management system, to significantly reduce the facility's carbon footprint.

As the gas storage market leader, Storengy develops and operates a comprehensive network of facilities across Europe. In line with ENGIE's long-term commitment to net zero, their Peckensen natural gas storage facility in Germany recently launched a project to decarbonize its operations.

The Aquilon project deploys an annual production capacity of 1-GWh renewable energy, power storage using a 420-kW redox-flow battery, and a carefully tuned energy management system to maximize self-consumption. The project receives €2 million in funding from the European Union Innovation Fund's small-scale project programme.

AIRBORNE WIND ENERGY, AN EXCITING INNOVATION

Aquilon's eyecatcher is undoubtedly the deployment of a SkySails airborne wind energy (AWE) solution, a technology that uses a giant kite to harvest wind energy at higher altitudes than wind turbines. Launched from a mast on a ground platform, the kite makes meticulously controlled yo-yo movements at altitudes between 200 and 400 metres, driving a generator inside the ground platform to produce electricity.

CO-DEVELOPER, OWNER'S ENGINEER, AND EMS SUPPLIER

Yet the use of airborne wind energy is not Aquilon's only innovation. The project's ultimate purpose is to maximize self-consumption of this power produced by renewables using a well-tuned energy management system and the system's redox-flow battery (RFB). ENGIE Laborelec is engaging its teams of wind, storage, EMS and microgrid experts in a comprehensive multidisciplinary effort. "We will in fact assume a triple role in Aquilon," explains ENGIE Laborelec expert Olivier Van Oost. "In the first place, we are a co-developer of the whole solution, committed to developing a sound business case for the project. At the subsequent deployment stage, we act as the owner's engineer, managing the tendering and purchasing process and validating the RFB and AWE converter performance. And we're also the supplier of the energy management system, which will tie the different components together." ■

EoW and first-generation turbines both merit rigorous inspection

In addition to end-of-warranty inspections, ENGIE Laborelec increasingly provides auditing services for wind turbines 10 to 15 years old. This helps owners decide whether and how they should further invest in these first-generation turbines.

Our OEM-independent end-of-warranty (EoW) wind farm inspection involves an in-depth look at the turbines' core components, including the blades, gearbox, and generator. Last year, for example, we carried out a major EoW inspection project on the 165 MW Belgian Nobelwind offshore platform, which first came into operation in 2017.

We are also increasingly called upon to carry out similar inspections at much older wind farms of the first commercially viable generation, typically consisting of 2 MW turbines. Owners want to decide which O&M strategy they should pursue for these older assets.

COLLECTING FACTS AND ARGUMENTS

We have been carrying out quite a number of such inspections lately, primarily for ENGIE. The audit involves more-or-less the same procedures as an EoW inspection, with a major focus on the gearbox and generator. However, rather than recommending a claim to the OEM, it's more about collecting facts and arguments for prolonging the wind farm's operation.

Many factors need to be considered, including the fact that receiving permission to develop a new project can easily take four years or more. ENGIE Laborelec expert Stephane Bronckers clarifies: "If we can demonstrate that these 2-MW assets could perform well for a few years more without having to invest a lot, we recommend giving them another round." ■



Smart wind turbine monitoring addresses leading-edge erosion

ENGIE Laborelec is participating in a research project aimed at developing better prevention and mitigation strategies for handling leading-edge erosion (LEE) in offshore wind turbines.

LEE is a topic of growing concern for the larger latest-generation wind turbines. The trend towards longer blades leads to much higher nominal tip speeds. Consequently, raindrops and hailstones have a much heavier impact on the blade surface, making it rougher and impacting its aerodynamic performance. Eventually, protection layers erode and expose the blade laminate. Annual repair costs can run into millions of euros for a sizeable 500-MW wind farm.

MONITORING THE POWER CURVE OVER FOUR YEARS OF OPERATION

To deal with this important issue, ENGIE Laborelec has engaged in the RAINBOW project funded by Flanders Innovation & Entrepreneurship. The project aims to acquire a deeper understanding of LEE and develop new preventive maintenance

solutions and better strategies for inspecting, monitoring, and repairing blades. Our work has focused on one wind turbine in the Rentel-Otary development off the Belgian coast. In November 2021, we installed and put a Lidar measurement system into operation on the turbine's nacelle. Measuring will continue until the project is due to close in 2024, allowing us to monitor the turbine's power curve, an indication of how its efficiency evolves over time.

ACCURATE ASSESSMENT OF LEADING-EDGE EROSION

Lidar measurements will also be used for very short-term weather forecasting two to six hours ahead, known as 'precipitation nowcasting', to gain more insight into how LEE is affected by rain, lightning, and hailstorms. In-depth analysis of these measurements will allow us to evaluate whether gradual efficiency degradation can be used as an accurate indication of ongoing LEE. We are also developing a decision-making model, allowing operators to use Lidar



measurements and analyses to decide at what point in time (or at what level of efficiency degradation) a blade maintenance or repair operation becomes economically viable. ENGIE Laborelec expert Stephane Bronckers points out the benefits: *"Our Lidar monitoring and analysis provides extremely valuable information that can be used to better protect turbines against leading-edge erosion."* ■

Accurately assessing wind distortion in complex wind farm terrains

In-depth analysis allowed ENGIE Research to challenge OEM-imposed wind sector management (WSM) on a turbine in the port of Ghent. The study sheds additional light on how to better assess the phenomenon of wind distortion in complex terrain.

In the future, wind turbines will need to be deployed on more complex terrain because the availability of simple flat landscapes is becoming scarce. Complex terrain presents higher wind flow distortions, but how does that impact production and loads? Current flow models and wind speed measurements at hub level do not adapt well to such complex landscapes.

That's why ENGIE Research (including ENGIE Laborelec) launched a program to assess the impact of industrial environments and buildings on wind farm development, focusing on the Rodenhuijs Repowering Wind Farm in the port of Ghent.

THREE COMPLEMENTARY ASSESSMENT METHODS

The Rodenhuijs development consists of three wind turbines. On one turbine, the OEM imposed 60° of WSM to avoid running the

turbine in the presumed disturbed airflow created by the presence of a cooling tower and boiler house in the immediate vicinity. We challenged this decision, demonstrating that the software used for the impact analysis tends to overestimate wind shear phenomena and thus is inappropriate for this kind of analysis. In concurring with this, the OEM was prepared to discuss other assessment methodologies. We then launched a comprehensive analysis involving the calculation of flow disturbance using computational fluid dynamics (CFD), along with Lidar and wind tunnel measurements.

CFD ANALYSIS INDICATES LESS DISTURBANCE

The CFD calculation had already indicated that the structures had a lesser impact than estimated by the OEM, which allowed us to bring the WSM back to 40°. However, the Lidar measurements were inconclusive in this respect because the disturbed flow created too much uncertainty in the measurements in the sectors concerned. Nevertheless, analysis of the measurements confirmed our hypotheses concerning undisturbed flow, because the results were coherent and in line with expectations. The wind tunnel measurements indicated lower wind shear values than those calculated using CFD, probably due to inadequate assumptions about the turbulence characteristics in the CFD model.

STEEP LEARNING CURVE

ENGIE Laborelec expert Jeroen Martens confirms to the challenge of accurately modelling and measuring such complex flows: *"We still need to learn more about this phenomenon. None of the three methods used is conclusive by itself. It will be crucial to make a qualitative analysis by cross correlating the results."*

In 2022, we will be investigating further how CFD modeling and Lidar measurement can be combined to better assess the impact of wind characteristics on production and loads. ■



Shoring up the business case for offshore floating wind farms

ENGIE Laborelec has installed permanent Lidar measurement systems on the nacelle of one of the WindFloat Atlantic turbines off the coast of Portugal. The measurements and analyses are expected to shore up the business case for floating wind turbine technology.

Fixed-bottom offshore wind turbines can only be installed in waters of moderate depth, up to 40 metres. In coastal areas with deeper sea levels, alternative solutions are deployed using floating platforms to support the wind turbines. But little is currently known about how movement in the platform due to tidal agitation affects wind turbine performance.



ENGAGING IN THE WINDFLOAT PROJECT

That's why ENGIE Laborelec is engaging in a long-term research project to assess the actual real-world performance of floating wind turbines. Last year, we installed permanent Lidar measurement systems on the nacelle of one of the 8.4-MW WindFloat Atlantic turbines installed on semi-submersible platforms off the coast of Viana do Castelo in the north of Portugal.

The platforms and turbines were prefabricated on land, assembled in Viana Do Castelo and transported 20 km from shore by conventional tugboats, and are expected to provide year-round renewable power for 60,000 people.

MAPPING POWER OUTPUT CURVES TO LIDAR MEASUREMENTS

The Lidars were configured to measure wind speed and direction 400 metres ahead of the nacelle. These data will be combined with power output data and data on the platform movements to determine the yield achieved at different wind speeds and directions.

ENGIE Laborelec expert Stephane Bronckers summarizes what this can mean for offshore wind farm operators: "We hope to make the case to OEMs that well-tuned wind turbines hardly suffer at all from being installed on floating rather than fixed -bottom platforms." ■

SMART GRIDS & INDUSTRIAL CYBER SECURITY LAB

ENGIE Laborelec

Assessing PV plant design grid code compliance

ENGIE Laborelec has developed an innovative method to assess whether PV plant design and inverters comply with the grid code, involving setting up a sophisticated test bench.

While grid code compliance in small-scale installations (up to several kW) can simply be assessed by checking the power output of a single converter, the matter is much more complicated in large-scale PV plant where hundreds of multi-MW inverters are connected. Even where inverters comply individually, compliance at the grid connection point is not guaranteed unless the entire architecture as a whole is evaluated.

INSIGHT INTO THE INVERTERS' REAL CAPABILITIES AND BEHAVIOURS

That's why ENGIE Laborelec has developed an innovative method to assess the grid code compliance of the combined output of a series of inverters of the same type. ENGIE Laborelec experts determined that the key to solving the puzzle is to acquire in-depth insight into the inverter's real capabilities beyond specification, as well as the device's control algorithms. But since large multi-MW inverters cannot be tested in a laboratory, ENGIE Laborelec experts developed an approach which involved testing small-

scale inverters to gain experience and make accurate predictions.

EXPOSING THE GRID TO MASSIVE PV POWER PRODUCTION – VIRTUALLY

The experts subsequently developed an integrated setting in which to safely test a single 50-kW inverter connected to a controllable DC source – representing PV panels, and a controllable bi-directional power source – representing the grid. The inverter can then be exposed virtually to multiple renewable power production scenarios in a variety of grid situations.

When running the scenarios, multiple measurements are constantly carried out at the virtual grid connection point to evaluate grid code compliance. The service has already been of great value to ENGIE, says ENGIE Laborelec expert Stijn Uytterhoeven: "We have been able to give solid reassurance to ENGIE engineers that their PV plant designs will not violate the local grid code."

The test bench has served other purposes too. For example, it has been used to test whether the Belgian distribution grid's capacity is sufficiently strong to withstand the rapid dynamic injection of current from a PV plant in the event of a short circuit. The conclusion was in the affirmative. ■



WIND LAB + SMART GRIDS LAB + ENERGY STORAGE LAB

ENGIE Laborelec

Energy hybridization: accelerating the commercial deployment of floating tidal energy by combining it with other renewables and power storage solutions for a stable zero-carbon baseload

ENGIE Laborelec is partnering in FORWARD2030, aiming to demonstrate the viability of a zero-carbon energy system which combines wind and tidal energy with energy storage solutions and green hydrogen production.

Running from 2021 to 2025, the FORWARD2030 project consortium has received €21.5 millions of grant support from the European Union's Horizon 2020 research and innovation programme. Its goal is to develop a multi-vector energy system for the future and demonstrate how predictable tidal energy, wind energy, energy storage technologies, and green hydrogen production can be combined in a smart way so that a reliable and stable zero-carbon baseload can be injected into the grid.

The project will also look at reducing the cost and life-cycle carbon footprint associated with offshore tidal energy, making it more environmentally sound and achieving better public acceptance, while

improving commercial return and system integration. Some of these conclusions will be extrapolated to offshore energy. ENGIE Laborelec brings to the project its expertise in combining different types of renewable energy with energy storage systems and grid integration.

PRELIMINARY INVESTIGATIONS AND ANALYSIS

The project is currently at the preliminary investigation stage, with the first challenge being to define, size and purchase the most suitable power storage solution to be installed at the project site in Orkney, Scotland (EMEC). We're gathering information on the site layout, profile, and set-up, as well as energy data on existing

tidal power production and specifications for additional wind and tidal systems.

WIDE RANGE OF SCENARIOS EVALUATED

Various scenarios can then be developed combining these renewable power generation systems with a range of power storage solutions as well as the existing redox-flow batteries and hydrogen fuel cells. "We'll be looking at the viability of combining different solutions, together with complicating factors such as ramp-up times and sensitivity to temperature fluctuations," says ENGIE Laborelec expert Fiona Buckley. "It means we'll be deploying the full potential of our inhouse expertise." ■



WIND LAB + ADVANCED MATERIALS LAB

ENGIE Laborelec



Towards 100% recyclable wind turbine blades

A consortium of six partners is developing and testing a 100% recyclable wind turbine blade. ENGIE Laborelec is participating in the project to scrutinize the blade's life cycle focusing on the recycling options.

At present, somewhere between 85% and 90% of a wind turbine can be recycled. This should reach 100% if we want wind turbines to be essential contributors to the circular economy of the future. The weak spots are the blades, which are currently made of complex composite materials based on thermosetting resins with carbon or glass fibre.

Since the resins are thermosets, they are currently difficult to recycle. This means that at the end of their life cycle the blades are treated as waste, potentially ending up in landfill.

THERMOPLASTIC INSTEAD OF THERMOSETTING COMPOSITES

In the autumn of 2020, ENGIE, Arkema, Canoe, LM Wind Power, Owens Corning, and Suez, joined promoter IRT Jules Verne in the ZEBRA (Zero Waste Blade Research) consortium to develop and test two alternative blades manufactured using thermoplastic instead of thermosetting composites.

The thermoplastic Elium® resin is used, offering the same levels of mechanical performance, light weight and resistance as the materials used previously, but with the added advantage that it can be recycled using chemical and mechanical recycling routes.

SCRUTINIZING THE PRODUCTION AND RECYCLING PROCESS

The first prototype blade was produced at the beginning of the year and the second will follow later in 2022. *"The project involves scrutinizing the manufacturing process to eliminate any production of waste along the line by not only recycling the blade material but also the waste created during production,"* says ENGIE Laborelec expert Frederic Monnaie. ■

ENVIRONMENT & SOCIETY LAB

ENGIE Lab CRIGEN

CLIMA thematic & CIRA Tool: modeling impact of climate change

CONTEXT

Since 2019, CRIGEN co-coordinates with the CSR Department a collaborative project to assess the financial impact of climate change on ENGIE's renewable assets (centralized PV, wind onshore, wind offshore, hydro) by 2030 and 2050. It involves internal and external collaboration with many experts. Internally, colleagues from many entities such as DOP, R-GBU, Tractebel France, Tractebel, ENGIE Laborelec, NECST, LATAM, ENGIE Brazil, France Renouvelables, Global Care, CNR, SHEMA provided methodological support through contribution to expert committees on each type of assets. T3A, Finance, Strategy and Insurance & Risk also provided insights.

Externally, a partnership with the Institut Pierre Simon Laplace (IPSL), a world-class research center, expert in climate modeling, who contributes to the work of the IPCC, has been set up.

In 2020, the project identified the impacts of climate change in 2030 & 2050 on the potential production of wind onshore, centralized PV and wind offshore assets. The results have been calculated at site level but

also, more generally, for any location in the world with representative turbines.

NEWS

In 2021 the work focused on:

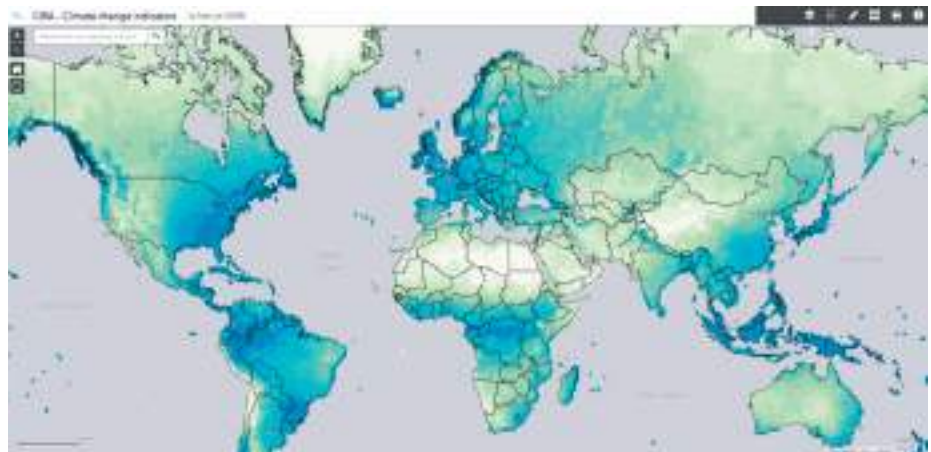
- _ Hydro assets with 102 assets from 5 countries studied;
- _ Additional studies on wind and solar assets;
- _ Deepening of our knowledge on extreme events and how they will evolve with climate change;
- _ Deepening of our knowledge on types of climatic models with a report comparing the opportunities of CMIP6/CMIP5/ CORDEX models;

- _ Providing support to operational entities (exposure to climate change for 2 BUS);
- _ Making our online cartographic tool CIRA available for the Group's operational entities (80+ people, still growing).

WHAT ARE THE BENEFITS FOR ENGIE?

The ongoing studies and CIRA tool the impact of climate change on our activities to be better understood by providing various, worldwide data. With this information, ENGIE can better anticipate its exposure to climate change. It provides complementary information for both project development and adaptation plans for existing sites. ■

Source: CIRA tool



The SharEF project: ENGIE's GHG emission factors database

CONTEXT

Several ENGIE entities are carrying out assessments on greenhouse gas emissions (GHG) for different purposes, e.g. the Groups annual environmental reporting (CSR), monitoring the GHG emission reductions of customers (ENGIE Impact, GEM), etc... It became apparent that each of these initiatives used their own set of Emission Factors (EFs). In order to ensure consistency between the different approaches and uses, a database was set, called SharEF, grouping together the official EFs used by the Group for the verification and publication of data related to GHGs.

NEWS

The creation of the EFs database is managed by the CSR Department with CRIGEN's operational support. ENGIE Impact, GEM, Strategy and others, are also working on the database principles, requirements, structure, content, availability and updates in order to meet all of the Group's needs.

SharEF includes a wide range of data sets, including EFs upstream and on the combustion of different fuels (natural gas, biomethane, hydrogen, etc.), electricity production and electricity consumption by country etc. These EFs cover different geographical areas from a macro level (global) to a micro level (specific regions and states). For example, EFs for biomethane 1G are given for 7 different countries and Europe. All EFs include various GHG: CO₂ – fossil and biogenic, CH₄ – fossil and biogenic, N₂O, SF₆ and other GHGs.

The first version of the database will be soon available in the Common Data Hub (CDH). Going forward, an API will be created for the database.

WHAT ARE THE BENEFITS FOR ENGIE?

SharEF allows the Group to have a unique database gathering EFs for the GHG accounting of many types of fuels, electricity, technologies, etc. across the value chain within different geographical area. This will guarantee consistency in EFs across the ENGIE group. ■



NANOTECHNOLOGIES, SENSORS & WIRELESS LAB

ENGIE Lab CRIGEN

BREATHE: field tests for air quality remediation

CONTEXT

According to the World Health Organization air pollution represents the main environmental health risk factor in the European Union. Air quality objectives defined in European Directives for various air pollutants are difficult to achieve by EU member countries. In fact, a majority of these countries breach one or more of these limit values. This is why there is a growing interest in short-term air depollution solutions to help cities to reach air quality goals while waiting for their preventive actions on emissions to be effective enough. ENGIE Lab CRIGEN supports ENGIE Business Units intending to provide infrastructures to depollute air in cities.

NEWS

Following the first experiment launched by ENGIE Solutions and ENGIE Lab CRIGEN at the CPCU facility in Saint-Ouen (France) (SOAT project), our 2021 works were used to prepare the experiment at Vélizy-Villacoublay (France) (assessment of two technologies inside and outside of the ATIV project). Monitoring solutions have already been installed and initial air quality data has been collected. In parallel, ENGIE Lab CRIGEN installed an air treatment solution on the premises of its R&D center in order to optimize the evaluation protocols (EPARS project). ATIV and EPARS projects will continue in 2022.

WHAT ARE THE BENEFITS FOR ENGIE?

The R&D work led by ENGIE Lab CRIGEN aims at giving the BUs tools with which to provide services in order to help local authorities comply with air quality regulatory thresholds by 2025. ENGIE Lab CRIGEN's knowledge on air quality makes ENGIE a potential advisor and reference on air quality data, a provider of cost-optimized solutions for outdoor air quality monitoring and the first provider of innovative air treatment solutions. ■



RFID-asset tracking solutions

CONTEXT

The valuation and localization of material assets is essential data for Engie. At a time when data is becoming essential for industry 4.0, building 4.0 and operator 2.0, the traceability of objects is an essential tool. From manufacturing to installation, from storage to maintenance, each step must be recorded in IT tools. For a unique link between IT and assets, an RFID tag is placed on each object or asset. Adapted to new or existing objects, the RFID technology facilitates access to information, installation and maintenance forms and stockpiles. This project was born with the aim of demonstrating to BUs the value of automatically identifying and tracing all assets.

NEWS

Three documents detail the advantages of unit identification for asset tracking and the means to integrate them into the management of industrial facilities, buildings, maintenance services or stockpiles. The KPIs for this management mode are detailed as well as the elements to be taken into account in the calculation of the ROI. A particular point is described for the monitoring of personal or collective protective equipment and the monitoring of equipment subject to regulations. The last document provides calculation and organizational methods for RFID-assets in order to consider management savings of about 20%.

WHAT ARE THE BENEFITS FOR ENGIE?

The purpose of this project is to give our BUs the keys and motivation for a unit management of their assets but also to describe the benefits of this monitoring. The correct identification of assets influences operational performance, preventive, corrective or predictive maintenance, the safety of goods and people and has a significant financial impact. Who hasn't dreamed of knowing everything about the life of an asset? Today, at ENGIE this is possible thanks to the deployment of RFID-Asset Tracking solutions. ■



DRONES & ROBOTS LAB

ENGIE Lab CRIGEN

Autonomous drone for wind turbine visual inspection

CONTEXT

The visual inspection of blades is a key element for wind turbine maintenance. Visual inspection provides important information about the external structure of the blade which optimizes the maintenance scheduling and reduces operation costs. Today, wind turbine visual inspection is performed in various ways:

- _ Using an aerial work platform;
- _ On-ground data capture using fixed cameras;
- _ Teleoperated drones;
- _ GPS-based automatic drones.

These techniques are either inaccurate or risky and often take too much time to put in place.

NEWS

The solution is based on the visual detection of the blade, while maintaining a constant distance to it.

The project started in 2020. The autonomous behavior of the drone was developed and tested in a simulated environment. The solution was then tested on a wind turbine.

In 2021, in collaboration with the CSAI Lab, we developed AI models that accurately detect the blade's different components.

The module allows an estimate of a blade's orientation to be made, enabling the drone to inspect the blades, regardless of the turbine configuration.

In collaboration with Drones-center, we also developed a new prototype capable of

integrating a high resolution camera that captures the images used for the visual analysis of the blade's condition.

WHAT ARE THE BENEFITS FOR ENGIE?

Since autonomous inspection is 4 times faster, the inspection costs are expected to drop from €2000 per turbine to €500 per turbine. The operation will be easier to deploy and less risky than aerial work platform-based visual inspection.

The same technology can be used for many other applications: the AI algorithms can be adapted to detect and track other objects (pipes, solar panels, antennae, vents, etc.). The autonomous drone can also be used for indoor and outdoor applications. ■





Mohamed Mahdi,
Drones & Robots Lab, ENGIE Lab CRIGEN

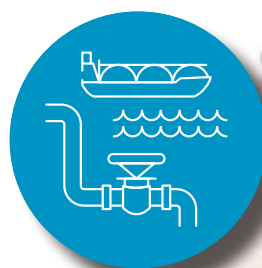
NETWORKS

GBU



Frédéric Legrand,
Chief of staff to
ENGIE EVP in charge
of Networks

“ The Global Business Unit Networks supports the group's strategy by being at the heart of the energy transition through the management of receiving LNG deliveries and regasification, gas transportation, storage and distribution, production of biomethane and power transmission. As a key lever in the implementation of the GBU Networks strategic roadmap, R&D challenges are huge. 2021 was a year of major achievements that tangibly illustrate support for R&D.





BIOGAS, BIOMETHANE & WASTE LAB

ENGIE Lab CRIGEN

Metha-HYn: a collaborative project to develop an integrated commercial offer of *in situ* biomethanation and biological hydrogen production

CONTEXT

Production of biomethane from anaerobic digestion (AD) is growing over the years but is still subject to financial and regulation mechanisms. As such, AD business suffers from a lack of attractiveness due to uncertain profitability, which limits its development. This is due in particular to the high costs of biogas purification for its recovery in biomethane, which represents 30% of the production cost.

NEWS

In late 2021 ENGIE won a French call for projects launched by the ADEME to develop a combination of technologies to increase the production of methane in AD units, thus limiting the costs related to purification. The objectives of the project are to:

- Maximize the methanogen potential of substrates through dark; fermentation to produce biological H_2 which will react with CO_2 to produce more methane;
- Conduct process optimization by performing *in situ* biomethanation & digestate pyrolysis;
- Optimize production control & command through sensor development.



The consortium is made up of 4 national partners: ENGIE, INRAE, APESA and IS2M and is partially funded by the ADEME with the call "Investissements d'avenir : un appel à projets pour développer la compétitivité de la filière méthanisation". At the end of this 45-year project, a commercial solution will have been achieved. ENGIE Bioz and Storengy are involved in the project as members of the supervisory board and the commercial solution could be deployed in their units.

WHAT ARE THE BENEFITS FOR ENGIE?

The Metha-HYn project will accelerate the development of the AD thanks to optimization and improved methane production yields. Thanks to an integration of technologies, gains on the productivity of the units are expected to be 30-40%, and CAEX should as well be reduced. These innovations aim to significantly improve the financial balance of existing units and new projects in order to make the sector more attractive to project developers and local authorities. ■

Biomethane deoxygenation: a challenge for anaerobic digestion development

CONTEXT

In case of biomethane production by anaerobic digestion, air or pure oxygen is usually injected in digester headspace to oxidize H_2S into elemental sulfur or into sulfates. These can lead to a biogas with high O_2 content. This content can impact biomethane end quality. Today, exemptions (to the 100 ppmv usual specification) are granted by gas operators to producers to inject biomethane with 0.75% of oxygen, relying on its dilution into natural gas. As the share of biomethane is going to grow significantly in the coming years, oxygen injection will not only impact gas grids but also underground gas storage systems (UGS). Therefore, exemptions for biomethane

producers may have to be reduced in the near future.

NEWS

ENGIE Lab CRIGEN studied in 2021 several solutions to control the amount of O_2 injected into the digester. The results are:

- Based on CFD modeling expertise, we can optimize the injection methodology to improve the oxygen diffusion into the digester in order to ensure that all the oxygen will react with the H_2S ;
- Based on chemical engineering expertise, we can develop the control and command for oxygen injection to ensure that the minimum amount of oxygen is injected and to evaluate the related costs;



- Based on Green Booth facilities, we can test technical solutions to remove oxygen and evaluate their performances;
- Based on a multiphase simulation tool and expertise, we are able to model a pipe system in order to evaluate the performances of liquid oxygen scavenger injection into the grid or into underground gas storage systems.

WHAT ARE THE BENEFITS FOR ENGIE?

Identifying simple solutions to limit biomethane oxygen content is a challenge for all ENGIE's assets. Indeed, if the oxygen content increases at the inlet of underground gas storage, this could damage the underground reservoirs but also increase the maintenance costs of surface facilities due to corrosion threats. Moreover, if the oxygen content allowance in biomethane is too restrictive, this will drastically increase the biomethane production costs and impair its future development. Thereby, we need to evaluate the best compromise to limit oxygen content in biomethane and whether it should be treated at production sites, in the grids or at the inlet of sensitive users or underground gas storage systems. ■

Biogas and CO₂ grids: a technical study of potential new gas grids

CONTEXT

The development of anaerobic digestion for biomethane injection into the grid presents two main challenges:

- _ How to recover CO₂ to increase unit profitability;
- _ How to reduce OPEX and CAPEX related to biogas treatment as it represents around 30% of biomethane production costs, which opens the discussion for a centralized purification.

In both cases, the building of dedicated gas grids can facilitate the development of these solutions.

NEWS

In 2021 ENGIE Lab CRIGEN studied the technical feasibility to develop dedicated biogas and CO₂ gas grids. The objectives were to identify the technical conditions of such pipes, suitable materials, operating conditions, the equipment and sensors needed, the associated costs and the regulatory context also based on technical and operational feedback from similar projects in Europe.

WHAT ARE THE BENEFITS FOR ENGIE?

A centralized purification step, thanks to a raw biogas grid, could decrease AD OPEX and CAPEX by 15% over 15 years for small units under 25 Nm³/h of biogas production and if the grid network length is less than 48 km. Regulations for biogas grids are few so we used natural gas grid regulations as a reference for odorization and automatization. Two projects on raw biogas grid are ongoing in the United Kingdom and the Netherlands.

Development of CO₂ grids are technically feasible and already in place for large-scale CO₂ capture and storage. The main projects are in Rotterdam (the Netherlands). Regarding the anaerobic digestion application, some solutions exist, for instance the connection to larger CO₂ grids, a dedicated grid if the CO₂ selling price is over 30€/t for 15 km of pipes or CO₂ liquefaction if the CO₂ selling price is above 45€/t. ■



Biogas development in India: support to New Business Factory



CONTEXT

In India, Compressed Natural Gas (CNG) and biogas are two growing markets; the number of technologies and suppliers to convert the feedstocks into biogas is increasing fast. Primove Engineering is one of them. ENGIE Mescata wants to perform complete due diligence in order to evaluate the suitability of Primove Engineering with the objective to invest in several projects with this company. The Biogas, Biomass & Waste Lab team of ENGIE Lab CRIGEN has been asked to define the relevance of such technology and New Business Factory is in charge of the financial assessment.

NEWS

Primove Engineering developed an integrated solution for lignocellulosic feedstocks recovery as bio-CNG. ENGIE Lab CRIGEN's analysis is the following: Primove

Engineering is developing interesting technology, with market potential as rice straw is an important source of feedstock with low competition. The availability of the feedstock will not be a source of concern for the projects, but we recommend to operate the technology in co-digestion instead of mono digestion as is the case to date.

WHAT ARE THE BENEFITS FOR ENGIE?

Biogas, Biomass & Waste Lab expertise is able to perform due diligence for any BUs and any technologies for biomethane development. This expertise is applied to a specific business case and the ENGIE Lab CRIGEN's technical opinion is that the technology provided by Primove seems to be robust, efficient and profitable. ■


 gaya

Successful closing committee of the R&D GAYA project: all the objectives were achieved!

CONTEXT

The GAYA platform was built in 2013 within the framework of the GAYA project, financially supported by the French environmental agency the ADEME. Originally, the GAYA project aimed at developing an innovative, competitive and sustainable production chain of a bio-substitute of natural gas (bio-SNG) from lignocellulosic biomass. In 2020, ENGIE took a new and complementary direction by focusing on waste recovery, especially Solid Recovered Fuels (SRF). Indeed, in the French context only, the government plans to reduce the quantity of landfilled waste and wants to reduce the French dependence towards fossil fuels. So, by avoiding this waste being landfilled and by producing synthetic methane used as a substitute to natural gas - i.e. injected, storable and transportable in gas networks, used as fuel for vehicle, burnt in boilers... - ENGIE's new approach is in line with the current energy transition goals.

NEWS

After 10 years of R&D work, the GAYA project held its closing meeting with ADEME on December 13th, 2021. ADEME validated that the project goals have been achieved: validation of technical performance on a portfolio of technologies including the

methanation reactor developed by the Biogas, Biomass & Waste Lab, and validation of the economic optimization efforts via, in particular, the implementation of an eco-design approach with an LCA for two phases of the project by the Environment & Society Lab.

A major result produced through the project was the implementation of a detailed analysis/screening campaign on the quality of the biomethane produced by pyrogasification, which demonstrated the compatibility of the biomethane quality with current network injection specifications. These results provided to the ADEME as well as French operators GRTgaz, GRDF, Storengy and Teréga are contributing to the current debate on the revision of the technical specifications of the networks in relation to the various "methanes" injected. As a follow up, the ADEME would like the GAYA project to draw up an "Example to Follow" sheet that will be made public on its website.

Last but not least, given the reliable technical results obtained on the GAYA catalytic methanation reactor, ENGIE Lab CRIGEN in collaboration with ENGIE's Corporate Operational Project Department had, in 2021, numerous opportunities to propose a technical and commercial offer based on this technology, whether for ENGIE's BU as well as for external projects.

Part of the tremendous R&D work on the GAYA methanation reactor was published in a scientific journal, the *Journal of CO₂ Utilization* (see here).

WHAT ARE THE BENEFITS FOR ENGIE?

The project and its platform are deeply rooted in order to reinforce ENGIE's competitive advantages to act as a Market Maker in the green gas sector, by decreasing this biomethane's production costs. By enhancing its competitiveness, it facilitates the development of bio-SNG industry, thus securing ENGIE's infrastructure business. Moreover, there are several business opportunities for ENGIE, and the Group can position itself: as an asset owner the savings of which come from bio-SNG and heat sales, as an EPC contractor and/or as an O&M contractor. Indeed, operation and maintenance on GAYA site were entrusted to ENGIE Solutions, which developed know-how on acceptance, commissioning, start-up as well as operational phases for all the platform's equipment. It is worth noting as well that the R&D work conducted on the platform is currently used as a reference for a future commercial and industrial unit: the Salamandre project based in Le Havre (Seine-Maritime) could provide an opportunity. ■

HYDROGEN LAB

ENGIE Lab CRIGEN

PANAM: improving the thermochemical methanation process

CONTEXT

PANAM is a POC to demonstrate the interest of several patents filed by the CRIGEN for improving the thermochemical methanation process. The technical solutions of these patents can both improve SNG quality and consequently reduce post-treatment operations, and reduce the manufacturing costs of a methanation reactor.

NEWS

The tests undertaken showed that the concept for improving SNG's final quality (by reducing the residual percentage of H_2) works well. The results obtained so far are in keeping with the ones obtained in similar modes on the GAYA platform (same technology but not the same reactor). Further testing is now needed in order to confirm the manufacturing cost of a methanation reactor and assess the performance of an innovative patented catalyst. To achieve these, further testing is required and the pilot now needs to be installed on a mechanization plant operated with real gases, requiring a few modifications. This will be carried out at the beginning of 2022.

WHAT ARE THE BENEFITS FOR ENGIE?

For ENGIE, this project can bring a competitive advantage by lowering the cost of Power-to-Gas projects thanks to in-house technology, ready in its first version for industrialization. ■



Methane pyrolysis: an opportunity to complement other hydrogen production technologies



CONTEXT

Methane pyrolysis (the conversion of natural gas into hydrogen and solid carbon) seems to be environmentally acceptable with no direct CO_2 emissions, is expected to be cost competitive versus SMR+CCS and electrolysis, and should be technically accessible by 2030. It fits ENGIE's strategy to become zero carbon by 2050 and could represent an opportunity to complement other hydrogen production technologies.

NEWS

- Pursuit of the HyTinBath collaboration, which started in June 2021, on a methane pyrolysis reactor technical feasibility study carried out by Univ. Politecnica Madrid, DBI, TUBAF, Hydrogen Lab and Future Industry Lab.
- Follow-up and support to the EMBER consortium, under TNO's governance, and including ENGIE (GEM), GRTgaz, Wintershall, Cabot, Tata Steel, Aramco, OMV).

WHAT ARE THE BENEFITS FOR ENGIE?

Methane pyrolysis could widen ENGIE's hydrogen reach and create additional value as from 2030. Benefiting from their existing competences and assets, several ENGIE entities may benefit from the value along the methane pyrolysis value chain. ■



Engero: a technology converting gases in a faster, cheaper and more eco-friendly way

CONTEXT

Engero is a French startup developing plasma-catalytic technology with various applications. The first application considered and developed is methanation, both methanation of CO₂ (Power-to-Methane application) and methanation of syngas (Biomass/Waste-to-Methane application). The main advantages of this technology are its start & stop properties and its tolerance against pollutants. Engero also aims at developing other catalytic applications such as water gas shift, reverse water gas shift, ammonia production, methanol production, dry reforming, etc. Periodic exchanges have been organized to follow Engero developments and explore collaborations pathways and ENGIE Lab CRIGEN has now developed an exhaustive vision of Engero technology possibilities.

NEWS

In October 2021, Engero launched its first significant scale demonstrator for CO₂ methanation (2,5Nm³/h e-methane production) on a biogas plant in the North of France (near Compiègne). ENGIE Lab CRIGEN was present for this inauguration in the presence of local authorities and many representatives of gas infrastructures. Thanks to its demonstrator, Engero obtained a regulatory exemption from French authorities to inject the e-methane produced into GRDF gas grid. An agreement has been signed between Engero and ENGIE Lab CRIGEN to jointly inject the first m³ of e-methane into the French gas grid. In addition, other joint projects are being explored for methanation and other applications, as well as the possibility for ENGIE, through ENGIE New Ventures, to invest in the startup.

WHAT ARE THE BENEFITS FOR ENGIE?

The methanation technology developed by Engero is extremely promising as it could avoid the need for expensive equipment throughout the renewable methane production process chain. This technology is complementary with the in-house Gaya technology as it can both unlock the potential of decentralized e-methane production and address very polluted feedstocks. As the market of renewable methane is expected to grow exponentially in the coming years, Engero is an opportunity for ENGIE to diversify its technology portfolio. ■

LIQUEFACTION LAB

ENGIE Lab CRIGEN

Boosting recognition of our expertise regarding LNG's behavior and supply chain

CONTEXT

In 2021, thanks to its unique and recognized tools the Liquefaction Lab increased its high-level of expertise that is provides to internal and external clients.

NEWS

Business development support for LNG projects:

- LNG ageing for trading activities within GEM: the Liquefaction Lab performed several LNG ageing simulations using its unique LNG behavior tools for GEM Trading teams. These simulations were used by traders to optimize LNG supply throughout the world by testing aged LNG with different terminal specifications;
- LNG ageing and rollover studies in Liquefaction plant and regasification terminal: in 2021 the Liquefaction Lab performed various rollover simulations for Driftwood LNG and GTT aiming at evaluating the efficiency of site boil-off gas management systems in order to

prevent damage from rollover inside their storage tanks. We also performed a study for Hoëgh LNG to predict the change from stratification to rollover inside the Artic Princess LNG Carrier;

- LNG supply to remote areas: The Liquefaction Lab performed a study for ENGIE Indonesia, to assess and optimize the delivery of LNG through remote areas in order to supply 30 gas-powered power plants, using fluid supply chain optimization for LH2, LNG, bio-LNG and LCO2 delivery. In 2022 the Liquefaction Lab will perform on behalf of ENEGIR, in collaboration with TechTeam, a feasibility study to build an LNG supply chain for one of their clients.

LNGTransfer ready for commercialization:

In 2021 the interface of the new LNG behaviour module has been developed. The objective of LNGTransfer is to simulate LNG transfer between 2 sites and to evaluate the behaviour of LNG in both sites at the same

time. This tool will enable us to provide support to ENGIE Group projects on LNG and fuel management. The tool is now ready to be marketed.

Launch of business development to promote Liquefaction tools to external clients: In 2021 we started marketing and communication activities to increase the sale of tools and expertise outside ENGIE.

ENGIE/CMA CGM agreement on LNG as fuel: one of the common interests between CMA CGM and ENGIE Lab CRIGEN is the good management of LNG as a fuel for LNG/ bio-LNG fueled ship. Thanks to the models we have developed to measure real-time characteristics of LNG fuel (the Smart Gauge tool) and to predict changes in these (LNGMaster®), common R&D activities will be conducted with CMA CGM in 2022.

WHAT ARE THE BENEFITS FOR ENGIE?

Increased revenues to finance R&I activities and the recognition of ENGIE Lab CRIGEN's high-level of expertise. ■



The Liquefaction Lab presented its work on synergies between liquid hydrogen and liquid natural gas at Gastech 2021 in Dubai

CONTEXT

Liquid hydrogen will likely play a major role in the development of hydrogen markets. It is a solution for heavy transport solutions such as trains, ships and aircraft by increasing their autonomy and for massive hydrogen distribution within a country. However, its current cost is a drawback for it to be widely used due to both intensive capital investments and high specific energy consumption. Alongside cost trimming by production scale-up, the possible synergy between LNG-regasification and hydrogen pre-cooling offers an appealing opportunity to lower the cost of hydrogen liquefaction. By implementing LH2 near an LNG terminal, the cold energy recovery from LNG regasification can significantly diminish the precooling and compression stages of the liquefaction process.

NEWS

Thanks to its expertise on hydrogen liquefaction and liquid natural gas value chain, the Liquefaction Lab, studied a technico-economic evaluation of the impact of LNG regasification synergy on hydrogen liquefaction. Three configurations were studied and derived from the most mature and efficient liquefier technology. By considering a realistic NG emissions profile, it was shown that LNG consumption in the hydrogen liquefier is reasonable.



WHAT ARE THE BENEFITS FOR ENGIE?

Thanks to considerable knowledge of the operational guidelines and technological aspects of the hydrogen liquefaction and its value chain, ENGIE can strategically position itself on projects to recover the cold energy wasted at its LNG import terminals and significantly lower hydrogen liquefaction costs at its future plants. ■

Bio-LNG: a renewable fuel for heavy duty transport

CONTEXT

Bio-LNG (or liquid biomethane or liquefied biomethane) is a renewable fuel capable of quickly reducing the carbon footprint and the air pollution linked to the transport sector thanks to its properties, the maturity of the sector and the availability of resources.

Produced through biogas liquefaction, bio-LNG represents a green solution for heavy transport (maritime and heavy vehicles). It allows CO₂ emissions to be reduced by 90% compared to conventional fuels used for

transport in order to meet the targets for reducing GHG emissions from transportation in France and the European Union.

Bio-LNG still requires a regulatory context favoring its development as well as a significant decrease in its production costs to make it more competitive.

NEWS

In 2020, the Liquefaction Lab launched a 3-year R&I program with ENGIE Research and Elengy to develop low cost biogas liquefaction technology, from process design

to the industrialization phase. Liquefaction Lab is also supporting ENGIE'S BUs on bio-LNG projects by presenting technical insights to help activate the market.

WHAT ARE THE BENEFITS FOR ENGIE?

- Develop a new market for ENGIE.
- Promote bio-LNG as a renewable fuel for heavy duty transport.
- Accelerate the transition to a carbon-neutral economy.
- Increase profitability of biogas projects. ■





Toward a cost-effective biomethane liquefaction technology

CONTEXT

Bio-LNG is used to recover local resources, through the fermentation of organic and agriculture waste, based on circular economy principals and increase the density of biogas through liquefaction. It is thus a fuel solution fully appropriate for heavy mobility.

Bio-LNG still requires a significant decrease in its production cost in order to become more competitive than traditional fossil fuels. An R&I program was launched in 2020 with ENGIE Research and Elengy to develop low cost liquefaction technology. The objective of this new technology is to reduce the cost of biogas liquefaction by 30%.

ENGIE Lab Liquefaction's high level of expertise in the field of gas liquefaction can provide support to this goal.

NEWS

Liquefaction Lab has built two test benches at 1/5 scale to assess and validate the performances of the new biomethane liquefaction technology:

- _ Polishing test bench at Stains to test a patented technology;
- _ Liquefaction test bench in Montoir-de-Bretagne (Loire-Atlantique department) to test an innovative liquefaction process.

The polishing tests at ENGIE Lab CRIGEN in Stains have started in late 2020 and have already exhibited some interesting results.

WHAT ARE THE BENEFITS FOR ENGIE ?

- _ Propose a more energy-efficient and environmental solution.
- _ Debottleneck biogas production by enhancing its value through liquefaction.
- _ Propose a competitive solution for biomethane liquefaction.
- _ Reduce well-to-wheel GHG emissions. ■

Maritime mobility on its way to zero carbon

CONTEXT

The International Maritime Organization has set ambitious targets to curb greenhouse gas emissions (at least 50% below 2008 levels by 2050). Since 2015, the IMO has also imposed a progressive reduction in the maximum permitted sulphur content (from 3.5% in 2015 down to 0.5% in 2020) in the bunker fuels of some 50,000 ships worldwide.

Different solutions are available for shipowners to help them comply with requirements: they can change fuel for LNG, bio-LNG or LH2 and progressively decrease their CO₂ emissions respectively from 20%, 80% and 95%. Shipowners are also looking at CO₂ capture for the LNG-fueled ships.

NEWS

At the end of 2021, ENGIE has signed a partnership with CMA CGM, one of the largest containership companies in the world. In this context, Liquefaction lab will work with them on two main topics:

- _ Implementation of the Smart Gauge: unique algorithm for predicting the composition and methane number from pressure, temperature and the initial composition for loading. This is a low-cost solution that is easy to operate in



comparison with the installation of a gas chromatograph onboard ships. The Smart Gauge tool is now ready for marketing in partnership with Wärtsilä;

- _ Assessment of the cryogenic capture onboard with the integration of cold energy recovery from liquefied natural gas.

WHAT ARE THE BENEFITS FOR ENGIE?

Participation in the zero-carbon transition by helping shipowners to decarbonize marine transport either by developing an operational assistance tool for current LNG transport and by launching an ambitious R&D project around CO₂ capture. ■

FUTURE BUILDING LAB

ENGIE Lab CRIGEN

THyGA: setting the conditions for hydrogen/natural gas blending from an end user point of view (residential and commercial appliances)



CONTEXT

Blending hydrogen with natural gas can help to decarbonize the energy mix while taking advantage of existing infrastructure assets. Understanding and mitigating any end-user impacts are vital elements in this context. The Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) funded project THyGA, Testing Hydrogen admixtures for Gas Appliances, aims at supporting the wide adoption of hydrogen and natural gas (H2NG) blends by assessing their technical impact on a wide selection of residential and commercial gas appliances. ENGIE Lab CRIGEN's Future Building & Cities Lab is project coordinator.

The project covers technical and normative aspects. An experimental campaign on hydrogen tolerance is being performed, based on a theoretical background from material science and combustion theory. Results are being used to adapt and improve standardization activities related to the impact of H2NG blends for gas appliances, and to identify mitigation strategies to cope with high levels of hydrogen admixture.

Using this approach, the project will determine how different levels of hydrogen blending impact the various appliance technologies, and will identify the conditions in which safe, efficient, and low-polluting operation is possible.

NEWS

The test campaign is on-going; 35 appliances have been tested out of the 100 target (boilers, cookers, catering, CHP, fuel cells...). Several deliverables have been published and a public workshop in December 2021 allowed the preliminary results to be shared, highlighting the resilience of most appliances of up to 30 to 40% hydrogen volume. The main issues are the adjustments required for condensing boiler and the flashback for atmospheric appliances (cooking hobs) and that will require that existing standards are adjusted.

WHAT ARE THE BENEFITS FOR ENGIE?

The project will determine how different levels of hydrogen blending impact the various appliance technologies, and identify

the conditions in which safe, efficient, and low-polluting operation is possible. This information will be compulsory in order to prepare stakeholders for the injection of hydrogen that will occur in the years to come.

Results from the THyGA project are not only already used by the French infrastructure to lay down the possibilities of injection in France ('Sous-GT Injection - GRDF'), but also by CEN/CENELEC Technical Committees and the Pre-Normative Research project (GERG PNR). The results, especially in terms of a mitigation strategy, will feed the Business Units dealing with Local Energy Communities involving electrolysis, electricity and heat energy vectors. ■

Project website <https://thyga-project.eu>

First results are also summarized in this open source article "The Impact of Hydrogen Admixture into Natural Gas in Residential and Commercial Gas Appliances"



NANOTECHNOLOGIES, SENSORS & WIRELESS LAB

ENGIE Lab CRIGEN

PARHyS: a new approach in measuring natural hydrogen in the subsurface

CONTEXT

Hydrogen is a hot topic in the energy domain and a key component of the energy transition.

Hydrogen can be produced by electrolysis or by reforming steam methane but in this case the CO₂ impact can be rather high.

An alternative is natural hydrogen, an energy source emanating from the ground. It has been detected in several places around the world.

Energy companies and research centers are currently working together to understand these hydrogen emanations in order to better quantify natural hydrogen emissions and estimate this new energy source's potential.

NEWS

To detect natural hydrogen emissions in the field and over a long period of time, ENGIE Lab CRIGEN has developed a technology for real-time continuous hydrogen measurement that autonomously analyzes hydrogen pumped in the soil. This is the PARHyS system.

In 2020, ENGIE monitored hydrogen seeps in the São Francisco basin in Brazil thanks to a hundred generation V2 PARHyS systems

over an 8-month campaign in extreme climatic conditions.

In order to launch a new campaign in Brazil at the beginning of 2022 and to meet the first requests from international customers, the 99 PARHyS systems were repatriated from Brazil in 2021 in order to evaluate and restore them.

The growing interest of oil companies for natural hydrogen means that the demand for sensors are increasing and that more precise measurements in terms of volumetric quantities are required. This is why in 2021, the Nanotech, Sensors & Wireless Lab started to develop a new, V3 version of the sensors meeting these new expectations. One hundred new generation sensors should be available in 2022.

WHAT ARE THE BENEFITS FOR ENGIE?

The project will determine how different levels of hydrogen blending impact the various appliance technologies, and identify the conditions in which safe, efficient, and low-polluting operation is possible. This information will be compulsory in order Due to the lack of a full understanding of the widespread occurrence of natural hydrogen, the total planetary volume for a geologic

source has not been evaluated. However, by combining available data, Zgonnik (2019) estimated a value of 256 109 m³/year (23 million tons per year).

The use of the PARHyS' network of low-cost connected sensors for monitoring hydrogen over time is key for a better understanding of the origin, the accumulation and the migration of hydrogen flow in soil and for creating value from this potentially disruptive natural green energy. ■



AirCom: an innovative solution to enable data collection from sensors in an ATEX environment

CONTEXT

ATEX environments are very confined environments and, although new solutions are being developed, a lot of work still needs to be undertaken. ENGIE developed AirCom to enable data to be collected from sensors in an ATEX environment. In an ENGIE project, where part of the issues addressed was how the cost of biogas production in anaerobic digestion units could be reduced, ENGIE had to address this: either carry out sensor data collection on a new production unit or retrofit one in an ATEX environment.



NEWS

ENGIE Lab CRIGEN designed an all-in-one device, AirCom, which is compliant with ATEX regulations and can turn most sensors into self-powered, radio-communicating ones. AirCom converts a conventional sensor into an IoT using the LoRaWAN protocol, a dedicated IoT radio communication protocol. Thanks to its two configurable inputs, AirCom can address two sensors at the same time, with a very large number of linkages possibilities.

These two inputs are configurable with a smartphone via Bluetooth communication using a dedicated App to connect to AirCom. This solution's originality lies in the fact that ENGIE preferred to develop a system that makes the sensors communicate rather than carrying out a specific development for each sensor. In this way, ENGIE was able to pool development costs and be able to respond to a multitude of use cases faced by its subsidiaries.

With its industrial partner, ENGIE has already sold more than 200 AirCom units for demonstration projects only. This means there is much more to come if these demonstration projects succeed. If these projects are successful then the commercial perspectives are huge ENGIE is working with its partner on a new module named AirCom mini which will integrate only 1 type of input to decrease the costs. This new version will be available in 2022.

To expand its geographical sale area, AirCom obtained CSA approval (US radiofrequency license) in 2021 and is now ready to be sold in US market.

Throughout 2021, AirCom's software and hardware were improved:

- The hardware has been modified to improve radio communication by integrating:
 - A new LoRaWAN radio communication module;
 - A new radio antenna to give the possibility to connect a remote radio antenna;
 - Different electronic components to increase the number and type of sensors to be connected.
- The software:
 - The smartphone application was improved to make its interface more intuitive;
 - ENGIE Lab CRIGEN and its partner Westwood tech started to develop new software able to collect data from a gas grid to calculate gas flow. Today this is a high-cost operation due to the equipment involved. Tomorrow, with AirCom Flow computing, a low-cost solution will be available for ENGIE's BUs.

WHAT ARE THE BENEFITS FOR ENGIE?

ENGIE's subsidiaries will be able to increase operational efficiency on ATEX sites where dedicated sensors are needed. AirCom costs about half the price of conventional solutions. This price makes sensor deployment possible in fields where it was not possible before. ■

J-Net: correlative system to pave the way for energy metering

CONTEXT

New players, such as biomethane producers, are active in gas networks. The impact is huge for the distribution network, which is moving from «passive» operations, self-regulated by consumption, to in some cases complex operations with delicate flow management.

This is why a network's operating tools must be adapted to guarantee industrial safety and operational performance. One of the solutions consists in integrating intelligence into the networks thanks to information and communication technologies.

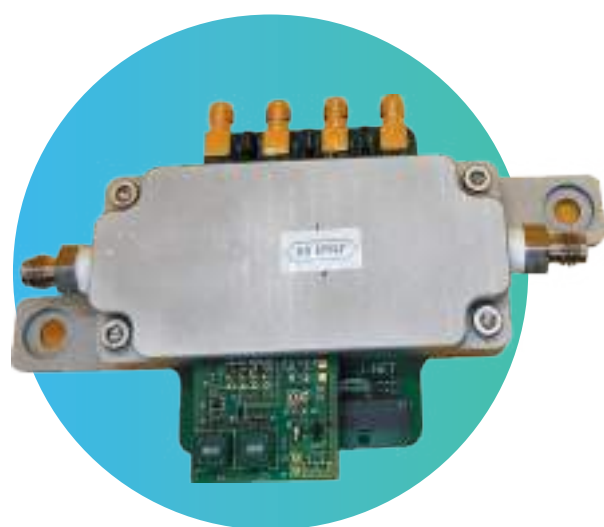
NEWS

Network operators are looking for new connected systems capable of measuring gas energy in a fast and accurate way and taking into account the nature of new gases (hydrogen and oxygen contents which will increase). ENGIE Lab CRIGEN

has been working for the past 4 years on the development of the J-Net system. This system is a correlative solution based on the physical properties of gas and integrates an algorithm allowing users to obtain gross calorific value of gas (GCV). As it is low cost and self-powered, the J-Net system can be deployed on numerous points in a gas network and be easily integrated in gas meters to perform energy metering on site. The 2022 program work will enable the performance of the J-Net system to be validated in a relevant environment and the industrialization with a partner to be started.

WHAT ARE THE BENEFITS FOR ENGIE?

As a major player in the energy transition, ENGIE needs innovative solutions to position itself along the entire value chain. The deployment of solutions such as the J-Net system is a boost to the development of



the green gas industry. This facilitates the injection of gases such as biomethane and hydrogen. This project positions ENGIE in direct relation with the main European gas network operators. ■

DRONES & ROBOTS LAB

ENGIE Lab CRIGEN

Drones for gas leak detection

CONTEXT

Historically, gas leak detection was a fundamental safety issue. Nowadays, it is also an essential factor in the fight against climate change. With an objective to drastically reduce GHG (greenhouse gases) within the European Union, not only does detection, but also the quantification of the gas emissions become crucial issues. For the gas industry, this is also about continuity because the place of gas in the energy mix, and the social acceptance of the construction of renewable gas production sites, are often brought up in public debates. Gas leak detection technology is now mature: the last generation of products are compact, cost effective and can be easily integrated in robots or UAVs, enabling "difficult to access" areas (under bridge pipelines, pipe racks, etc. to be inspected. Consequently, UAVs now start to be used on a regular basis for methane leak detection in the field, but the leakage rate estimation remains a technical challenge.

NEWS

In 2021, the Drones & Robots Lab supported GRDF in the renewal of the master agreement specific to drones. This agreement concerns the visual inspection and the leak detection on aerial pipelines. A leak detection solution has been selected and qualified on 2 different sites in December. Its performances, compliance to regulations, as well as the ease of use have been verified by the Lab and GRDF and it will be recommended within the agreement. A short training course may be organized by the Lab for service suppliers to ensure that they are operational by mid-2022.

As this solution (drone-embedded gas leak detection system) will be used on a near daily basis, the challenge is now to be able to estimate the leakage rate quantification with the same technology.

Thus, the Drones & Robots Lab started studying a first approach combining standard sensors and reverse modelling (both analytical or numerical modelling are possible), to tackle this issue.

2022 developments will focus on a proof of concept for this approach.



WHAT ARE THE BENEFITS FOR ENGIE?

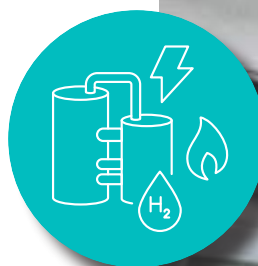
The benefits for ENGIE are:

- **Operational excellence/safety:** this solution is economically viable to inspect difficult-to-access infrastructures (aerial, underdeck, etc.). Most of these areas were not fully inspected before;
- **GHG reduction:** this flexible solution helps reduce the GHG emission by the early detection of leaks. In the short to medium term, quantification will be possible;
- A combination of the two previous points contribute to work on the **social acceptance** of renewable gas production and therefore to being able to defend the place of gas in the energy mix. ■

THERMAL & SUPPLY GBU



Pascal Bourdeaux,
Head of Greening the
Fleet, Research &
Innovation, Advocacy
Thermal & Supply Global
Business Unit.



ENGIE has announced to reduce its carbon emissions by more than 40% in 2030 and to be NET ZERO CARBON in 2045.

Efficient Green Hydrogen production, Carbon Capture, E-fuels are - amongst others - new solutions to decarbonize energy production.

In parallel, Water demand is increasing in several regions of the world and R&D efforts are required to optimize and greenify desalination processes.

This new paradigm is also an opportunity for ENGIE to Offer new solutions to its BtoC Customers, such as smart tools to optimize EV charging, in combination with roof top PV production at home.

Research and Innovation allow Engie to develop and test those new solutions and de-risk their implementation at industrial level.





GREEN THERMAL GENERATION LAB

ENGIE Laborelec

Demonstrating that up to 25% H₂ co-combustion is viable

ENGIE Laborelec has demonstrated that using a gas fuel mix with up to 25% hydrogen in an SGT-600 gas turbine is safe and requires no hardware modification.

How much hydrogen (H₂) can be put in the fuel mix of gas turbines without inducing hardware damage, unacceptable wear, or safety hazards? From March to May 2021, ENGIE Laborelec carried out a pioneering series of tests on an ENGIE operated 24.5MW(e) Siemens SGT-600 gas turbine at the Ineos Phenol plant in the Port of Antwerp to find that out.

USEFUL PRELIMINARIES

We began the project by developing a mixing installation with an expansion kit connected to a truck trailer, which we would then use to feed the mix into the turbine's combustion chamber. We also carried out a preliminary stress test to assess whether higher H₂ concentrations would risk inducing hardware damage due to flashback phenomena.

The test, at a DLR research installation in Germany, showed that we could safely carry

out testing at the Ineos Phenol plant with up to 30% H₂ in the mix, although the OEM warranty allows only a maximum of 10%.

25% H₂ MIX CUTS CARBON EMISSIONS BY 9%

We carried out nine tests in total, gradually increasing the H₂ concentration from 2.5% to 25%. After each test, we carried out maintenance to find out whether hot spots had developed, or any damage had been incurred. We also measured the overall efficiency, the resulting power output, and the CO₂ and NOx emissions.

The final test with 25% H₂ was a big success, according to ENGIE Laborelec expert Luc Gooren: *"The hardware did not suffer, no additional maintenance was necessary, efficiency and power output remained stable, and CO₂ emissions resulting from this combustion went down by 9%."*

MORE H₂ PROJECTS COMING UP

On the downside, NOx emissions increased as expected. However, by modulating the combustion we tried to counteract this increase and were able to neutralize it completely with H₂ concentrations of up to 10%.

In 2022, we'll be continuing our research into H₂ co-combustion and its long-term impact on the mechanical integrity of the downstream hot gas path components as one of multiple H₂-related projects. We're developing a testing ground at the Linkebeek site, for example, with a hydrogen electrolyzer integrated into a smart grid that includes a PV installation and battery storage. ■





Safe maintenance interval extension roll-out in gas-fired stations

In 2021, ENGIE Laborelec worked with OEMs to scrutinize the methodology for gas turbine maintenance interval extension (MIE), confirming that our approach is safe and can be used in most gas power stations.

For core equipment, gas-fired power station operators see MIE as a promising pathway to significantly bring down investment and operating costs. Maintenance and reconditioning can be extended from once every 33,000 operating hours to every 41,000. But there are some risks involved because extending maintenance intervals goes against initial OEM recommendations.

STRUCTURED APPROACH FROM DECADES OF EXPERIENCE

For this reason, ENGIE Laborelec has developed a smart MIE program based on decades-long experience with almost every common type of gas turbine. The program is designed to assess the

risks associated with extending maintenance intervals and to take measures to mitigate these risks.

A failure mode and effects analysis (FMEA) is carried out on the machine in question, assessing how frequently a failure is expected to occur, how severe it would be, and whether it would be detectable before the system crashes. We then develop a maintenance matrix for the installation, listing around 60 potential vulnerabilities requiring attention, including design specifics such as the coatings used and the position and size of cooling holes.

ENGAGING WITH OEMS AND INSURERS

During the year, we worked with Ansaldo to evaluate our method using the specific case of the AE94.3A turbine at the Leini power plant in Italy. Our assessment was that the maintenance interval could be extended from 33,000 to 41,000 operating hours, which we put into effect in agreement with the insurer. We subsequently carried out a destructive analysis, cutting some of the blades and investigating the microstructure. The blades proved to be in good shape even after the extended interval, confirming the validity of our method.

The approach was successfully applied to three GT26 units at the Combigofole, Cycofos (France) and Tocopilla (Chile) power stations with positive support from the OEM and the insurer. ENGIE Laborelec expert Luc Gooren has observed a shift in attitudes: *"Our work on the Leini and Tocopilla power stations confirms that OEMs and insurers are both beginning to be more positively inclined towards MIE programs."*

FURTHER RISK ANALYSES ARE ONGOING

Meanwhile, we successfully applied MIE to almost all the ENGIE gas-fired power stations in the EU, and we're continuing the program elsewhere, rolling out safe MIE deployment on a global scale. We are also now carrying out risk analyses to investigate whether maintenance intervals can be extended even further. ■

Root cause analysis involving Combined Cycle Power Plants equipment

ENGIE Laborelec's root cause analysis (RCA) activities for CCPPs have seen enormous growth over the past few years. Customers appreciate our comprehensive multidisciplinary approach and our capacity to successfully challenge OEMs and other stakeholders.

The company has been conducting RCAs of issues occurring in electrical and mechanical equipment at ENGIE's fleet of combined cycle power plants for several decades. More recently, the service has been extended to assist external power plant owners and operators. In 2021, for example, four major RCA projects were carried out by ENGIE Laborelec engineers to investigate various kinds of damage occurring in gas turbine compressors at power plants in the Middle East and Turkey.

ACTING FAST, DEPLOYING MULTIDISCIPLINARY EXPERTISE

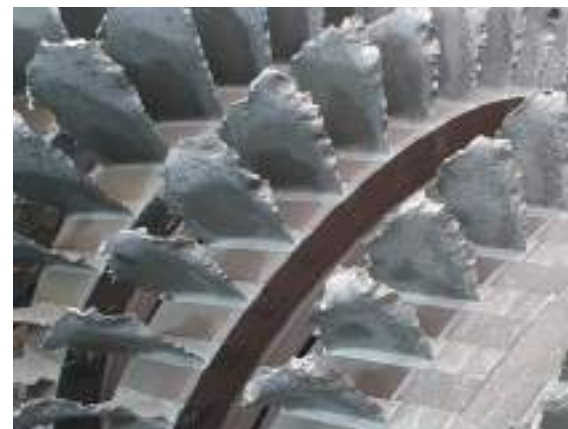
In every RCA, acting fast is crucial, mobilizing experts and setting up fact-finding missions on the ground as soon as possible after incidents occur. Relevant evidence of any kind is collected, including

as-found asset condition, operational circumstances, process parameters and human interventions prior to and during the event. Components and material from the damaged equipment are selected for further investigation.

After the onsite mission, there are a series of in-depth investigations in the laboratories, calling on ENGIE Laborelec experts in materials, processes, vibrations, and structural mechanics, who then iteratively analyze dependencies and contingencies to determine all the factors contributing to the event and identify the root causes.

SUCCESSFULLY CHALLENGING STAKEHOLDER VIEWPOINTS

Most importantly, ENGIE Laborelec is then able to challenge any parallel analysis made by the OEM as well as the measures they recommend to preserve asset integrity. Other stakeholders are challenged too. In one case last year, ENGIE Laborelec engineers demonstrated that the initial analysis was inaccurate and unreliable, subsequently uncovered the actual cause of the event, and made much more pertinent recommendations.



PREVENTING OPERATORS FROM TAKING UNACCEPTABLE RISKS

In another case, ENGIE Laborelec provided life-saving advice to an O&M company who wanted to resume operation of their power augmentation system after an equipment failure, even before the RCA had reached a conclusion. In numerous discussions – sometimes tough because of the significant impact on plant profitability – ENGIE Laborelec experts demonstrated that this would incur unacceptable risks.

"Our in-depth RCA can make a huge difference for operators," sums up ENGIE Laborelec expert Xavier Degive. *"And we've shown that we're well-prepared for even the most demanding cases."* ■

Scrutinizing zero-emission supercritical CO₂ cycle technology

ENGIE Laborelec is conducting technical due diligence on NET Power's supercritical CO₂ power cycle. This groundbreaking technology is a potential game changer for power production, using natural gas and oxygen to generate zero-emission electricity while also capturing CO₂.

The supercritical CO₂ cycle is an ingenious technique to avoid both CO₂ and NO_x emissions, simply by burning natural gas (CH₄) with pure oxygen (O₂), instead of air which comprises 78% nitrogen and other gases in addition to oxygen. This oxy-combustion process produces pure water (H₂O) and pure carbon dioxide

(CO₂), which cycles through a turbine, a heat exchanger, and a compressor to produce power with zero emissions. At the end of the cycle, most of the undiluted CO₂ is reheated in the heat exchanger and returned to the combustor to keep the cycle going. Any excess CO₂ is captured in a pipeline and can either be sequestered or sold to industry.

THE WORLD'S FIRST LARGE-SCALE SUPERCRITICAL CO₂ PLANT

The technology, which has been under study since 2010, has reached a promising level of maturity in recent years, especially after clean energy technology company NET Power brought the world's first supercritical CO₂ pilot plant into operation in La Porte, Texas in 2018.

One of the fascinating aspects of this technology is the extreme density of the supercritical CO₂ pumped through the system, meaning that the installation can be very compact and could even be built underground. Other advantages are the

highly recuperative character of the cycle, minimizing natural gas consumption, and the fact that CO₂ capture is part of the cycle, which is not the case in classic combined cycle power production processes.

AUDITING THE DEMONSTRATION PLANT AND DEVELOPING A SIMULATOR

ENGIE Laborelec is now conducting technical due diligence at the La Porte demonstration facility, witnessing a series of tests and analyzing the results using data mining. ENGIE Laborelec experts are also developing a NET Power cycle simulator, which will allow variants of the cycle to be examined and benchmarked, accelerating the process of optimizing the design.

For ENGIE Laborelec expert Frederiek Demeyer this is just the beginning: "We'll also be using the experience gained on the project to evaluate whether the technology is a feasible solution for ENGIE, both technically and financially." ■



Monitoring torsional vibrations in turbo groups at low cost

Power plant turbo groups are increasingly at risk of suffering damage from torsional vibrations. ENGIE Laborelec has developed and commercialized a cost-efficient early warning detection system.

Torsional vibration occurring in turbo

groups is a 'silent killer'. Although it can lead to dramatic failures, it is generally overlooked by plant operators as an issue requiring special attention, largely because it has always been a very rare phenomenon. The issue has been gaining prominence recently because of constantly changing grid conditions, the fact that classic power systems are running in cycling mode, and frequent interactions with renewables and power electronics. This could lead to excessive levels of torsional vibration in the rotating shafts or couplings, leading to fatigue and ultimately severe damage such as shaft cracking, blade loss, and gearbox failure. Unfortunately, current shaft lines are not equipped to detect and mitigate this specific type of vibration.

COST-EFFICIENT EARLY WARNING PROVIDES PEACE OF MIND

Some recent incidents, including in ENGIE's European fleet in 2019, and discussion with various OEMs, have confirmed the importance of access to torsional vibration

data. That's why ENGIE Laborelec developed TORSO Detect as a cost-efficient and plug-and-play detection system.

TORSO Detect deploys the same technology as our respected high-end TORSO Protect solution. ENGIE Laborelec expert Felipe Vergara explains how it provides peace of mind to operators: "It simply uses the available speed sensors to monitor the torsional vibrations, acting as an early warning system."

PLUG-AND-PLAY INSTALLATION WITH REMOTE SUPPORT

In 2021, we installed TORSO Detect in a range of ENGIE power plants, confirming the solution's maturity and ease of installation. We are now rolling it out over the entire ENGIE fleet in Europe, most often in conjunction with the ENGIE Laborelec Vibration Monitoring System (LVMS). In most cases, physical installation of the TORSO unit will be carried out by local power plant staff, with ENGIE Laborelec providing remote assistance. ■



CO₂ AS A RESOURCE LAB

ENGIE Laborelec

Assessing the viability of solvent-based carbon capture in newbuild CCGTs

ENGIE Laborelec is conducting research on how viable carbon capture is in newbuild CCGT plants. A mobile carbon capture unit will allow operational experience to be gathered and the technology and cost to be validated for CCGTs running in flexible operation and for different solvents under various operating conditions.

Post-combustion carbon capture solutions are expected to be the most mature and cheaper option for decarbonizing newbuild CCGT plants by 2030, with the European emission trade system gradually improving the economics of it all. Yet post-combustion carbon capture still comes with significant challenges, given the large volumes of exhaust gas to be treated. Carbon capture processes must also be in sync with the CCGTs, which today are designed to operate in flexible mode.

THE TYPE OF SOLVENT SIGNIFICANTLY IMPACTS THE COST OF CARBON CAPTURE

ENGIE Laborelec's research programme was launched to assess how viable carbon capture solutions are in the new generation of CCGTs. In 2021, a market consultation was carried out in collaboration with Tractebel and the Thermal & Supply business unit to assess the cost of state-of-the-art post-combustion carbon capture. The study revealed that the type of solvent significantly impacts both capital and operational expenditures, meaning there is a trade-off between performance and solvent costs.

Detailed engineering studies will be needed to evaluate the best

design configuration. Uncertainties remain concerning whether a CCGT running in flexible operation has an impact on the operability and cost of carbon capture.

BUILDING A MOBILE UNIT AND MODELLING LARGE-SCALE CARBON CAPTURE

The current research programme, which runs until 2025, is designed to gain more insight into the phenomena and quantify the potential of reducing the cost of carbon capture for newbuild CCGTs. Operational experience will be gathered using a mobile capture unit, which will be installed for testing purposes at an ENGIE power plant. ENGIE Laborelec developed its design in 2021, and the unit will be built and commissioned in 2022. A large-scale carbon capture process simulation model will also be developed and validated with experimental data.

"The model will allow us to evaluate operational flexibility and assess strategies to reduce the costs," says ENGIE Laborelec expert Han Huynh Thi. "It will give us the know-how we need to challenge the technology providers, ensuring the best value and the lowest risk for future ENGIE projects. This is part of a broader study on the development of tools, infrastructure and technical know-how carried out by the CO₂ as-a-resource lab for several years to support ENGIE in its deployment of CCUS. This has allowed Laborelec to support ENGIE from conceptual design to detailed engineering on innovative but also highly challenging large scale CCU projects such as Columbus, REUZE or North C Methanol." ■



FUTURE COLLECTIVITIES & HOME LAB

ENGIE Laborelec

Developing an energy community in a real-world rural neighborhood

In a pilot project in Oud-Heverlee (Belgium), ENGIE Laborelec is carrying out a real-world test to reduce residents' dependence on the grid and maximize their renewable energy self-consumption.

The pilot is our contribution to the MUSE GRIDS project, sponsored by the European Commission, investigating how local communities can be empowered to develop their own self-reliant energy system, based

solely on locally produced renewable energy. The Oud-Heverlee test site is a residential street in a rural area located at the end of a power distribution line. The street has about 40 houses, some of which have been suffering from grid problems such as phase unbalances, voltage swings and even blackouts. Many houses have rooftop PV installations, some are equipped with heat pumps, and quite a few owners have an EV, so the street makes an excellent case for developing a more autonomous and independent energy community.

MANAGING POWER STORAGE AT HOME AND STREET LEVEL

To test this out, additional equipment was needed, including energy storage solutions at street level. Last year, ENGIE Laborelec and project partners tested and installed all the necessary equipment, including a 120 kWh (56 kW) community battery, four 1 kW hybrid heat pumps, two vehicle-to-grid charging stations, and a series of 3 kW water heaters. We also installed measurement systems in all the connected homes to monitor each home's energy

consumption and production.

Our cloud-based energy management system decides a day in advance which devices should charge, and when. ENGIE Laborelec expert Matthijs Doclo outlines the thinking: *"The assets shared by the community provide power when it's most needed and store it when power production exceeds demand. The EV batteries can also contribute to fulfilling power demand."*

ALL SET FOR THE REAL-LIFE TESTS

Everything is now in place for the real-world tests in 2022. During the test period, power demand and supply will be balanced daily using ENGIE Laborelec's optimization algorithm, which analyzes the power consumption and production of the previous few days and predicts PV yield based on the following day's weather forecast.

The goal is to demonstrate that such an arrangement is viable and contributes to reducing power consumption and making communities less dependent on (capital intensive) grid supply. We also expect that it will encourage homeowners to install additional PV capacity, since increasing self-consumption will mean they should no longer worry that their system is disconnected during periods of excess PV power production. ■



Evaluating the potential benefits of renewable energy communities

ENGIE Laborelec is participating in AMORCE, a project designed to evaluate how beneficial renewable energy communities are for their members or the distribution system.

A renewable energy community (REC) is a community of citizens, often extending to small and medium enterprises and local authorities, whose electricity systems are connected virtually in such a way that they can optimize self-consumption of the locally produced renewable power.

REDUCING THE STRAIN ON THE DISTRIBUTION GRID

The primary purpose of RECs is to provide environmental, economic, and social benefits to community members or the local areas in which they operate. As such, they are believed to be an important tool in the energy transition. For example, RECs are

thought to stimulate members to invest in additional PV capacity with the production shared optimally within the community at an attractive rate and with lower impact on the distribution grid. This could lead to less strain on the grid than in situations where consumers and prosumers behave individually rather than collectively. At the same time, it could help consumers reduce their electricity bills.

A FLAGSHIP REC PROJECT IN WALLONIA

The AMORCE project is designed to figure out whether RECs can live up to this promise. The project was initiated by the Walloon Region of Belgium as part of its aim to increase decentralized renewable power generation, reduce energy insecurity, and boost the electrification of energy use in the home. It also aims to assess the societal challenges linked to this development and to propose consistent schemes and models related to pricing, protocols, and security for everyone concerned.



DEVELOPING SCENARIOS AND EVALUATING THE POTENTIAL

Launched in 2021, AMORCE is currently at the study phase. ENGIE Laborelec is developing comprehensive virtual models to evaluate the viability and technical potential of the REC concept in four representative topologies: an apartment building in Brussels, a rural area near Marche-en-Famenne, a peri-urban area in Liège, and an urban street in Schaerbeek.

ENGIE Laborelec project manager Benjamin Pierre outlines the technical challenge: *"We are developing scenarios to evaluate the potential benefits, both for the members of the community and the grid operator."* The results will be shared with business units to evaluate the potential for introducing such RECs in Belgium and France. ■

Guidance in the residential batteries market

As demand for residential batteries started to boom in the Flemish region of Belgium in 2021, ENGIE Laborelec's experience in this area, developed through years of R&D, proved to be invaluable.

A growing number of households is considering purchasing a home battery to help increase self-consumption of the yield from their PV installation. However, many still wonder if prices anywhere between €2,500 and €8,000 represent value for money, and safety concerns are also an issue.

TESTING AND BENCHMARKING

ENGIE Laborelec has been developing its expertise and experience in this area for many years. We have tested and benchmarked commercially available lithium-ion and other types of batteries for



domestic use. These tests involve verifying and comparing technical specifications and functionalities such as the ability to increase self-consumption, backup capability, charging or discharging in response to energy prices, and forecasting production and consumption. We have also developed and maintain safety guidelines for installing home batteries.

R&D DELIVERING GREAT VALUE

This long-term commitment to R&D means that we are fully equipped to provide authoritative and accurate advice wherever it is needed. In 2021, we clearly demonstrated this in Belgium's Flemish region.

With new regulations coming into force in 2020 and 2021, PV owners were suddenly spurred on to maximize self-consumption and optimize injection into the grid. As a result, many households were looking for a suitable battery solution, not least because of subsidies being offered from 2020. ENGIE Laborelec was on hand to support ENGIE in establishing an attractive offering to meet this market need.

FINDING THE BEST SOLUTION FOR ANY GIVEN SITUATION

It's clearly not a one-size-fits-all thing - context is extremely important. What region are we in? Is there an existing PV installation? What's the PV capacity and what type of inverter has been installed? What's the annual consumption? Are any major consumption units, such as an EV or a heat pump, likely to be added in the future?

"We've been conducting simulations based on a wide range of consumption and production profiles," says ENGIE Laborelec expert Erwin Brouwers. "This allows us to find the optimum battery size for every situation."

FEEDBACK TO AUTHORITIES

We're currently monitoring and analyzing a selection of installed batteries. Based on this analysis and backed by our years of experience with power storage solutions, we also provided feedback to help the Flemish authorities in their decision-making. ■

ESyPAC: simulating residential electrical systems to develop viable business cases

ENGIE Laborelec further developed ESyPAC, which is a versatile, modular application for the simulation of small- to medium-scale electrical systems, to develop viable business cases for the diversity of the residential market.

ESyPAC, an acronym for Energy Systems Performance Assessment and Comparison, is designed to simulate any residential electrical system. This includes the typical baseload consumption of dwellings supplemented by contributions specifically from household assets such as heating and hot water appliances, electric vehicles, solar production, and battery storage. Users can be separately characterized as having their own consumption behaviour profiles, for example driving and vehicle charging habits, or hot water usage patterns.

EVALUATING USE CASES

ENGIE Laborelec uses ESyPAC to support ENGIE business units in shaping their offering to households, apartment building residents, and energy communities, in the context of the energy transition. Possible use cases, among many, include maximizing self-consumption of renewables, peak shaving (to avoid main fuses tripping or to increase contractual power), financial optimization of individual tariff schemes

(peak/off-peak, dynamic, or capacity-based), and reducing CO₂ emissions.

EXPANDING AND ENRICHING MODELS, LIBRARIES, AND OPTIMIZATION TECHNIQUES

Digital models of residential electrical devices are the building blocks of ESyPAC, so it is essential that they are accurate and capable of being fully parametrized. ENGIE Laborelec experts are therefore constantly developing new models and finetuning those already in use. One model developed in 2021 is the heat pump.

The library of tariff schemes was also refined by integrating a capacity-based cost component. Mathematical optimization models have also been extended to include financial optimization, leading to better control over flexible assets to keep customer bills down.

BOOSTING ENGIE BUSINESS UNIT PERFORMANCE

ENGIE Laborelec also builds software

products that allow ENGIE advisors to efficiently craft tailor-made proposals to customers. A prime example is the web service put in place for ENGIE's France BtoC MyPower team. Developed as an extra layer on top of ESyPAC, the simulation tool allows MyPower advisors to rapidly assess the most appropriate energy system for given building and consumer profiles, including the design of the PV installation. "This clearly demonstrates how ESyPAC helps us boost the performance of ENGIE business units and increase their market reach," says ENGIE Laborelec expert Raphael Gehrenbeck. ■





Agathe Pharel,
Lighting & Urban Solutions Lab,
ENGIE Laborelec

LIQUEFACTION LAB

ENGIE Lab CRIGEN

A new partnership on cryogenic carbon capture to develop an energy-effective carbon capture solution



CONTEXT

Cryogenic capture via anti-sublimation appears to be promising solution to capture CO₂ from the Group's Combined Cycle Gas Turbine (CCGT).

Elengy's goal is to anticipate a significant level of a green gas production in France in the coming decades. For its future industrial activity, Elengy is interested in the possible benefit of using LNG cold energy in CO₂ capture processes and of exporting liquid CO₂.

NEWS

In 2021, the liquefaction Lab developed a process to capture carbon from low content industrial flue gases with the integration of cold energy recovery from liquefied natural gas from Elengy terminal. In collaboration with Elengy and other industrial and university partners, a joint project was created in order to demonstrate the technical and economic feasibility of a large-scale cryogenic carbon capture method via anti-sublimation in an industrial environment with the integration of LNG cold energy recovery. A request for subsidies was made by partners under the Horizon Europe request for proposals and should be submitted at the beginning of 2022. In 2022, the Liquefaction Lab will assess the potential replicability of the technology for ENGIE's CCGTs and for LNG-fueled ships, in line with Elengy's ambitions and the CMA CGM partnership.

WHAT ARE THE BENEFITS FOR ENGIE?

- An LNG recovery pathway for Elengy terminals.
- A boost for the development of a new business for Elengy.
- Design of a cost-effective CO₂ capture technology and the development of intellectual property.
- Decarbonisation of ENGIE industries (CCGT).
- Strengthening of the ENGIE/CMA CGM partnership. ■

The Liquefaction Lab provides support to the Hydrogen Business Unit for the development of liquid hydrogen projects

CONTEXT

The Green Cluster H₂ develops projects to produce and sell renewable hydrogen. Some of these projects include liquid hydrogen production and distribution.

NEWS

By supplying technico-economic analysis and feasibility studies to determine whether liquid hydrogen is relevant or not for a business case, the Liquefaction Lab provided its services to several ENGIE's clients:

- Liquid hydrogen distribution to build a network of refueling stations across Germany;
- Innovative liquid hydrogen storage and operations for the European railroad industry;
- Call for quotation for an LH₂ supply in North America;
- Storage data supply to JIP Marine;
- The interest of LH₂ as backup energy storage for datacenters;
- The conversion of mining engines to LH₂.

WHAT ARE THE BENEFITS FOR ENGIE?

ENGIE Lab CRIGEN's Liquefaction Lab services helps ENGIE to promote liquid hydrogen as a renewable fuel for heavy duty transport solutions, thereby opening new markets to ENGIE while accelerating the transition to a carbon-neutral economy. ■



HYDROGEN LAB

ENGIE Lab CRIGEN

C2FUEL: green hydrogen for smarter industrial ecosystems



CONTEXT

The C2FUEL project aims at developing energy-efficient, economically and environmentally viable Power-to-Liquid technologies for the displacement of

fossil fuel emissions through a concept of industrial symbiosis between carbon-intensive industries, power production, and the local economy. This concept will be demonstrated at Dunkirk at ENGIE's DK6 combined cycle power plant, Arcelor Mittal's steel factory and one of the major European harbors, a showcase for future replication. The C2FUEL consortium is composed of 11 companies from 7 countries and is coordinated by ENGIE Lab CRIGEN.

NEWS

In 2021, outstanding R&D developments were achieved in terms of all the unit components developed. Regarding CO₂ capture, a pilot has been installed on the DK6 power plant site in order to assess impact of blast furnace gas impurities on capture performances and reliability. First results are promising and long-term testing will be carried out to ensure that any risks related to the installation of the whole integrated pilot in 2023 will be mitigated. Regarding high-temperature electrolysis, we have already achieved our target in

terms of specific consumption obtained at cell and stack levels. Regarding DME and FA production, catalysts has been selected and reactor design is on-going. In parallel, the preliminary work needed to install the integrated pilot at the DK6 plant is still on-going in terms of consolidated designs, safety assessment, regulatory aspects, etc.

WHAT ARE THE BENEFITS FOR ENGIE?

The C2FUEL project will allow CO₂ emission from the steel-making factory to be reused, renewable electricity surplus to be used in the Dunkirk area and the operational and environmental performance of ENGIE DK6 combined cycle to be improved through the production of hydrogen based fuels to be used for transport applications within Dunkirk Harbor environment. The demonstration phase will enable very innovative technologies to be assessed in a relevant industrial environment and the fuels produced will be tested in real end-user systems. The work achieved by ENGIE via C2FUEL as an integrator of innovative technologies for the production of e-fuels based on CO₂, is directly available for use in the Group's on-going commercial projects (REUZE, Hy-NL, etc.). ■

ARENHA: demonstrating how ammonia can provide safe and profitable large-scale energy storage

CONTEXT

The key objective of ARENHA is to demonstrate the viability of ammonia as a dispatchable form of large-scale storage in order to promote the integration of renewables. Breakthrough technologies will be developed and integrated within the overall value chain. The ARENHA project will identify the most suitable business cases, develop sustainable and ground-breaking energy storage systems through advanced technologies based around a green ammonia value chain and will increase the market readiness of the ARENHA technologies by demonstration units at TRL 5.

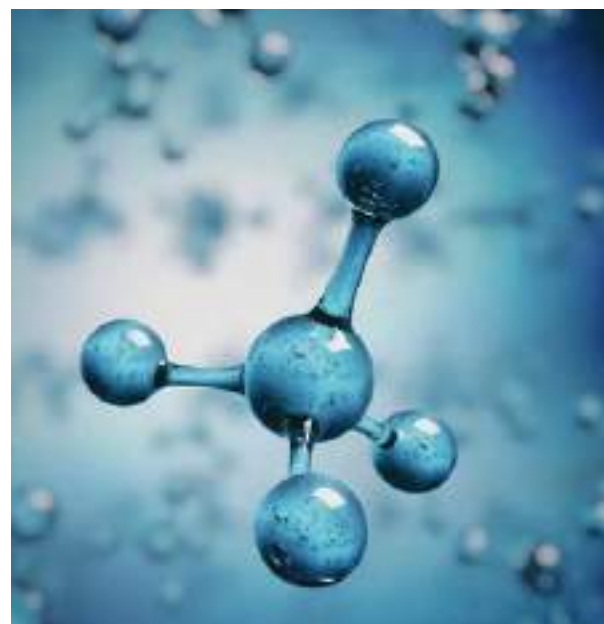
NEWS

In 2021 ARENHA moved forward with the work packages regarding system requirements, design and modeling, and key component development. Partners have proposed their modeling component in their respective technologies, ammonia synthesis (Proton Ventures), ammonia storage (DTU),

ammonia decomposition (TUE), while ENGIE has proposed a modeling component on solid oxygen electrolysis in collaboration with partners developing these technologies (IKTS and ELCOGEN). Partners have reported on the development of several key components (electrolysis cells, catalysts for ammonia synthesis, ammonia absorbents, H₂ separation membranes).

WHAT ARE THE BENEFITS FOR ENGIE?

Today ammonia is considered as a prime candidate for chemical energy storage, directly linked to hydrogen because of its chemical composition (NH₃) which makes it a carbon-free hydrogen carrier. ARENHA evaluates a complete chain of groundbreaking technologies allowing ammonia-based energy storage aiming at demonstrating feasibility, reducing costs and increasing safety in future commercial applications, which ENGIE will help evaluate and develop during the project. ■



WINNER: exploring new materials to tackle the challenges of high temperature electrolysis

CONTEXT

The WINNER project comprises both industrials and academic & research institutions leading the development of materials for high temperature electrolysis. The project seeks to develop and demonstrate novel materials for proton-conducting cells (PCC) which can be applied to electrolysis and many chemical reactions. It builds on the pioneering, multidisciplinary expertise of its partners and will combine materials science, multi-scale multi-physics modelling and advanced in-situ and operando characterization methods to unveil innovations at the frontier of knowledge in PCC systems. Starting at TRL2 level, WINNER will develop innovative cells and modules that will be validated at laboratory scale in regards to their mechanical stability, proton throughput and electrochemical performance and ultimately further develop the PCC technology to TRL4/5 levels.

NEWS

In 2021, in its first year, WINNER started the development of model electrodes based on Ba_{0.5}La_{0.5}CoO_{3-δ} (BLC) and developed

knowledge and methodologies to create innovative cell architectures and new current collectors. Modelling activities commenced too, with the development of an engineering model which will integrate different disciplines and length scales (atomistic, electro-chemical, mechanical, fluid flow, reactor engineering, electric, heat).

WHAT ARE THE BENEFITS FOR ENGIE?

WINNER focuses on the development of PCC technologies which are considered as next generation materials with application for high temperature electrolysis and chemical reactors in the medium to long term. The project focuses on two applications for energy storage with commercial potential, i.e., reversible electrolysis and ammonia cracking to hydrogen and power for which ENGIE will participate in LCA and techno-economic analyses. Participation in the development of these materials and applications allow the group to identify technological and/or commercial opportunities at an early stage. ■



Jet fuel production for aviation sector

CONTEXT

The aviation sector is responsible for approximately 3% of total CO₂ emissions worldwide and for producing 600 billion metric tons per year. It is however considered a hard sector to abate, due to the lack of proven green technological solutions (batteries, hydrogen, etc.) especially for long distance flights. Consequently, synthetic jet fuel has become a key solution to decarbonize the sector and smooth the energy transition for this sector with the goal being to achieve a carbon neutral solution, based on capturing CO₂ from the atmosphere or a nearby industry and to hydrogenate it to produce aviation fuel, which will be blended with the conventional solution in increasing proportions, thereby decreasing the carbon footprint in this sector.

NEWS

Along with Safran, ENGIE has acquired the German start-up Ineratec to boost the development of carbon-neutral synthetic fuel production for the aviation industry. ENGIE and Infinium™, supplier of technology for low carbon print e-fuels, announced a partnership to develop together "Reuze",



a synthesis e-fuels production project in Dunkirk for the aviation and maritime sectors, both of which are hard to abate.

NEXT STEPS

Continue the development of digital models and simulations of key business models

continuously aligned with the results of Hydrogen Lab's stack tests and thereby accompanying GBUs in their ongoing investment decisions and the development of new synthetic fuel production projects. ■

Low temperature electrolysis

CONTEXT

Low-temperature electrolysis technologies have the ability to unlock the full potential of electrical renewable energies thanks to their flexibility and reliability. Thus, ENGIE has the ambition to install 4GW of electrolysis within 2030. However, some R&D aspects need to be addressed (direct coupling with renewables, piloting strategies,



manufacturing, PGM free catalysts, operation at high temperature and high pressure, etc.), and new technologies are emerging (such as alkaline electrolysis membrane). In addition, GBU operating electrolysis systems need support to both select the most relevant technologies, and then operate these in the most competitive way, especially taking into account the impacts of operating this intermittently on their assets.

NEWS

In 2021, ENGIE Lab CRIGEN finalized the installation of a PEM electrolysis system at the Stains facilities. This asset will enable the hydrogen needed for the H2FACTORY testing platform to be produced and some specific testing to be performed in order to exhaustively characterize the impact of intermittency on performance and durability of electrolysis systems. On this topic, a PhD has been started in collaboration with an academic partner, FCLAB. The objective of this PhD project is to quantify the impact of intermittency and propose suitable mitigation measures. For this purpose, ENGIE Lab CRIGEN will rely on data from the H2FACTORY electrolysis system, from on-going modeling and simulations works and operational data available within the Group. In regards to this, preliminary work has been carried out in 2021 to draw comprehensible conclusions from wide operational datasets. ■

HyFill, a tool for refueling H₂ stations

CONTEXT

The Hydrogen Lab is developing HyFill, a thermodynamic modeling and simulation tool for refueling stations in order to better understand hydrogen refueling station design and performance, to help reduce HRS CAPEX and OPEX and to develop a refueling protocol for heavy duty vehicles entering the market.

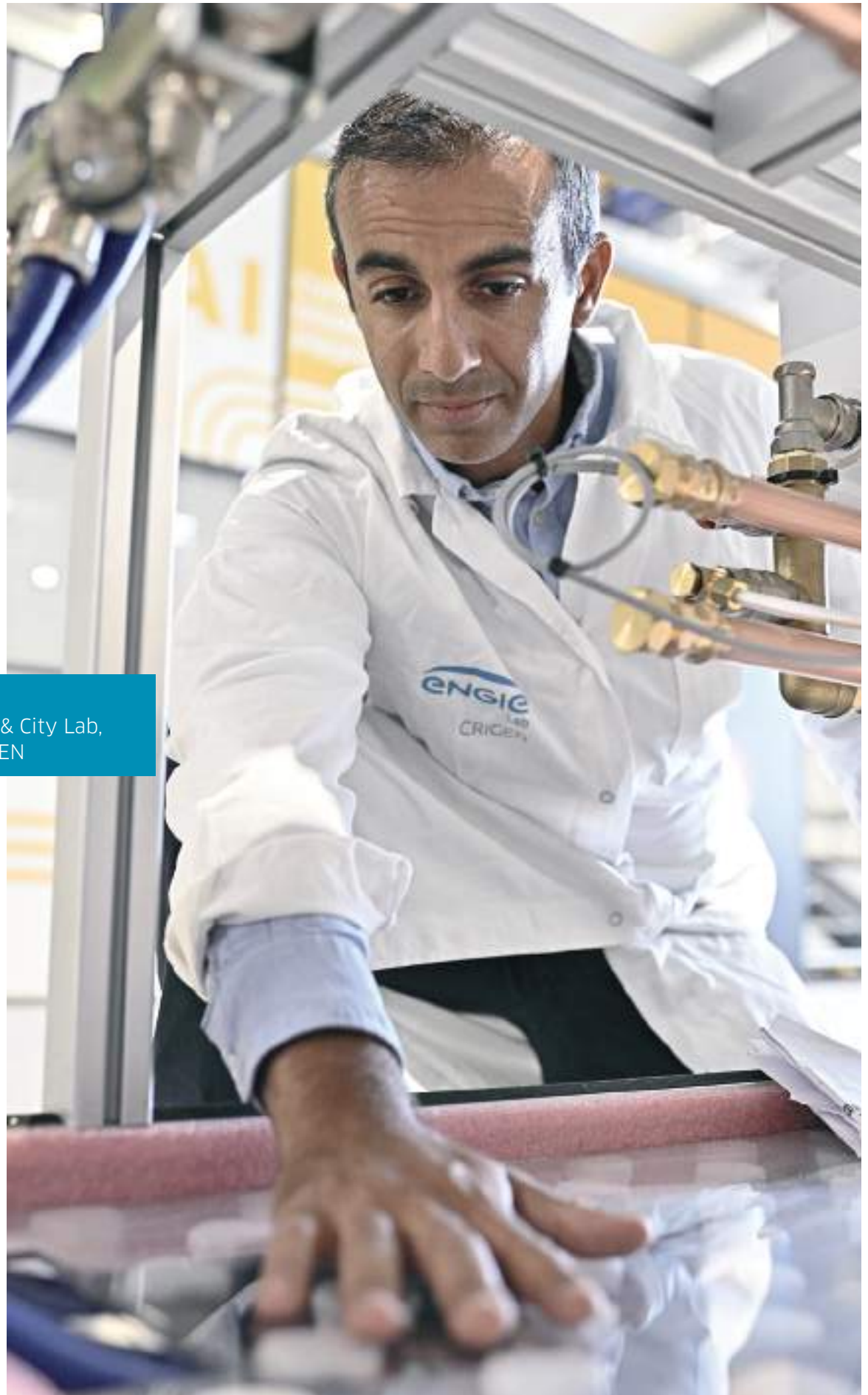
NEWS

HyFill tool has been used to perform a study on a hydrogen trailer refueling for Storengy. A sensitivity study, based on several simulations taking into consideration different pressure and temperature conditions, was performed in order to define the level of performance that can be achieved during hydrogen trailer refueling in a refueling center, in order to transport hydrogen from a large scale electrolysis plant to the final client.

WHAT ARE THE BENEFITS ENGIE?

ENGIE business units can rely on ENGIE Lab CRIGEN's Hydrogen Lab and Hyfill tool to study and define the refueling conditions of different hydrogen storage systems either for their own trailer refueling purposes or for their client's vehicle storage. ■





Karim Djama,
Future Building & City Lab,
ENGIE Lab CRIGEN

INTELLECTUAL PROPERTY PATENTS ISSUED IN 2021



The Intellectual Property Mission located at ENGIE Lab CRIGEN helps researchers promote their technical inventions and manages the entire patent process, from filing the application to obtaining approval and exploiting the patent.





ENGIE Lab Cylergie

« Méthode de mesure continue de la concentration en trichloramine dans l'air » [Method for continuously measuring the trichloramine concentration in air], Mesure Trichloramine. [Patent application FR1873946, issued in France.](#)

ENGIE Lab CRIGEN

BIOGAS, BIOMASS & WASTE LAB

« Réacteur de méthanation pour faire réagir de l'hydrogène avec au moins un composé à base de carbone et produire du méthane et de l'eau » [Methanation reactor for reacting hydrogen with at least one carbon-based compound and producing methane and water], Gaya-2 Injection d'eau. [Patent application FR1359313, issued in Canada and in Korea.](#)

« Réacteur de methanation pour faire réagir du dihydrogène avec au moins un composé à base de carbone » [Methanation reactor for reacting dihydrogen with at least one carbon-based compound], Gaya-3. [Patent application FR1359314, issued in Europe.](#)

« Procédé et dispositif de traitement d'un gaz de synthèse provenant d'une étape de gazéification de biomasse » [Method and device for treating a synthesis gas from a biomass gasification step], Gaya-4 Epuraton. [Patent application FR1453328, issued in Brazil and Malaysia.](#)

« Dispositif et procédé de production de gaz naturel de substitution et réseau le comportant » [Device and method for producing substitute natural gas and network comprising same], Gaya-5. [Patent application FR1360488, issued in Brazil, Korea, Canada and Malaysia.](#)

« Dispositif de refroidissement pour réacteur catalytique de méthanation de dioxyde de carbone » [Cooling device for carbon dioxide methanation catalytic reactor], Gaya-6. [Patent application FR1502627, issued in Brazil, France and in Europe.](#)

« Dispositif et procédé de production de gaz de synthèse » [Device and method for producing synthesis gas], Gaya-7 Filière gazéification. [Patent application FR1650494, issued in Malaysia.](#)

« Dispositif et procédé d'hydrogénation du CO₂ pour produire du méthanol et dispositif et procédé de cogénération de méthanol et de méthane de synthèse » [Apparatus and process for the hydrogenation of CO₂ to produce methanol and apparatus and process for the cogeneration of methanol and synthetic methane], Gaya 9. [Patent application FR1653354, issued in France.](#)

« Matériau catalytique à base d'oxyde d'alumine, d'oxyde de nickel et d'oxyde de praséodyme et son utilisation pour la méthanation » [Method for converting a gas comprising carbon monoxide into methane by means of a cathalytic containing praseodymium and nickel on alumina], Catalyseur praséodyme. [Patent application FR1759927, issued in the USA.](#)

FUTURE INDUSTRY LAB

« A combustion method applied to melting materials such as glass in an end-fired furnace », CT Glass 2 Cross-Fired. [Patent application EP17305979.1, issued in the USA.](#)

« Procédé de prévention du dépôt de biosalissures sur un matériau en contact avec un milieu aqueux » [Method of preventing the deposition of biofouling on a material in contact with an aqueous medium], Antifouling A. [Patent application WO2016/050219, Issued in Saudi Arabia and China.](#)

« Procédé de prévention du dépôt de biosalissures sur un matériau en contact avec un milieu aqueux » [Method of preventing the deposition of biofouling on a material in contact with an aqueous medium], Antifouling B. [Patent application WO2016/050214, issued in Saudi Arabia and China.](#)

GREEN GASES MOBILITY LAB

« Véhicule hybride comportant un groupe électrogène » [Vehicle comprising an electricity generator set], G-City. [Patent application FR1363478, issued in Europe.](#)

NANOTECHNOLOGIES, SENSORS & WIRELESS LAB

« Dispositif électronique destiné à être inséré dans une canalisation, et procédé d'installation du dispositif » [Electronic device intended to be inserted into a pipe, and method of installing the device], Perforateur avec débitmètre intégré. [Patent application FR1563505, issued in Europe.](#)

« Procédé et dispositif de localisation rapide et in situ de sources de pollution en environnement intérieur » [Method and device for the rapid and in situ localisation of pollution sources in indoor environments], Evaluation QAI. [Patent application FR1563486, issued in France.](#)

« Système et dispositif de détermination de la valeur d'un paramètre de cuve de stockage de liquide, utilisation dudit dispositif » [System and device for determining the value of a local deformation parameter of a liquid storage tank and use of said device], Lidar pour GNL. [Patent application FR1663142, issued in Europe and in Singapore.](#)

« Equipement de sécurité et procédé de protection » [Safety harness, safety equipment comprising said harness and protection method], Harnais connecté. [Patent application FR1760357, issued in France.](#)

« Dispositif de mesure, en particulier pour la détection de dihydrogène dans le sol d'une région » [Measuring device, in particular for the detection of dihydrogen in the soil of a region], Détecteur NanotechH2. [Patent application FR1901121, issued in France.](#)

FUTURE BUILDING & CITY LAB

« Dispositif de cuisson » [Cooking device], Sélecteur multibrûleurs. [Patent application FR1555225, issued in Europe.](#) Hydrogen Lab

« Réacteur de méthanation biologique » [Biological methanation reactor], BioM lit fluidisé. [Patent application FR1757705, issued in France.](#)

LIQUEFACTION LAB

« Installation de stockage portuaire de combustible liquide » [Harbour storage facility for liquid fuel], Smart LNG Plug - Solution bunkering. [Patent application FR1354655, issued in Brazil and Canada.](#)

« Procédé et système pour calculer en temps réel la durée d'autonomie d'une cuve non réfrigérée contenant du GNL » [Method and system for calculating in real time the duration of autonomy of a non-refrigerated tank containing LNG], Smart Gauge 1 - Holding Time). [Patent application FR1562854, issued in Australia, Korea, USA, Japan and Singapore.](#)

« Procédé et système pour calculer en temps réel la quantité d'énergie transportée dans une cuve de GNL pressurisée et non réfrigérée. » [Method and system for the real-time calculation of the amount of energy transported in a non-refrigerated, pressurized, liquefied natural gas tank], Smart gauge 2 - GHV). [Patent application FR1656241, issued in Korea, Japan and Singapore.](#)

« Procédé pour calculer en temps réel l'indice de méthane MN d'un gaz naturel liquéfié » [Method for calculating in real time the methane number MN of a liquefied natural gas], Smart gauge 3 - MN. [Patent application FR1662507, issued in Australia, Japan, Korea.](#)

« Dispositif et procédé de fourniture de gaz naturel liquéfié » [Device and method for supplying natural gas], Limitation BOG LBV. [Patent application FR1761146, issued in France.](#)

« Procédé et installation de transport et liquéfaction de gaz » [Process and installation for the transport and liquefaction of gas], Lilibox 0. [Patent application FR1451707, issued in Europe.](#)

« Système de purification d'un mélange de gaz, procédé et installation associés » [Gas mixture purification system, associated process and installation therfor], Lilibox 1. [Patent application FR1856747, issued in France.](#)

« Installation de production de bio-méthane et procédé de pilotage d'une telle installation » [Installation for the production of bio-methane and method for controlling such an installation], Lilibox 4. [Patent application FR1750920, issued in France.](#)

« Dispositif et procédé autonome de fourniture d'électricité » [Autonomous electricity supply device and method], Distributeur autonome de GNL. [Patent application FR1761148, issued in France.](#)

« Dispositif amovible de prélèvement d'un échantillon de gaz liquéfié et canalisation de transfert de gaz liquéfié » [Removable liquefied gas sampling device and liquefied gas transfer line], Prélèvement GNL. [Patent application FR1859990, issued in France.](#)

« Dispositif, système et procédé de régulation de la pression pour un réservoir de stockage de gaz naturel liquéfié » [Device, system and method for pressure regulation for a liquefied natural gas storage tank], Système anti venting truck. [Patent application FR1663065, issued in Europe.](#)

ENGIE Laborelec

WIND, HYDRO MARINE LAB

GBU Renewables

« Measurement Processing System for condition monitoring of a wind turbine ». [Patent application EP2998812A1, issued in Europe.](#)

SOLAR LAB

GBU Renewables

« Method for detecting PV anomaly and determining long-term degradation ». [Patent application BE2020/5445, issued in Belgium.](#)

FUTURE COLLECTIVITIES & HOME LAB

GBU Energy Solutions

« System and Method for detecting a change on a moving surface ». [Patent application US10907987, issued in the United States of America.](#)



Maxence Bureau,
ENGIE Lab Cylergie

COLLABORATIVE FUNDED PROJECTS



In 2021, ENGIE Lab CRIGEN and ENGIE Laborelec conducted and won a number of projects that received funding from the European Union's Horizon 2020 Research and Innovation Program under a grant agreement as well as funding from third-party organizations.





ENGIE LABORELEC

Projects began in 2021 →

AMORCE

AMORCE or Analyse Macro et micro-économique pour l'Optimisation et la Réplicabilité des Communautés d'Energie

Project began in 2021 > Funding Agency is BE-SPW

The project will study the societal gain linked to the development of new modes of energy exchange, and propose pricing/protocol/security schemes and models that are coherent for all actors, and above all, understandable for citizens and end users.

To feed the studies, close links are established with the stakeholders of the Walloon ecosystem and also with citizens' groups, users or investment companies, developers and property managers present on the territory of the City of Liege, where the Living Labs can then be deployed, making it possible to nuance and bring to life the conclusions of the previous studies.

The aim of the project is therefore to propose models and tools to replicate the energy communities in the configurations identified as the most relevant for the community. It will then be possible to quantify the potential for energy and environmental savings in the coming years and to plan its realisation.

Consortium partners: 1. MULTITEL (BE) (Lead); 2. U-Liège-HEC (BE); 3. U-Liège-DSGE-BEMS (BE); 4. **ENGIE Laborelec (BE)**; 5. Cluster TWEED (BE); 6. U-Mons (as subcontractor).

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CO2OLHEAT

CO2OLHEAT, or Supercritical CO₂ power cycles demonstration in Operational environment Locally valorising industrial Waste Heat.

Project began in 2021 > Funded by EC-H2020

Demonstrate at TRL7 in the CEMEX cement manufacturing plant in Prachovice (CZ) the operation of a 2 MW Waste-Heat-to-power (WH2P) skid based on a 2MW-sCO₂ cycle able to efficiently valorize local waste heat at a significant temperature of 400°C. Capitalizing consortium excellent knowledge coming from previous sCO₂ turbomachinery design experience and EU funded projects on industrial waste heat valorization (TASIO, i-THERM, sCO₂-FLEX etc.) and stimulated by SPIRE roadmap and EU sCO₂ R&D initiatives, CO2OLHEAT aims to valorize waste heat even at higher temperature if compared with the traditional steam/ORC solutions.

The project will analyze sCO₂ WH2P potential from a technical, economic and environmental point of view, developing innovative models for the design of the cycle and of the turbomachinery as well as investigating CO2OLHEAT cycle benefits in the cement, glass, aluminium, power generation sectors via techno-economic and Life Cycle based replication feasibility studies. The project is coordinated by ETN and involves an industry driven consortium with key turbomachinery OEM (SIE-BH), energy intensive industries, energy utilities and R&D partners all committed to bring soon CO2OLHEAT sCO₂ cycle technologies on the market.

Consortium partners: 1. EUROPEAN TURBINE NETWORK (BE) (Lead); 2. RINA CONSULTING SPA (IT); 3. SIEMENS GAS AND POWER GMBH & CO KG (DE); 4. UNIVERSITAET DUISBURG-ESSEN (DE); 5. NUOVO PIGNONE SRL (IT); 6. POLITECNICO DI MILANO (IT); 7. SimeROM S.R.L. (RO); 8. CEMEX Czech Republic, s.r.o. (CZ); 9. BRUNEL UNIVERSITY LONDON (UK); 10. MAS AE PROIGMENES TECHNOLOGIES ENERGEIAS KAI ISCHYOS (EL); 11. UNIVERSITA DEGLI STUDI ROMA TRE (IT); 12. ETHNIKO KENTRO EREYNAS KAI TECHNOLOGIKIS ANAPTYXIS (EL); 13. ACONDICIONAMIENTO TARRASENSE ASSOCIACION (ES); 14. MEGGITT (UK) LIMITED (UK); 15. **ENGIE Laborelec (BE)**;

16. ELECTRICITE DE FRANCE (FR); 17. MYTILINAIOS ANONIMI ETAIREIA (EL); 18. TURKIYE SISE VE CAM FABRIKALARI AS (TR); 19. BOSAL EMISSION CONTROL SYSTEMS NV (BE); 20. COMPANIA ESPANOLA DE LAMINACION SL (ES).

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CSP-PLUS CSP+

CSP-PLUS, or Enhanced PV integrated Concentrator Solar Power system.

Project began in 2021 > Funding Agency is BE-VLAIO

Create a hybrid photovoltaic (PV) and concentrating solar thermal power (CSP) system that combines the high efficiency of a PV system with the energy storage benefits of a CSP system.

The result will be a CSP+ power plant with an efficiency 50% higher than that of a conventional CSP plant for only 10% additional cost. This is achieved by splitting the broad solar spectrum and sending selected wavelengths to PV cells while sending the rest to the CSP system.

Consortium partners: 1. AZTEQ (BE) (Lead); 2. Borealis Polymers (BE); 3. IMEC (BE); 4. KUL (BE); 5. **ENGIE Laborelec (BE)**; 6. SOLTECH (BE); 7. VITO (BE).

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DigSub

DigSub, or Transition towards DIGgital SUBstations.

Project began in 2021 > Funding Agency is BE-VLAIO

Develop consistent methodology, based on FMEA, to assess the reliability performance of digital substations:

- Reduce engineering time in future projects through (semi-) automated procedures and identification of concrete integration pitfalls, allowing equal or higher reliability in digital substations at lower (implementation) costs compared to traditional systems. Time required for testing will be reduced with 50%;
- Making the consortium partners thought leaders in the field by providing a roadmap for acceptance of digital substations as a reliable smart grid technology;
- Demonstrating to potential users the reliability of Digital Substations and thereby giving the industrial partners the opportunity to conceive new products and new types of turn-key solutions for the market.

Consortium partners: 1. KU Leuven (BE) (Lead); 2. BASF (BE); 3. **TRACTEBEL-ENGIE (BE)**; 4. ABB (BE); 5. Siemens (BE); 6. VITO (BE); 7. **ENGIE Laborelec (BE)**.

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FORWARD2030

FORWARD2030, or Fast-tracking Offshore Renewable energy With Advanced Research to Deploy 2030MW of tidal energy before 2030.

Project began in 2021 > Funded by EC-H2020

To advance the commercialisation and rollout of tidal stream energy FORWARD-2030 has five overall objectives:

- Reducing Levelized Cost of Energy (LCOE) from €200/MWh to €150/MWh;
- Enhancing environmental and societal acceptance;
- Enhancing commercial returns and energy system integration (with battery storage and green hydrogen production and other renewables);
- Reducing life cycle carbon emissions by 33% from 18 gCO₂ eq/kWh to 12 gCO₂ eq/kWh;
- Complete the industrial design and develop the manufacturing and supply chain for volume rollout.

Consortium partners: 1. Orbital Marine Power (UK) (Lead); 2. **ENGIE Laborelec (BE) with support of ENGIE Lab CRIGEN (FR)**; 3. EMEC (UK); 4. University of Edinburgh (UK); 5. SKF (DE); SKF (SWE); 6. University College Cork (Irl).

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RAINBOW

RAINBOW, or Optimized prediction and decision support for rain erosion and lightning-driven degradation of blades.

Project began in 2021 > Funding Agency is BE-VLAIO

Develop new monitoring tools, including rain and lightning detectors and camera inspection by drones coupled with improved data-driven weather forecasting on short and long term.

The impact by rain droplets and lightning strikes will be studied in controlled laboratory conditions and by CFD modelling to assess material and coating degradation and the impact on the wind turbine power curve.

Consortium partners: 1. Von Karman Institute - VKI (BE) (Lead); 2. VUB (BE); 3. SIRRIIS (BE); 4. SABCA (BE); 5. RC Takeoff (BE); 6. OTARY (BE); 7. Norther (BE); 8. Nitto Belgium (BE); 9. Siemens Gamesa Belgium (BE); 10. **ENGIE Laborelec (BE)**.

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STARGATE

STARGATE, or Sustainable airports, the green heart of Europe.

Project began in 2021 > Funded by EC-H2020

Develop, test and deploy a set of innovative solutions making the airport ecosystem significantly more sustainable. STARGATE is grounded on five main pillars:

- Application of a Digital Twin ecosystem for airports and extensive development to model the Lighthouse Airport;
- Focus on multimodal, sustainable and smart mobility through an innovative mobility governance practice and dedicated tools;
- Optimisation of terminal operations, circular resource management and the minimisation of resources and waste generated;
- Investigation in the energy field and production and use of SAF;
- Minimisation of noise and emissions, assessing non-technological framework conditions and promoting new multi-actor governance.

Consortium partners: 1. BRUSSELS AIRPORT COMPANY (BE) (Lead); 2. TO70 BV (NL); 3. ATHENS INTERNATIONAL AIRPORT S.A. (EL); 4. Budapest Liszt Ferenc International Airport (HU); 5. AEROPORT TOULOUSE BLAGNAC SA (FR); 6. LUXMOBILITY S.A.R.L. (LU); 7. UNIVERSITEIT HASSELT (BE); 8. ERASMUS CENTRE FOR URBAN, PORT AND TRANSPORT ECONOMICS BV (NL); 9. IES R&D (IE); 10. SOPRA STERIA GROUP (FR); AIR CARGO BELGIUM (BE); 11. DHL Aviation NV (BE); 12. VLAAMS-BRABANT (BE); 13. **ENGIE Laborelec (BE) included support of Tractebel-ENGIE (BE)**; 14. Skytanking NV (BE); 15. Quatra (BE); 16. VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V. (BE); 17. BRUSSELS AIRLINES (BE); 18. TUI Airlines Belgium nv (BE); 19. SOCIETE NATIONALE DES CHEMINS DE FER BELGES (BE); 20. VLAAMS INSTITUUT VOOR DE LOGISTIEK VZW (BE).

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Projects began in 2020 →

ACES

ACES, or Towards improved Assessment of safety performance for long-term operation of nuclear Civil Engineering Structures.

Project began in 2020 > Funded by EC-H2020

Advance the assessment of safety performance of safety-critical concrete infrastructure by addressing remaining scientific and technology gaps for the safe and LTO of NPPs.

- Clarify, enhance and unify methods of structural integrity assessment in support of LTO.
- Focuses mainly on safety critical reinforced and prestressed concrete structures. ACES is aimed at an experimental proof of concepts, and validates the developed methodologies at both a laboratory scale and a quasi-full scale level (mock-ups).

Consortium partners: 1. VTT(FI) (Lead); 2. EDF (FR); 3. **ENGIE Laborelec (BE)**; 4. CEA (FR); 5. INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE - IRSN (FR); 6. CENTRUM VYZKUMU REZ SRO (CZ); 7. CESKE VYSOKE UCENI TECHNICKE V PRAZE (CZ); 8. LIMITED LIABILITY COMPANY ENERGORISK (UA); 9. SCK-CEN (BE); 10. UT BATTELLE LLC (US); 11. ZAVOD ZA GRADBENISTVO (SL).

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AquaSPICE

AquaSPICE, or Advancing Sustainability of Process Industries through Digital and Circular Water Use Innovations.

Project began in 2020 > Funded by EC-H2020

Materialize circular water use in the European Process Industries, fostering awareness in resource-efficiency and delivering compact solutions for industrial applications.

Follows a systemic approach in water management where optimal efficiency can be achieved through an adaptation of appropriate technologies and practices in different levels, from a single industrial process.

Consortium partners: 1. Rheinisch-Westfaelische Technische Hochschule Aachen University RWTH (DE) (Lead); 2. Dow Olefinverbund GmbH Industry DOW (DE); 3. BASF Antwerpen NV Industry BASF (BE); 4. Solvay Chimica Italia s.p.a. Industry SOLVAY (IT); 5. Türkiye Petrol Rafinerileri Anonim Sirketi Industry TUPRAS (TR); 6. JEMS, Energetska Druzba, d.o.o. Industry JEMS (SI); 7. Agricola International SA Bacau Industry AGRICOLA (RO); 8. **ENGIE Laborelec (BE) with support of ENGIE CRIGEN (FR)**; 9. Water-Link Water Utility (BE); 10. Consorzio ARETUSA PPP ARETUSA (IT); 11. KWR Water BV Research (NL); 12. Fundacio Eurecat Research EUT (ES); 13. VITO Research VITO (BE); 14. Water Europe Platform (BE); 15. Maggioli SpA Large Ent. MAG (IT); 16. Ghent University University UGENT (BE); 17. Università Polytecnica Delle Marche University UNIVPM (IT); 18. Polytechnic Kritis University TUC (GR); 19. Institute of Communication and Computer Systems Research ICCS (GR); 20. Athens University of Economics and Business University AUEB (GR); 21. University of Huddersfield University (UK); 22. Business Development Group SRL SME (RO); 23. Strane Innovation SAS SME (FR); 24. Audencia Business School University (FR); 25. Qlector Razvoj Celovitih Resitev za Pametne Tovarne DOO SME (SI); 26. Accelligence LTD SME (CY); 27. Evides Industriewater Large Ent. (NL); 28. HZ University of Applied Sciences University HZ (NL).

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BLUERA

BLUERA, or Blue Energy Resource Assessment.

Project began in 2020 > Funding Agency is BE-VLAIO

Pre-emptively assess the viability and of ocean energy in Belgian waters by developing two online digital products: a digital wave atlas and an energy yield evaluation tool. Focus on overcoming the challenges inherent to assessing and promoting ocean energy including:

- The diverse nature of the resource in both deep and shallow waters;
- The wide range of technical solutions under development with a lack of a clear convergence of technologies;
- And the inherent complexity of considering the nexus between technology and resource availability.

Consortium partners: 1. IMDC (BE) (Lead); 2. ENGIE Laborelec (BE); 3. POM-West Vlanderen (BE); 4. NSW/Otary (BE); 5. UGent (BE).

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CONDOR

CONDOR, or Combined suN-Driven Oxidation and CO₂ Reduction for renewable energy storage.

Project began in 2020 > Funded by EC-H2020

Develop a modular device for the production of fuels by using water and CO₂ as feedstock and sunlight as the sole energy source through a photosynthetic device made of two main compartments:

- A photoelectrochemical (PEC) cell that splits water and CO₂ and generates oxygen and syngas, a mixture of H₂ and CO;
- A (photo)reactor that converts syngas into methanol and dimethylether (DME), via bi-functional heterogeneous catalysts.

Consortium partners: 1. U-Bologna (IT) (Lead); 2. FUNDACIO PRIVADA INSTITUT CATALA D'INVESTIGACIO QUIMICA - ICIQ (ES); 3. CONSIGLIO NAZIONALE DELLE RICERCHE (IT); 4. UNIVERSITEIT UTRECHT (NL); 5. UNIVERSITÀ DEGLI STUDI DI FERRARA - UniFE (IT); 6. ENGIE CRIGEN (FR); 7. ENGIE Laborelec (BE); 8. THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL (US); 9. HYGear BV (NL); 10. AMI (CZ).

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FLEXnCONFU

FLEXnCONFU, or FLExibilize combined cycle power plant through power-to-X solutions using non-CONventional Fuels.

Project began in 2020 > Funded by EC-H2020

- Develop novel power-to-X-to-power (P2X2P) solutions to be integrated with power plants to enhance Combined Cycle (CC) flexibility.
- Overtake the use of natural gas (NG) in combined cycle with the combustion of non-conventional fuels (H₂/NH₃) reducing CC environmental impact.
- Enhance energy storage integration to load levelling power generation increasing its efficiency.
- Exploit real data from pilot site and demo site to demonstrate its contribution to a smart, affordable and resilient power system, with an enhanced share of intermittent renewable energy.

Consortium partners: 1. RINA CONSULTING SPA (IT) (Lead); 2. EDP - GESTAO DA PRODUCAO DE ENERGIA SA (PT); 3. EDP CNET - CENTRE FOR NEW ENERGY TECHNOLOGIES SA (PT); 4. HYDROGENICS EUROPE NV (BE); 5. ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS CERTH (EL); 6. NUOVO PIGNONE TECNOLOGIE SRL (IT); 7. EUROPEAN TURBINE NETWORK - ETN (BE); 8. PROTON VENTURES BV (NL); 9. MAS S.A. ADVANCED TECHNOLOGIES FOR POWER AND ENERGY (EL); 10. FUNDACION CIRCE CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS (ES); 11. UNIVERSITA DEGLI STUDI DI GENOVA (IT); 12. CARDIFF UNIVERSITY (UK); 13. TECHNISCHE UNIVERSITAT DARMSTADT (DE); 14. UNIVERSITE

CATHOLIQUE DE LOUVAIN - UCL (BE); 15. KUNGLIGA TEKNISKA HOEGSKOLAN - KTH (SE); 16. COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES - CEA (FR); 17. TECHNISCHE UNIVERSITEIT EINDHOVEN TUE (NL); 18. TIRRENO POWER SPA (IT); 19. ENGIE Laborelec (BE); 20. UNIVERSITE D'ORLEANS (FR).

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IN-HABIT

IN-HABIT, or Inclusive Health And wellBeing in small and medium size ciTies.

Project began in 2020 > Funded by EC-H2020

Test visionary and integrated solutions to foster Inclusive Health and Wellbeing (IHW) in Small & Medium Scale Cities with a focus on gender and diversity. IN-HABIT visionary approach consists in the innovative mobilization of existing undervalued resources (culture, food, human-animal bonds and art and environment) to increase IHW.

The integrated approach is based on the combination of technological, digital, nature based, cultural, and social innovations in selected urban public spaces. These solutions will be co-designed, co-deployed and co-managed with and by local stakeholders.

Consortium partners: 1. UNIVERSIDAD DE CORDOBA (ES) (Lead); 2. Ayuntamiento de Cordoba (ES); 3. Asociación Vecinal Unión y Esperanza de Las Palmeras (ES); 4. NODIBINAJUMS BALTIC STUDIES CENTRE (LV); 5. RIGAS PLANOSANAS REGIONS (LV); 6. SABIEDRIBA AR IEROBEZOTU ATBILDIBU BC MANUFATURA (LV); 7. UNIVERSITA DI PISA (IT); 8. COMUNE DI LUCCA (IT); 9. LUCCA CREA SRL (IT); 10. SLOVENSKA POLNOHOSPODARSKA UNIVERZITA V NITRE (SK); 11. MESTO NITRA (SK); 12. TRIPTYCH (SK); 13. THE UNIVERSITY OF READING (UK); 14. Isimpact (IT); 15. Istituto A.T. Beck per la terapia Cognitivo-comportamentale (IT); 16. ENGIE Laborelec (BE); 17. Bridge for Billions SL (ES); 18. DESIGN FOR CHANGE ESPANA (ES); 19. BOOK ON A TREE LTD (UK); 20. COLINI-TRIPODI GBR (DE); 21. Alcaldía Mayor de Bogotá D.C. (CO); 22. PONTIFICIA UNIVERSIDAD JAVERIANA (CO).

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LEILAC2

LEILAC2, or Low Emissions Intensity Lime And Cement - phase 2.

Project began in 2020 > Funded by EC-H2020

- Pilot a breakthrough technology that aims to enable Europe's cement and lime industries to capture their process CO₂ emissions.
- Scale up from 5% CO₂ capture realized at LEILAC1 to 20% of a typical cement plant's CO₂ emissions in a deployable and scalable module.
- Demonstrate the use of multiple energy sources (particularly electricity with rapid ramping to enable renewable load-balancing).
- Show how the new technology can be immediately, cheaply and incrementally or fully retrofitted to all cement plants.

Consortium partners: 1. CALIX - EUROPE (FR) (Lead); 2. HEIDELBERGCEMENT AG (DE); 3. IKN GMBH INGENIEURBURO-KUHLERBAU-NEUSTADT (DE); 4. CERTH- ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (EL); 5. BUNDESANSTALT FUER GEOWISSENSCHAFTEN UND ROHSTOFFE (DE); 6. POLITECNICO DI MILANO (IT); 7. INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE (BE); 8. ENGIE Laborelec (BE); 9. HAVENBEDRIJF ROTTERDAM NV (BE); 10. CALIX LTD (AU); 11. CIMPOR-INDUSTRIA DE CIMENTOS SA (PT); 12. LHOIST RECHERCHE ET DEVELOPPEMENT SA (BE).

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MORE

MORE, or Management of Real-time Energy Data.

Project began in 2020 > Funded by EC-H2020

Develop a platform, utilizing advanced analytics, edge and cloud computing and modelling techniques for sensor data:

- _ Allows more accurate predictions and better diagnostic models;
- _ Introduce an architecture that combines edge computing and cloud computing to be able to guarantee both responsiveness and provide sophisticated analytics simultaneously;
- _ Introduce advanced analytics tools for prediction, forecasting and diagnostics based on two technological directions: machine learning and pattern extraction, with emphasis to motifs, which is the state-of-the-art for time series;
- _ Adjust these techniques to work directly on models of data, thus enabling them to scale beyond state-of-the-art;
- _ The ability to ingest huge volumes of data will have an important impact to the accuracy of the prediction and diagnostics models.

Consortium partners: 1. ATHENA RESEARCH AND INNOVATION CENTER IN INFORMATION COMMUNICATION & KNOWLEDGE TECHNOLOGIES (EL) (Lead); 2. AALBORG UNIVERSITET (DK); 3. INACCESS NETWORKS S.A. (EL); 4. IBM IRELAND LTD (IE); 5. PERCEPTION DYNAMICS LIMITED (CY), 6. **ENGIE Laborelec (BE)** incl support of **ENGIE DIGITAL (FR)**.

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NUCOBAM

NUCOBAM, or Nuclear Component By Additive Manufacturing.

Project began in 2020 > Funded by EC-H2020

- _ Develop the qualification process and provide the evaluation of the in-service behaviour allowing the use of additively manufactured components in nuclear installation.
- _ Conduct the required studies to implement AM process in nuclear design codes and standards to produce components for nuclear power generation equipment. The project will be based on two coupled strategies.
- _ The first part will consist of a collection of the physical, mechanical and microstructural characterization of the materials that result from AM process in order to establish a qualification and codification process.
- _ The second part will be dedicated to the evaluation of AM material behavior in service, especially regarding main degradation mechanisms that occur in LWR (thermal ageing, irradiation...).

Consortium partners: 1. COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES - CEA (FR) (Lead); 2. ELECTRICITE DE FRANCE EDF (FR); 3. **ENGIE Laborelec (BE)**; 4. TRACTEBEL ENGINEERING (BE); 5. NAVAL GROUP (FR); 6. FRAMATOME (FR); 7. CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICASCIEMAT (ES); 8. THE UNIVERSITY OF SHEFFIELD (UK); 9. Teknologian tutkimuskeskus VTT Oy (FI); 10. STUDIECENTRUM VOOR KERNENERGIE / CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE CEN-SCK (BE); 11. JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION (BE); 12. Ramen Valves AB (SE); 13. INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE IRSN (FR).

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PLATOON

PLATOON, or digital PLATform and analytic TOOLS for eEnergy.

Project began in 2020 > Funded by EC-H2020

Deploy distributed/edge processing and data analytics technologies for optimized real-time energy system management in a simple way for the energy domain expert.

- _ The data governance among the different stakeholders for multi-party data exchange, coordination and cooperation in the energy value chain will be guaranteed through IDS based connectors.

- _ Develop and use the PLATOON reference architecture, COSMAG-compliant, for building and deploying scalable and replicable energy management solutions that contribute to increased renewable energy consumption, smart grids management, increased energy efficiency and optimized energy asset management.
- _ Offer access to cheaper and sustainable energy for energy consumers and maximize social welfare.

Consortium partners: 1. **ENGIE Lab CRIGEN (FR) (Lead)** with support of **ENGIE Laborelec (BE)**; 2. FUNDACION TECNALIA RESEARCH & INNOVATION (ES); 3. RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITAT BONN (DE); 4. FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. (DE); 5. ENGINEERING - INGEGNERIA INFORMATICA SPA (IT); 6. VRIJE UNIVERSITEIT BRUSSEL - VUB (BE); 7. INSTITUT MIHAJLO PUPIN (RS); 8. GIROA SOCIEDAD ANONIMA (ES); 9. SISTEPLANT SL (ES); 10. SAMPOL INGENIERIA Y OBRAS S.A. (ES); 11. TECHNISCHE INFORMATIONSBIBLIOTHEK - TIB (DE); 12. POLITECNICO DI MILANO (IT); 13. ROMA CAPITALE (IT); 14. POSTE ITALIANE - SOCIETA PER AZIONI (IT); 15. MANDAT INTERNATIONAL ALIAS FONDATION POUR LA COOPERATION INTERNATIONALE (CH); 16. FUNDINGBOX ACCELERATOR SP ZOO (PL); 17. INDRA SOLUCIONES TECNOLOGIAS DE LA INFORMACION SL (ES); 18. COMSENSUS, KOMUNIKACIJE IN SENZORIKA, DOO (SI); 19. CLUSTER DE ENERGIA (ES); 20. UDG ALLIANCE (CH).

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ZEBRA

ZEBRA, or Zero waste Blade ReseArch

Thermoplastic Wind Turbine Blade - Arkema Technology.

Project began in 2020 > Joint Industry Project led by IRT Jules Verne

Brings together industrial players and research centers led by IRT Jules Verne, and aims to demonstrate the technical, economic and environmental feasibility of thermoplastic wind turbine blades in an eco-design approach to facilitate recycling. To accelerate the transition of the wind energy market towards a circular economy, the ZEBRA project has set up a strategic consortium that brings together the entire value chain: from materials development to the recycling of wind turbine blades, through manufacturing, operation and dismantling.

Demonstrate the feasibility of using Thermoplastic Elium resin system and adhesives for manufacturing composite wind turbines blades with a sustainability approach:

- _ Validate the material @ different scales (coupon, sub component, prototype blade);
- _ Improve design, manufacturing and process of blade with Elium resin;
- _ Improve recycling method for in Process waste and end of life waste of full Elium composites blades;
- _ Compare Elium blade vs polyester blade: recommendation for the manufacturer, operator and the recycler.

Consortium partners: 1. IRT-Jules Verne (FR) (Lead); 2. ARKEMA (FR); 3. CANOE (FR); 4. LM WIND Power (DE); 5. Owens Corning (FR); 6. SUEZ (FR); 7. **ENGIE Green (FR)**; 8. **ENGIE Laborelec (BE)** and **ENGIE CRIGEN (FR)**.

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Projects began in 2019 →

ANALYST PV

ANALYST PV, or IntegrAted seNsors and dAtA anaLYSis fault deTectioN tools for PV plants.

Project began in 2019 > Funding Agency is BE-VLAIO

Develop a fault diagnosis framework that relies on Internet of Things (IoT) sensors, Artificial Intelligence (AI)- enabled root cause analysis and automatic image analysis (from drone inspections). The project relies on 4 innovation goals:

- Use machine learning to develop a fully automated digital twin of the PV asset;
- Create an automated, efficient and reliable, trustworthy PV fault detection algorithm;
- Validate and measure the benefits of the new framework;
- Link framework observations with decision-making (e.g. repair/replacement actions, insights into PV equipment lifespan, loss estimate...).

Consortium partners: 1. 3E (BE) (Lead); 2. Allthingstalk (BE); 3. Sitemark (fka DroneGrid) (BE); 4. **ENGIE Laborelec (BE)**; 5. IMEC - IPI - Ugent (BE); 6. IMEC - PVMS (BE).

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BOPTIC

Monitoring of offshore power cables and foundations by Distributed Fiber Optic Sensing.

Project began in 2019 > Funding Agency is BE-VLAIO

Use of Distributed Acoustic Sensing (DAS) for monitoring of Cables and Foundations.

- Develop and validate a model-based monitoring approach to quantify important integrity assessment parameters.

Consortium partners: 1. MARLINKS (BE) (Lead); 2. 24SEA (BE); 3. **ENGIE Laborelec (BE)**; 4. IMDC (BE); 5. Com&Sens (BE); 6. OCAS (BE); 7. CALDIC NEDERLAND BV (NL); 8. VUB - OWI Lab (BE); 9. UGent (BE).

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HEAT-INSYDE

Bringing advanced HEAT batteries IN residential heat and electric SYstems closer to market through real life DEMonstration in different climates.

Project began in 2019 > Funded by EC-H2020

The project advances a ground-breaking closed-loop concept using thermochemical material to a compact domestic heat storage prototype at a Technology Readiness Level of 7 through a user-centric approach with real-life demonstrations in 3 different European climate zones.

Consortium partners: 1. NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO (NL) (Lead); 2. TECHNISCHE UNIVERSITEIT EINDHOVEN TUE (NL); 3. CALDIC NEDERLAND BV (NL); 4. EVONIK PERFORMANCE MATERIALS GMBH (DE); 5. ENTILAIRSEC (FR); 6. COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES CEA (FR); 7. GEMEENTE EINDHOVEN (NL); 8. STICHTING TRUDO (NL); 9. PRZESIEBNIORSTWO ROBOT ELEWACYJNYCH FASADA SP ZOO (PL); 10. ACCELOPMENT AG (CH); 11. BUREAUX D'ETUDES SOLAIRES SPRL (BE); 12. **ENGIE Laborelec (BE) with support of ENGIE CRIGEN.**

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HIPERION

HIPERION or Hybrid photovoltaics for efficiency record using integrated optical technology

Project began in 2019 > Funded by EC-H2020

- Develop an industrial process to manufacture highly efficient hybrid solar modules which combine photovoltaic and concentrated photovoltaic technologies. This goal will be achieved by building a pilot production line and by developing tailored assembly techniques.
- Deliver unique and highly efficient solar modules capable of providing record efficiencies (30% at Standard test conditions under direct sunlight and 15% at Standard test conditions efficiency under diffuse sunlight). HIPERION modules will be easy to install, with an estimated lifetime of 25 years.
- Perform a technical and economical assessment of the blueprint solution, including qualification testing, performance and reliability validation at several commercial pilot sites across Europe.

Consortium partners: 1. CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT (CH) (Lead); 2. INSOLIGHT SA (CH); 3. UNIVERSIDAD POLITECNICA DE MADRID (ES); 4. FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. (DE); 5. MONDRAGON ASSEMBLY SOCIEDAD COOPERATIVA (ES); 6. X-CELEPRINT LIMITED (IE); 7. ARGOTECH AS (CZ); 8. IQE plc (UK); 9. SOCIETE INDUSTRIELLE DE SONEBOZ SA (CH); 10. 3S Solar Plus AG (CH); 11. POLITECHNIKA LODZKA (PL); 12. **ENGIE Laborelec (BE)**; 13. Muon Electric Lda. (PT); 14. milieu studio (FR); 15. ASSOCIATION COMPAZ (CH); 16. L - UP SAS (FR).

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ROLECS

ROLECS, or Roll out of Local Energy Communities: a cooperative research project.

Project began in 2019 > Funding Agency is BE-VLAIO

Intends to gain a deeper understanding of the development and role of Local Energy Communities (LECs) in Belgium & in Europe. Funded by Flemish institutions BE-VLAIO & INNOVIRIS, it is comprised of 27 member organizations, 23 companies and 4 knowledge institutions, leading research across different topics regarding LECs. The project aims at providing answers to questions relative to, amongst others, triggering end-consumers participation to LECs, integrating technical energy models to social behaviours, defining the impact of large scale roll-out of LECs regarding the decarbonization of the energy system, etc. ROLECS strives at testing theory on 10 complementary pilot sites where key question can be asked: which type of data to collect, what type of tariffs works with end-users, how to control and operate to maximise potential of energy exchange, etc. The role of the end-user is essential in the development of innovations and technology implementations in the context of energy use. The opinions, attitudes, drivers and barriers of end-users cannot be neglected in local energy community that is why ROLECS has a whole work package focusing on end-user engagement. The prime target is to optimize the local energy flows to reduce the current grid costs, and to realize the electrification of the energy use while respecting the constraints of the existing distribution grid.

Consortium partners: 1. Th!nkE (BE) (Lead); 2. 3E (BE); 3. 70GigaWatt Consulting (BE); 4. ABB NV (BE); 5. Antea Group (BE); 6. Aspiravi Energy (BE); 7. Blixt (BE); 8. C-Valley Leuven vzw (BE); 9. Ducoop cvba (BE); 10. **ENGIE Electrabel NV (BE)**; 11. ENERAGENT cbva (BE); 12. Enervalis NV (BE); 13. **ENGIE Laborelec (BE)**; 14. Farys Solar bvba (BE); 15. Fieldfisher LLP (BE); 16. Fluvius System Operator (BE); 17. Hilde Derde Advocatenkantoor (BE); 18. Ingenium NV (BE); 19. KBC Bank (BE); 20. Metha (BE); 21. Magenta Tree (BE); 22. Openmotics (BE); 23. Powerdale (BE); 24. Quares Facility Management NV (BE); 25. Thermovault (BE); 26. Wattson (BE); 27. IMEC (BE); 28. KUL (BE); 29. U-Ghent (BE); 30. VITO (BE); 31. VUB (BE); 32. Flux50 (BE).

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SunRISE (PENTA)

SunRISE (PENTA), or ShaRed IoT Security.

Project began in 2019 > Funding Agency is BE-VLAIO

Develop secure end-to-end system solutions, based on the use of Security Intelligence Data (SID) for Machine Learning (ML). Research on novel Privacy-Preserving Technologies (PPT) will allow the combined usage of data across clients or industrial competitors, enabling a new level of (shared) security. Third parties that provide Machine Learning as a Service (MLaaS) will be able to utilize privacy-sensitive customer data in a way that is compliant with the General Data Protection Regulation (GDPR). IoT devices, which are usually easy prey for hackers are protected with an immutable, hard-coded, unique identifier ensuring the authenticity.

SunRISE targets a crucial point in future IoT systems: a comprehensive chain of security evidence gathering and dissemination. Leveraging on recent advances in semiconductor manufacturing, machine learning, and privacy-preserving technologies, SunRISE targets:

- Implementation of novel Privacy-Preserving Techniques (PPT) for Machine Learning (ML);
- Development of hardware accelerators for cloud and edge computing;
- High volume production of immutable, hard-coded, unique identities to secure IoT devices in CMOS 200nm technology;
- Design of system and communication architectures enabling security by design.

Consortium partners: 1. NXP Semiconductors Germany GmbH (DE) (Lead); 2. ANCUD IT-Beratung GmbH (DE); 3. Cloud&Heat Technologies GmbH (DE); 4. Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. (DE); 5. Technische Universität München (DE); 6. Ulm University (DE); 7. NXP Semiconductors Belgium N.V. (BE); 8. **ENGIE Laborelec (BE)**; 9. Sirris (BE); 10. Philips Electronics Nederland B.V. (NL); 11. Philips Medical Systems Nederland B.V. (NL); 12. SandGrain B.V. (NL); 13. Technolution B.V. (NL); 14. AnyWi Technologies B.V. (NL); 15. Stichting IMEC Nederland (NL); 16. Technische Universiteit Eindhoven (NL); 17. Technische Universiteit Delft (NL).

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Projects began in 2018 →

BIOCONCO2

BIOCONCO2, BIOTEchnological processes based on microbial platforms for the CONVersion of CO₂ from iron and steel industry into commodities for chemicals and plastics.

Project began in 2018 > Funded by EC-H2020

Develop and validate in industrially relevant environment a flexible platform to biologically transform CO₂ into added-value chemicals and plastics. The versatility and flexibility of the platform, based on 3 main stages (CO₂ solubilization, bioprocess and downstream) will be proved by developing several technologies and strategies for each stage that will be combined as puzzle pieces. BIOCON-CO₂ will develop 4 MCFs based on low-energy biotechnological processes using CO₂ from iron&steel industry as a direct feedstock to produce 4 commodities with application in chemicals and plastics sectors using 3 different biological systems: anaerobic microorganisms (C3-C6 alcohols by Clostridia), aerobic microorganisms (3-hydroxypropionic acid by Acetobacter) and enzymes (formic acid by recombinant resting E. coli cells and lactic acid by multi-enzymatic system).

The technologic, socio-economic and environmental feasibility of the processes will be assessed to ensure their future industrial implementation, replicability and transfer to other CO₂ sources, such as gas streams from cement and electricity generation industries. BIOCON-CO₂ will overcome the current challenges of the industrial scale implementation of the biotechnologies routes for CO₂ reuse by developing engineered enzymes, immobilization in nanomaterials,

genetic and metabolic approaches, strain acclimatization, engineered carbonic anhydrases, pressurized fermentation, trickle bed reactor using advanced materials and electro fermentation.

The project aims to capture at least 4% of the total market share at medium term (1.4Mtonnes CO₂/year) and 10% at long term (3.5Mtonnes CO₂/year) contributing to reduce EU dependency from fuel oils and support the EU leadership in CO₂ reuse technologies. Policy recommendations and public perception and acceptance will be explored and a commercialization strategy will be executed by a detailed exploitation plan and technology transfer.

Consortium partners: 1. ACONDICIONAMIENTO TARRASENSE - LEITAT (ES) (Lead); 2. ARCELORMITTAL (BE); 3. ARKEMA (FR); 4. FRAUNHOFER (DE); 5. NATIONAL TECHNICAL UNIVERSITY OF ATHENS NTUA (GR); 6. PERVATECH (NL); 7. RWTH-Aachen (DE); 8. STICHTING WAGENINGEN RESEARCH (NL); 9. ARTTIC (FR); 10. AquaTT UETP Ltd (IE); 11. NUTRITION SCIENCES NV (BE); 12. NESHER ISRAEL CEMENT ENTERPRISES LTD (IL); 13. UNIVERSITAT AUTONOMA DE BARCELONA (ES); 14. **ENGIE Laborelec (BE)**; 15. BIO BASE EUROPE PILOT PLANT VZW (BE); 16. RIJSUNIVERSITEIT GRONINGEN (NL); 17. TECNALIA (ES); 18. COVESTRO (DE).

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DESTINY

DESTINY, or Development of an Efficient microwave System for material Transformation in energy INTensive processes for an improved Yield.

Project began in 2018 > Funded by EC-H2020

- Conceive cellular microwave kilns in a mobile modular plant, with high energy efficiency, flexibility, replicability and scalability for continuous material processing in energy intensive industries (steel, ceramics, cement).
- Improve the performance of the industrial process in terms of stability and efficiency.
- Reduce the environmental footprint.

Consortium partners: 1. KERABEN GRUPO SA (ES) (Lead); 2. INNCEINNMAT SL (ES); 3. NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA (GR); 4. UNIVERSITA POLITECNICA DELLE MARCHE (IT); 5. UNIVERSITAT POLITECNICA DE VALENCIA (ES); 6. AL-FARBEN,S.A. (ES); 7. PROYECTOS MECANICOS LEVANTE S.L. (ES); 8. VDEH-BETRIEBSFORSCHUNGSINSTITUT GMBH (DE); 9. K1-MET GMBH (AT); 10. DK RECYCLING UND ROHEISEN GMBH (DE); 11. CEMEX RESEARCH GROUP AG (CH); 12. CIAOTECH Srl (IT); 13. **ENGIE Laborelec (BE)**; 14. INSTITUTO SUPERIOR TECNICO (PT).
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MUSE-GRIDS

MUSE-GRIDS, or Multi Utilities Smart Energy GRIDS.

Project began in 2018 > Funded by EC-H2020

The project aims to demonstrate, in two weakly connected areas (a town on a top of a hill and a rural neighbourhood), a set of both technological and non-technological solutions targeting the interaction of local energy grids (electricity grids, district heating and cooling networks, gas grids, electromobility etc.) to enable maximization of local energy independency through optimized management of the production via end user-driven control strategies, smart grid functionality, storage, CHP and RES integration. Two large-scale pilot projects will be implemented in two different EU regions, in urban (Osimo) and rural (Oud-Heverlee) contexts with weak connections with national grids. These pilots will test and promote the main project concepts: Smart energy system and Local Energy Community. A Smart Energy System is defined as an approach in which smart electricity, thermal, water, gas grids etc are combined with storage technologies and coordinated to identify synergies between them towards maximization of energy independency and reduction of operation costs. The purpose is to reduce energy carbon footprint while meeting

energy demands and creating real and sustainable energy islands. To achieve this both physical networks (electricity, natural gas, district heating and cooling, water) and non-physical networks (mobility and citizens/communities) have to interact in order to become a Local Energy Community where inhabitants can act and exchange energy to provide reliable and cheap energy in collaboration. MUSE GRIDS will promote these two concepts not only in pilot projects but also in virtual demo-sites in India, Israel and Spain. Social and environmental aspects of smart multi-energy system transition will be investigated. Osimo and Oud Heverlee citizens will be directly involved. The project involves leading EU companies and energy utilities and will be a muse of inspiration for dedicated policy redaction also providing insights to the BRIDGE initiative.

Consortium partners: 1. RINA CONSULTING SPA (IT) (Lead); 2. FUNDACION CARTIF (ES); 3. AALBORG UNIVERSITET (DK); 4. UNIVERSITA POLITECNICA DELLE MARCHE (IT); 5. ASTEA S.P.A. (IT); 6. THINK E (BE); 7. SIEMENS GAMESA RENEWABLE ENERGY INNOVATION & TECHNOLOGY S.L. (ES); 8. TECHNISCHE UNIVERSITEIT EINDHOVEN (NL); 9. Energetica S.Coop. (ES); **10. ENGIE Laborelec (BE)**; 11. Galu Ltd (IE); 12. DUFERCO ENERGIA SPA (IT); 13. EUROPEAN ASSOCIATION FOR STORAGE OF ENERGY - EASE (BE); 14. GLEN DIMPLEX HEATING & VENTILATION IRELAND UNLIMITED COMPANY (IE); 15. Eptisa Servicios de Ingeniería S.L. (ES); 15. MUNICIPALITY OF EILAT (IL); 16. ABB OF ASEA BROWN BOVERI (BE); 17. Scame Parre S.P.A. (IT); 18. ALTRA (IT).

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Projects began in 2017 →

ASSURED

ASSURED, or fAst and Smart charging solutions for full size Urban hEavy Duty applications.

Project began in 2017 > Funded by EC-H2020

- Analyse the needs of cities and operators to derive requirements for the next generation of electrically chargeable buses (≥ 12m), trucks and vans.
- Develop the next generation of modular high-power charging solutions (up to 600kW) with standardized interfaces and interoperability.
- Improve TCO through understanding of impact of fast charging on battery and grid reliability and through the development of innovative charging management strategies.

Consortium partners: 1. VRIJE UNIVERSITEIT BRUSSEL - VUB (BE) (Lead); 2. Union Internationale des Transports Publics - UITP (BE); 3. IVECO S.p.A (IT); 4. Volvo Bus Corporation (SE); 5. MAN Truck & Bus AG (DE); 6. Solaris Bus & Coach S.A.(PL); 7. Vectia Mobility Research & Development A.I.E. - VECTIA R&D (ES); 8. VDL Enabling Transport Solutions bv (NL); 9. IRIZAR S COOP. (ES); 10. Turk Otomobil Fabrikasi Anonim Sirketi - TOFAS (TK); 11. SIEMENS Aktiengesellschaft (AT); 12. ALSTOM TRANSPORT S.A (FR); 13. ABB B.V.(NL); 14. HELIOX BV (NL); 15. Schunk Bahn- und Industrietechnik GmbH (DE); 16. JEMA ENERGY SA (ES); 17. ALTRA SPA (IT); 18. Fraunhofer Gesellschaft zur Förderung der angewandten Forschung E.V. (DE); 19. FEV Europe GmbH (DE); 20. AVL List GmbH (AT); 21. Austrian Institute of Technology GmbH - AIT (AT); 22. Kompetenzzentrum Das virtuelle Fahrzeug Forschungsgesellschaft mbH - VIF (AT); **23. ENGIE Laborelec (BE)**; 24. IKERLAN SCL (ES); 25. Nederlandse Organisatie voor toegepast-natuurwetenschappelijk Onderzoek -TNO (NL); 26. Teknologian tutkimuskeskus VTT Oy - VTT (FI); 27. POLIS - Promotion of Operational Links with Integrated Services; Association Internationale (BE); 28. D'Appolonia SPA (IT); 29. Iberdrola Distribucion Electrica SA (ES); 30. ENEXIS B.V. (NL); 31. Institute of Communications and Computer Systems - ICCS (GR); 32. Rupprecht Consult - Forschung & Beratung GmbH (DE); 33. IDIADA Autom Ingenieurgesellschaft Fuer Auto Und Verkehr GmbH - IAV (DE); 36. SAET SPA (IT); 37. POLITECNICO DI TORINO (IT); 38. Przedsiębiorstwo Komunikacji Miejskiej Spółka Z Ograniczona Odpowiedzialnoscia -PKM (PL); 39. Transports de Barcelona SA (ES); 40. Stadtwerke Osnabrueck AG (DE).

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Energy Storage Lab, ENGIE Laborelec.

GHOST

GHOST, or InteGrated and Physically Optimised Battery System for Plug-in Vehicles Technologies.

Project began in 2017 > Funded by EC-H2020

Two demonstrators will be realized using the single battery system: a plug-in electric vehicle and an electric bus. In a second time, the modular battery will be evaluated at the end of its first life for second life applications as well as dismantling actions.

Consortium partners: 1. Centro Ricerche Fiat SCPA CRF (IT) (Lead); 2. IVECO S.p.A. IVECO (IT); 3. Toyota Motor Europe(BE); 4. Vrije Universiteit Brussel VUB (BE); 5. Johnson Matthey Battery System (UK); 6. INFINEON Technologies Austria AG (AT); 7. UMICORE AG & CO KG (DE); **8. ENGIE Laborelec (BE)**; 9. Ikerlan SCL (ES); 10. EVE Systems (FR); 11. Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V- FhG-IISB & FhG-LBF (DE); 12. AVL List GmbH (AT); 13. Valeo Climate Control (DE).

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ENGIE LAB CRIGEN

Projects began in 2021 →

AMBHER

Ammonia and MOF Based Hydrogen for EuRope

Project will begin in 2022 > Funded by Horizon Europe 2021-2027

AMBHER (Ammonia and MOF based Hydrogen for Europe) is a European project under the RIA (Research & Innovation Action) Advanced Materials for Hydrogen sStorage. Expected outcomes are multiple: provide commercially attractive and safe new technologies for long-term storage and transport of hydrogen, enable efficient and safe hydrogen short-term storage for mobility or stationary storage, elimination of economic dependence for EU's energy needs, and ability for distributed production, providing opportunities for new business ventures and the development of new centers for economic growth in both rural and urban areas that currently find it difficult to attract investment in the current centralized energy system. AMBHER will develop technological solutions for both short-term and long-term hydrogen storage based on advanced manufacturing techniques. For short-term storage, AMBHER will develop a conformable cryo-vessel that can accommodate MOF (Metal Organic Framework) stacks, of tailored-made shaped bodies capable of storing high quantities of hydrogen by adsorption. A capacity of 40g/L of usable space at 100 bars is achieved at competitive cost with respect to current high-pressure cylinders (600-1.000 euros/kg H₂). For long-term storage, AMBHER will develop innovative intensified membrane reactors for green ammonia production based on 3D-printed periodic open cellular structures, new catalysts for low temperature and low-pressure NH₃ synthesis, and new carbon-based NH₃ selective membranes. Both prototypes will be tested at TRL 5. The project stems from collaboration between ENGIE Laborelec's metal additive manufacturing laboratory and ENGIE Lab CRIGEN's Hydrogen Lab and includes 17 partners including top research institutes and companies.

Consortium partners: 1. FUNDACION TECNALIA RESEARCH & INNOVATION (ES); 2. TECHNISCHE UNIVERSITEIT EINDHOVEN (NL); 3. CONSIGLIO NAZIONALE DELLE RICERCHE (IT); 4. THE UNIVERSITY OF BIRMINGHAM (UK); 5. UNIVERSITEIT UTRECHT (NL); 6. AGENCIA ESTATAL CONSEJO SUPERIOR (ES); 7. MAX PLANCK INSTITUT (DE); 8. UNITED KINGDOM RESEARCH AND INNOVATION (UK); 9. 1Cube B.V. (NL); 10. RINA CONSULTING SPA (IT); 11. CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (FR); 12. THYSSENKRUPP INDUSTRIAL SOLUTIONS AG (DE); 13. JOHNSON MATTHEY PLC (UK); 14. IBERDROLA CLIENTES SOCIEDAD ANONIMA (ES); 15. MAHYTEC SARL (FR); 16. **ENGIE, ENGIE Lab CRIGEN (FR)**; 17. BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE, **ENGIE Laborelec CVBA (BE)**.

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Green H₂ Atlantic

Electrolyser for green, affordable electrolysis

Project began in 2021 > Funded by EC-H2020

Green H₂ Atlantic is a European project under the Green Deal Call. The aim is to install a 100MW electrolysis system in the region of Sines in Portugal to supply green hydrogen for a refinery and inject part of the production into the local gas grid to help gas consumers to decarbonize their usages. The project is coordinated by EDP and ENGIE is part of the consortium. Various ENGIE entities are participating into the project: GBU Thermal & Supply (H2GREENCLUSTER), Global Energy Management (GEM), Tractebel, ENGIE Laborelec, and ENGIE Lab CRIGEN. ENGIE's role within the

project is to develop an Advanced Hydrogen Management System (AHyMS) able to take into account various constraints (the renewable power available, weather forecasts, electrical grid status, hydrogen needs downstream, etc.) in order to optimize the operation of the whole hydrogen chain, especially the electrolysis system. ENGIE Lab CRIGEN is involved by providing electrolysis expertise into the development of the AHyMS and by developing specific Artificial Intelligence features.

Consortium partners: 1. (coordinator) EDP RENOVAVEIS SA (ES); 2. EDP - GESTAO DA PRODUCAO DE ENERGIAS (PT); 3. CNET CENTRE FOR NEW ENERGY TECHNOLOGIES SA (PT); 4. EDP PT PROMOCAO E OPERACAO SA (PT); 5. PETROLEOS DE PORTUGAL - PETROGAL SA (PT); 6. GALP ENERGIA SA (PT); 7. ENGIE ENERGIE SERVICES (FR); 8. **ENGIE (FR)**; 9. TRACTEBEL ENGINEERING (BE); 10. BELGISCH LABORATORIUM VAN ELEKTRICITEITSINDUSTRIE (BE); 11. MARTIFER-CONSTRUACOES METALOMECHANICAS SA (PT); 12. VESTAS WIND SYSTEMS A/S (DK); 13. BONDALTI CHEMICALS SA (PT); 14. MCPHY ENERGY (FR); 15. MCPHY ENERGY ITALIA SOCIETA A RESPONSABILITA LIMITATA (IT); 16. McPhy Energy Deutschland GmbH (GE); 17. DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV (GE); 18. INSTITUTO DE SOLDADURA E QUALIDADE (PT); 19. INESC TEC - INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES, TECNOLOGIA E CIENCIA (PT); 20. COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (FR); 21. AXELERA - ASSOCIATION CHIMIE-ENVIRONNEMENT LYON ET RHONE-ALPES (FR); 22. EFACEC ENERGIA - MAQUINAS E EQUIPAMENTOS ELECTRICOS SA (PT).

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Metha-HYn

Development of an integrated commercial offer of in situ biomethanation with biological hydrogen production

Project will begin in March 2022 > Funded by ADEME

The objective of the project is to develop a combination of technologies aimed at increasing the methane production in anaerobic digestion units, thus limiting the costs linked to biogas upgrading while limiting the costs linked to the anaerobic digestion stage. To meet these challenges, the project consortium aims to integrate several technological building blocks including dark fermentation and in situ biomethanation. The project will accelerate the development of the anaerobic digestion sector by optimizing and improving methane production yields.

Consortium partners: 1. **ENGIE, ENGIE Lab CRIGEN (FR)**; 2. INRAE, Laboratory of Environmental Biotechnology (FR); 3. APESA (FR); 4. IS2M, Institut de Science des Matériaux de Mulhouse (FR).

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NEON

Next-Generation Integrated Energy Services for Citizen Energy Communities

Project began in 2021 > Funded by EC-H2020

The EU-funded NEON project will deliver next-generation integrated energy services for citizen energy communities to enhance the quality of life of building occupants, save energy along the value chain, and improve grid operation. The concept maximises the impact of traditional energy efficiency services through holistic optimisation of building operation and energy asset utilisation. NEON aims to enable integration of energy efficiency services for multi-measure building efficiency improvement; optimal energy asset scheduling for improved self-sufficiency, virtual power plant/virtual energy storage; advanced building control for optimal operation of heating/cooling systems, lighting, smart appliances, etc.; demand response services for grid flexibility improvement via explicit and implicit mechanisms; and use-tailored services for ensuring comfort, health and safety requirements.



**Julie Clavreul, Caroline De Zutter
and Anne Prieur-Vernat,**
Environment & Society Lab, ENGIE Lab CRIGEN

Consortium partners: 1. (coordinator) **ENGIE, ENGIE Lab CRIGEN (FR)**; 2. AXPO ENERGY SOLUTIONS ITALIA-SOCIETA PER AZIONI (IT); 3. ALBEDO ENERGIE (FR); 4. R2M SOLUTION SPAIN SL (ES); 5. GRID ABILITY SCARL (IT); 6. R2M ENERGY SRL (IT); 7. FORUM PER LA FINANZA SOSTENIBILE (IT); 8. INSTITUTO PARA LA DIVERSIFICACION Y AHORRO DE LA ENERGIA (ES); 9. ASOCIACION DE EMPRESAS DE ENERGIAS RENOVABLES - APPA (ES); 10. GENERACIONES FOTOVOLTAICAS DE LA MANCHA SL (ES); 11. UNIVERSITY OF CYPRUS (CY); 12. CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT (CH); 13. INSTITUT MIHAJLO PUPIN (RS); 14. TRAIZA TERRITORIO, S.L.L. (ES); 15. COMET GLOBAL INNOVATION, SL (ES).

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OLGA

Holistic & Green Airports - Flying high for aviation decarbonization
Project began in 2021 > Funded by EC-H2020

Today's aviation community - from the airport and airlines to ground handling services - is facing the challenge of environmental transition. Guided by the ambitions of the European Green Deal in ensuring that transport (including air transport) makes an important contribution to climate neutrality by 2050, the EU-funded OLGA project is part of the bigger plan for aviation decarbonisation. The consortium, consisting of airports, airlines, ground handlers, industry, research bodies and SMEs, will integrate sustainable aviation fuels supply chains in conventional jet fuel infrastructure and demonstrate complementary types of low-emission mobilities, electric ground support equipment, hydrogen infrastructure and reduced carbon airside operations. OLGA expects to achieve significant quantified advances in the first 3 years.

Consortium partners: 1. (coordinator) AEROPORTS DE PARIS SA (FR); 2. SOCIETA PER AZIONI ESERCIZI AEROPORTUALI SEA (IT); 3. AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH (AT); 4. IFP Energies Nouvelles (FR); 5. AIRPORT REGIONS COUNCIL (BE); 6. ENVISA SAS (FR); 7. AIR FRANCE SA (FR); 8. L - UP SAS (FR); 9. SNAM S.P.A. (IT); 10. BUREAU VERITAS EXPLOITATION (FR); 11. BUREAU VERITAS ITALIA SPA (IT); 12. SERVICE TECHNIQUE DE L'AVIATION CIVILE (FR); 13. EUROCONTROL - EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION (BE); 14. ASSOCIATION FRANCAISE POUR LA PROMOTION DES EQUIPEMENTS ET SERVICES AEROPORTUAIRES ET ATC PROAVIA (FR); 15. PARCO LOMBARDO VALLE DEL TICINO (IT); 16. SAFETY LINE (FR); **17. ENGIE (FR)**; 18. INEO ENERGY AND

SYSTEMS (FR); 19. ENGIE ENERGIE SERVICES (FR); 20. ENGIE GLOBAL MARKETS (FR); 21. ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS (FR); 22. ECOLE NATIONALE SUPERIEURE DES MINES DE PARIS (FR); 23. TRANSDEV GROUP (FR); 24. SMART AIRPORT SYSTEMS (FR); 25. MEDUNARODNA ZRACNA LUKA ZAGREB DD (HR); 26. MZLZ-ZEMALJSKE USLUGE DOO (HR); 27. MZLZ - UPRAVITELJ ZRACNE LUKE ZAGREB DOO (HR); 28. INFRA PLAN KONZALTNIG JDOO ZA USLUGE (HR); 29. UNIVERSITE PARIS XII VAL DE MARNE (FR); 30. ECATS INTERNATIONAL ASSOCIATION AISBL (BE); 31. DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV (DE); 32. THE MANCHESTER METROPOLITAN UNIVERSITY (GB); 33. ASSAIA INTERNATIONAL AG (CH); 34. AEROPORTUL INTERNATIONAL AVRAM IANCU CLUJ RA (RO); 35. INSTITUTUL NATIONAL DE CERCETARE-DEZVOLTARE TURBOMOTOARE - COMOTI (RO); 36. AIR LIQUIDE FRANCE INDUSTRIE (FR); 37. L'AIR LIQUIDE SA (FR); 38. UNIVERSITATEA TEHNICA CLUJ-NAPOCA (RO); 39. B & S RESO NET SRL (RO); ADDAIR (FR); 40. WALTR (FR); 41. BATIRIM SAS (FR); 42. ITW GSE (DK); 43. ERICSSON NIKOLA TESLA D.D. (HR); 44. SVEUCILISTE U ZAGREBU, FAKULTET STROJARSTVA I BRODOGRADNJE (HR); 45. SVEUCILISTE U ZAGREBU FAKULTET PROMETNIH ZNANOSTI (HR); 46. GDI DRUSTVO S OGRANICENOM ODGOVORNOSCU ZA PROIZVODNJU, TRGOVINU I USLUGE (HR); 47. MUNICIPIUL CLUJ-NAPOCA (RO); 48. RINA CONSULTING SPA (IT); 49. RINA TECH UK LTD (GB); 50. CONSORZIO INTERUNIVERSITARIO PER L'OTTIMIZZAZIONE E LA RICERCA OPERATIVA (IT); 51. UNIVERSITA DEGLI STUDI DI MODENA E REGGIO EMILIA (IT); 52. CENTRO TESSILE COTONIERO E ABBIGLIAMENTO SPA (IT).

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Projects began in 2020 →

ARENHA

Demonstrating how ammonia can provide safe and profitable large-scale energy storage

Project began in 2020 > Funded by EC-H2020

ARENHA (Advanced Materials and Reactors for Energy Storage through Ammonia) is a European project seeking to develop, integrate and demonstrate key material solutions for using ammonia for the flexible, safe and profitable storage and utilization of energy.

Ammonia is an excellent energy carrier due to its high energy density, carbon-free composition, industrial use and relative ease of storage. ARENHA demonstrates the feasibility of ammonia as a dispatchable form of large-scale energy storage, enabling the integration of renewable electricity in Europe and creating global green energy corridors for Europe's diversification in energy imports. Innovative materials are developed and integrated into ground-breaking systems in order to demonstrate a flexible and profitable power-to-ammonia value chain as well as several key energy discharge processes. ARENHA's ambitious objectives will be tackled by a consortium of 11 partners from universities. Considering the global nature of the ARENHA project, the consortium will strongly interact with its international advisory board, composed of key energy stakeholders from the 5 continents. ENGIE Lab is co-coordinating this project and will be supervising and integrating the entire value chain, providing business cases, modeling the entire value chain, performing the techno-economic analysis, life cycle analysis, and social acceptance study, and taking part in pilot demonstration trials.

Consortium partners: 1. Tecnalia (ES); 2. Technische Universiteit Eindhoven (NL); 3. Centro Nacional del Hidrógeno (ES); 4. Danmarks Tekniske Universitet (DK); 5. Fraunhofer IKTS (DE); 6. Science and Technology Facilities Council (GB); 7. Proton Ventures BV (NL); 8. Elcogen AS (EE); 9. H2SITE (ES) 10. PSA ID (FR); **11. ENGIE Lab CRIGEN (FR).**

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BUNGALOW

Reducing the energy consumption of hotel buildings

Project began in 2020 > Funded by Energy Savings Certificate program

The BUNGALOW project, started in 2019, aims to reduce the energy consumption of hotel buildings in the Réunion and Mayotte. The project focuses on raising the awareness and training of staff and users in the proper functioning of buildings and energy systems. During the first part of this project, a detailed mapping of hotel establishments has been carried out. This inventory has led to the selection of 30 pilot establishments, which are currently undergoing a detailed energy audit. At the same time, communication work, including the creation of a website, with the aim of communicating the results of the project and the initiatives that will be implemented.

The work will continue in 2021 with the study of the influence of human behavior on the energy performance of these establishments. Awareness-raising, training and energy improvements will be implemented in the pilot establishments.

Consortium partners: 1. (coordinator) ENGIE Lab CRIGEN (FR); 2. SAS TIPEE (FR); 3. Université de La Rochelle (FR); 4. Université de la Réunion (FR); 5. IMAGEEN, SCOP ARL (FR); 6. GREEN TECH (FR).

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C2FUEL

Developing energy-efficient, economically and environmentally viable CO₂ conversion technologies for the displacement of fossil fuels emissions

Project began in 2019 > Funded by EC-H2020

C2FUEL is an R&D project set up to explore the potential of green hydrogen as a means of converting industrial CO₂. A demonstrator will be built at the site of the DK6 gas-fired combined cycle power plant in Dunkirk (Nord department, France) to check – in real-life conditions – that hydrogen can be produced by electrolysis and CO₂ can be converted into an energy vector, and then used to recharge boats at the adjacent port. ENGIE's CRIGEN Lab will work with nine renowned partners, including European research centers and manufacturers.

Consortium partners: 1. (coordinator) ENGIE Lab CRIGEN, Hydrogen Lab (FR); 2. ENGIE Thermique France (FR); 3. Dutch Energy Solutions (NL); 4. Fundacion Tecnalia Research & Innovation (ES); 5. CNRS (FR); 6. Technische Universiteit Eindhoven (TUE) (NL); 7. Technical University of Denmark (DTU) (DK); 8. Elcogen Oy (FI); 9. Breuer Technical Development (BE); 10. Volkswagen (DE); 11. Ayming France (FR).

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CONDOR

Combined suN-Driven Oxidation and CO₂ Reduction

Project began in 2020 > Funded by EC-H2020

CONDOR addresses the direct conversion of sunlight into fuels and added-value chemicals by developing highly efficient solar-driven conversion of CO₂. We have developed a photosynthetic device made of two compartments (a) a photoelectrochemical cell that splits water and CO₂ and generates oxygen and syngas, a mixture of H₂ and CO; (b) a (photo)reactor that converts syngas into methanol and dimethylether (DME). The proposed modular approach enables different configurations to be established depending on the target product. The oxidation process is not limited to O₂ production, but includes chlorine and small organic molecules, such as 2,5-furandicarboxylic acid, derived from the oxidation of low-cost and easily available precursors like salt water or alcohol derived biomass, respectively. Employed materials will be obtained through low energy/low temperature routes, mainly based on wet chemical procedures, such as sol-gel chemistry, mild hydrothermal processes, electrochemical processes at ambient temperatures. Raw materials/precursors will not be limited by availability on a global scale, making use of organic substances, silicon, earth abundant metal oxides, first row transition metals. The final target is a full photosynthetic device with 8% solar-to-syngas and 6% solar-to-DME efficiencies with a three-month continuous outdoor operation. This represents significant progress with respect to the state-of-the-art and requires international collaboration and a multidisciplinary approach, which integrates expertise in the preparation and characterization of nanomaterials by operando microscopy and spectroscopy, homogeneous and heterogeneous catalysis, photochemistry/photoelectrochemistry, PEC engineering and assessment of the environmental and socio-economic impact of the proposed technology, including life cycle assessment. The Hydrogen Lab is leading WP5 of the project and has the task of supervising the assembly and testing of the PEC device allowing the production of hydrogen and the reduction of CO₂.

CONDOR focuses on a modular device for solar-driven production of energy carriers and added value chemicals from biomass recovery. Reactants are simple molecules and waste chemicals such as water and CO₂ or biomass-derived alcohols. The only energy source to drive the process is sunlight. This is the most convenient way to store an intrinsically intermittent primary energy source (sunlight) as syngas then convert it into methanol or DME. The latter are termed solar fuels. The role of ENGIE in this project is to build and test the final device, insuring that performances are met with an upscalable design. ENGIE is also leading the TEA/LCA activities. Preliminary work has been performed by partners and demonstrator detailed engineering will be undertaken in 2022.

Consortium partners: 1. Università di Bologna (IT); 2. Institut Català d'Investigació Química (ES); 3. Consiglio Nazionale Delle Ricerche (CNR) (IT); 4. Universiteit Utrecht (NL); 5. Università degli Studi di Ferrara (IT); 6. ENGIE Laborelec (BE); 7. HYGear BV (NL); 8. Amires (CZ); 9. The University of North Carolina at Chapel Hill (USA); **10. ENGIE Lab CRIGEN, Hydrogen Lab (FR).**

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EPC-RECAST

The next generation of regulatory Energy Performance Certificates (EPC). The EPC RECAST program started in September 2020 and lasts for 4 years. It involves 11 partners across Europe, and is led by the French public organization CSTB

Project began in 2020 > Funded by EC-H2020

The project will support the emergence of the next generation of regulatory Energy Performance Certificates (EPC). These certificates play a major role in renovation policies. They provide a picture of the energy performance of buildings in Europe, they are the structure on which financial and non-financial incentives are based, and they are the first level of information that is commonly available to evaluate whether or not renovation is required, and if so, what type of renovation should be performed. The goal of the project is not to replace professional EPC assessors, but instead to better and further support their work in order to achieve improved EPC reliability, comparability between building assets, user-friendliness and ultimately generate an impact for owners and occupants in order to engage them on a realistic pathway to an efficient-energy retrofit.

Consortium partners: 1. **ENGIE Lab CRIGEN (FR)**; 2. CSTB (FR); 3. Fundacion Tecnalia Research & Innovation (ES); 4. Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); 5. Luxembourg Institute of Science and technology (LU); 6. Politecnico di Milano (IT); 7. EDF (FR); 8. Bimeo (FR); 9. ENBEE (SK); 10. REHVA (BE).

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INNOMEN

Sharing innovation infrastructures via a Single Entry Point (SEP)

> Funded by EC-H2020

INNOMEN is a European funded project bringing together 32 partners, with an overall budget of 16 million euros. The INNOMEN project highlights the Open Innovation Testbed (OITB) concept, which – by sharing innovation infrastructures – attracts and consolidates collaboration among SMEs and large companies, as well as research, technological and academic bodies. INNOMEN will provide companies in Europe and overseas with its network of facilities and services via a Single Entry Point (SEP), especially taking into account the needs of SMEs (single point of contact, external project management, etc.). Within the framework of INNOMEN, ENGIE Lab CRIGEN will take part in the showcase devoted to advanced membranes for purifying and reforming hydrogen, and will provide its future testing platform, H2FACTORY, installed in its new R&D center in Stains, France, as a billable service.

Consortium partners: 1. Fundacion Tecnalia Research & Innovation TEC (ES); 2. Technische Universiteit Eindhoven (TUE) (NL); 3. Consiglio Nazionale delle Ricerche (CNR) (IT); 4. Vlaamse Instelling voor Technologisch Onderzoek N.V. (VITO) (BE); 5. Universidad de Zaragoza (UNIZAR) (ES); 6. Imperial College of Science Technology and Medicine (ICL) (GB); 7. Aston University (AU) (GB); 8. Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung (FHG) (DE); 9. Helmholtz-Zentrum Geesthacht Zentrum (HZG) (DE); 10. Foundation for Research and Technology Hellas (FORTH) (EL); 11. Université de Montpellier (UM) (FR); 12. Universiteit Twente (UT) (FR); 13. Universität Duisburg-Essen (UDE) (DE); 14. Rheinisch-Westfälische Technische Hochschule Aachen (RWTH) (DE); 15. National Center for Scientific Research “Demokritos” (DEMOK) (EL); 16. LiqTech International A/S (LIQTECH) (DK); 17. Polymem (POLYM) (FR); 18. DBI Gas und Umwelttechnik GmbH (DBI) (DE); 19. FURTHResearch GmbH & Co. KG (FURTH) (DE); 20. Ellinogermaniki Etairia Diacheirisis Apovlition Kai (SUK) (EL); 21. Etairia Metaforas Ipsilis Technognosias Kai (HTF) (EL); 22. Water and Environmental Engineering (ECOTE) (EL); 23. Filatech Filament Technology u. Spinnanlagen GmbH (FILATE) (DE); 24. Rauschert Kloster Veilsdorf GmbH (RKV) (DE); 25. Ciaotech Srl (PNO) (IT); 26. Evonik Creavis GmbH (EVONIK) (DE); 27. Hydrogen Onsite, SL (H2SITE) (ED);

28. Me-Sep Szymon Dutczak (MESEP) (PL); 29. Tecnalia Ventures, SL (VNTRS) (ES); 30. Asociación Española de Normalización (UNE) (ES); 31. NX Filtration (NXF) (NL); 32. **ENGIE Lab CRIGEN (ENGIE) (FR)**.
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INUIT

Feasibility study for the eco*design of a public lighting service

Project began in 2020 > Funded by ADEME

The INUIT project is one of 9 award winners in the ADEME's PERFECTO call for projects on R&D and innovation and enabling the project's feasibility study to be funded.

The INUIT (Innovation for nighttime) project is a feasibility study on the eco-design of a public lighting service and was launched in November 2020 for an 18-month period. It is managed by the ENGIE Lab CRIGEN (Environment and Society Lab) and also includes ENGIE Laborelec's Lighting Lab. It specifically involves working on the main combinations of lighting components: LED modules, supply, optical component and sensors that allow the product's use to be adjusted. Several combinations are currently offered by manufacturers. It is difficult but essential to understand the technical, energy, environmental implications and those of usage for each combination in order to be able to select the best assembly combination. The aim is to maximize yield, reduce energy consumption, prevent the “lighting of space-time” to be protected, and in particular to reduce the effects on biodiversity. Therefore, work is focused on the impacts during their use and at the end of the service life by successfully bringing together all stakeholders (manufacturers, lighting designers, and operators) to work together on developing eco-designed lighting.

Consortium partners: 1. **ENGIE Lab CRIGEN (FR)**;

2. **ENGIE Laborelec (BE)**.

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Lif-OWI

Environmental, Socio-economic and Technological challenges for Life cycle assessment (LCA) of Offshore Wind Farms (OWF)

Project began in 2020 > Funded by ANR, Avenir Investment program

This project is managed by MINES Paris – PSL and France Energies Marines. It has received funding from France Energies Marines funding, from its members and partners, as well as State funding managed by the ANR within the Investissements d'avenir program. The purpose of the project is to establish a comprehensive methodological framework for the environmental and societal life cycle analysis of offshore wind turbine farms and then validate it on such farms (pilot and commercial, floating and fixed) and to identify areas of improvement in the environmental and societal sustainability of offshore wind turbine farms by using the LCA findings. The project lasts 3 years, from 2020 to 2023.

Consortium partners: 1. (coordinator) Ecole nationale supérieure des Mines de Paris (FR); 2. France Energies Marine (FR); 3. Total (FR); 4. EDF (FR); 5. INNOSSEA (FR); 6. Naval Energies (FR); 7. Vallourec (FR); 8. Norwegian University of Science and Technology (NO); 9. **ENGIE Green (FR)**; 10. **ENGIE Lab CRIGEN (FR)**.

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MACBETH

Test and validate a biogas reformer connected to a commercial methanization unit able to produce 100kg/day of green hydrogen

Project began in 2020 > Funded by EC-H2020-European project-SPIRE

The MACBETH project started in November 2019, involving a consortium of 25 partners in Europe over 5 years. The MacBeth

consortium will provide a breakthrough technology for advanced downstream processing by combining catalytic synthesis with the corresponding separation units in a single highly efficient catalytic membrane reactor (CMR). The direct industrial applicability will be demonstrated by the long-term operation of TRL 7 demo plants for highly relevant, large-scale processes: hydroformylation, hydrogen production, and propane dehydrogenation. The work is already well under way with ongoing pilot construction and plans for various safety analyses at the beginning of 2020, based on available technical resources.

Consortium partners: 1. (coordinator) Evonik Performance Materials GmbH EPM (DE); 2. Evonik Technology & Infrastructure GmbH ETI (DE); 3. LiqTech International A/S LIQ (DK); 4. Friedrich-Alexander-Universität Erlangen-Nürnberg FAU (DE); 5. Technical University of Denmark DTU (DK); 6. Agencia Estatal Consejo Superior de Investigaciones Científicas CSIC (ES); 7. Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH HZG (DE); 8. Eindhoven University of Technology TUE (NL); 9. Fundacion Tecnalia Research & Innovation TEC (ES); 10. ICI Caldaie S.p.A. ICI (IT); 11. Politecnico di Milano POLIMI (IT); 12. Rauschert Kloster Veilsdorf GmbH RKV (DE); 13. Centro Nacional de Experimentación de Tecnologías de Hidrogeno y Pilas de Combustible Consorcio CNH2 (ES); 14. KT – Kinetics Technology S.p.A. (IT); 15. Università degli Studi di Salerno UNISA (IT); 16. Ciaotech s.r.l. a socio unico (PNO Innovation BV) PNO (IT); 17. Enzymicals AG ENZY (DE); 18. ChiralVision BV CHIVI (NL); 19. VITO N.V. VITO (BE); 20. Johnson Matthey PLC JM (GB); 21. Chemelot Campus BV CHML (NL); 22. Solutex GC SL SOLU (ES); 23. Microinnova Engineering GmbH MICRO (AU); 24. Türkiye Petrol Rafinerileri Anonim Şirketi TUPRAS (TR); **25. ENGIE Lab CRIGEN (FR).**

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METROHYVE

Address metrological challenges in hydrogen refueling stations
Project began in 2020 > Funded by EMPIR

The METROHYVE 2 project aims at leveraging metrological challenges in the sector of hydrogen mobility, such as flow metering in refueling station, sampling and analyzing hydrogen fuel quality and assessing the impact of impurities on fuel cells. ENGIE Lab CRIGEN will develop and test a new mobile sampling and analysis methodology for punctual hydrogen quality analysis; this means that hydrogen quality can be analyzed directly at the station without samples having to be sent to a laboratory, thus increasing the representativeness of the analysis and reducing hydrogen quality analysis costs for the operator.

Consortium partners: 1. NPL Management Limited (GB); 2. Physikalisch-Technischer Prüfdienst des Bundesamt für Eich- und Vermessungswesen (BEV-PTP) (AT); 3. Césame-Exadébit SA (FR); 4. Justervesenet (NO); 5. Eidgenössisches Institut für Metrologie METAS (CH); 6. TUV SUD Limited (GB); 7. Research Institutes of Sweden AB (SE); 8. Teknologian tutkimuskeskus VTT Oy (FI); 9. Air Liquide (FR); 10. CEA (FR); 11. EMCEL GmbH (DE); 12. Eidgenössische Materialprüfungs- und Forschungsanstalt (Empa) (CH); 14. ITM Power (Trading) Limited (GB); 15. Linde GmbH (DE); 16. SINTEF AS (NO); 17. Zentrum für Brennstoffzellen Technik GmbH (DE) 18. Toyota Motor Europe NV (BE); **19. ENGIE Lab CRIGEN (FR).**

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MultHYfuel

Increase the deployment of hydrogen refueling stations (HRS)
Project began in 2020 > Funded by EC-H2020

The collaborative FCHJU project MultHyFuel will increase the deployment of HRS allowing HRS to be co-located alongside conventional fuel stations. During this first year, Hydrogen Lab is heading the WP3 best practice guidance by drafting the deliverables on fuel station risk assessment benchmarking and preliminary risk assessment for refueling stations with Air Liquide, INERIS, Shell,

ITM in order to identify critical scenarios and equipment on an H₂ dispenser, with experiments to be carried out in 2022 by INERIS and HSE executive.

In regards to the 2020 Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) annual work plan call for project proposals, the Hydrogen Lab is part of the project MultHYfuel in order to increase the deployment of hydrogen refueling stations (HRS) and allow them to be co-located alongside conventional fuels stations. The development of multifuel stations is mainly limited by the:

- Lack of administrative experience and guidance;
- Restrictive zoning and land use plans;
- Lack of streamlined rules on separation distances and safety barriers in Europe;
- Lack of knowledge on the conditions causing accidents in multi fuel stations.

The consortium's work will contribute to the effective deployment of hydrogen as an alternative fuel by increasing knowledge on risk assessment, safety distances and leakage phenomena in hydrogen refueling stations in order to integrate hydrogen distribution at existing conventional refueling stations.

The Hydrogen Lab is leading the "Generate best practice guidance" work package specifically focusing on the definition of a set of targeted use cases and the elaboration of a tailored risk assessment methodology, based on the evidence and experimental data resulting from the project.

Consortium partners: 1. (coordinator) Hydrogen Europe (BE); 2. Air Liquide (FR); 3. Shell (NL); 4. HSE UK (GB); 5. INERIS (FR); 6. ITM Power (GB); 7. Snam (IT); 8. ZSW (DE); 9. Kiwa (FR);

10. ENGIE Lab CRIGEN (FR).

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MULTIPLHY

The world's first high-temperature electrolyzer on a multi-megawatt scale

Project began in 2020 > Funded by EC-H2020

The aim of MULTIPLHY is to install, integrate and operate the world's first high-temperature electrolyzer (HTE) system at about 2.4 MW, in a chemical biorefinery in Rotterdam (NL), to produce hydrogen (≥ 60 kg/h) for the biorefinery's processes. MULTIPLHY offers a unique opportunity to demonstrate the technological and industrial leadership of the EU in Solid Oxide Electrolyzer Cell (SOEC) technology. With a hydrogen production rate of ≥ 670 Nm³/h, this HTE will cover about 40% of the current average hydrogen demand of the chemical refinery. This will lead to greenhouse gas emission reductions of about 8,000 metric tons during the planned minimum operation time (16,000 h). MULTIPLHY's electrical efficiency (85%el, LHV) will be at least 20% higher than those of low-temperature electrolyzers. The result will decrease operational costs and reduce the connected load at the refinery, with a corresponding impact on the local power grid. ENGIE Lab CRIGEN's Hydrogen Lab will support the Hydrogen Business Unit in the operation of the demonstrator and the long-term validation of the system, stacks and cells.

Consortium partners: 1. CEA (FR); 2. SunFire GmbH (DE); 3. Hansen & Rosenthal KG (DE); 4. Paul Wurth SA (LU); **5. ENGIE Lab CRIGEN (FR).**

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PLATOON

Developing interoperable and open AI tools for existing and new energy services

Project began in 2020 > Funded by EC-H2020

PLATOON, (Digital PLATform and analytics TOOlS for eNergy): The aim of this R&D project is to build and deploy a platform for large scalable distributed semantic data processing, using knowledge models applied to computer inference processing and automatic learning for large volumes of data. This platform will be able to

support, extend and consolidate energy management solutions in real time, to boost the smart production and consumption of renewable energy, manage smart networks, manage increases in energy efficiency, and optimize energy assets. ENGIE's CRIGEN Lab will coordinate the work of the group, consisting of 23 participants from 8 different countries.

Consortium partners: 1. (coordinator) **ENGIE Lab CRIGEN (FR)**; 2. Fundacion Tecnalia Research & Innovation (ES); 3. Rheinische Friedrich-Wilhelms-Universität Bonn (DE); 4. Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); 5. Engineering Ingegneria Informatica S.p.A. (IT); 6. Vrije Universiteit Brussel (BE); 7. Institut Mihaljo Pupin (RS); 8. Giroa Sociedad Anonima (ES); 9. Sisteplant SL (ES); 10. Sampol Ingeniera y Obras S.A. (ES); 11. Technische Informationsbibliothek (TIB) (DE); 12. Politecnico di Milano (IT); 13. Roma Capitale (IT); 14. Poste Italiane - Societa per Azione (IT); 15. Mandat International alias Fondation pour la Coopération Internationale (CH); 16. Fundingbox Accelerator sp. z o.o. (PL); 17. Indra Soluciones Tecnologías de la Información S.L.U. (ES); 18. ComSensus, komunikacije in senzorika, d.o.o. (SI); 19. Cluster de Energía (ES); 20. UDG Alliance (CH).
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PRHYDE

Develop protocols for fast refueling of heavy-duty vehicles
Project began in 2020 > Funded by EC-H2020

The PRHYDE project aims at building the foundations of heavy-duty refueling protocols for large tank systems (> 10kg) used in heavy-duty hydrogen applications such as for trucks and trains. The objectives of PRHYDE are therefore to:

- Determine the relevant requirements for fueling Heavy Duty Vehicles (HDV);
- Determine the limitations and gaps of current fueling hardware capability;
- Develop concept(s) for HDV fueling protocol(s), based on thermodynamic simulation (1D and 3D) and an experimental campaign;
- Make recommendations for HDV fueling protocol(s) for use in a relevant standards group with the aim of achieving standardization.

The project, with a total budget of 1.5 million euros, is coordinated by LBST and includes the following partners: Toyota, Man, Nikola Motors, NEL Hydrogen, Shell, Air Liquide, ITM Power, CEA, and ZBT. The FCH JU funded project PRHYDE will contribute to unlocking the hydrogen heavy-duty vehicle market by developing new a refueling protocol based on advanced communication enabling refueling to be safe and efficient for any type of vehicle including trucks, trains and boats. During 2021, new concept of refueling protocol was developed and assessed and a refueling experimental campaign was performed in order to validate HyFill (ENGIE internal hydrogen refueling simulation tool).

Consortium partners: 1. LBST GmbH (DE); 2. Toyota Motor Europe (BE); 3. Nikola Motor (US); 4. Zentrum für BrennstoffzellenTechnik GmbH (DE); 5. Shell (DE); 6. CEA (FR); 7. Air Liquide (FR); 8. ITM Power (GB); 9. NEL Hydrogen (DK); 10. **ENGIE Lab CRIGEN (FR)**.
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RECA

Réduction d'Emission Carbone pour l'Autoconsommation d'énergie renouvelable (Carbon Emission Reduction for Renewable Energy self-consumption)

Project began in 2020 > Funded by ADEME

The RECA project is a part of a call for projects issued by the ADEME (French Environment and Energy Agency) and brings together the following stakeholders: Atlantech, Armines, Université de La Rochelle (le LaSIE) and ENGIE Lab CRIGEN.

This project results from the 2015 Paris Agreement in which each State signing the agreement committed to reducing greenhouse gas

emissions. Measuring the carbon impact of renewable energy is currently performed via emissions related to how they are produced and their impact on the national energy mix. However, the increase in the rate of penetration of renewable energy requires looking at renewable energy self-consumption prospects that has already been started. This results in a change in viewpoint by moving from a system where production is adapted to consumption to one where consumption is adapted to production according to the availability of renewable energy. Therefore, self-consumption goes beyond production methods by moving from self-consumption that was initially individual self-consumption to one that is collective self-consumption thanks to profusion of uses and pooling of uses. Carbon emissions reporting must therefore be extended.

This 3-year project, started in March 2020, consists in analyzing the different emission reporting methods and costs, in building and validating a method based on the Atlantech® district followed by other suitable districts and from this define the organization required in terms of stakeholders to ensure that the carbon impact of the projects is optimized.

Consortium partners: 1. (coordinator) ATLANTECH (FR); 2. Université de La Rochelle (LaSIE) (FR); 3. ARMINES (FR); 4. **ENGIE Lab CRIGEN (FR)**.

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SUN-to-X

Building a low-carbon, climate resilient future: secure, clean and efficient energy

Project began in 2020 > Funded by EC-H2020

SUN-to-X is a Horizon 2020 European project funded by the EC within the scope of a call for tender entitled "Building a low-carbon, climate resilient future: secure, clean and efficient energy". This call for tender addressed the development of disruptive technology to decarbonize the energy value chain. The aim of the project is to demonstrate an integrated, solar-powered, process of synthesis of a silicon-based polymer that acts as a hydrogen storage solution. Indeed, this molecule can be catalytically hydrolyzed to release dihydrogen and silica. More precisely, a photo-electrochemical cell will produce hydrogen and oxygen via photocatalytic water-splitting of air moisture. The hydrogen generated will then feed a thermochemical reactor that will produce a silicon-based polymer, using silica as a starting material. The heat necessary for the reaction will be supplied by solar concentration. The objective of the project is to deliver a demonstrator and bring the core concept to TRL 5. This project is coordinated by Toyota Motor Europe (BE) and gathers together some of the most distinguished European experts in photo-electrochemistry. The academic institutions of the consortium are: EPFL (CH), CEA (FR), Helmholtz Zentrum Berlin (DE) and DIFFER (NL). As an industrial partner, ENGIE Lab CRIGEN will oversee the integration of the two modules (hydrogen production and Si-based polymer synthesis reactor) developed in the project in one functional Proof-of-Concept (POC). It will also lead the testing of the demonstrator. In this task, it will work in close collaboration with Nanoptek, a long-term partner in the development of solar-assisted hydrogen production, and HySiLabs, a French startup that developed and is currently industrializing the silicon-based polymer under the trademark HydroSil.

The SUN-to-X project focuses on using solar energy to produce a carbon-free, non-toxic, energy-dense, liquid fuel - Hydrosil (developed by the French startup HySiLabs), with very good long-term stability, which can be used in the transport and energy sectors. We will first produce hydrogen as a chemical intermediate through a photoelectrochemical (PEC) device. This will then be converted to Hydrosil through a thermochemical reaction. This project, led by Toyota EM, and gathering experts from CEA, EPFL or Helmholtz Berlin will use NanoH2 technology to demonstrate the integration of PEC and Hydrosil synthesis processes. ENGIE's task is to build and operate the technology's final demonstrator. This demonstrator is currently under development.

Consortium partners: 1. Toyota Motor Europe (BE); 2. CEA (FR); 3. NWO-I DIFFER (NL); 4. Ecole Polytechnique Fédérale de Lausanne

(CH), 5. Helmholtz Berlin (DE); 6. HYSILABS (FR), 7. LGI Consulting (FR), 8. Nanoptek (US); **9. ENGIE Lab CRIGEN (FR)**.

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THyGA

Clearing the way for the use of hydrogen/natural gas blends for European consumers

Project began in 2020 > Funded by EC-H2020

THyGA, or Testing Hydrogen admixture for Gas Applications. The aim of this research project is to add to the knowledge in the gas sector with regard to the technical impacts that hydrogen and gas blends have on gas-powered devices in the residential and tertiary sectors. More than a hundred devices (boilers, fuel cells, cooking facilities, combined heat and power systems, etc.) will be tested, based on several scenarios, in order to find out what technical changes need to be made for new devices, what modifications need to be made to existing ones, and what amendments need to be made to certification guidelines. The THyGA project involves nine well-known partners, including six European research centers and two manufacturers. The advisory committee is made up of a number of European and international associations, device manufacturers and GRDF.

Consortium partners: 1. (coordinator) **ENGIE Lab CRIGEN (FR)**; 2. Dansk Gasteknisk Center (DK); CEA (FR); 3. Gas-und Wärme-Institut Essen e.V. (DE); 4. GAS.BR (BE); German Technical and Scientific Association for Gas and Water (DVGW) (DE); 5. BDR Thermea Group (NL); 6. Electrolux (SE); 7. GERG (BE).

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VERCANE

Reducing carbon in the glass industry

Project began in 2020 > Funded by ADEME

The glassmaking sector is facing the challenge of carbon neutrality. CO₂ emissions in this sector are mainly produced by the glass melting process, accounting for 70-80% of a production site's total emissions. The project "VERCANE" aims to develop sustainable energy transition scenarios by designing solutions based on decarbonized energy sources.

For this purpose, VERCANE is studying the different carbon neutral energy systems that could be compatible with the glass melting process: hydrogen, bioresources and process electrification. VERCANE is also exploring possibilities in adapting existing melting furnaces to new energy sources. Targeting viability and sustainability, the first phase of the project also takes into account available local resources and transport solutions to the production site. The project will ultimately include real-life case studies at Saverglass and Verescence production sites with a view to preparing the deployment of large-scale industrial demonstration units.

Consortium partners: 1. (coordinator) **ENGIE Lab CRIGEN (FR)**; 2. Saverglass (FR); 3. Verescence (FR); 4. Fives Group (FR); 5. IMT Mines Alès (FR).

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WINNER

Contribute to a move towards more sustainable energy in the future by developing an efficient and sustainable technology platform based on electrochemical proton conducting ceramic (PCC)

Project began in 2020 > Funded by EC-H2020

The WINNER project will contribute in a move towards a more sustainable energy in the future by developing an efficient and sustainable technology platform based on electrochemical proton conducting ceramic (PCC) cells designed to pave the way for commercially viable production, extraction, purification and

compression of hydrogen on a small to medium scale. This platform will be integrated with renewable energy sources to make use of green electrons, as illustrated here:

The novel PCC process will be thermally and energetically integrated with three selected process chains based on the strong scientific and technological background of the WINNER partners, their industrial relevance and their alignment with the European Commission and Mission Innovation – Hydrogen Innovation Challenge roadmaps:

- Ammonia cracking to produce pressurized hydrogen or power
- Ethane dehydrogenation to produce ethylene and pressurized hydrogen
- Reversible steam electrolysis for pressurized hydrogen production

The WINNER project builds on the pioneering multidisciplinary expertise of its 11 partners and will combine material science, multi-scale multi-physics modelling and advanced in-situ and operando characterization methods to reveal innovations at the frontier of knowledge in PCC systems. Starting at TRL2, WINNER will develop innovative cells and modules that will be validated at laboratory level with respect to their mechanical stability, proton throughput and electrochemical performance and ultimately grow the PCC technology to TRL4/5. The project coordinated by SINTEF, started officially on 01/01/2021. Project duration is 36 months. The Hydrogen Lab will participate in process engineering, technico-economic and Life Cycle Analysis tasks as well as use and distribution of results and the establishment of technological roadmaps.

Consortium partners: 1. (coordinator) SINTEF (NO); 2. Consejo Superior de Investigaciones Científicas (CSIC) (ES); 3. University of Oslo (NO); 4. Technical University of Denmark (DTU) (DK); 5. CTMS (NO); 6. SMT Sweden AB (SE); 7. Shell (NL); **8. ENGIE Lab CRIGEN (FR)**.

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ZEBRA

Feasibility study on zero waste wind turbine blades

Project began in 2020 > Joint Industry Project led by IRT Jules Verne

The ZEBRA (Zero waste Blade ReseArch), managed by IRT Jules Verne, groups together industrial players and research centers, and aims at demonstrating the technico-economic and environmental feasibility of eco-designing wind turbine blades in thermoplastic, in order to make it easier to recycle them. The budget for this 42-month project, launched at the end of 2020, is 18.5 million euros. To accelerate the wind power industry's transition to a circular economy, the ZEBRA project established a strategic consortium covering the entire value chain ranging from the development of materials enabling wind turbine blades to be recycled to their manufacturing, operation and dismantling.

Consortium partners: 1. Arkema (FR); 2. CANOE (FR); 3. LM Wind Power (FR); 4. Owens Corning (GB); 5. SUEZ (FR); 6. ENGIE France Renouvelable (FR); **7. ENGIE Laborelec**, **Wind Lab (BE)**; **8. ENGIE Lab CRIGEN (FR)**.

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Projects began in 2019 →

E2DRIVER

Training on energy audits as an Energy Efficiency DRIVER for the automotive sector

Project began in 2019 > Funded by EC-H2020

The aim of the E2DRIVER project is to train small and medium-sized automotive supplier companies on energy efficiency and energy auditing, to curb wasteful energy expenditure, reduce carbon emissions and save companies costs. To achieve this, the E2DRIVER

approach focusses on an innovative learning platform that serves a dual role: as a depository for training material adapted to companies' needs and as a networking hub for energy efficiency and energy training.

E2DRIVER will develop a collaborative/cooperative training platform to enhance the automotive supply industry's collective intelligence on energy efficiency. The platform will provide access to training material, online lessons, guidelines, energy and financial tools, virtual reality modules, and a community of key players in the sector for SMEs to undergo energy audits and implement their recommendations. To this end, the E2DRIVER training methodology will be used to develop specific training plan itineraries based on the company's needs and the role of trainees within the company: this will increase the effectiveness of the training sessions and staff awareness on energy issues.

The execution of the project will not result in a static development of the E2DRIVER platform, but rather a continuous update of the training material, best practices, benchmarking analysis and guidelines due to the implementation of an ontological flip teaching method: using this method, trainees can generate their own knowledge and training materials to be shared through E2DRIVER cooperative networks.

The E2DRIVER platform will be tested and validated in 40 companies, in particular in the automotive supply industry in four countries that represent over 50% of EU employees in this sector: Spain, France, Italy and Germany. Moreover, a total of 60 trainers will be certified in the E2DRIVER training methodology, which will make it easier to replicate project results and the business consolidation of E2DRIVER platform.

Consortium partners: 1. CIRCE (ES); 2. Politecnico di Milano (IT); 3. Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); 4. Eproplan GmbH Bertende Ingenieure (DE); 5. Sinergia Società Consortile a Responsabilità Limitata (IT); 6. Asociación Española de Proveedores de Automoción (ES); 7. Automotive.Engineering.Network (DE); 8. Centro Servizi Industrie Srl (IT); 9. MOV'EO (FR); 10. EPC – Projektgesellschaft für Klima Nachhaltigkeit Kommunikation MbH (DE); 11. Merit Consulting House sprl (BE).

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HyCARE

Develop a hydrogen storage tank using a solid-state hydrogen carrier on a large scale

Project began in 2019 > Funded by EC-H2020

The tank will be based on an innovative concept, linking hydrogen and heat storage to improve energy efficiency and to reduce the footprint of the whole system. It will be connected to a 20 kW Proton Exchange Membrane (PEM) electrolyzer to provide hydrogen and a 10 kW PEM fuel cell to use hydrogen. The tank will be installed at the ENGIE Lab CRIGEN site, a research and operational expertise center dedicated to gas, new energy sources and emerging technologies.

The FCH JU funded project HyCare will assess and demonstrate an innovative hydrogen storage technology based on a metallic hydride enabling hydrogen to be stored at a lower pressure thereby increasing safety and efficiency. During 2021, an experimental campaign was performed on a mini-pilot to prove the concept, the design of the demonstrator was finalized and the risk analysis study performed, including HAZOP, ATEX study as well as a main dangerous phenomena effect calculation based on 2D and 3D modeling. The HyCARE demonstrator will be installed at CRIGEN in mid-2022 for 6 months of testing.

Consortium partners: 1. (coordinator) University of Turin (IT); 2. Institutt for Energiteknikk (NO); 3. Environment Park S.p.A. (IT); 4. CNRS (FR); 5. Helmholtz-Zentrum Geesthacht (DE); 6. Fondazione Bruno Kessler (IT); 7. Stühff GmbH (DE); 8. Tecnodelta s.r.l. (IT); 9. GKN Sinter Metals Engineering GmbH (DE);

10. ENGIE Lab CRIGEN (FR).

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LIVING H₂

Develop a green micro-cogeneration system fuel with pure hydrogen, which will provide green power and heat the new offices of ENGIE Lab CRIGEN in Stains

Project began in 2019 > Funded by ANR and BMBF project (German Federal Ministry of Education and Research)

Living H₂, started in October 2019, is co-funded by ANR (French Research Agency) and BMBF (German Federal Ministry of Education and Research). The aim of the project is to develop and test a hydrogen-based micro-CHP system for providing green electricity and heat to tertiary and residential buildings. The system includes a PEM fuel cell and a hydrogen catalytic burner; it will be installed in ENGIE Lab CRIGEN's facilities in Q4 2020, for both testing and supplying heat and electricity. With regard to safety concerns, hydrogen odorization will be developed and tested at ENGIE Lab CRIGEN. The project gathers together high-level industrial and academic partners from France and Germany: CEA Liten, InHouse as system developer, DBI, a major German Gas Institute, and the University of Regensburg. ENGIE Lab CRIGEN will install the system in its offices' boiler room, and perform technical, economic and social studies.

Consortium partners: 1. (co-coordinator) ENGIE Lab CRIGEN (FR);

2. (co-coordinator) InHouse engineering GmbH (DE); 3. DBI Gas- und Umwelttechnik GmbH (DE); 4. Université de Ratisbonne (DE); 5. CEA Liten (FR).

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Projects began in 2018 →

HyCAUNAIS

Produce synthetic methane by combining green hydrogen and CO₂ from biogas, through an innovative biological methanation reactor
Project began in 2018 > Funded by ADEME

The HyCAUNAIS Project aims to build a flexible 1 MW Power-to-Gas demonstrator in order to produce synthetic methane combining CO₂ from landfill biogas and H₂ from an electrolyzer. Main objectives of the HyCAUNAIS project are to valorize the CO₂ stream from the existing landfill biogas, upgrading plant of Saint-Florentin (France) into Synthetic Natural Gas to be injected into the distribution gas network, while assessing the flexibility of the and ensuring power network services. Storengy is coordinating the consortium constituted by ArevaH2Gen, FCLab, Electrochaea, ENGIE Green, ENGIE Lab CRIGEN, SDEY and SEM Yonne Energie. The overall budget is 10.9 M€. In the framework of this project, ENGIE Lab CRIGEN will co-develop with Electrochaea the biological methanation reactor. In 2020, ENGIE Lab CRIGEN finalized the gas analysis campaigns on the CO₂ and raw biogas streams, worked on the best gas analysis strategy, performed techno-economic study and participated in the feasibility study.

Consortium partners: 1. (coordinator) Storengy (FR); 2. ENGIE Green (FR); 3. Electrochaea GmbH (DE); 4. AREVA H2Gen (FR); 5. Syndicat Départemental d'Energies de l'Yonne (FR); 6. SEM Yonne Energie (FR); 7. FC Lab (FR); **8. ENGIE Lab CRIGEN (FR).**

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THE PROJECTS



THE FUNDERS



STANDARDIZATION



Cristian Muresan,
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Standards are bridging the gap between research and the market. For companies today, especially large ones, standards represent major advantages for protecting their market share and for developing new, differentiating offers via enabling technologies and/or services.





Introduction

Standards are bridging the gap between research and the market. For companies today, especially large ones, standards represent major advantages for protecting their market share and for developing new, differentiating offers via enabling technologies and/or services.

Above 9 full-time experts from ENGIE Research centers are involved each year as independent experts, mainly in CEN and ISO working groups, while at the same time representing the interests of our Group. The participation takes place through 3 complementary activities:

- Coordination and institutional representation of the Group;
- Performing market intelligence, alerting Labs and Business Units or corporate entities on emerging topics related to their own specific activities, and when lobbying is required for the Group's positions;
- Involvement of the various Labs in their specific field of expertise, in close connection with Business Units or Corporate entities in order to create new standards and review current ones.

Standards and research

Standardization is an effective route for exploiting research results. There is a one-to-one correspondence between research and standardization:

- Upstream research feeds pre-normative research: standards help in the massive dissemination of cross-cutting research, technologies and associated services, as well as demonstration projects. Standards acknowledge the safeguarding of early positioning on disruptive technologies bringing leadership. Standardization is an effective and efficient channel of knowledge transfer alongside other well-known channels (such as research partnership and development, licensing, etc.);
- Standardization activities are highlighting everyday research requirements: Standardization without science is not meaningful. Existing standardized methodologies, calculation methods, sizing tools and operation rules are not useful without accurate input. Standardization has to be based on sound scientific data, and on sound measurement methodologies and techniques, so that standards can keep pace with the state-of-the-art practices. Pre-normative research is also addressing the technical knowledge gap between industry know-how and technology disruptions.

PRE-NORMATIVE RESEARCH ACTIVITIES

GERG The European Gas research Group

The European Gas Research group (GERG) along with CEN established a shortlist of potential priority subject areas for pre-normative research actions to reduce barriers to the injection of hydrogen in the natural gas grid and its use in buildings and districts. The subject areas first establish the scope of literature reviews which could initiate a pre-normative work program. The GERG project covers the extension of the certification processes for appliances in buildings and associated specific rules to hydrogen. One of the aims of the project is to widen the scope of existing standards to include the value chain of natural gas to the hydrogen uses.

Several ENGIE entities (including ENGIE Lab CRIGEN, ENGIE Laborelec, Storengy...) were involved in pre-normative research for hydrogen and H2NG blends across the whole chain gas. The GERG project covers the extension of the certification processes for appliances in buildings and associated specific rules to hydrogen. One of the aims of the project is to widen the scope of existing standards to include the value chain of natural gas to the hydrogen uses.

Advanced Materials Lab

ENGIE Laborelec

COFREND Additive Manufacturing Working Group

Scope: COFREND (French Confederation for Non-destructive Testing), known as the reference body in certifying and qualifying non-destructive testing operators in France, launched the Additive Manufacturing Working Group in 2019. Its purpose is to define guidelines for non-destructive techniques applied to laser powder bed fusion and directed energy deposition, defining their limits and maturity to detect process-induced flaws. The end goal is to deliver a French technical proposal that could be used as an important contribution to the future standards within ISO/TC 261 and ASTM F42.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec is member of the Working Group and contributed by delivering an assessment of defects. This describes different types of flaws induced by the laser powder bed fusion process, including their most probable root cause, morphology and expected location.

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ECCC (European Creep Collaborative Committee) membership

Scope: ECCC is earnestly involved in the European data development coordination on creep and in the ensuing activities of assessment and comparison, the purpose being to gather the resources available in each single member state, build up an optimal assessment based on creep values and ultimately set up high production and design standards. ECCC has provided creep data assessments for the CEN working groups in the past, to be incorporated in the standards and is planning to increase its current interactions with EN/ISO standards and European Pressure Vessel Directive PED to support them with long term creep data.

ENGIE Laborelec's contribution in 2021: Active participation in the different working groups on martensitic steels like Grade 91 and Grade 92, austenitic steels like AM 316L and Ni-base steels like AM Hastelloy X and IN718+.

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Scientific Committee of the Belgian Welding Institute

Scope: The Scientific Committee is defining the strategy of the Institute regarding research of relevant and innovative topics for the industry. Among these topics, the focus is on new materials for future use in industrial applications e.g. power plants, petro- and chemical plants, offshore wind, aerospace, pipelines etc. Material property datasets which can be included in industrial datasheets and standards complete these research programs.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec has been presiding the Committee since 2008.

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International Welding Institute - IIW

Scope: The International Welding Institute is a worldwide platform for the joining and welding industry consisting of 58 different national member bodies. It provides a platform for material and welding technologies through expert commissions dealing with all aspects involved i.e. additive manufacturing, arc and beam welding, solid-state welding, brazing, micro- and nanojoining, polymer joining, physics of welding etc. The Institute is collaborating with the ISO standards organization and provides technological input for Best Practices, Qualification and Training requirements, certification and future standards (a.o. fatigue, carbon equivalents, welding procedure and welder qualification etc.).

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec is represented in the TMB (Technical Management Board) and Advisory Council of the IIW. Besides this strategic role, ENGIE Laborelec is also active in expert Commission IX (Behaviour of Metals subjected to Welding) and Commission XI (Pressure Vessels, Boilers and Pipelines).

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Green Mobility Lab

ENGIE Laborelec

ASSURED H2020 project

Scope: ASSURED is an EU Horizon H2020 (2017-2022), with the objective of boosting the electrification of urban commercial vehicles and their integration into high power fast-charging infrastructures. ASSURED contributed to testing and standardizing charging technologies for urban buses and vans by writing Assured 1.0 specifications and test protocols. It is a pre-normative document that will be used by the consortium at Cenelec.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec contributed to the tests, including by assessing electromagnetic compatibility (EMC) of chargers.

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Energy Storage Lab + Future Collectivities & Home Lab

ENGIE Laborelec

AREI/RGIE – Belgium Electrical code

Scope: RGIE/AREI is the document defining the mandatory rules to be followed for every new electrical installation in Belgium, published by the SPF Economy (public federal entity in Belgium). In 2021, the Energy Storage Lab participated in the preparatory work in the working group related to the safety of installations of battery in residential and non-residential areas.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec contributed to the explanation of safety risks related to battery storage in



Nabil Bouchair, Future Collectivities & Home Lab, ENGIE Laborelec.

general with a specific explanation of the risks in residential area during the installation.

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Lighting Competence Center ENGIE Laborelec

NSVV (Nederlandse Stichting Voor Verlichtingskunde)

Scope: NSVV is a Dutch independent knowledge center for light and lighting. Its goal is to share and connect knowledge through publications, workshops, conferences and partnerships, and to advise individuals, governments, educational institutions and the business community about, for example, new lighting technologies, but also about energy consumption. It also sets up new light research and shares this knowledge in, conferences and workshops.

Topics explored during 2021 are:

- Implementation of the Dutch recommendation on light pollution (document is from 2020, but the implementation raises many market concerns and discussions);
- Initiating an update of the Dutch recommendation on light measurements (indoor and outdoor);
- New recommendation on EN12464 (indoor lighting);
- Dutch governmental subsidy on lighting products.

ENGIE Laborelec's contribution in 2021: Board member and responsible for technical developments.

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NORMATIVE RESEARCH ACTIVITIES

Hydrogen Lab

ENGIE Lab CRIGEN

European project PRHYDE dedicated to heavy duty vehicles standardization

Scope: PRHYDE European project addresses pre-normative research related to the development and testing of a refueling protocol for the fast refueling of heavy duty vehicles.

ENGIE Lab CRIGEN's contribution in 2021: In close cooperation with the major players in the field of heavy duty vehicles, ENGIE Lab CRIGEN's experts will improve the standards arena in order to scale up the most cost-efficient and sustainable technologies. High temperature electrolysis is a key issue for specific sectors such as refineries.

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Future Building & City Lab

ENGIE Lab CRIGEN

MACROGAZ - Technical Association of the European Gas Industry

Scope: Marcogaz is the European natural gas industry's technical association and is the representative body of the European Natural Gas Industry on all technical issues. The Standing Committee Gas Utilisation (SCGU) of Marcogaz is supervising the working groups and task forces dealing with gas appliances for domestic and commercial use, industrial processes, gas installations inside buildings, industrial gas installations, new technologies.

ENGIE Lab CRIGEN's contribution in 2021: Within the framework of the SCGU, ENGIE Lab CRIGEN's experts attend and contribute to the Task Force on the primary energy factor (PEF) of electricity including its update in the Energy Efficiency Directive and its use in the Ecodesign Directive, its implementing Regulations and Energy Labelling Regulation. CRIGEN also represents Marcogaz in the Ecodesign directive revision working groups to ensure the good positioning of new gas appliances, relative to other energies.

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CNPG - (Centre National d'expertise des Professionnels de l'énergie Gaz)

Scope: Founded at the request of the public authorities in 2011, the CNPG's main mission is to contribute to the regulation in the fields of construction sector and uses of gas.

ENGIE Lab CRIGEN's contribution in 2021: ENGIE Lab CRIGEN is also representing ENGIE in the framework of CNPG (Centre National d'expertise des Professionnels de l'énergie Gaz) in charge of developing regulations for the installation of gas appliances (natural gas, biomethane, hydrogen) in conjunction with the French Ministry of Safety and Risks. 2021 has been a very active year with the update of 5 thematic guidelines allowing for the application of the regulation A23/02/2018's requirements for safety of gas installations.

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European project THYGA dedicated to H₂ and H₂/GN blend usages in buildings

Scope: The H2020 European project THYGA (coordinated by ENGIE Lab CRIGEN) is focusing on the impact of H2NG blends on end-use for residential and commercial appliances.

ENGIE Lab CRIGEN contribution in 2021: One of its Working Groups is closely working on the topic of certification with the GERG PNR project and CEN Technical Committees. Several workshops or reports have already been published (<https://thyga-project.eu/>).

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Fatima Lelandais,

Future Building & City Lab, ENGIE Lab CRIGEN

Air Quality Lab

ENGIE Lab Cynergie

Visionn'Air project

Scope: Visionn'air is a technical solution combining air quality, hygiene and energy performance for hospital operating rooms. It ensures complete traceability of «air» compliance parameters of Controlled Dusting Zones in the hospital sector, combined with the optimization of air treatment equipment maintenance.

ENGIE Lab Cynergie's contribution in 2021: The approach developed within the framework of the project was an AFNOR 2021 Trophies finalist "LES TROPHÉES OR'NORMES" thanks to its genericity and capacity to be standardized.

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ENGIE LAB INVOLVEMENT IN STANDARDIZATION WORKING GROUPS

The standardization activities performed by ENGIE Research are focused on technical aspects and in line with the Corporate European Affairs team and Regulatory and Public Affairs entities within our Business Units. The ENGIE Research centers (ENGIE Lab CRIGEN, ENGIE Lab Cylergie and ENGIE Laborelec) are constantly in contact with the Business Units in order to provide the best responses within the framework of CEN and ISO working groups. The following summarises the main contributions of our experts in the working groups from monitoring standards to writing standards or in convenor activities.

Biogas, Biomass & Waste Lab ENGIE Lab CRIGEN

ISO/TC 255

Scope: The entire biogas chain (anaerobic digestion, gasification and conversion to electricity from biomass), which is key for ensuring a quick, competitive roll-out of this sector.

ENGIE Lab CRIGEN's contribution in 2021: ENGIE Lab CRIGEN is the convenor of the biomass gasification workstream (WP6) and is also involved as an active member in other working projects such as biogas definition, domestic installations based on biogas, non-domestic usages, safety and sustainability. ENGIE Lab CRIGEN participated in drafting the standard ISO 24252 on industrial anaerobic that successfully passed the DIS ballot. Moreover, the flaring standard NF ISO 22580 was published in November 2021.

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CEN/TC 408

Scope: Biomethane for injection into the gas grids and (together with CNG) as a fuel, including the impact of siloxanes on engines and boilers, of sulfur on catalysis, and of the oxygen impact on UGS and pipes.

ENGIE Lab CRIGEN's contribution in 2021: An ENGIE Lab CRIGEN expert is fully in charge of managing the Biomethane GERG project in order to develop a new standard. Moreover, this expert was appointed President of the BNG 408-255 (mirror committee of the CEN TC 408) and took over in September 2020.

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Hydrogen Lab ENGIE Lab CRIGEN

CEN/TC 268/WG5

Scope: Specific hydrogen technology applications.

ENGIE Lab CRIGEN's contribution during 2021: ENGIE Lab CRIGEN is contributing to the revision of "EN 17127 - Outdoor hydrogen refueling points dispensing gaseous hydrogen and incorporating filling protocols" and "EN 17124 H₂ Fuel - Product Specification and Quality Assurance. PEM FC application for road vehicles". These two standards will become mandatory in Europe and must be revised before enforcement.

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ISO/TC 197/WG 19

Scope: ISO/DIS 19880-2 Gaseous hydrogen Fueling stations - Part 2: Dispensers.

ENGIE Lab CRIGEN's contribution during 2021: ENGIE Lab CRIGEN was among the experts in the Work Group 19 in the drafting of ISO

19880-2. This was recently re-opened following the finalization of ISO 19880-1 on the HRS General Requirement.

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ISO/TC 197/WG 28

Scope: Gaseous hydrogen - Fueling stations Part 1: Requirements.

ENGIE Lab CRIGEN's contribution during 2021: ENGIE Lab CRIGEN was among the experts in Work Group 28 which produced the amendment on the document "ISO 19880-8 Gaseous hydrogen - Fueling stations Part 8: Fuel quality control.

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AFNOR 29D WG

Scope: Hydrogen technologies.

ENGIE Lab CRIGEN's contribution during 2021: ENGIE Lab CRIGEN was among the experts of this French mirror committee on hydrogen technologies, monitoring all standard activities on hydrogen, providing review comments and voting France's position on the standardization decision (new work item proposal, validation of draft, publication, etc.).

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Liquefaction Lab ENGIE Lab CRIGEN

ISO/TC 28/SC 4/WG 17

Scope: Specification of Liquefied Natural Gas as a fuel for marine applications.

ENGIE Lab CRIGEN's contribution during 2021: The experts contributed to the following documents "Specifications of Liquefied Natural Gas for Marine Applications" and to ISO 23306, published in 2020.

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BNG 282-67SC9

Scope: Liquefied Natural Gas facilities and equipment.

ENGIE Lab CRIGEN's contribution during 2021: BNG 282-67SC9 aims at developing and maintaining standards in the field of facilities, equipment and procedures used for the production, transportation, transfer, storage, regasification and use of LNG, taking into account the program of work of ISO/TC 67/SC9 and CEN/TC 282. Standardization covers the supply chain from the inlet to the outlet of the relevant natural gas/LNG facilities, and comprises both onshore and offshore siting options for them. ISO/TC 67/SC9 further coordinates issues concerning LNG in the technical work of technical committees dealing with cryogenic equipment. Aspects subject to IMO requirements are excluded (ISO/TC 8).

During 2020 the ENGIE Lab CRIGEN's experts contributed to the following standards:

- ISO 20088-2, Determination of the resistance to cryogenic spillage of insulation materials - Part 2: Vapor phase (JWG3);
- ISO 20257-1, Design of floating LNG installations - Part 1: General Requirements for Floating LNG installations (WG7);
- ISO 20257-2, Design of floating LNG installations - Part 2: Specific Requirements for FSRU;
- ISO 20257-3, Design of floating LNG installations - Part 3: Specific Requirements for FLNG.

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ISO/TC 67/SC9/WG1

Scope: Equipment and procedures for LNG when used as fuel for marine, road and rail activities.

ENGIE Lab CRIGEN's contribution during 2021: WG 1 is currently revising ISO/TS 18683 on LNG bunkering (Guidelines for systems and facilities for supply of LNG as fuel to ships) in order to retain what is missing in ISO 20519 (such as risk analysis).

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ISO/TC 67/SC9/WG9

Scope: LNG railcar applications.

ENGIE Lab CRIGEN's contribution during 2021: The background to the new ISO-TC67-SC9-WG9 is a growing market worldwide for LNG, with diversification of LNG sources and transport methods. Transport overland is expanding, and road transport is in the lead, while rail transport is emerging in the EU.

The problem is that multiple players are developing by themselves, process lineups, design principles and internal 'best practices' for LNG cargo loading/unloading into railcars and ISO containers. This approach runs the risk of markets becoming flooded with bespoke "one-off" facilities that can create: a) at best, inconvenience during loading/unloading and increased operator burden, b) at worst, loss of LNG containment leading to potential industrial accidents.

The ENGIE Lab CRIGEN's experts are involved in the WG 9 in order to develop a timely guideline which can help to create consistency in design and operational approaches and to minimize the risks. Such guidelines would cover general process and equipment design and operations, as well as typical layout, emissions management, safety functions and monitoring systems. The target time for officially launching the New Work Item Proposal (NWIP) is June 2021.

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ISO/TC 67/SC9/WG10

Scope: Greenhouse gas emissions at LNG plants.

ENGIE Lab CRIGEN's contribution during 2021: The new ISO-TC67-SC9-WG10 is part of a global context where the LNG industry is increasingly challenged on GHG emissions versus global warming, CO₂ taxes, carbon credit market and an emerging market demand for a "carbon neutral LNG" product. The scope of this Working Group is to define the methodology and the parameters to be considered in order to assess GHG emissions of LNG plants (identify, quantify and report). The project scope covers LNG plants (from Inlet facilities up to LNG loading arms), taking into account the plant in operation (excluding the construction and decommissioning phases but including commissioning and start-up) and the following gases: CO₂, CH₄, N₂O and fluorinated gases.

The ENGIE Lab CRIGEN's experts are working on developing a calculation method for the LNG liquefaction facility. This methodology could then be extended to the other parts of the chain, with the goal ultimately being to cover the entire LNG value chain. The objective is in particular: a) to provide LNG operators with a standardized and international methodology (that can be audited) in order to benchmark their LNG plants with peers, b) to determine a way to classify LNG plants (regarding their carbon footprint), such as a Low Carbon certification.

A New Work Item Proposal (NWIP) was prepared, which was transmitted to IOGP (International Association of Oil & Gas Producers). Work will be carried out under the IOGP umbrella, meaning that a group is created with the same participants and where documents are exchanged using the IOGP platform.

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Future Building & City Lab

ENGIE Lab CRIGEN

ISO TC 291: Domestic cooking technologies

Scope: The scope of the TC 291 is to standardize the certification of cooking technologies for safety.

ENGIE Lab CRIGEN's contribution during 2021: The TC developed a new standard for domestic cooking based on European EN30-1 as well as American, Chinese and Japanese standards. ENGIE Lab CRIGEN experts contributed in mitigating the risks of too stringent requirements, thus preventing European manufacturers from having to re-design their products.

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TC 238: Test gases, test pressures, appliance categories

Scope: Standardization of test gases, test pressures, appliance categories and gas appliance types.

ENGIE Lab CRIGEN's contribution during 2021: The TC has contributed to British Standard PAS 4444 for the certification of 100% hydrogen-compatible appliances. It has also begun work on updating EN 437 for natural gas - hydrogen mixtures by defining new categories of gases. This standard plays a critical role in the testing of appliances in order to guarantee safe appliance operation with different gas qualities. The ENGIE Lab CRIGEN expert helped the TC with his knowledge on gas combustion and the impact of gas quality on appliances.

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TC 49 and TC 106: Domestic cooking and professional catering

Scope: Standardize the certification of domestic and professional cooking technologies for safety and energy efficiency.

ENGIE Lab CRIGEN's contribution during 2021: Most of 2021 work in these TC was focused on rewriting the EN 30 and EN 203 standards in order to ensure that they comply with the recently published Gas Appliances Regulation. These standards define test procedures and limit values that guarantee the robustness, safety and energy efficiency of appliances. Some test procedures were updated in parallel to the revision of Eco-Design for cooking appliances. Others were created and tested in manufacturers' labs as well as in ENGIE Lab CRIGEN test facilities.

The ENGIE Lab CRIGEN expert contributed to the definition and testing of new test procedures in order to measure the energy efficiency of appliances.

Following the publication of the "Guidance on testing and certification of hydrogen gas appliances" by the BSI, manufacturers are becoming increasingly interested in developing hydrogen-compatible technologies and are raising questions related to the standardization of sizing, ageing, pollutants, leakages and safety in buildings.

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TC 109: boilers

Scope: Standards related to natural gas appliances providing heating (boilers, CHP, hybrid heat pumps...).

ENGIE Lab CRIGEN's contribution during 2021: EN15502-1:2021 was published in November 2021. The main topic of 2021 was the proposal from some experts from CEN/TC109 WG1 to limit the acceptable gas quality variation by modifying the EN15502 product standard (by default, a 2.0MJ/m³ Wobbe index bandwidth (Z) was proposed), the idea was to favor the low fluctuation of gas quality. Several countries, including France and CRIGEN's experts, were opposed to this position because it went against the Sector Forum WG "Gas Quality Study" conclusions, and the TC238's control of the gas quality definition for gas appliances.

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TC 109: Ad-hoc group on Hydrogen: hydrogen for boilers

Scope: Update standards on boilers for natural gas hydrogen mixtures and hydrogen.

ENGIE Lab CRIGEN's contribution during 2021: The adhoc group TC109 AHG-H₂ reviewed standard 15502-1 dedicated to the safety

and performance of condensing boilers. Its experts have updated it for natural gas hydrogen mixtures of up to 20% H₂. In order to anticipate the work of TC 238 in the definition of test gases, the JWC has suggested several new tests gases/test methods. This adhoc group is also a platform of exchange of information on different European projects dealing with natural gas/hydrogen mixtures. The ENGIE Lab CRIGEN expert, along with other European experts, contributed to this shared work. He was also in charge of liaising with the THyGA European project which is dedicated to testing gas appliances with natural gas - hydrogen mixtures up to 60% H₂.

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JWC of TC 109/TC58: On auto-adaptative control function for boilers

Scope: Update standards on boilers combustion-controlled boilers (that adapt themselves automatically to gas quality).

ENGIE Lab CRIGEN's contribution during 2021: The Joint Working Committee TC109/TC58 reviewed standard 15502-1 dedicated to the safety and performance of condensing boilers. Its experts have updated it with specific tests and a requirement for combustion-controlled boilers.

The ENGIE Lab CRIGEN expert and other European experts, shared their knowledge on gas quality and boiler operations.

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TC 109 ADH C(10)/C(11)

Scope: Explore lack of knowledge regarding certification of boilers on collective chimney systems (CLV).

ENGIE Lab CRIGEN's contribution during 2021: The adhoc group C(10)/C(11) was created at the initiative of the French mirror committee to tackle problems arising from incompatibility between the sizing tools of CLC systems and appliance certification. The ENGIE Lab CRIGEN expert is co-piloting this ADH with Bosch since it started in January 2021, the activity has mainly been focused on exploring actual certification rules and their origin, begin comparison of data from experimentation done at ENGIE Lab CRIGEN's experimental tower with results generated by sizing tools.

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CEN TC 371: Holistic performance of buildings

Scope: The TC 371 is strongly focused on a systemic approach to calculate the energy performance in buildings and CO₂ emissions. The main objective is to assess the global energy performance by setting up the minimum requirements (energy needs of buildings, energy consumption), compensating energy uses through local production and storage and without discriminating technologies.

ENGIE Lab CRIGEN's contribution during 2021: After the adoption of EN 17423-1, the standard for assessing the evaluation of primary energy factors and CO₂ content of energy vectors was adopted. 2021 has been mainly devoted to its transposition into an ISO standard. It should also be noted that this standard has been proposed by the European Commission to be referenced in the next Energy Performance of Buildings Directive (EPBD).

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UF105/JTC17

Scope: Natural gas Micro-CHP (internal combustion engines, fuel cells).

ENGIE Lab CRIGEN's contribution during 2021: JTC17 is in charge of standards related to micro-CHP under 70 kWe for stationary use. This Joint Technical Committee reports to CENELEC/UF105 (Fuel Cells) and CEN/TC109 (Central Heating boilers). The main activity of the committee deals with the adaptation of the current prEN62282-3-400 (Stationary fuel cell power systems - small stationary fuel cell power systems with combined heat and power) to cover all micro-CHP applications and requirements of European directives (GAR and Ecodesign) so that this standard can replace the current micro-CHP's EN50465. 2021's activity has mainly been focused on finalization of the draft of the prEN 62282-3-400.

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BNG 62

Scope: Independent gas-fired space heaters.

ENGIE Lab CRIGEN's contribution during 2021: Activities related to the update of EN 613 (published in January 2022) and EN14829. The revision of Ecodesign which was on standby started again in end of 2021.

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P51D/TC166

Scope: Chimneys.

ENGIE Lab CRIGEN's contribution during 2021: Many activities related to the revision of standards (EN 14471, prEN 13216-2, prEN 15287-1, prEN 15287-2, prEN 1856-1, prEN 1856-2) are being monitored by CRIGEN. A point of interest is that the TC166 has started working on H₂ and H₂NG, with the aim of gathering information on the impacts of chimney's sizing and compatibility with a humid atmosphere brought by hydrogen (lower dew point than natural gas).

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Nanotechnologies, Sensors & Wireless Lab

ENGIE Lab CRIGEN

Energy Equipment Working Group within GS1 for the preparation of a standard

Scope: Energy Equipment Working Group within GS1 for the preparation of a standard. The TEE (Traceability of Energy Equipment) Working Group within GS1 is aimed at identifying and bringing together representative players in the energy sector in order to identify and list common needs and promote the deployment of innovative, standardized, shareable and interoperable solutions around connected objects, with the objective of publishing a standard.

ENGIE Lab CRIGEN's contribution in 2021: ENGIE Lab CRIGEN is mostly contributing to the PPE (personal protective equipment) Working Group / the CPE (collective protective equipment) Working Group and the Working Group for regulated monitoring equipment, whose aim, whatever the type of site or laboratory visited, is to identify and trace regulated monitoring equipment and the PPE or CPE of internal contributors and subcontractors.

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Green Mobility Lab

ENGIE Laborelec

IEC TC69 and CEBEC TC69

Scope: IEC TC69 covers energy transfer for electric vehicles. This includes functional requirements, electric magnetic compatibility, charging technologies (conventional charging stations, wireless, etc.). CEBEC TC 69, is the national committee of standardization in Belgium, it contributes to the same standards as IEC TC 69 plus the national grid code.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec participates in IEC TC69. The lab is active in JWG 11 (Management of Electric Vehicles charging and discharging infrastructures) that is developing IEC 63110 (communication between the charging station and charging management system) that could replace OCPP used by ENGIE and the industry. Moreover, ENGIE Laborelec participates in IEC 63380 (communication of charging station and local energy management system) and follows other standards such ISO 15118, Megawatt chargers, etc.

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European directives and regulations linked to electric vehicles

Scope: Development and update of European directives and regulations linked to electric vehicles.

ENGIE Laborelec's contribution in 2021: Through the ENGIE Business E-mobility Platform (formerly Acceleration Task Force, aka ATF) and ENGIE European Affairs Department, ENGIE Laborelec prepares comments on EU commission directive and proposals regarding electric vehicles. This includes the review of the Alternative Fuels Infrastructure Directive. Through ENGIE France BtoC, ENGIE Laborelec prepares comments on French regulations regarding smart charging, V2X (i.e., bidirectional charging), the implementation of EU directives, etc. The focus is on ensuring non-discriminatory, standardized access to relevant data and on removing regulatory barriers on smart charging and V2X. This includes contributing to position and white papers from AVERE-France (stakeholders in electric mobility) and UFE (organization of French energy suppliers).

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Energy Storage Lab

ENGIE Laborelec

IEC TC21 and SC21A and CEBEC TC21 and SC21A

Scope: IEC TC21 is related to the standardization of electrochemical systems. It encompasses standards for all secondary cells and batteries related to product (dimension and performance), safety (including marking and labelling), testing, and safe application (installation, maintenance, operation) irrespective of type or application or configuration (hybrid, stand alone, module). The work is shared between TC 21 and SC 21A according to technologies and applications. CEBEC TC21 (and SC21A) is the national committee of standardization in Belgium, it contributes to the same standards as IEC TC21 (resp. SC21A).

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec participates in IEC TC21 and SC21A. The lab is active in working groups related to safety of batteries for stationary applications, having staff members declared as experts in these topics.

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IEC TC120 and CEBEC TC120

Scope: IEC TC120 is related to the standardization in the field of grid integrated EES Systems. The level of interest is the energy storage system for stationary applications. TC120 considers all storage technologies as long as they are capable of storing and discharging electrical energy. Thermal storage systems are included in the scope but only from the electricity exchange point of view. Unidirectional energy storage systems such as UPS are not included in the scope of TC 120. Energy storage itself is not in the scope of the work (which is the scope of other TCs like TC21 for secondary cells and batteries).

ENGIE Laborelec's contribution in 2021: In 2019, ENGIE Laborelec changed the status of the Belgian Committee from O-Member to P-Member. CEBEC TC120 is chaired by ENGIE Laborelec. The lab is active in working groups related to the safety of batteries for stationary applications and in having staff members declared as experts on these topics. The lab is also following the activities related to unit parameters and testing methods.

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Lighting Competence Center

ENGIE Laborelec

IEC TC 34

Scope: To prepare, review and maintain international standards and related IEC deliverables regarding safety, performance and compatibility specifications for electric light sources and components, caps and holders, control-gear and control devices for electric light sources, and electronic lighting equipment, luminaires and lighting systems. Compatibility specifications may include requirements necessary for coexistence, interoperability and interchangeability between components in a lighting system.

ENGIE Laborelec's contribution in 2021: Follow-up of the draft standards for testing laboratory activities.

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Smart Grids & Industrial Cyber Security Lab

ENGIE Laborelec

IEC TC17

Scope: To prepare, review and maintain international standards related to Switchgear & Controgear.

ENGIE Laborelec's contribution in 2021: The main 2021 activities are related to the:

- Preparation of the amendment to standard IEC 62271-200 (Metal enclosed switchgear Ur<52kV) with regard to LSC class, internal arc tests and pressure withstand test to take into account the alternative gases to SF6 used at higher pressures compared to SF6. This follows European regulations on the reduction of greenhouse gases. This work is still in progress;
- Preparation of the amendment to standard IEC 62271-1 (Switchgear < 52kV, General clauses) concerning the risks of restarting electrically controlled manoeuvres after a power failure.

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CEB-BEC 20

Scope: In 2021, 9 Teams meetings were held by the CEB-BEC 20 related to cables. The standardization of all cable types, including more specifically this year the cables for electric vehicles, cables with a big cross-section, photovoltaic cables, and current ratings.

ENGIE Laborelec's contribution in 2021: The participants at these meetings were cable manufacturers, people from the industry, from the grids (Medium Voltage and High Voltage) and test laboratories. The documents issued by the IEC and CENELEC concerning cables and their accessories are commented by ENGIE Laborelec experts. Task forces on some specific subjects were created where the experts make proposals to improve the standards (dealing with the review of the HD620 on distribution cables).

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Cenelec TC14

Scope: Transformer losses in Europe are limited by European Commission Directive 2009/125/EC. The first restrictions went into force in 2015 and became even more stringent in 2021. Some of the standards became obsolete after publication of these Directives.

ENGIE Laborelec's contribution in 2021: ENGIE Laborelec experts contributed in 2021 to improving the following standards:

EN 50708-1-2 (2021) Power transformers - Additional European requirements: Part 1-2 Common part - Assessment of energy performance

EN50708-2-1 (2021 and ongoing) Power transformers - Additional European requirements - Part 2-3: Medium power transformer - Accessories.

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ABBREVIATIONS

AFNOR = Association française de normalisation
CEN = European Committee for Standardization
COFREND = French Confederation for Non-destructive Testing
ECCC = European Creep Collaborative Committee
<https://www.cofrend.com/>
EPBD = Energy Performance of Buildings Directive
GERG = The European Gas Research Group
ISO = International Organization for Standardization
IIW = International Institute of Welding
NSVV = Nederlandse Stichting voor Verlichtingskunde
NWI = New Work Item (CEN and ISO procedure in order to initiate a new standard)
TC = Technical Committee
WG = Working Group



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