



—
INNOVATING
FOR A LOW-CARBON
AND SUSTAINABLE
WORLD
+

2023 **ACTIVITY
REPORT**

OUR MISSION

IFPEN, THE ESSENTIALS

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BACKGROUND

CLIMATE CHANGE AND THE ECOLOGICAL TRANSITION

+ CHALLENGES



PROMOTING SUSTAINABLE MOBILITY



DIVERSIFYING THE ENERGY MIX

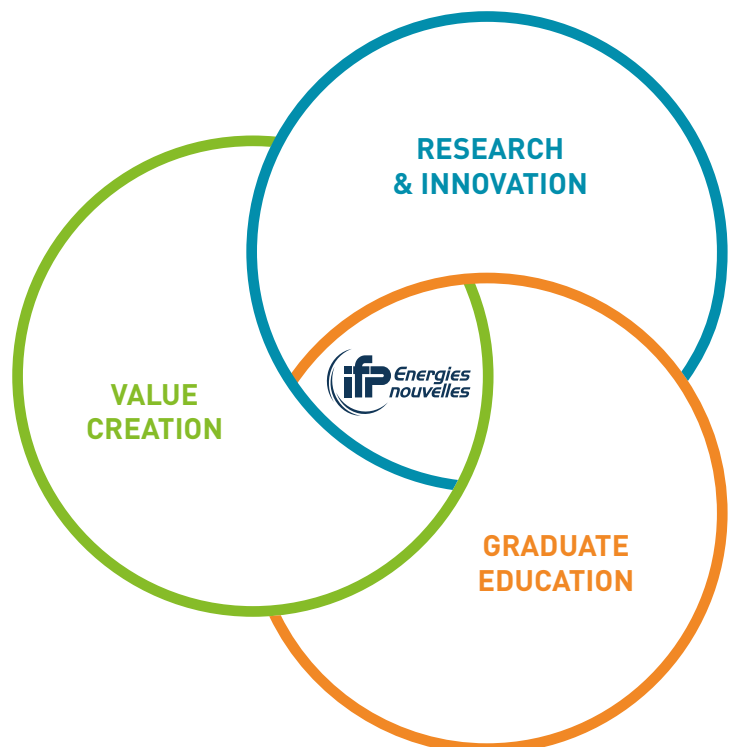


INCREASING ENERGY EFFICIENCY



REDUCING THE ENVIRONMENTAL IMPACT OF FOSSIL RESOURCES

+ 3 PRIORITY AREAS



IFP ENERGIES NOUVELLES

IFP Energies nouvelles (IFPEN) is a major research and training player in the fields of energy, mobility and the environment. From scientific concepts in fundamental research to technological solutions in applied research, its activities revolve around innovation. As part of its public-interest mandate assigned by France's public authorities, IFPEN's work focuses on providing solutions to the challenges facing society and industry in terms of energy and the climate, for the benefit of the threefold ecological, energy and digital transition. IFPEN's own graduate engineering school, IFP School, trains future generations so that they can take up these challenges.

INNOVATION-DRIVEN RESEARCH

The aim of IFPEN's R&I programs is to overcome existing scientific and technological challenges in order to develop innovations that can be used by industry. Faced with a broad range of open scientific questions, **fundamental research** at IFPEN is aimed at producing a cross-functional bedrock of new knowledge, concepts and methodologies, a platform for the development of the innovations of tomorrow. Projects are often conducted within a collaborative environment with academic and industrial partners. IFPEN's researchers regularly lend their scientific expertise to the public authorities, providing insights to help them in their decision-making process. IFPEN is an active player in numerous projects, technological platforms and networks within the context of the European Horizon Framework Program, and is also contributing to the emergence of a European vision of research in the fields of mobility and energy.

Applied research programs are structured around four **strategic priorities**:

- **climate, environment and circular economy**: reducing the impact of human and industrial activities on the climate and the environment,
- **renewable energies**: producing energy, fuels and chemical intermediates from renewable sources;
- **sustainable mobility**: developing efficient, environmentally-friendly solutions for the transport sector;
- **responsible oil and gas**: meeting the demand for energy and chemical products in a more environmentally-friendly manner.

IFPEN is funded both by a state budget and by its own resources provided by subsidiaries and industrial partners.

VALUE CREATION

IFPEN contributes to the creation of wealth and jobs by fostering the economic development of sectors related to mobility, energy, and eco-industry. IFPEN's model is based on leveraging the innovations developed by its researchers. Innovations are brought to market through IFP Group subsidiaries and through close partnerships with industrial players. In emerging or mature markets, IFPEN thus creates companies or acquires shareholdings in companies showing great potential. In addition, IFPEN supports the development of start-ups and SMEs as part of collaboration agreements, contributing its technical and legal expertise.

GRADUATE EDUCATION, A VECTOR FOR COMPETITIVENESS

In the context of the energy transition, IFP School trains talented young people to take up the technical, economic and environmental challenges facing society, while providing industry with the highly qualified personnel it requires. With an international reach, IFP School provides young graduates with Master's degree programs for the professions of today and tomorrow in the fields of energy, transport and the environment. Over 500 students from around the world graduate from the school each year.

INTERVIEW WITH PIERRE-FRANCK CHEVET, CHAIRMAN AND CEO OF IFPEN



Based on its strategic vision Horizon 2035, IFPEN is currently developing technologies, processes, products, software and services to diversify the energy mix, reduce carbon emissions in industry and transport, and promote the circular economy.

The year 2023 marked a turning point in our efforts to position ourselves as a key player in the threefold ecological, energy and digital transition. This approach went hand in hand with a reorganization of our structure into four new business units: “Energy systems”, “Energy products”, “Chemistry for industry” and “Mobility”.

In 2023, IFPEN set itself apart, with its ability to bring innovations to market in a variety of ways, through subsidiaries, demonstration plants or early-stage industrial plants. For example, we set up a subsidiary in the wind power sector, GreenWITS, which offers advanced digital services. We are also involved in the DMX™ CO₂ capture process demonstrator at ArcelorMittal's Dunkirk site, which is designed to validate the efficiency of the process on an industrial scale.

In 2023, we affirmed our position as a trusted third party alongside public authorities and industry.

Another example is the choice of the BioTfuel® process, developed and demonstrated by IFPEN and its partners, for the BioTJet™ plant in the Lacq Basin. The plant is expected to supply sustainable aviation fuel as a means of reducing the carbon footprint of air transport, and to supply naphtha for the green chemicals industry. These achievements are the culmination of more than 10 years of Research & Innovation.

In so doing, IFPEN is helping to develop new industrial sectors.

Furthermore, our expertise in hydrogen technologies has earned us second place in the world ranking of public research organizations in terms of patent applications.

IFPEN is also pursuing its policy of industrial development and leveraging its innovations through a global approach to incubation, spin-offs and equity investments in companies focused on the ecological transition.

In 2023, we affirmed our position as a trusted third party alongside public authorities and industry. This is illustrated by our active participation in a variety of working groups with public authorities and industrial firms on issues relating to rolling out environmentally-friendly technologies across France and Europe. Fully committed to the France 2030 investment plan, we are proud to be leading or jointly leading three French priority research programs and equipment (PEPR). This commitment consolidates our open approach and our research partnerships.

At the same time, we have significantly increased our commitment to training in and through research by funding a record number of theses in 2023, with the aim of anticipating the challenges of new research topics.

Lastly, our IFP School has continued to adapt to changes in industry and society by launching new graduate programs, such as the Master's degree in Geosciences for the energy system transition, in partnership with the University of Strasbourg, and by planning the launch of a Specialized Master's® in Hydrogen in September 2024.

More than ever, IFPEN's commitment to innovation and technological solutions will be reflected in the challenges ahead, and this is one of the reasons why we plan to adopt a new name in the near future that more accurately embodies our commitment to the ecological transition.

I hope you enjoy reading this report!



CORPORATE GOVERNANCE

THE EXECUTIVE COMMITTEE*

GENERAL MANAGEMENT



Pierre-Franck Chevet
Chairman and CEO



Catherine Rivière
Executive Vice-President
Research & Innovation



Éric Lafargue
Executive Vice-President Administration
and management of subsidiaries

BUSINESS UNIT DIRECTORS



Benjamin Herzhaft
Energy systems



Florence Delprat-Jannaud
Energy products



Cécile Barrère-Tricca
Chemistry for industry



Gaëtan Monnier
Mobility



Pascal Longuemare
Education and Training



Nathalie Alazard-Toux
Industrial Development

OTHER MEMBERS OF THE EXECUTIVE COMMITTEE



Véronique Ruffier-Meray
Human Resources Director



Dominique Humeau
Director of Digital Science
and Technology, Digital Office
and Information Systems

* As of 1 May 2024.

THE BOARD OF DIRECTORS*

Pierre-Franck Chevet

Chairman

Frédéric Ravel

Scientific Director of the Energy, Sustainable Development, Chemistry and Processes sector supporting research and innovation strategy at the General Directorate for Research and Innovation, representing the Minister of Higher Education and Research

A representative

of the French Ministry of the Economy, Finance and Industrial and Digital Sovereignty, *to be appointed*

A representative

of the French Ministry of Industry, *to be appointed*

Monique Axelos

Scientific Director for Food and Bioeconomy, Board of Directors Unit, INRAE

François Dassa

Director of Foresight and International Relations at EDF, based in the Innovation, Corporate Responsibility and Strategy Department

Laurent Duval

Staff representative

Carla Gohin

Director of Research, Innovation and Advanced Technologies at Stellantis

Didier Holleaux

Executive Vice-President, Engie

Hervé Le Treut

Member of the Académie des sciences (French Academy of Sciences), Director of Research at the CNRS (French National Centre for Scientific Research)

Sophie Paturle-Guesnerot

Founding partner of Demeter Partners

Sylvie Perrin

Staff representative

Axel Plasse

Research & Development and Marketing Director, Powertrain Driveline Systems Product Group, Valeo

Bruno Sportisse

Chairman and CEO of Inria

Anne Varet

Scientific Director and Deputy Executive Director Foresight and Research, ADEME (French Environment and Energy Management Agency)

A qualified person

to be appointed following the resignation of a director

WITH THE ATTENDANCE OF

Pierre Amidey

General Economic and Financial Controller

A Government Commissioner

for IFPEN, *to be named*

Guillaume Gougeul

Secretary of IFPEN's Central Works Committee (CSEC)

THE SCIENTIFIC BOARD*

Luc Vervisch, President

University Professor at the Institute of Applied Sciences in Rouen (CORIA laboratory)

Jean-Yves Berthou

Director of the Inria-Saclay Centre

Philippe Cassagnau

University Professor at Lyon 1 University, Director of the Lyon research platform: Polymer Science & Engineering, Chairman of the French Rheology Group

Christophe Coperet

Professor of Molecular Chemistry and holder of the surface and interface chemistry chair at the École Polytechnique Fédérale, Zürich (Switzerland)

Marc-Olivier Coppens

Ramsay Memorial Professor and Head of the Chemical Engineering Department at University College London (UK)

Sylvie Dequin

Head of INRAE's Microbiology and the Food Chain Division (Jouy-en-Josas)

Mohamed Gabsi

Professor and Head of the Department of Electronics – Electrical Engineering – Automatic control – Energy Conversion at the École Nationale Supérieure de Paris-Saclay

Anke Lindner

Professor of Physics at Paris-Diderot University and Researcher for the Physics and Mechanics of Heterogeneous Media Laboratory at the ESPCI Engineering School in Paris

Nicolas Moes

University Professor at the École Centrale de Nantes, Research Institute in Civil and Mechanical Engineering (GeM) and member of the French Academy of Sciences

Yannick Perez

University Professor of Economics at CentraleSupélec

Nicolas Petit

Professor at Mines ParisTech, Director of the Systems and Control Center (CAS)

Catherine Pinel

Director of IRCELYON

Christine Rousselle

Professor of Combustion and Optical Diagnostics at Orléans University, IEA Clean and Efficient Combustion TCP Delegate

Marc Schoenauer

Research Director (DR1) at Inria (Saclay), Co-Director of the TEAM (Artificial Intelligence & Machine Learning) group

Sophie Violette

Professor of Hydrogeology, École Normale Supérieure de Paris

SOCIAL & FINANCIAL DATA

SOCIAL DATA



1,531

Total full-time equivalent (FTE) workforce for 2023

including

1,078

R&I researchers and technicians

nearly

175

PhD students, post-doctoral researchers and placement students (FTE)

and

35

work/study students

FINANCIAL DATA

Own resources increased, mainly due to growth in royalties and dividends.

Operating expenses rose against a backdrop of widespread inflation.

The net contribution from the hydrocarbons sector has been growing steadily and rapidly since 2019, mainly as a result of the reorientation of R&I activities towards the fields of energy transition. Conversely, the contribution from the budget allocation increased slightly.

€283.1 MILLION

including €241.1 million for R&I
Operating expenses

76%

Weight of new energy technologies in IFPEN R&I in 2023

€124.1 MILLION

Budget allocation

€156.7 MILLION

Own resources

BREAKDOWN OF OPERATING EXPENSES



■ Personnel costs
■ Operating costs
■ Amortisation, provisions
■ Taxes
■ Other

BREAKDOWN OF OPERATING REVENUES



■ Net budget allocation
■ Public funds
■ Services and collaborative research
■ Royalties
■ Dividends
■ Fixed-asset production

IFPEN NEWS IN 2023: PANORAMA



ECOLOGICAL TRANSITION AND PLANNING: IFPEN CONSOLIDATES ITS POSITION AS A TRUSTED THIRD PARTY

As part of its commitment to the threefold ecological, energy and digital transition, IFPEN is playing a pivotal role in the planning and implementation of ecological and energy policies in France and Europe. Its highly-acclaimed expertise in fields such as mobility, decarbonization of air transport, hydrogen and biomass, positions it as a prime partner. As a committed player, IFPEN was actively involved in a number of projects and initiatives in 2023, working alongside public authorities and industrialists. It was instrumental in initiatives such as the interdepartmental working group on sustainable aviation fuels, France's strategic advisory board for civil aviation research (CORAC), the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance, ETIP Bioenergy, to name but a few. The aim is to shape policies and regulations that encourage the deployment of environmentally-friendly technologies throughout France and across Europe. In addition to its participation in decision-making bodies, IFPEN has endeavored to make the general public more aware of the challenges of the ecological transition. Its appearances at events such as the Paris Air Show and the Pau Grand Prix were opportunities for it to share its vision and expertise with a wide audience.

+ FOCUS

IFPEN has once again achieved 100/100 on the gender equality index, a clear indication of its commitment to this issue. It ranks among the mere 2% of French companies to have achieved this maximum score, with the national average* being 88/100.

* Source: French Ministry of Labor.



PRESENTATION OF THE 3D CARBON CAPTURE PILOT, DURING ROLAND LESCURE'S VISIT TO THE ARCELORMITTAL SITE

On Monday January 16, a delegation comprising Cécile Barrère-Tricca, Florence Delprat-Jannaud, Vania Santos-Moreau, Head of the 3D carbon capture project, and Axens representatives accompanied Roland Lescure, the French Minister for Industry, on a visit to the ArcelorMittal site in Dunkirk. This visit was part of the creation of low-carbon industrial zones (ZiBaC), an initiative launched following the pact to decarbonize French industry proposed by the President of the Republic, in November 2023, to the heads of the 50 industrial sites with the highest greenhouse gas emissions. The aim is to roll out on selected industrial zones all the infrastructure needed to introduce low-carbon production processes, based on new technologies such as hydrogen and CO₂ capture. On this occasion, Vania Santos-Moreau and Laurent Viellard, Operations Manager, presented the 3D project and the demonstration plant for the DMX™ industrial CO₂ capture process, which came on stream in September 2022, marking a first milestone towards capturing, by 2026, one million metric tons of CO₂ per year on the ArcelorMittal site. By 2030, the European Dunkirk – North Sea cluster should be able to capture, transport and store more than 10 Mt of CO₂ per year in the North Sea.



INDUSTRY DECARBONIZATION, BIOPRODUCTS AND MOBILITY: IFPEN COMMITTED TO LAUNCHING THREE FRENCH PRIORITY RESEARCH PROGRAMS AND EQUIPMENT (PEPR)

IFPEN is a stakeholder in the France 2030 investment plan, through its involvement in priority research programs and equipment (PEPR), and together with the CNRS, is joint leader of the SPLEEN PEPR, an upstream research component supporting the French national acceleration strategy relating to the “Decarbonization of industry”. Launched in June 2023, SPLEEN is aimed at bringing together the French scientific community for the design of industrial systems that emit lower levels of greenhouse gases. The B-BEST PEPR, an upstream research component supporting the French national acceleration strategy relating to “Bio-based products and industrial biotech – sustainable fuels”, was launched in July 2023. The project, which is being conducted by IFPEN and INRAE, aims to gain a better understanding of the various chemical, thermal and biological processes and their synergies, and to exploit them more efficiently to transform biomass. Lastly, IFPEN is leading the MOBIDEC PEPR, an upstream research component supporting the French national acceleration strategy for the digitalization and decarbonization of mobility, launched in December 2023, alongside Gustave Eiffel University, joint leader of the research program. Integrated in the France 2030 objective, this priority research program is aimed at developing an efficient, sovereign and resilient mobility sector.

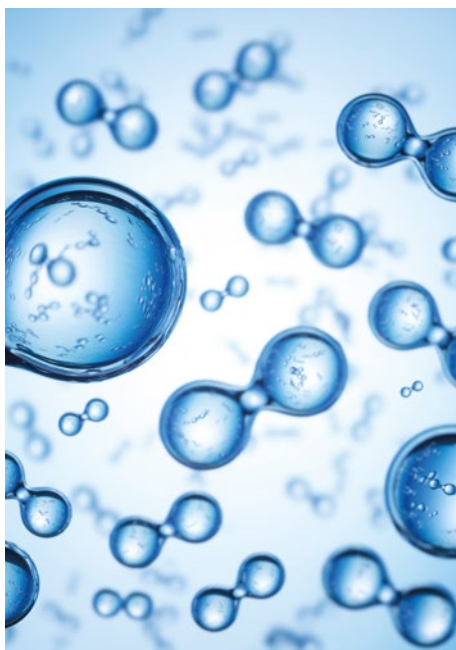


+ **FOCUS**

To find out more about IFPEN and the priority research programs that it is leading or jointly leading, **please check out the website** www.ifpenouvelles.fr



PATENTS: IFPEN, 2ND IN THE WORLD RANKING OF PUBLIC RESEARCH ORGANIZATIONS IN HYDROGEN TECHNOLOGY



The “Hydrogen patents for a clean energy future” study conducted jointly by the European Patent Office (EPO) and the International Energy Agency (IEA), was published in January 2023. This study presents the major trends in the field of hydrogen technologies for the period 2011-2020, measured in terms of international patent families. It covers a broad range of technologies, from hydrogen sourcing to storage, distribution and processing, as well as end-use applications. IFPEN is ranked second worldwide among public research organizations with the highest number of international patent applications, in the field of H₂ technologies. The patents focus on the production of carbon-free hydrogen by CCS, the pursuit of materials to replace the catalysts used in electrochemical reactions, the behaviour of materials during the transport and storage of hydrogen, and its application in carbon-free mobility (fuel cells, internal combustion engines, low-carbon fuels: e-fuels and especially e-biofuels). It is worth noting that the top three in this same ranking are French organizations: CEA, IFPEN and CNRS.



GREENWITS: A NEW COMPANY TO MATCH THE AMBITIONS OF THE WIND POWER INDUSTRY



May 2023 witnessed the launch of GreenWITS, an IFPEN subsidiary offering advanced digital services to wind turbine project developers and operators. The skills and expertise of the IFPEN Ressources Energétiques (RE) Carnot Institute teams behind the GreenWITS™ technologies stem from more than 12 years of research across the entire value chain, from wind resource assessment to wind turbine maintenance, within several research networks (such as France's Energy Research Alliance, ANCRE, or the International Energy Agency's IEA Wind TCP technology cooperation program) and with leading national, European or international research organizations. This collaborative network has been further consolidated by dynamic partnerships with major wind energy players such as SBM Offshore, Principia and Vaisala. GreenWITS can now step up to Europe's ambitious wind energy targets.



BIOTJET™ PLANT AT LACQ: BIOTFUEL® TAKES OFF

IFPEN, Axens, Elyse Energy, Avril and Bionext have unveiled plans to build a BioTJet™ plant in the Lacq Basin (64). This new plant is a cornerstone in the development of France's sustainable aviation fuel industry. It ties in perfectly with France's ambition to become a champion of "ultra-sober aircraft". This project will be the first industrial unit based on the BioTfuel® process, developed and demonstrated by IFPEN and its partners at the Venette and Dunkirk sites. BioTJet will build and operate a plant to produce sustainable aviation fuels from lignocellulosic biomass and low-carbon hydrogen. By 2028, it is expected to supply 75,000 metric tons of sustainable aviation fuels per year as a means of reducing the carbon footprint of air transport, and 35,000 metric tons of naphtha per year for road transport and the green chemicals industry. "BioTfuel® technology, which will be central to this sustainable aviation fuel production plant, is the culmination of 10 years of intense partnership research in which we have been, and still are, heavily invested. This achievement is perfectly in line with the IFPEN group's ambition to use its innovations to drive progress in reducing carbon emissions in industry and transport", explains Pierre-Franck Chevet, Chairman of IFPEN. Notable points: The BioTJet™ project is the winner of the call for projects for the "Development of a French production sector for sustainable aeronautical fuels", operated by the French Environment and Energy Management Agency (ADEME), as part of the 4th future investment program – France 2030 with €7.9 million in aid, including €3 million in refundable advances.



Between August and October, IFPEN geologist Yuri Hamon, embarked on an International Ocean Discovery Program (IODP), Expedition 389, dedicated to the topics of climate and environmental fluctuations through the study of coral reefs. Corals are witnesses to past climate change and can help us to more accurately predict the climate of tomorrow.



SENATORS EMBRACE IFPEN-LYON VISIT



* Gilbert-Luc Devinaz, Senator for the Rhône department and Chairman of the mission to promote the development of biofuels, sustainable synthetic fuels and green hydrogen sector; Vincent Capo-Canellas, Senator for the Seine-Saint-Denis department; Bernard Buis, Senator for the Drôme department; Béatrice Gosselin, Senator for the Manche department; Étienne Blanc, Senator for the Rhône department; Henri Cabanel, Senator for the Hérault department; Pierre Cuypers, Senator for the Seine-et-Marne department; and Lucien Stanzione, Senator for the Vaucluse department.

Following IFPEN's Senate hearing on "Research into sustainable synthetic fuels, hydrogen and biofuels", a group of senators* made a visit to the Solaize site in March to find out more about IFPEN's work, particularly on biofuels, as well as some of the hydrogen mobility activities. The topics of e-fuels and CO₂ capture were also addressed. The French politicians welcomed IFPEN's role in the ecological transition. They also delved deeper into the subject of available technological resources and their complementarity, the potential for action that can be taken today, and the targeted trajectories. Lastly, they underlined IFPEN's commitment to corporate social responsibility in the region.



THE CHALLENGES FOR MATERIALS IN THE ECOLOGICAL TRANSITION: IFPEN TAKES PART IN THE FRENCH OBSERVATORY OF MINERAL RESOURCES FOR INDUSTRIAL SECTORS (OFREMI)

In connection with the French Observatory of Mineral Resources for Industrial Sectors (OFREMI), launched at the end of 2022, IFPEN took part in a seminar on the challenges involved in materials for the ecological transition. Five topics were selected as the basis for future work: the potential for relocating a titanium production chain in France or Europe; the feasibility of balancing supply and demand for copper in France by combining primary and secondary supply; metals for the automotive sector (knowledge of value chains and industry players); the impact of lithium production on industrial supply chains; and the launch of an OFREMI information system. A team from the Economics & Technology Intelligence Division presented the roadmaps for projects on titanium, copper and metals for the automotive sector to OFREMI's stakeholders – industrialists, ministries and, in particular, the French interministerial delegate for the supply of strategic ores and metals. On the heels of these presentations, initial work is expected to focus on the subject of metals for the automotive sector, in line with France's national low-carbon strategy (SNBC) to achieve carbon neutrality by 2050.



KEY FIGURES

2 Carnot Institutes



AWARDED **ISO 9001**
 CERTIFICATION for their R&I activities

154



basic patent applications, including **125** in the field of new energy technologies

More than

500



IFP School students graduate

IFPEN'S R&I, INNOVATING TRANSITION TECHNOLOGIES

As a committed player in the threefold ecological, energy and digital transition, IFPEN is playing a role in implementing ecological policies in France and Europe, by helping to forge the industrial sectors that will lead to achieving international decarbonization targets. To achieve this, IFPEN is focusing on technologies that are technically proven and economically profitable, while at the same time developing breakthrough innovations for the long term.

More than 10 years ago, IFPEN initiated forward-looking studies in fields such as wind power, biomass conversion, CCUS and even the electrification of mobility, which are now leading to fully mature technologies poised to find an industrial outlet. IFPEN is pursuing this strategy of anticipation to prepare the technological solutions of tomorrow and thereby help provide answers to the accelerating pace of energy history.



IFPEN has developed a methodology that assesses the “weight” of technologies (products, processes, equipment, software, services, etc.) to identify which technologies it needs to focus on or reduce its efforts, and to take stock of emerging opportunities. This methodological approach is in effect since 2023. More than 30 technologies were analyzed, with twenty identified as being of major public interest, themselves subdivided into three categories according to the degree of maturity:

- **mature technologies** demonstrate IFPEN's scientific expertise and incorporate one or more products that can be marketed in identified markets;
- **promising technologies**, with proven technical prowess at IFPEN, must be consolidated;
- as for **prospective technologies**, their feasibility and potential outlets are still under analysis. Nevertheless, classifying a technology as “mature” does not mean that all the work carried out on this technology is actually mature. Some of the work carried out in relation to the technology may still be at the “promising” or even “prospective” stage, with longer-term research and innovation activities to prepare for future generations of these products or services. For example, CO₂ capture using Direct Air Capture (DAC), certain biotechnologies for biofuel production (new enzymes), recycling of battery materials, the water cycle (encouraging efficient use, optimizing resource management from the outset), management of microplastic flow in the environment, etc. are currently in the early stages of development.

IFPEN's R&I activities are aligned with its strategic priorities:

- **Climate, environment and circular economy:** reducing the impact of human and industrial activities on the climate and the environment.
- **Renewable energies:** producing energy, fuels and chemical intermediates from renewable sources.
- **Sustainable mobility:** developing efficient, environmentally-friendly solutions for the transport sector.
- **Responsible oil and gas:** reducing the environmental footprint of oil and gas-related activities.

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**CONSOLIDATING
MATURE TECHNOLOGIES**

Climate, environment and circular economy

CO₂: capture, storage & negative emissions

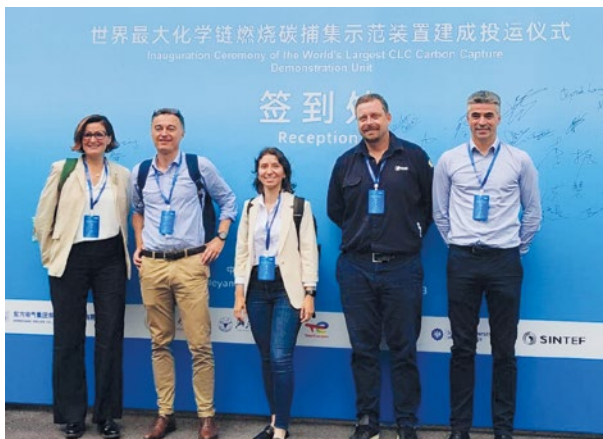
Faced with the challenges of decarbonization on a global scale, the IPCC (Intergovernmental Panel on Climate Change) and the IEA (International Energy Agency) have identified CO₂ capture, storage and utilization technologies as key levers in the fight against global warming. While these technologies are clearly integrated into sectoral and national roadmaps, such as the strategy published by France in June 2023, they are now the focus of tangible industrial projects. The work carried out by the IFPEN teams, aimed at speeding up the large-scale deployment of the sector, covers the entire CO₂ capture, transport and storage chain. They showcase a reliable and secure CCS (Carbon Capture and Storage) chain across the entire spectrum of technological components.

This is evidenced by the success of the initial tests carried out on the industrial pilot located at the ArcelorMittal site in Dunkirk, aimed at demonstrating how well the DMX™ process captures CO₂ from industrial activities. At the same time, IFPEN's teams are assessing the benefits of implementing CCS through life cycle analyses and by creating deployment scenarios at various scales.

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FOCUS

In December 2023, the IFPEN's 9th Energy innovation event was a source of lively discussions and lessons learned on CCS. France's strategy for deploying CO₂ capture and storage, an application example in the Dunkirk area, the need to reduce the carbon footprint of the cement industry, an update on current research, innovation and technologies: find out more or watch the replay of the event on the website www.ifpenergiesnouvelles.fr.

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HIGHLIGHT



CHEERS project: CLC plant up and running up in Deyang, China

In June 2023, the Sino-European CHEERS project, which associates nine industrial, academic and institutional partners, entered an important phase with the start-up of the largest CLC (Chemical Looping Combustion) demonstration plant in the world (with a capacity of 3 MWth) for the process developed by IFPEN and TotalEnergies, which will validate this CO₂ capture technology on energy production plants using solid fuels (fossil, biomass, waste) at a competitive cost and thus contribute towards reducing the carbon footprint of industry.

Plastics recycling

By leveraging the skills pooled through partnerships, IFPEN is developing tried, tested and economically viable technologies for the chemical recycling of plastics, which can be used in addition to mechanical recycling in order to be able to process almost all types of plastic and offer industry the solutions required to address society's increasing expectations in terms of reducing plastic waste in line with public circular economy policies. The year 2023 was marked by major advances for Rewind[®]Mix technology, which purifies plastic-based pyrolysis oils enabling them to be directly treated in existing petrochemical plants for recycled plastic production. Trials on high-quality pyrolysis oils and testing of new feedstocks, more difficult to process, have confirmed that the process is highly adaptable. Meanwhile, the commissioning of the chemical PET recycling demonstrator (see below) marked the culmination of 10 years of R&I efforts in this field.



HIGHLIGHT

The chemical PET recycling plant comes on line

On October 24, 2023, Japan's Rewind[®] PET demonstration plant for the chemical recycling of PET (polyethylene terephthalate, used to package 70% of all beverages) was inaugurated in Kitakyūshū. To mark the occasion, IFPEN, Axens and Jeplan officially announced the start of operations for the plant built on Jeplan's industrial site.

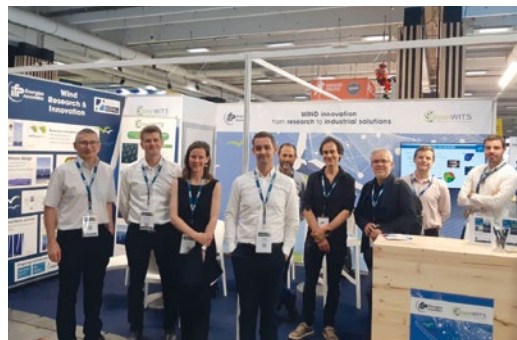


This new plant clearly demonstrates the benefits and efficiency of the Rewind[®] PET process for all players in the plastics circular economy, from waste management specialists to end-users, which are essentially brands in the packaging and textile sectors, as well as PET producers. A good example of this was the presence of representatives from Toray, in connection with the project to install the first Rewind[®] PET industrial plant at their PET production site in the Auvergne-Rhône-Alpes region by 2027.

Renewable energies

Wind & ocean energies

IFPEN's long-standing expertise in offshore equipment design and advanced control, combined with the innovative solutions now proposed by the IFPEN Ressources Énergétiques (RE) Carnot teams, have helped to further set the institute apart in 2023. The creation of its new subsidiary GreenWITS and the launch of the Provence Grand Large floating wind farm (with floats designed by SBM Offshore in partnership with the teams of the IFPEN RE Carnot Institute) represent major milestones for the sector. Other highlights include the start-up of consortia with industrial partners – the Wind Avatar JIP, which aims to develop and qualify a solution combining physical modeling and data science to monitor wind farm assets, and the Fame program, which is investigating the impact of floating wind turbines on electricity production.



HIGHLIGHT



Installation of the first floating wind farm in the Mediterranean

2023 marked a new milestone in offshore wind power, with the complete installation of the three floats of the Provence Grand Large wind farm, the first floating wind farm off the French Mediterranean coast. These floats, which were designed by SBM Offshore in partnership with the teams of the IFPEN RE Carnot Institute, use "tensioned line float" technology and represent a real technological innovation owing to their excellent stability and the potential for deployment in areas of great depth. Another example of how IFPEN's simulation expertise can be put to good use: the multiphysics calculations were carried out using Deeplines Wind™ software, jointly developed by IFPEN and Principia. This new project demonstrates IFPEN's support for practical applications that contribute to the energy transition and to French and European objectives in the field of wind power.

HIGHLIGHT

GreenWITS: responding to the sector's ambitions right now

In May 2023, GreenWITS (see also page 9) came into existence, a subsidiary offering advanced digital services to project developers and operators in four business areas: wind farm design, floating wind turbine and foundation engineering, digital wind turbine monitoring and wind farm control. GreenWITS is the culmination of a long technological maturation process and can step up to Europe's ambitious wind energy targets. N.B.: GreenWITS was awarded the 2023 Innovation Prize by Evolen (A French trade association serving energy industry companies and professionals) for its farm-scale wind turbine control solution. It was selected from a pool of 18 candidate companies.

FOCUS

IFPEN and GreenWITS were featured guests on L'Esprit Sorcier TV's "Science en questions", an episode devoted to the issues, challenges and ambitions of French wind power deployment. Can be found on YouTube!

Underground resources and usage for the energy transition

The challenges of the underground environment, strategic for tapping into resources (heat, hydrogen, hydrothermal fluids/metals, etc.) and for the large-scale storage of fluids, have been of great interest to the IFPEN RE Carnot Institute from a very early stage. Recent events have given pride of place to natural hydrogen, a resource that has been of interest to IFPEN researchers for over 15 years. Its teams are studying the emanations from various locations on the earth's surface, quantifying the resources available and working to gain a clearer understanding of the processes involved in transforming water into hydrogen deep underground.

HIGHLIGHT



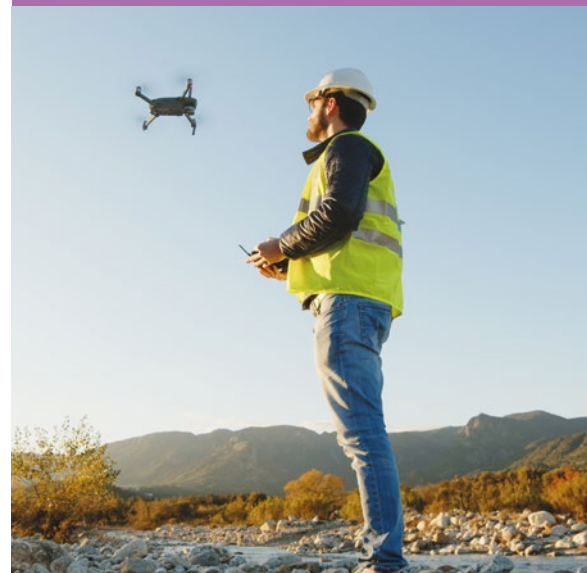
Glitter: assessing the geothermal and lithium co-production potential of the Upper Rhine Plain

Coordinated by BRGM – and involving, alongside Carnot IFPEN RE, Lithium de France, CGG, and the University of Paris-Sorbonne – the ANR Glitter project aims to assess lithium resources in the geothermal waters of the Rhine Graben. Initially, Glitter will focus on the tectonic evolution of the Rhine Graben and its impact on flow properties. Subsequently, this structural evolution and lithium source rocks will be integrated into basin modeling to evaluate the current distribution of lithium in geothermal waters. Finally, flow modeling in these fractured reservoirs will be used to measure the evolution of lithium concentration in the produced waters, enabling recommendations for well placement and data acquisition to reduce uncertainties and better understand the economic viability of production.

HIGHLIGHT

Natural hydrogen: the origins and behavior of geological hydrogen cast under the microscope

IFPEN's initial research, dating back to 2008, revealed that natural hydrogen is preferentially reconcentrated in several types of geological environments. Today, the IFPEN Ressources Energétiques Carnot teams aim to acquire a thorough understanding of the mechanisms by which hydrogen is formed at depth, as well as the mechanisms by which hydrogen degrades during its migration to the surface (geochemical transformations or consumption by micro-organisms). By combining these results, IFPEN's work aims to develop geological exploration tools that will enable industry to benefit from methods for quantifying potential natural hydrogen resources and reserves. This work is underpinned by a collaborative project with the ORHYON Chair focusing on micro-organisms and hydrogen reactivity in the underground environment, which started in 2022, in partnership with the Institute of analytical sciences and physical chemistry for the environment and materials (joint CNRS/UPPA research unit UMR 5254), the University of Pau and the Pays de l'Adour, Engie and its subsidiaries Storengy and BU-Brazil, to study the behavior of hydrogen in the subsoil. Knowledge to shed light on the potential of geological hydrogen to contribute to a more sustainable energy system.



Biofuel production

IFPEN is developing processes to produce sustainable fuels from renewable feedstocks such as lignocellulosic biomass or waste cooking oil. These fuels can be used individually, blended with other sustainable fuels or mixed with conventional oil-based fuels. These resources also allow refining facilities to evolve into energy hubs that process multiple resources. This shift offers two major advantages: it optimizes the investments needed to produce biobased fuels, and it reduces the carbon footprint of existing industrial facilities by introducing renewable carbon and even low-carbon hydrogen. Resource diversification is a major challenge addressed by IFPEN, with research into the transformation of waste and residues from biomass, oils and fats of various origins (waste cooking oils, animal fats, etc.), and waste and residues from plastics, paper or cardboard. The biofuels market is currently stimulated by regulations aimed at reducing CO₂ emissions from transport, such as the ReFuelEU Aviation initiative for the aeronautical sector.



IFPEN has developed three advanced biofuel production chains with technologies marketed by Axens:

- hydrotreatment of vegetable oils (waste cooking oils, residues from the production of food-grade vegetable oils, animal fats, etc.) with the Vegan® process. Licenses for the Vegan® process have already been granted worldwide, including one in France at the TotalEnergies La Mède site.
- BtL (Biomass-to-Liquid): biomass is transformed into a mixture of carbon monoxide and hydrogen by gasification, then converted into advanced biofuels using Fischer-Tropsch GASEL® technology. This process chain forms the basis of BioTfuel® technology, currently being deployed on the BioJet™ industrial project;
- ethanol with FuturoL® technology, which converts lignocellulosic materials into ethanol. This process involves using IFPEN's proprietary enzymes to extract sugars from raw materials, and then fermenting these sugars into ethanol through the action of yeast. IFPEN also developed the Jetanol™ suite of processes making it possible to convert advanced bioethanol from FuturoL® into biokerosene.

+ FOCUS

2023 witnessed major advances on the Vegan® project, with the delivery of two new hydrotreating and isomerization catalysts for the single-stage process, and the roll-out of the Vegan® two-stage process to maximize SAF® production.

+ FOCUS

In May 2023, IFPEN organized a round table on the challenges and prospects for sustainable aviation fuels. Technological solutions, environmental impact, regulatory framework... watch the replay on www.ifpenergiesnouvelles.fr

Bioproduct production

The main chemical intermediates are part of biorefinery complexes that incorporate breakthroughs in second-generation biofuel production processes developed by IFPEN. These complexes also incorporate processes to produce bio-based molecules. IFPEN's teams are focusing their efforts on investigating the production of bio-alcohols, bio-olefins, oxygenated platform molecules and bio-aromatics. They are also working on lower-volume molecules with high added value. Highlights of 2023 included the start-up of the BioButterfly pre-industrial experimental plant in Bassens, followed by the production of batches of butadiene for elastomer manufacture by Michelin, finalization of the basic specifications for the process to produce 5-HMF (5-HydroxyMethylFurfural) from sugar, and engineering studies for the first industrial plant.



Interview with **Laurent Lemonnier,** **CEO of ResiCare**

ResiCare, an entity of the Michelin Group, develops and markets innovative adhesive resins combining high performance, non-toxicity and renewable materials. Initially developed for the tire industry, our technology is now being rolled out across a range of industrial applications: wood, insulation, abrasives, composites, etc. After a decade or so of laboratory research into the transformation of sugar into a bio-based molecule, 5-HMF, IFPEN joined forces with ResiCare in 2021 to develop an industrial-scale 5-HMF production process. Pilot-scale trials yielded the production of 1.2 metric tons of 5-HMF. We successfully confirmed the feasibility of bio-based, non-toxic chemistry on an industrial scale, paving the way for oil-free chemistry. This is a key step in the scale-up of our new adhesive technology. We believe in this promising movement and invite other industry players to come and join us. ””



Energy storage and management

At a time when the roll-out of renewable energies is becoming ever more widespread, the IFPEN RE Carnot Institute continues to tackle the growing need for flexibility and stability in power grids and heating networks with massive electricity storage technologies and digital energy management solutions (EMS). In 2023, the IFPEN RE Carnot Institute approached several partners, including the solar panel installer Soalis and the aggregator and solar energy specialist Urban Solar Energy, to work on deploying IFPEN's EMS battery management solution for a variety of uses and services. It has stepped up its collaboration with industrial start-up STOLECT, which is implementing its Carnot battery technology.



Sustainable mobility

Electric powertrains

The work carried out by the IFPEN Transports Energie Carnot Institute (TE) aims to improve the performance of electric propulsion systems, and in particular their energy efficiency and environmental impact. Numerical models are used to capitalize on knowledge and to identify new solutions for motors, control electronics and monitoring, using multi-criteria optimization tools. This research is fueled by numerous industrial partnerships, particularly in the field of power electronics. A partnership with the SME EREM for the GCK group has validated the performance of new active parts (stators and rotors) designed by the IFPEN TE Carnot Institute. This work has been done for two motor designs: the first at low voltage and high power density for light mobility; the second at high voltage and continuous power in excess of 300 kW for off-road applications. Other projects were launched in 2023, with partners including the GCK group and its subsidiary Solution F, and the SME Mov'Ntec



Interview with **Jean-François Le Romancer,** CEO of STOLECT



The start-up STOLECT turned to IFPEN to speed up and improve the reliability of the development of our large-scale electricity storage solution: a “Carnot battery” producing hot air, which can be stored in a refractory material and then released to drive an electric turbine. Positioned on various energy storage and management technologies, a fundamental pillar to support the deployment of renewable energies, IFPEN teams have the robust skills and experimental resources we needed to meet the demand for electricity through an environmentally-friendly process. The synergies already established between our industrial offering and IFPEN’s R&I, backed by a mutual desire to work towards achieving a low-carbon energy mix, have a bright future ahead of them, with a strategic partnership on the cards in 2024.”



FOCUS

The IFPEN TE Carnot Institute has joined the European ARCHIMEDES project, which was launched in June 2023 as part of a European public-private partnership, aimed at increasing the efficiency and lifespan of power electronic components and energy storage devices in the automotive, aviation and industrial sectors. The IFPEN TE Carnot Institute will contribute to reliability studies on Wide Bandgap semiconductor materials used in bi-directional chargers (V2H) and traction inverters for applications requiring high levels of power, frequency or temperature.

HIGHLIGHT



Conclusion of the Melchior project: a prototype recyclable electric motor

The Melchior* project, conducted jointly by the IFPEN TE Carnot Institute and CEA-Liten through its Énergies du Futur Carnot Institute from 2022 to 2023, has yielded an innovative electrical machine with recyclable magnets. With supply shortages expected over the next few years for the materials used in motors (magnets, iron, copper and aluminium), Melchior has focused on architectures that minimize the use of critical materials and facilitate component disassembly and recycling without impacting performance. The IFPEN TE Carnot Institute designed the motor and assessed its environmental impact, while CEA-Liten implemented an innovative recyclable magnet technology. This activity is continuing, notably thanks to the Magellan project, led by Orano and launched in early 2024, which seeks to use innovative permanent magnet manufacturing technologies (powder injection molding) and improvements in the design of electrical machines to make the separation of materials from end-of-life motors simpler and cleaner, thus optimizing the recovery of magnets.

* Electric machines in a recycling-oriented value chain.



Interview with Vincent Lallemand, Director of Solution F (GCK group)

What drives us today with the IFPEN TE Carnot Institute is the development of new generations of very specific high-power, compact electric powertrains to equip different vehicle categories, including racing models, passenger cars, trucks and off-road vehicles. As early as 2022, we adopted the active parts – designed by the IFPEN TE Carnot Institute – using magnet-assisted synchronous reluctant motor technology, as part of the electric retrofit of the Lancia Delta HF Integrale classic car. In 2023, this technology was extended to ultra-high-voltage (800 V) powertrains for snow groomers, and low-voltage (48 V) drivetrains for leisure vehicles and retrofit hybridization of compact city cars. In particular, the low-voltage solution comes with an operating license for an inverter developed by the IFPEN TE Carnot Institute, which optimizes control of the motor. This global solution sets us apart and is strategic for our Group. It gives us a head start in electric traction technologies designed either for retrofitting combustion-powered vehicles, or for small-scale production of high-performance, premium electric cars.

+
**DEVELOPING PROMISING
TECHNOLOGIES**



Climate, environment and circular economy

Climate/soil interactions and the water cycle

The IFPEN RE Carnot Institute is developing technologies to monitor carbon stocks in soils and agroecosystems, in line with the French national climate change adaptation plan (PNACC), which aims to strengthen the resilience of ecosystems (soils, forests, sea and coast, biodiversity and water resources) to enable them to adapt to climate change and extreme events. Carbon is a major component of biogeochemical cycles, and monitoring carbon stocks in soils and agroecosystems is one of the solutions to the ecological challenges we face. IFPEN is collaborating with national partners (INRAE, IRD, BRGM), notably through various publicly-supported projects, as well as with industrial players to validate its carbon analysis technologies and contribute to providing solutions for the ecological transition. In 2023, the IFPEN RE Carnot Institute worked alongside BRGM to launch the Gesipol project (research for the integrated management of polluted sites),

subsidized by the French Environment and Energy Management Agency, ADEME, which aims to remediate soils, and on a stimulus plan project with Valorhiz to study the potential of low-carbon soils. IFPEN has also developed environmental monitoring tools to track polluting molecules (Flair Suite) and tested them under industrial conditions. Lastly, the IFPEN RE Carnot Institute is developing tools and solutions for water resource management. As part of the OneWater exploratory priority research program (PEPR), a new project has been accepted: IFPEN's teams, in collaboration with BRGM and Hydrosience Montpellier, are focusing on karst aquifers in the south of France, while the KARST project on the cataloguing and modelling of karst aquifers in general was also started in 2023.



**Interview with
Benoit Noetinger,
KARST Project Director**

Launched in May 2023, the six-year KARST project is funded by an ERC (European Research Council) Synergy grant awarded by an international jury. A significant recognition for IFPEN and its partners, in line with the challenges posed by karst aquifers in the face of climate change. KARST aims to establish a “catalog” of cave systems to gain a better understanding of how they are formed, their structure and the behavior of the fluids (water, air, even pollutants) that flow through them, particularly under the influence of extreme climatic events. KARST is further proof of how the IFPEN Ressources Energétiques Carnot Institute is able to forge strategic links with international partners (IDAEA-CSIC Spain, Universities of Ljubljana and Neuchâtel). I am delighted to be part of a quartet of experienced researchers jointly managing this project, and to be able to combine my skills with theirs, and with those of the IFPEN teams involved, thus creating a tenfold research force at the service of the ecological transition.”

HIGHLIGHT

The Flair Box™ takes off in a new direction

The year 2023 marked the consolidation of Flair technology’s positioning in the industrial and environmental gas monitoring segment, with the deployment at Teréga’s gas storage site in southwest France of eight Flair Box™ stations (seven fixed stations and one mobile station). These self-contained stations, installed on site or mounted in the Flair Car™ for mobile measurements, use their sensor to analyze a wide range of molecules at very low levels by UV spectrometry. In partnership with Tidav, a start-up that has developed a drone capable of withstanding strong gusts of wind, and ONERA, the French aerospace research centre, IFPEN is developing an airborne multi-gas monitoring solution under the name of the Falkor project. The sponsors of this partnership are Teréga, GRTgaz and TotalEnergies.



Eco-design and recycling of catalysts

In 2023, activities focusing on the recycling of metals and catalyst materials were extended to include analysis of the environmental footprint of catalyst production. This covers emissions characterization, particularly nitrogen oxide (NOx) emissions, water management and conservation, as well as energy efficiency. A project is currently underway to reduce the environmental footprint of the processes that are the biggest emitters and consumers of water. Catalyst recycling and material reintegration projects are ongoing, with a broader focus on used catalysts.

Renewable energies

Electro-fuels (e-fuels) production

IFPEN is developing the e-fuels pathway using carbon dioxide captured on industrial sites or in the air and low-carbon electricity to produce hydrogen through water electrolysis. The combination of these gases by means of the Reverse Water Gas Shift (RWGS) process produces a synthesis gas that is then transformed into e-fuels through Fischer-Tropsch synthesis. These fuels can be used alone or blended with gasoline, kerosene and diesel in existing engines. In June 2023, EDF, IFPEN and Axens signed an agreement to participate in the creation of the French e-fuel air transport industry, through the Take Kair™ project, supported by Air France-KLM. IFPEN is also a member of the French e-fuels office created in July 2023. It rallies experts, professors, researchers, academics, industrialists, technicians and financiers around the role of e-fuels in the energy transition and the development of a French sector.



Interview with
Cédric Lewandowski,
Group Executive Director
in charge of EDF's nuclear
and thermal power plants

With the Take Kair™ project, EDF, the world's leading producer of decarbonized electricity, largely through its nuclear power portfolio, confirms the commitment it has made, particularly through its hydrogen plan, to accelerate the deep decarbonization of the sectors that emit the most CO₂. While helping to decarbonize industry, it also offers a complement to bio-energies to decarbonize the air transport sector. Our skills and expertise, combined with those of our industrial partners, are being put to good use to help build a thriving, innovative French e-fuel industry. With Take Kair™, we are collectively taking another essential step towards achieving carbon neutrality.

Read the full press release at www.ifpenergiesnouvelles.fr

HIGHLIGHT

e-fuels: IFPEN, Axens and Paul Wurth join forces to co-develop RWGS technology

RWGS technology is an essential component of the CO₂ conversion technology package for renewable fuels and low-carbon chemical intermediates. To optimize Reverse Water Gas Shift (RWGS) technology and its integration into sustainable aviation fuel projects, IFPEN, Axens and Paul Wurth-SMS Group signed a joint development agreement in 2023. "Our research has prompted us to propose an integrated solution, combining proven technologies, such as Axens' DMX™ CO₂ capture and Fischer-Tropsch Gasel® fuel synthesis, with cutting-edge RWGS technology. This solution also benefits from joint development with Paul Wurth's equipment to take the entire process to industrial scale," emphasizes António Pires da Cruz, Program Manager for Decarbonization and Digitization of Processes at IFPEN.



Sustainable mobility

Strategic metals

Most batteries used in electric vehicles are based on cathode active materials (CAM), consisting of nickel, manganese and cobalt (NMC chemistry). These component active materials currently account for half of the cost of NMC-type automotive batteries. Consequently, the recycling of car batteries is a top priority issue at both an economic and environmental level. IFPEN is actively developing processes for battery metal recycling and the synthesis of CAMs. Its knowledge and expertise in processes for conversion of materials and solvents for purification/separation stages are major assets when it comes to offering solutions that are technologically innovative, cost-effective and environmentally-friendly. 2023 marked the first step in the roadmap drawn up with Axens and Eurecat, with the objective of deploying industrial plants in France to recycle CAM metals from lithium-ion batteries and synthesize CAM from recycled metals. Experimental and pilot tools were set up. This ambitious project aims to consolidate French sovereignty in the critical metals and CAM manufacturing sectors.

Hydrogen and low-carbon mobility



Hydrogen-powered internal combustion engines are ideally suited to mass transit and heavy goods vehicles, mainly because of their long range and manageable cost, offering a solution with zero CO₂ emissions. The IFPEN TE Carnot Institute is seeking to maximize energy efficiency and minimize nitrogen oxide emissions (NOx) by optimizing the combustion system. Advanced combustion systems using low-carbon liquid or gaseous fuels (natural gas, biogas, hythane) are also the focus of work to reduce CO₂ emissions. Finally, as part of the European PHOENICE project, coordinated by the IFPEN TE Carnot Institute, and which ended in 2023, conclusive tests were carried out on a combustion engine equipped with a Swumble™ cylinder head and dedicated to a highly efficient plug-in hybrid vehicle with very low pollutant emissions. 3D numerical simulations of turbulent reactive multiphase flows for combustion system optimization are conducted using Converge™ software, which has been developed since 2014 in partnership with Convergent Science Inc. (CSI) and renewed over the period 2023-2027.

HIGHLIGHT

PLH2 project: a cost-effective decarbonization solution for heavy goods vehicles

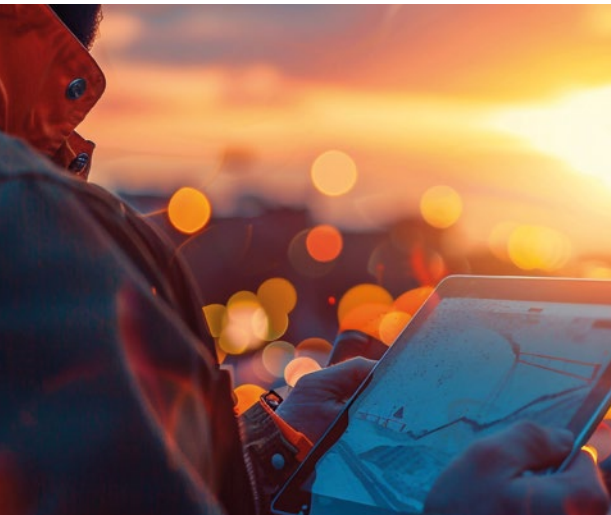
In 2023, after two years of work, the PLH2 project, spurred on by the CORAM call for projects and coordinated by Volvo Group-Renault Trucks with the IFPEN TE Carnot Institute as a partner, demonstrated the feasibility of equipping heavy goods vehicles with hydrogen-powered combustion engines at a cost comparable to that of their diesel counterparts. The IFPEN TE Carnot Institute was responsible for calibrating the MDE 8-type 6-cylinder engine. The 3D combustion calculations were validated by experimental results, namely cylinder pressure, combustion speed and wall heat transfer. In parallel, the influence on combustion of control parameters (injection phasing, equivalent ratio, etc.) or geometrical parameters (hydrogen injector, spark plug, etc.) was clarified. This high-performance engine is currently undergoing final in-vehicle evaluation by the Volvo Group-Renault Trucks teams.



HIGHLIGHT

INOCEL enlists the support of the IFPEN TE Carnot Institute for its fuel cell test campaign

The IFPEN TE Carnot Institute has entered into a strategic partnership with INOCEL, a specialist in the development of high-power fuel cells, to conduct a trial campaign to test and validate its INOCEL Z300 fuel cell system. The high-power installations of the IFPEN TE Carnot Institute were used by INOCEL to conduct an extensive assessment of the system as a whole and optimize the performance of its technology. "This is a significant step forward for INOCEL, marking the first time the system has been taken out of the design office environment. We are determined to meet all the challenges that will enable us to maximize the performance and reliability of our fuel cell," explained Marie-Laure Michaux, INOCEL's Technical Director.

**Digitalization in the mobility sector**

To keep pace with changing environmental regulations in the field of transport and mobility, the IFPEN Transports Energie Carnot Institute (TE) is conducting impact studies and life cycle analyses, and developing decision-making tools. In 2023, a life cycle analysis study was carried out for the French General Directorate for Energy and Climate (DGEC) on bioethanol-fueled engines for motorcycles. Additionally, the interactive environmental footprint comparator for plug-in hybrid vehicles (PHEV), developed from 2021 to 2022 for Concawe, was extended to heavy-duty vehicles in 2023. These studies and tools were compiled in 2023 in a FAQ dedicated to the decarbonization of mobility, designed to be user-friendly and easy to access.

HIGHLIGHT

**R-TAMS: a precise, reliable tool to guide decision-making on air quality and pollutant emissions**

The R-TAMS* tool was developed in 2023 by the IFPEN TE Carnot Institute to provide guidance to regions on air quality and pollutant emissions. R-TAMS can be deployed in any territory, offering a solution tailored to local circumstances. R-TAMS provides accurate, real-time data on road traffic pollutant emissions, from both exhaust (NO_x, CO₂, PM) and non-exhaust (brake and tire abrasion) sources. R-TAMS also measures road traffic noise levels in real time, providing a global view of the impact of mobility on the environment.

* Real-Time Air Quality Monitoring System.

FOCUS

ELEMENTS* is a gaseous pollutant sensor that employs UV spectrometry. This innovation from the IFPEN TE Carnot Institute has been successfully integrated into the REAL-e analyzer, which measures automotive pollutants, and the Flair Box™, an environmental monitoring tool.

* The Embeddable Emissions MEasurement System.

+
**LEVERAGING ON HISTORICAL
ACTIVITIES TO STRENGTHEN FINANCING
FOR NEW ENERGY TECHNOLOGIES**



Research into responsible hydrocarbons, a legacy of IFPEN's historical activities, is now very much reduced to a minority and entirely self-financed. In line with the expected 50% reduction in the use of fossil fuels by 2035 compared with the 2020 level, based on the IEA's Net Zero Emissions by 2050 scenario, they are declining steadily. Profitable activities, including, for example, ecologically efficient processes for producing fuel and chemical intermediates according to the most demanding standards, act as an internal carbon tax mechanism, thus helping finance research into low-carbon technologies.

Responsible oil and gas

Fuels: supporting an industry in the process of transition

IFPEN is assisting the transformation and decarbonization of the refining industry. The research aims to develop innovative, eco-efficient fuel production processes that comply with increasingly stringent standards in terms of air quality, CO₂ emissions, water use, etc. IFPEN is developing processes and catalysts to produce fuels for road, air and sea transport with a smaller environmental footprint, in particular through energy efficiency. Innovative catalytic solutions are therefore being used to increase selectivity and yields in the fields of hydrotreating and hydrocracking of heavy cuts, as well as in the field of final conversion. Significant advances in gasoline production and purification are also helping to optimize hydrogen consumption/production cycles.

FUNDAMENTAL RESEARCH AS THE BREEDING GROUND FOR FUTURE INNOVATIONS

IFPEN's expertise and ability to innovate are rooted in a fundamental research program organized around 9 scientific challenges, and which benefits from intense collaboration with other institutions. Based on this structure, the program paves the way for the future by providing the knowledge, methods and tools needed to develop new products, processes and services.

Organized around 9 scientific challenges

Since 2016, IFPEN's fundamental research has been conducted around a set of nine research challenges encompassing the full range of scientific issues facing researchers, from understanding physico-chemical systems to assessing the environmental and economic impact of new technologies. These challenges can be broken down into fundamental scientific questions related to the characterization, modeling, simulation, evaluation of complex systems, to identify the research areas that are most likely to meet the needs of applied research. Finally, these challenges lead on to projects, with doctoral and post-doctoral work making a major contribution, as part of a general approach to openness, collaboration and knowledge sharing.



VIBRANT, DYNAMIC FUNDAMENTAL RESEARCH

The environment currently accounts for a significant proportion of IFPEN's research activities within the framework of the "climate, environment and circular economy" strategic priority. This covers a number of fast-growing topics such as plastics recycling, climate/soil interactions and the water cycle.





Guided by the National Acceleration Strategies of the France 2030 program

IFPEN's research is largely based on the National Acceleration Strategies (SNA) of the France 2030 program, which are broken down into Priority Research and Equipment Programs (PEPR). IFPEN is leading, jointly with other major research organizations three of them: the SPLEEN PEPR with the CNRS, the B-BEST PEPR with INRAE and the MOBIDEC PEPR with Gustave Eiffel University (see page 8). IFPEN is taking part in four other PEPRs focusing on recycling, batteries, hydrogen and advanced energy systems technologies. Exploratory PEPRs also provide backing for IFPEN research, such as Sous-Sol, bien commun (The subsurface as a common good, which is jointly led by the CNRS and BRGM), Maths-VivES (mathematics for life, the environment and society – led by the CNRS), FairCarboN (carbon and continental ecosystems – jointly led by CNRS and INRAE), OneWater (water as a common good – jointly led by BRGM, CNRS and INRAE), NumPEX (high-performance numeric for the EXascale – jointly led by CEA, CNRS and INRIA) and DIADEM (integrated devices to accelerate the deployment of emerging materials – jointly led by CEA and CNRS). Within these two types of PEPR (national acceleration strategies and exploratory), IFPEN is involved in 36 projects: 26 are of the first type and 10 of the second.

Backed by research partnerships

IFPEN's research benefits from extensive collaborations with research institutes and universities in France and abroad. IFPEN's spirit of openness is reflected by the collaboration contracts it has established with renowned research centres such as the CEA, ANDRA, INRIA, INRAE and CNRS. A partnership with the French national aerospace research center ONERA was signed in 2023 to respond to the challenges of several fields: new fuels, including electro-fuels, hydrogen combustion and the risks of alteration or corrosion of materials, identification and monitoring of carbon storage using data from drones or satellites, life cycle analysis in aeronautics, hybrid propulsion and on-board energy management, wind power, high-performance computing and data. Furthermore, IFPEN and ONERA have joined the French part of the Franco-Dutch Jules Verne consortium, which was awarded a contract for its Exascale-class supercomputer project in 2023 by EuroHPC, the High-Performance Computing Joint Undertaking that coordinates research and industrial resources in Europe. The consortium's French members also include the French High-Performance Computing agency – Grand Équipement national de calcul intensif (GENCI) and the CEA, which will host the Jules Verne supercomputer at the Très Grand Centre de calcul (TGCC) in late 2025.

+ **PROMOTING YOUNG RESEARCHERS AND PHD STUDENTS**

"PhD students are the lifeblood of research at IFPEN" declared Luc Vervisch, Chairman of IFPEN's Scientific Board, as he awarded the 2023 Yves-Chauvin thesis prize to Alexandre Delarouzée for his work in biotechnology. This conviction explains why IFPEN welcomes young researchers of many nationalities, by financing or jointly financing PhD theses, or by offering visiting PhD students the opportunity to spend time in its laboratories. The year 2023 witnessed a significant increase in the number of theses funded. From 45 launched in 2022, their number increased to 50 in 2023. This upward trend will continue in the years to come, because, as Andreas Ehinger, Director of Doctoral Studies, points out: *"Training in and through research is a major pillar of IFPEN's scientific policy. It is taking on even greater importance today with the emergence of new research topics."*

HIGHLIGHT

IFPEN-ANRT Cifre 2023 thesis prize: biology in the spotlight

In October 2023, the second IFPEN-ANRT (French National Association of Research and Technology) thesis prize was awarded to two candidates ex aequo, Julie Figueras for her work on the biomethanation of syngas and Raphaël Billot for his research on enzymes that block the activity of pathogenic bacteria. These two theses were carried out under Cifre agreements, the first between INSA Lyon's DEEP laboratory and the small business ENOSIS, the second between the MEPHI laboratory and the start-up Gene&GreenTK. IFPEN and ANRT have joined forces to create this award dedicated to "Science-industry collaboration for ecological transition". Each year, it rewards a young doctor whose thesis, conducted within the framework of a Cifre agreement signed with an SME, has helped to reduce the environmental footprint of human activities, and to perpetuate the quality of interaction between the SME and the academic world.

HIGHLIGHT

MoSHy: a scientific consortium explores a cost-effective route to hydrogen production

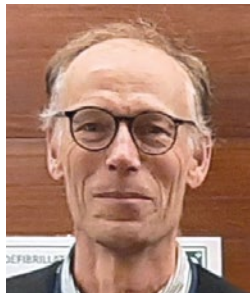
The MoSHy consortium, funded by the Auvergne-Rhône-Alpes region, has spent the last five years developing an economical, high-performance electrocatalyst by replacing platinum with molybdenum disulfide (MoS₂). The project, which involves IFPEN, the chemistry laboratory at ENS Lyon and LEPMI in Grenoble, has focused on improving MoS₂ by increasing its active sites using a substitutional doping technique. In 2023, using molecular modeling, the consortium assessed 17 elements for the partial replacement of molybdenum and 5 elements for sulfur.

Although most dopants are promising, calculations have shown that many are unstable. However, theoretical results have identified effective doping, notably with Group IV elements (Ti, Zr, Hf) or by replacing sulfur with phosphorus (P). These results have been confirmed experimentally, and patent applications have been filed for the most effective forms of doping.

Work is still underway at IFPEN to perfect the formulation of MoS₂ active phases.

+ FOCUS

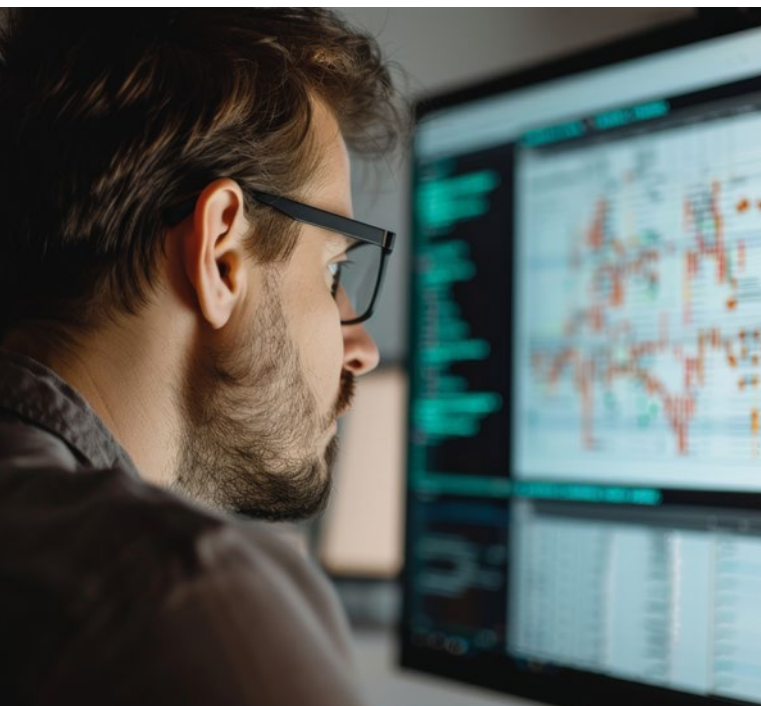
The AI and electron microscopy workshop, jointly organized in May by IFPEN, Paris-Cité, CNRS, ONERA and the University of Strasbourg, attracted 160 specialists who got the chance to discover the latest advances in the field, and in particular IFPEN's work, conducted within the framework of partnerships, on various issues: nanoparticle classification, noise reduction in high-resolution images, tomographic volume segmentation with very little annotated data, and atomic quantification.



**Interview with
Marc Fleury,
IFPEN research engineer
and co-organizer of the
porous media study days,
JEMP 2023**

IFPEN has always devoted substantial efforts to research on porous media, which play a crucial role in a variety of fields, from chemistry to Earth sciences. They are currently attracting renewed interest because of their importance for renewable energy and the ecological transition. The JEMP 2023 event, hosted by IFPEN, focused on these new issues and the promising advances being made to address them. These new topics include geothermal production, underground gas and energy storage, new soil pollutants and mining production. In the geothermal field, knowledge of rock transfer properties is crucial, with injectivity problems linked to nanometric size particles. For the storage of gases (CO₂, H₂) or nuclear waste packages, IFPEN is characterizing the barrier properties of cap rocks or different types of cement and concrete. Studies are also focusing on soil quality, where the spread of pollutants varies according to agricultural practices. Research work is also being carried out with ORANO on the behavior of rocks under the action of acids, with the aim of developing innovative uranium extraction processes. Nuclear magnetic resonance is one of the preferred tools for analyzing these porous media, particularly for logging during drilling operations. This technique, which has been constantly evolving since the 2000s, is used both in the laboratory and in the field, offering significant advantages in all these application areas.





+ **A CROSS-SECTIONAL BASIS FOR SIMULATION AND OPTIMIZATION**

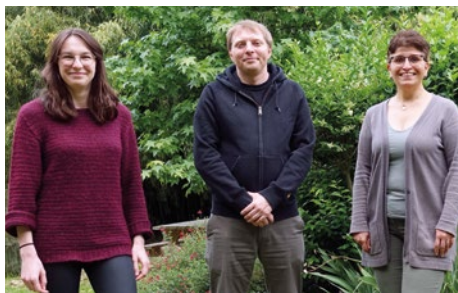
IFPEN scientific research deploys numerical simulations of physical phenomena and increasingly uses optimization and artificial intelligence techniques.

This work is facilitated by the pooling of computing resources and software platforms, some of which have been developed within the framework of partnership with other research players, such as the Arcane and Lagun open source platforms, jointly developed with CEA and Safran Tech respectively.

Collaboration with the University of Erlangen has stepped up the pace of wind field simulation calculations, with wake effects taken into account (see interview below). The approach adopted for this issue also applies to the simulation of pollutant dispersion in the atmosphere.



**Interview with
Ani Anciaux-Sedrakian,
Helen Schottenhamml
and Frédéric Blondel,
IFPEN**



Left to right: Ani Anciaux-Sedrakian, Frédéric Blondel and Helen Schottenhamml.

We are proud to see that the CLEAN “Grand Challenge” project was selected by GENCI in 2023. With the aim of optimizing wind energy production, it has made it possible to couple the simulation of kilometer-scale atmospheric flows with the physics of metric-scale wind turbine wakes. The waLBerla-wind solver, developed in collaboration with the German University of Erlangen (FAU), is based on the Lattice Boltzmann method and incorporates the necessary wind turbine modeling modules. The case study included 10 wind farms with 670 turbines. Their interaction over a period of 15 hours and 30 minutes was simulated with waLBerla-wind on the Adastra supercomputer by meshing the domain with more than two billion cells, and the calculation took less than nine hours. This performance opens up promising prospects, such as the creation of large databases for analytical or data-driven models, and the implementation of digital twins to monitor wind farms in real time.*

* The mission of the Grand Equipement National de Calcul Intensif is to promote the use of supercomputing combined with artificial intelligence and quantum technologies for the benefit of academic and industrial communities within the framework of open research, both nationally and across Europe.



AWARD WINNERS IN 2023...

The year 2023 was a particularly good one for catalysis researchers, but also saw some outstanding work in economics, fluid mechanics and electric mobility.



Hélène Olivier-Bourbigou was elected to the French Academy of Sciences in December 2023. Her work on the valorization of olefins by homogeneous catalysis and on the development of

sustainable and eco-responsible processes has led to a host of industrial applications.



Céline Pagis, research engineer at IFPEN, was appointed by the French Chemical Society (Société chimique de France – SCF), in January 2023 as a Junior Distinguished Member 2022.

After original work on the synthesis of hollow Y zeolite crystals and the study of the impact of these crystals on transport and catalytic activity for model reactions, she continued her research into heterogeneous catalysis and in particular, the photoreduction of CO₂.



Antoine Fécant, research engineer at IFPEN, was awarded in 2023, along with Claire Villeveille (CNRS – LEPMI, Grenoble), the “advanced researcher” prize by SCF for his research work in

catalysis, which covers existing chemical and refining processes as well as new materials and processes that exploit biomass and solar energy.



Céline Chizallet, research engineer at IFPEN, received the 2023 young researcher prize from the French zeolite group (GFZ) for her work in heterogeneous catalysis, molecular modeling and quantum chemistry (ab initio calculations).



Teddy Roy, IFPEN PhD student (2018-2021), received the DivCat-SCF thesis prize, for his work on the role of the support in the physicochemical impregnation processes of additive hydrotreatment catalysts.



Kim Larmier, a research engineer at IFPEN, received the 2023 Young Research Prize from the city and metropolis of Lyon, in the “coup de coeur” category, for his work in catalysis and his commitment to serving territories and the necessary transition towards a carbon-efficient society.



Emma Jagu Schippers, PhD student at IFP School from 2019 to 2022, received in March 2023 the first prize in the “Society Impact” category of the CentraleSupélec IMPACT 2022 Foundation thesis prizes, for her work on economic models for CO₂ capture, carried out as part of the Carbon Management (CarMa) chair on negative emission technologies.



Martin Gainville, research engineer in fluid mechanics at IFPEN, received the Cape-Open 2023 prize during the annual conference of the professional association CO-LaN (Cape-Open Laboratories Network), for his important contributions to the Cape-Open standard and its implementation.

Several young researchers have made their mark at conferences. **Candice Cottrez**, an IFPEN doctoral student since 2020, received the second prize for best oral communication at the 13th international symposium on the “Scientific bases for the preparation of heterogeneous catalysts” for her work on hydrotreating catalysts. Similarly, **Jérémy Creux**, doctoral student in electrical engineering at IFPEN, received the award for best conference paper at the 49th international congress of the IEEE Industrial Electronics Society (IECON 2023), for his work on defects in electric traction machines. In addition, **Mathilde Auxois**, IFPEN doctoral student in chemistry since 2021, received the prize for best communication at the annual scientific day of the process engineering development committee in Auvergne-Rhône-Alpes, for her presentation on aluminic catalytic supports obtained by kneading of boehmite pastes. Meanwhile, **Marine Dupoiron**, IFPEN research engineer, received in June 2023 the prize for the best poster at the Seanergy conference dedicated to offshore renewable energies, for her work on the production and wear of floating wind farms according to the position of the floats. Finally, **Sébastien Montalvo**, IFPEN doctoral student (2019-2023), received in May 2023 the prize for the best poster at the 39th spring days of the French Society for Metallurgy and Materials (SF2M), for his work on fretting fatigue of steel cable wires anchoring floating wind turbines.

ENCOURAGING AND SUPPORTING INNOVATION

Energy and environmental issues are increasingly important for economic players. With a culture of industrial value creation firmly rooted in its DNA, IFPEN is fully aligned with the demands of a changing market.



INDUSTRIALIZING AS OF NOW THE INNOVATIONS REQUIRED BY THE ENERGY TRANSITION

Through its IFP Investissements structure, IFPEN shoulders the capital risk required to bring to market the innovative technologies it develops alone or in partnership. Alongside other industrial and financial partners, it helped set up two project companies to build and operate the first industrial 2nd-generation biofuel production plants in France, using sustainable biomass and BioTfuel[®] and Futurol[®] technologies: BioTJet, a company operated by Elyse

Energy, aims to build France's largest industrial plant to produce advanced biokerosene; Nacre, a company operated by Axens, aims to supply 2nd generation ethanol. In 2023, IFPEN also created GreenWITS. This new company showcases the innovations of IFPEN research in the field of digital tools for wind power.

Subsidiaries undergoing diversification

In 2023, IFPEN's historical subsidiaries continued to diversify their activities with the development of solutions in line with the energy and ecological transition. Axens is continuing its efforts to bring technologies to market in the advanced biofuels sector, particularly for air transport, by participating in the creation of BioTJet and by participating in the creation and operation of Nacre. Axens is also active in the field of e-fuels with the Take Kair[™] project conducted in partnership with EDF, Holcim and IFPEN and backed by Air France-KLM. The subsidiary has also taken a firm position in the plastics recycling market, alongside IFPEN and JEPLAN, with the construction and commissioning of an industrial demonstration plant for the innovative Rewind[®] PET chemical recycling process at Kitakyūshū in Japan. Meanwhile, IFP Training has continued to expand its offering in new fields. This work has resulted in the development of several new offerings, including a long-cycle battery training course launched in October 2023. Beicip-Franlab has applied its geoscience expertise to the field of underground CO₂ storage and deep geothermal energy.



**Interview with
Pauline Bozonnet,
Farm Design Technical
Lead at GreenWITS**

I have held a number of positions at IFPEN, including wind power project manager. I am happy to play both an active part in and a witness to the story that, from laboratory research to the actual needs of the industrial world, led to the creation of GreenWITS in May 2023. The subsidiary, which is the culmination of 15 years of R&I and of solutions devised and developed with my teammates at the IFPEN Ressources Energétiques Carnot Institute, is not only a way of leveraging our expertise, it is also an opportunity for the whole team to discover another type of structure, a small company of around ten people. A highly motivating process, which brings with it the feeling of being part of a new adventure! This experience will be very rewarding for us, our partners and our future customers, and it paves the way for solutions that are even more in tune with demand and the new challenges of the energy transition.



SUPPORTING INNOVATIVE YOUNG COMPANIES

IFPEN has been actively supporting SMEs and start-ups spearheading innovation projects for more than thirty-five years, in line with the threefold transition towards ecology, energy and digital technology. To identify collaborative opportunities, IFPEN can draw on an extensive network of partners – business accelerators, competitiveness clusters and innovation support networks. IFPEN's team of Open Innovation managers is active throughout France, offering SMEs with specific innovation projects – within the framework of Boost&Link or Proof of Concept (POC) partnerships – access to the scientific, marketing and intellectual property skills of IFPEN experts, as well as access to technical resources.

This is a highly appreciated boost for the companies we support, as it enables them to move forward or finalize the development of an offering, or improve their production facilities.

IFPEN's policy of supporting innovation is also reflected in its spin-off policy, which aims to support researchers who wish to embark on an entrepreneurial adventure. IFPEN allows them to work on their project and can even contribute to the company's capital.

Lastly, supporting SMEs and start-ups takes the form of financial participation in investment funds specializing in eco-industries, eco-energies, or even sustainable mobility and cities, which invest in young companies.



MULTI-FACETED PARTNERSHIPS TO ADDRESS THE NEEDS OF THE ECOLOGICAL AND ENERGY TRANSITION

The year 2023 was marked by support for the development of innovation for many businesses. It took many forms, from technical support for the development of a proof of concept (POC) to patent applications. Some collaborative ventures have even paved the way for longer-term strategic partnerships. For Lubsens, which is developing a connected real-time lubricant monitoring technology, IFPEN tested the ability of its μ MoFF X-ray fluorescence sensor to track the oxidation of the start-up's industrial oils as part of a fully-funded proof of concept (POC). IFPEN has also worked with Dracula Technologies and Funcell as part of a Boost&Link partnership: the former on its data processing for the manufacture of organic photovoltaic (OPV) cells, a low-carbon alternative to button cells requiring no rare metals; the latter on the development of a continuous process for the manufacture of new green additives for the paper industry, the choice of equipment, monitoring the installation of a demonstration pilot plant, and finally the filing of a joint patent application. Boost&Link partnerships initiated with other companies – Save Innovations, YpHen, Ylec – have been particularly fruitful, and are likely to continue through new collaborative ventures. YpHen has approached IFPEN to help it characterize and validate the biodegradation performance of the micro-organisms and additives used in its solutions for the decontamination and recovery of soiled earth materials. YLEC Consultants needed to certify TURBYLEC, a compact, high-performance oil separator, in order to market its solution. Lastly, Save Innovations has benefited from technical solutions designed to space out maintenance operations on its energy-independent Smart Picogen solution, which pinpoints leaks in water networks and provides real-time diagnostics of the physico-chemical quality of water in pipes.



**Interview with
Isabelle Harter,
IFPEN Open Innovation
Manager**

All our partnerships start with a discussion with the regional Open Innovation manager to correctly identify the company's specific R&I needs, and to ensure that IFPEN has the in-house skills to respond to those needs within its 50 disciplines, 1,550 employees and 40 laboratories. Once the need has been clarified, the partnership enters the appraisal phase: we study the company, its product, its market vision and its business model, and work with the technical teams to define the R&I program, the deliverables and the budget. During the approval committee meeting that concludes the appraisal, we analyze the project's risks and propose a collaboration agreement that can be easily read and understood by the partner. IFPEN's remuneration, which is determined on the basis of the risk analysis, is conditional on a certain percentage of sales and capped at a multiple of the R&I expenditure incurred. A highly advantageous clause, in that the risk is shared, and the company can preserve its cash flow while remaining free to capitalize on its results. When R&I work creates an opportunity to file a patent, IFPEN offers to coordinate the operation. Our expertise in this field – we file 150 patents a year – is widely appreciated. That said, the framework of this partnership is flexible, with the emphasis on adapting to the company's needs.

HIGHLIGHT

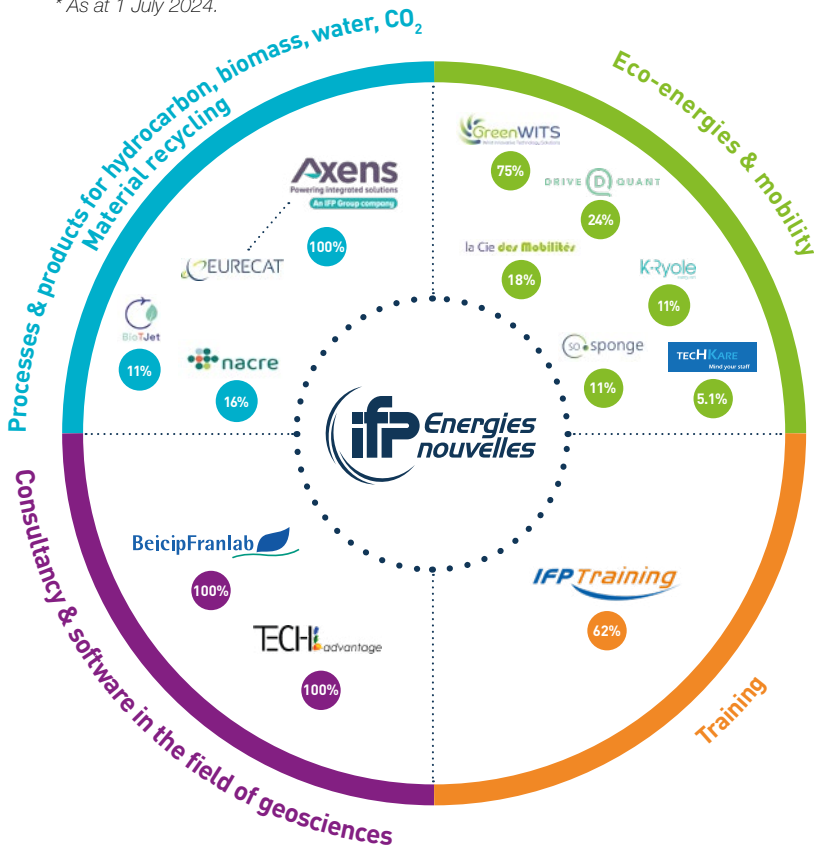
So Sponge: from spin-off to equity investment



Through IFP Investissements, IFPEN has acquired a stake in So Sponge: co-founded in January 2023, the young company is developing sober alternatives to energy-intensive, carbon-intensive humidity regulation solutions based on using mesoporous solids. So Sponge was launched by an IFPEN research engineer and project manager seconded to the Pulsalys incubator, and by a research professor affiliated with the Laboratory of Automation, Process Engineering and Pharmaceutical Engineering (University Lyon 1-CNRS). So Sponge benefits from IFPEN's spin-off policy and could be the focus of a Boost&Link partnership.

**PORTFOLIO OF INDUSTRIAL
STAKEHOLDINGS***

* As at 1 July 2024.



**IFPEN GROUP
CONSOLIDATED
ACCOUNTS**

AT DECEMBER 31, 2023

€1,173.7 million
Turnover

€31.6 million
EBIT

€14.9 million
Net profit Group share

ENERGY TRANSITION, THE FOCUS OF IFP SCHOOL TRAINING AND RESEARCH



AN OFFER ADAPTED TO EVOLVING INDUSTRIAL AND SOCIETAL NEEDS

At the interface between academia and industry, IFP School's mission is to provide young engineers with the skills and expertise needed to transform energy production, distribution and consumption systems, within the framework of a responsible and sustainable approach. Today, the training offering includes 18 programs for Master's level students and graduates with up to six years of higher education, 10 of which are taught in English. More than a third of graduates from the most recent programs in the four areas covered – Powertrains and sustainable mobility, Energy economics and management, Processes for energy and Chemicals, and Georesources and energy – are now working for companies focused entirely on new energy technologies.

This change reflects the decision taken by the School several years ago to incorporate courses dedicated to these new technologies. For example: in partnership with the University of Strasbourg, the opening of the "Geosciences for the Energy System Transition" Master's program in September 2023, providing training in exploiting georesources for a low-carbon future; or the accreditation, at the end of last year, of an Advanced-Master's degree – *Mastère spécialisé* in hydrogen, due to open in September 2024. Other programs dedicated to new energy technologies are also in the pipeline, to keep pace with changes in industry and society. ●●●

IFP School, a specialized engineering school and apprenticeship training organization, prepares new generations of engineers to become drivers of developments in the energy and mobility sector in order to build a low-carbon world. Through its innovative pedagogical approach, research activities, solid network of academic and industrial partners, and committed CSR approach, the School is well equipped to respond to the expectations of society and the needs of industry.



Since the School was founded in 1954, it has constantly sought to reinvent itself. Over the past few years, our programs have undergone profound change to focus on energy transition and sustainable mobility, drawing on IFPEN's scientific environment and our longstanding links with industry. This change is ongoing to embrace the challenges of environmental transition. Our teams are already heavily mobilized to create new programs in the fields of hydrogen, offshore wind energy, electricity and digital technologies, as well as carbon management. Another challenge lies in integrating data science and AI into our programs, since their development will have a major impact on the businesses of tomorrow!



Interview with
Pascal Longuemare,
IFP School Dean





Laëtitia Salessy



Marie-Hélène Klopffer



Interview with
Laëtitia Salessy,
Director of the Processes
for Energy and Chemicals
center, and Hydrogen
Coordinator at IFP School,
and Marie-Hélène Klopffer,
R&I Project Manager at
IFPEN and Supervisor
of the Advanced-Master's
degree – Mastère spécialisé
in Hydrogen Project
and Engineering

The first class will start in September. Why an Advanced-Master's degree – Mastère spécialisé entirely dedicated to carbon-free hydrogen?

L. S.: In France, as in Europe, hydrogen is a fast-growing market, generating high expectations from society and industry alike. As a school for energy innovation and sustainable mobility, one of our objectives is to help build this strategic sector by training the next generation of low-carbon hydrogen specialists. Therefore, this program is an important milestone in our roadmap.

M.-H. K.: Today, hydrogen is in fact one of the key elements in meeting the challenges of the energy transition. Many countries, including France, have strong ambitions to develop the production and use of low-carbon hydrogen. More than 100,000 direct jobs are expected by 2030, and new business needs are emerging. In R&I, research projects are gaining momentum. At IFPEN, we have already been working for a long time to develop economically sustainable technologies to integrate hydrogen into the energy mix.

What makes this training course so special?

L. S.: Up until now, our programs have featured a hydrogen component with a dedicated module. This new training program, which is taught in English, is dedicated 100% to hydrogen and covers the entire value chain. Our aim is to train project managers to understand the technical, economic, financial and environmental aspects that are specific to hydrogen. Through our discussions with key players in the ecosystem, notably within France Hydrogène, we have identified the core skills required by businesses.

M.-H. K.: We are one of the pioneers. This degree, with 6 years' higher education and accredited by the Conférence des Grandes Écoles (CGE, the French Association of Grandes Ecoles), will be one of the first training courses of its kind in France. Students will benefit from the IFPEN Group's expertise, with teachers from the School and lecturers from IFPEN, IFP Training, Axens and the expertise of our extensive network of partner companies. At the end of their training, future graduates will have a thorough grasp of all the facets of the hydrogen value chain, a profile that is highly sought-after by start-ups, major groups and R&I centers alike.



●●● While IFP School is well positioned to attract students, the labels it was awarded in 2023 also contribute to its appeal. In addition to the Qualiopi label, which certifies the quality of its training services, the School is also one of the top 5 engineering schools in the HappyIndex®AtSchool ranking for the best experience provided to students during their studies, in terms of teaching methods, quality of life on campus, professional integration and consideration of societal and environmental concerns. CSR is central to IFP School's development strategy, with the implementation of the "Initiatives for a sustainable campus", including an approach to reducing the carbon footprint, with particular attention paid to air travel by lecturers and students during field courses. In addition, in 2024, a dossier will be submitted seeking to obtain the DD&RS (Sustainable Development and Social Responsibility) label for higher education establishments. Students and doctoral students once again excelled in 2023: second and third prize for the best student poster organized by the French Automotive Engineers Society (SIA) at the Powertrain congress; third place in the final of the Laurie Dake Challenge of the European Association of Geoscientists and Engineers and second place in the Minus CO₂ Challenge competition, also organized by the EAGE; a doctoral student in the CarMa chair (2019-2022) received first prize in the "Society Impact" category of the CentraleSupélec IMPACT 2022 Foundation thesis awards for her work on decarbonization. The IFP School faculty also received awards. Six winners received the insignia of *Chevalier des Palmes académiques* (knighthood of the French Government for outstanding academic achievements).



INNOVATIVE AND AGILE TEACHING METHODS

The IFP School's teaching approach is grounded in innovation and agility. Teaching methods are continuously adapted to ensure that students are immediately operational. Emphasis is placed on solving real-world problems using methods that encourage learning through experimentation: serious games, design thinking, immersive realities – which encourage the acquisition of professional skills and the appropriation of the future work environment – go hand in hand with practical work on actual industry data and internships. The School makes particular use of Lab e-nov™, its digital culture laboratory, which supports initiatives in teaching and innovation. Achievements in 2023 include: virtual reality modules on the battery pack and the combustion engine; organization of a "Prototyping and 3D printing" hackathon; the "Energy transition" and "Hydrogen for mobility" MOOCs. These two modules combined the teaching, technical and scientific expertise of the teachers and Lab e-nov™ team, together with that of IFP Training and IFPEN, to delve into the depths of the energy transition and hydrogen technologies: the first aimed to understand the challenges of the energy transition and explore the sector's innovations for a low-carbon energy mix, whereas the second was designed to discover hydrogen technologies applied to heavy mobility. In early 2024, the third edition of this online training course was successfully launched, and a new MOOC entitled Hydrogen production, focusing on the shift from high-carbon to low-carbon hydrogen production, was launched. The Lab e-nov™ has also leveraged its expertise to support projects within IFPEN Group and with external partners through virtual laboratory tours. In parallel, an office has been opened in IFPEN-Lyon site to work closely with teams on creativity, digital production and virtual reality projects.



ENERGY TRANSITION, THE FOCUS OF IFP SCHOOL TRAINING AND RESEARCH

RESEARCH ACTIVITIES AND PARTNERSHIPS: LEVERS FOR DEVELOPMENT AND OUTREACH

IFP School's participation in scientific and technical networks, as well as its research activities, all play a key role in its appeal. Many of these activities are carried out within the framework of the four Chairs supported by the School: Electricity and digital transition (EDT), Electric, connected and autonomous vehicles for smart mobility (ECAV), Electrolyte thermodynamics (EleTher) as well as Carbon management and negative CO₂ Emissions Technologies Towards a Low-Carbon Future (CarMa). The other activities stem from partnership research contracts with industrial and research players, or from public support in France and abroad. The results of this work, which helps to anticipate the profound changes taking place in the energy and mobility sectors, also contribute to the development of curricula by fueling course content. Furthermore, IFP School's international prestige has been further enhanced by a number of spin-off operations and ongoing academic partnerships. These include the 20th edition of the Petroleum Engineering and Project Development Master's program in Nigeria, and the signing of an academic agreement

FOCUS

An initial scientific evaluation of IFP School's activities was carried out in 2023 by IFPEN's Scientific Board. Focusing on the 2018-2022 period, it highlighted the relevance of the topics related to the low-carbon transition, the quality of the research work, as well as its coordination with IFPEN's scientific policy. The Board emphasized the high number of HDRs (8 out of 32 teaching staff) and the high publication rate of the School's teaching staff.

with IFP Training and the Faculty of Engineering at Angola's Agostinho Neto University to launch a postgraduate program in oil and gas engineering. This partnership will pave the way for broader collaboration on renewable energies and energy transition in Angola. The School can also capitalize on a dynamic network of 16,000 alumni who take part, for example, in the IFP School Voices webinars on current topics in the energy and powertrain sectors, such as bio-based chemistry, SAF, electric mobility, decarbonization strategies, CO₂ storage, etc.



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as of 1 December 2023

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MEETING TOMORROW'S CHALLENGE TODAY

+ Research, innovation and skills transfer form the cornerstones of a world that progresses and improves. Thanks to these pillars, IFPEN has become an expert in energy, mobility and the environment, paving the way for a decarbonized and sustainable era.

IFPEN is a visionary and agile institute, working for tomorrow with a view to providing technological solutions that have been tested and proven on an industrial scale, meet society's needs and are economically viable. From technologies and software to equipment and services, our low-carbon innovations are driving the transition and facilitating the development of the industrial sectors of the future. IFPEN boldly imagines and rigorously designs solutions for society's future.

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