



+  
INNOVATING  
FOR ENERGY

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# THE ESSENTIALS

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2021

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



### 2021: COLLABORATION AND DIGITALIZATION

In 2021, IFPEN's teams rose to the dual challenges posed by the economic and health crises - with Covid slowing the pace for the second year running - and conducted fundamental research and applied research to support the ecological transition.

2021 was also a year of openness and cooperation within the research ecosystem. I am proud of the fact that we were selected to co-manage three priority research programs and facilities (PEPR) initiatives, related to the decarbonization of industry, biobased products and biofuels, and mobility digitalization. 



IFP Energies nouvelles (IFPEN) is a major research and training player in the fields of energy, transport and the environment. From scientific concepts within the framework of fundamental research, through to technological solutions in the context of applied research, innovation is central to its activities, hinged around four strategic priorities: climate, environment and circular economy – renewable energies – sustainable mobility – responsible oil and gas.

As part of the public-interest mission with which it has been tasked by the public authorities, IFPEN focuses its efforts on bringing solutions to take up the challenges facing society and industry in terms of energy and the climate, to support the ecological transition. An integral part of IFPEN, IFP School, its graduate engineering school, prepares future generations to take up these challenges.

### 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 thereby contributes to the creation of value by supporting French and European economic activity and the competitiveness of industrial sectors related to mobility, energy, and eco-industry.

# OUR MISSION

## BACKGROUND

CLIMATE CHANGE  
AND ECOLOGICAL TRANSITION

### + CHALLENGES



FOSTERING SUSTAINABLE  
MOBILITY



DIVERSIFYING  
THE ENERGY MIX

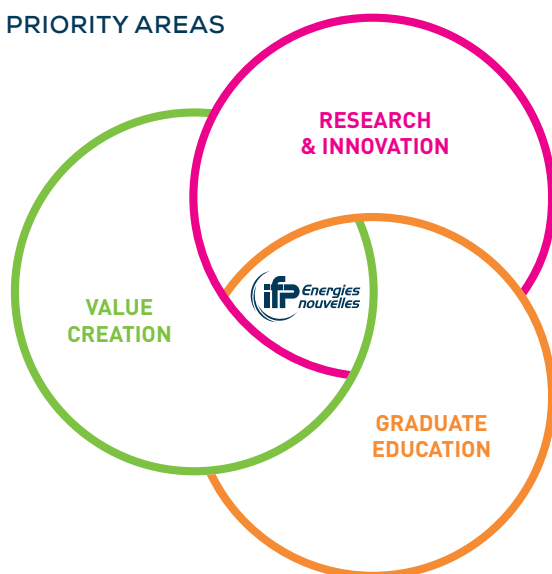


INCREASING ENERGY  
EFFICIENCY



REDUCING THE ENVIRONMENTAL  
IMPACT OF FOSSIL RESOURCES

### + 3 PRIORITY AREAS



## KEY FIGURES

1.549

Total full-time equivalent  
workforce for 2021

Including

1.095

R&I researchers and  
technicians

30

work/study students (FTE)

Nearly

150

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



€262.1 MILLION

including €228 million for R&I  
Operating expenses

68%

of budget dedicated to NETs\*

\* New energy technologies

2

Carnot Institutes: the IFPEN  
Transports Energie Carnot  
Institute and the IFPEN  
Ressources Énergétiques  
Carnot Institute



Awarded

ISO 9001

certification for their R&I  
activities

149



basic patent applications,  
including  
93  
in the field of NETs

More than

500



IFP School graduates

2.5

fold increase in number  
of contracts with startups  
and SMEs

# DEVELOPING TODAY THE INNOVATIONS OF TOMORROW



## CLIMATE, ENVIRONMENT AND CIRCULAR ECONOMY

Given the climate challenge and the negative impact of human activities on the environment and resource availability, IFPEN is reinforcing its actions via an ambitious strategy targeting three main objectives: the decarbonization of industry and CO<sub>2</sub> conversion, the recycling of plastics and metals from catalysts and batteries, the improvement of air quality and soil resilience.



## RENEWABLE ENERGIES

To address the demand for renewable energies, IFPEN develops processes to produce second-generation bioproducts and biofuels. IFPEN also designs tools targeting the development of ocean energies, particularly floating wind turbines. Lastly, to support the growth in nondispatchable energies and the increasing electrification of the economy, IFPEN is working to improve energy storage and management technologies.



## SUSTAINABLE MOBILITY

Boosting energy efficiency in transport, improving the environmental performance of powertrains and diversifying energy sources in order to evolve towards clean, low-carbon and increasingly connected mobility are the major challenges associated with sustainable mobility. To support companies, local authorities and citizens, the IFPEN Transports Energie Carnot Institute structures its research around three priorities: electric mobility, connected mobility and mobility with a low environmental impact.



## RESPONSIBLE OIL AND GAS

Given the need to increase energy efficiency and reduce CO<sub>2</sub> emissions and pollution generated by industry and transport, while meeting the global demand for mobility, energy and products for the chemicals sector, IFPEN conducts research aimed at producing fuels and chemical intermediates meeting existing standards. At the same time, it develops technologies making it possible to reduce the risks associated with the exploration and exploitation of oil and gas resources.



## FUNDAMENTAL RESEARCH SERVING INNOVATION

In order to ensure the scientific excellence of its research activities and support its innovation ambitions, IFPEN draws on a collaborative fundamental research program, organized around nine scientific challenges. This dynamic approach has already borne fruit. In order to anticipate long-term needs and pave the way for the development of new products and processes, IFPEN permanently adjusts its scientific questions with a view to acquiring new knowledge.

## ENCOURAGING AND SUPPORTING INNOVATION



IFPEN contributes to the development of green industrial sectors and sustainable mobility, speeding up the detection of new energy technology opportunities. To achieve this, IFPEN is diversifying, both in terms of its industrial partnerships and the development of its subsidiaries, and supporting the competitiveness of SMEs and innovative startups, thereby contributing to job creation and local wealth. Underpinning this, IFPEN encourages the expression of a genuine in-house innovation culture.

**+**  
**INNOVATION, THE FOCUS OF IN-HOUSE CHALLENGES**

The NET diversification strategy supporting innovation is reflected in the way IFPEN operates. For example, it regularly organizes a challenge open to employees, IFP School students and employees of IFP Group subsidiaries, aimed at stimulating the company's innovation culture. In 2021, progress was made in all five winning projects from the 2020 challenge: for several of them, testing and POC led to a partnership with an SME or an industrial group, or patents being filed. Alongside, a so-called "free creativity" approach is focused on the development of new skills, methodologies and experimental or digital tools. In addition, via its spin-off initiative, IFPEN helps employees seeking to set up their own companies.

**+**  
**SUPPORT FOR START-UPS AND  
SMEs: AN OUTSTANDING YEAR**

IFPEN has been actively supporting SMEs and startups spearheading innovation projects with a positive environmental impact for nearly 30 years. In 2021, the development of digital prospection tools helped publicize IFPEN's support provision more widely, which resulted in the number of partnership agreements signed more than doubling compared to previous years.

**+**  
**TARGETED PARTNERSHIPS  
TO DETECT OPPORTUNITIES**

To identify collaborative opportunities with SMEs and young innovative companies and optimize intelligence activities concerning new fields, IFPEN can draw on an extensive network of partners: target incubators, innovation support networks and the Carnot Institute network.

## TRAINING TALENTED YOUNG PEOPLE FOR THE ENERGY TRANSITION



To address the energy and ecological challenges of the 21st century, IFP School provides students with the skills they need to be immediately operational in the fields of energy and sustainable mobility. Via a training offer based on a resolutely innovative teaching model and an extensive partnership network made up of academic and industrial players in France and around the world, the School addresses societal expectations and the needs of industry.

**+**  
**AN EDUCATIONAL AND TRAINING OFFER ADAPTED TO EVOLVING  
INDUSTRIAL AND SOCIETAL NEEDS**

IFP School, which offers applied graduate programs, is recognized for the excellence of its training offer in the fields of energy and sustainable mobility, particularly via its apprenticeship system, introduced in 1996. In September 2021, it opened its own apprenticeship training center (CFA) to provide young people with the skills they need to contribute to the ecological transition, meeting the needs of industry and society as a whole. The educational and training offer based on a "learning by doing" approach is continuously adapted to reflect the major energy challenges and covers four fields: Powertrains and sustainable mobility, Energy economics and management, Processes for energy and chemistry, and Georesources and energy.

**+**  
**AN EDUCATIONAL APPROACH THAT IS CONSTANTLY  
BEING REINVENTED**

IFP School is at the cutting-edge of educational innovation. It proposes an agile model, adapted to new digital technology usages, which evolves in line with the expectations of new generations of students and industry. The introduction of soft skills into programs also helps students develop their interpersonal skills to ensure they are prepared for the diversity they will find in the workplace. A key feature of 2020 was the acceleration in the digitalization of programs. 2021 confirmed this transformation with, for example, the renewed success of the MOOCs on tomorrow's mobility and the energy transition. The latter took the form of a module containing a selection of videos, games and webinars, freely accessible to all. This capacity to innovate is also illustrated through numerous developments of the LAB e-NOV™, the digital culture laboratory.



## IFPEN 2021 NEWS IN BRIEF



### FRANCE RELANCE RECOVERY PLAN: IFPEN, CO-MANAGER OF THREE PEPRs

When he presented the France Relance economic recovery plan on 29 June 2021, the French Prime Minister announced the launch of 13 acceleration strategies for innovation within the framework of the country's fourth Investments for the Future Program (PIA4). The objective: to identify the principal economic and technological challenges of the future and dedicate substantial investments to them. These strategies are accompanied by PEPRs (priority research programs and facilities initiatives), each of which is assigned a leader responsible for steering the program. IFPEN was chosen as joint leader of the PEPR related to the decarbonization of industry acceleration strategy with the CNRS, the PEPR on biobased products and sustainable fuels with INRAE and the PEPR on the digitalization and decarbonization of mobility with Gustave Eiffel University. In addition, IFPEN was asked to contribute to the PEPR relating to the Hydrogen acceleration strategy and the PEPR relating to the acceleration strategy concerning recyclability, recycling and reincorporation of recycled materials.



### DEPLOYMENT OF HYDROGEN: IFPEN STEPS UP ITS ACTIONS

In 2021, IFPEN's contribution to the hydrogen value chain was reinforced. The Hydrogen for Europe (Hydrogen4EU) study was published in May 2021. Based on modeling carried out by the partners, IFPEN, SINTEF and Deloitte, the project aims to map out pathways exploring the role of hydrogen in a decarbonized European energy system. In June, IFPEN and the French Corrosion Institute created a research group the purpose of which is to assemble industrial partners in order to gain a better understanding of the behavior of materials in the presence of hydrogen. June also saw the organization of IFPEN's 5<sup>th</sup> Energy Innovation event, focusing on the conditions for deploying low-carbon hydrogen in the French energy mix. The year also saw the commissioning, in October, of a new 210 kW test bench for fuel-cell systems. Located at the Solaize site, this unique experimental tool, the most powerful in France, will enable IFPEN to accelerate its research into the use of hydrogen-powered fuel cells in electric vehicles, particularly for heavy road vehicles (buses and trucks) and for the rail sector.



### FRENCH DEPUTY TRANSPORT MINISTER LAUNCHES A CALL FOR PROJECTS DURING A VISIT TO THE BIOTFUEL® SITE

On 27 July, Jean-Baptiste Djebbari, French deputy transport minister, went to Venette (Oise, northern France) to visit the biomass torrefaction site, one of the demonstrators for the BioTfuel® project. The visit took place as Bionext and its partners had successfully completed the test programs on the BioTfuel® demonstration units, navigating a crucial step in the development of this technology designed for the production of low-carbon biokerosene. During his visit, the minister announced the launch of a call for projects aimed at accelerating the development of a French sector for the production of sustainable aviation fuel. Allocated a provisional budget of up to €200M, the call for projects falls within the framework of the Investments for the Future Program (PIA) and will be financed by the France Relance economic recovery program.



### PIERRE-FRANCK CHEVET BECOMES THE NEW PRESIDENT OF ANCRE

Pierre-Franck Chevet was appointed president of the French National Alliance for Energy Research Coordination (Ancre) for a period of two years. Appointed, as part of a two-yearly rotating presidency, by the alliance's coordination committee made up of the four founding members (CEA, CNRS, CPU and IFPEN) and the representative of associate members (BRGM), he succeeds Mohammed Benlahsen, president of Picardie Jules Verne University. He will continue the work of the alliance aimed at reinforcing links and exchange between research organizations, agencies and supervisory authorities; working more closely together in this way will make it easier to achieve national and European energy transition objectives.



### THE OGST JOURNAL BECOMES STET

The OGST (Oil and Gas Science and Technology) journal, created by IFPEN in 1946, has changed its scope and is now called (from January 2022) STET (Science and Technology for Energy Transition). This new positioning and new name underline IFPEN's strategy resolutely focused on the energy transition. To accompany this change, IFPEN has joined forces with the CEA, the other major French research organization dedicated to energy.



### THE SOLUTION MAKING IT EASIER TO MOVE HEAVY LOADS IN HOSPITAL LAUNCHES SUCCESSFULLY

In July 2021, IFPEN, via the IFPEN Transports Energie Carnot Institute, announced the creation of TechKare™, a company that offers solutions making it easier to transport heavy loads in hospitals. One such electric solution has been developed to help stretcher bearers move patients, addressing the challenges of mobility in the hospital environment. In particular, the solution makes it possible to reduce musculoskeletal disorders in hospital staff. TechKare™ thus addresses the societal challenges concerning the improvement of working conditions, ageing well and professional equality among hospital personnel.

*NB: TechKare™ was created by an employee via the spin-off policy (see 2020 activity report p. 33).*

# CLIMATE, ENVIRONMENT AND CIRCULAR ECONOMY

## + FOCUS

In 2021, IFPEN was chosen alongside the CNRS to manage the PEPR related to the decarbonization of industry acceleration strategy (see page 10).

### + CO<sub>2</sub> CAPTURE

#### 3D PROJECT: THE PILOT UNIT FOR THE DMX™ PROCESS DELIVERED IN DUNKIRK

The European 3D project, aimed at demonstrating the performances of the DMX™ process to capture CO<sub>2</sub> in blast furnace gases, reached a key milestone in 2021. The pilot unit, designed by IFPEN and Axens and built by ETCL in Lens, was installed at ArcelorMittal's steelworks site in Dunkirk. By 2026, 125 t of CO<sub>2</sub>/h will be captured, i.e., 1 Mt of CO<sub>2</sub>/year. By 2030, the European Dunkirk - North Sea cluster could capture, transport and store more than 10 Mt of CO<sub>2</sub>/year.

*The 3D project has been awarded funding from the European Union's Horizon 2020 research and innovation program through grant agreement No. 838031.*

### + AIR QUALITY ANALYSIS

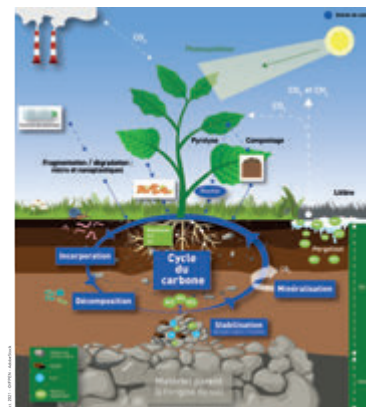
#### REAL-E, THE MOBILE AND CONNECTED VEHICLE EMISSION ANALYZER

At the start of 2021, the IFPEN TE Carnot Institute and SME Capelec, provider of automotive testing equipment, launched an innovative mobile and connected analyzer, Real-e™ (Real emissions). Real-e™ measures, in real conditions and with a high degree of accuracy, the pollutants emitted by moving vehicles and makes it possible to rapidly identify vehicles that do not meet regulatory requirements. It takes the form of a connected kit containing an exhaust gas analyzer (CO, CO<sub>2</sub>, NO<sub>x</sub>, PN, NH<sub>3</sub>), which samples pollutants continuously, and an onboard diagnostic system that collects the vehicle's parameters. With this system, the development of vehicles and the monitoring of a vehicle fleet are easier, quicker and less expensive than is the case with existing systems.

### + AIR QUALITY ANALYSIS

#### FLAIR: A PACKAGE OF TOOLS TO SUPPORT ENVIRONMENTAL MONITORING AND AIR QUALITY

In 2021, environmental monitoring research conducted by the IFPEN RE Carnot Institute culminated in the development of Flair, a comprehensive range of sensors and software making it possible to explore a geographic zone in order to detect natural or industrial pollutants, visualize them on a map, identify their origin and plot their future dispersal. Applications range from the detection of gas leaks through to the evaluation of air quality, via the study of soil and soil respiration as well as greenhouse gas emissions.



### + SOIL STUDIES

#### TWO PROJECTS TO UNDERSTAND THE ROLE OF MICROPLASTICS IN SOILS

The projects selected in 2021 by the ANR and Ademe will study the impact of the presence of microplastics (MPs) in soils. The e-DIP project, financed by the ANR, will evaluate the toxicity of MPs in different soil compartments and their impact on biogeochemical cycles depending on whether they are introduced directly or mixed with organic amendments. The IFPEN RE Carnot Institute will study the direct or indirect (by disrupting microbial activity) impact of MPs on soil

organic matter quality using Rock-Eval® methods dedicated to soil studies. The Plastisol project, financed by the Ademe, will consolidate this study by providing indicators for the presence of plastic matter in soils.

### + CHEMICAL RECYCLING OF PLASTICS

#### IFPEN DEVELOPS CUTTING-EDGE TECHNOLOGIES

IFPEN's aim is to be present across the various chemical recycling loops. For example, projects currently underway relate to the conversion of plastic via pyrolysis. In 2021, research in this field led to the development, in partnership with Repsol and Axens, of the Rewind® Mix process that purifies plastic-based pyrolysis oils enabling them to be directly treated in existing petrochemical plants for recycled plastic production. In addition, demonstration of the Rewind® PET recycling process based on depolymerization, conducted in partnership with Jeplan and Axens, is continuing with a market launch scheduled for the end of 2023.

# RENEWABLE ENERGIES

## OFFSHORE WIND AND OCEAN ENERGIES



### IFPEN AND TOTAL ENERGIES CONDUCT A STUDY TO EVALUATE FLOATING WIND TURBINE PRODUCTION

IFPEN and TotalEnergies joined forces to evaluate the impact of a floating wind turbine's movement on its energy production. Two types of floaters were evaluated and compared with a fixed turbine. Differences were quantified and their causes analyzed. The research was conducted using modeling tools developed at IFPEN, particularly DeepLines Wind™ for multiphysical floating wind turbine simulation.

## FOCUS

In 2021, IFPEN was selected to jointly manage, alongside INRAE, the PEPR related to bio-based products and sustainable fuels (see page 10).

## UNDERGROUND



### TELLUS: DIGITAL TECHNOLOGIES SERVING GEOSCIENCES

In March 2021, the IFPEN RE Carnot Institute launched TELLUS Share, a community of players from the underground sector led by IFPEN

focusing on the theme of digital technology. The role of the community is to evaluate the contribution of digital technologies (data science, artificial intelligence, virtual reality, etc.) to problems related to the underground environment. To do so, the IFPEN RE Carnot Institute set up an ecosystem made up of a multidisciplinary team of geoscientists and digital technology and data science specialists, close partnerships with digital sector players (academics, leading digital sector players, startups). Four industrial partners from the oil and underground storage sectors joined the community for its launch.

## BIOFUELS

### REDUCING THE ENVIRONMENTAL FOOTPRINT OF LAND TRANSPORT AND AVIATION SECTORS

IFPEN's commitment to the energy transition, in line with French and European public policies, is reflected in the development of eco-efficient technologies for the production of advanced biofuels for the road transport and aviation sectors.



**Interview with:**  
**Jean-Philippe Héraud,**  
**BioTfuel® project manager**



*We have successfully completed the test program on the Venette and Dunkirk BioTfuel® demonstration units, with our consortium partners\*. This demonstration phase enabled us to validate, develop and optimize the process chain on a semi-industrial scale for several types of biomass, following 1,000 hours of gasification and more than 1,500 hours of torrefaction. So we have reached a crucial milestone in the development of this technology for the production of low-carbon footprint biokerosene. Working with our partners, our focus now will be on research to move to a first industrial reference for the process that is adapted to meet the regulatory objectives set out for the aviation sector, with SAF incorporation targets of 5% in 2030 and more than 50% by 2050\*\*.*

\* IFPEN, Avril, Axens, CEA, Thyssenkrupp Industrial Solutions, TotalEnergies.

\*\* Fixed by the French State in 2020 and proposed by the European Commission in 2021 in its Fit for 55 package.

## BIO-BASED CHEMISTRY

### 100% BIO-BASED PET BOTTLES: A GLOBAL FIRST!



At the end of 2021, Japanese company Suntory announced the successful production of the first 100% bio-based PET bottle prototypes. It used bioparaxylene produced in the TCat-8® pilot unit operated by the American company Anellotech via the Bio-TCat® process developed in partnership with IFPEN and Axens, that converts lignocellulosic biomass into aromatics.

Bio-TCat® technology, which is ready for marketing, will enable chemical sector players and brands to achieve their environmental and product sustainability objectives, thanks to its low carbon footprint and its raw material derived from non-food renewable biomass.



# SUSTAINABLE MOBILITY

## ELECTRIFIED MOBILITY

### 2021: THE RAPID DEVELOPMENT OF EFFICIENT SOLUTIONS



In 2021, working collaboratively within a French eco-system, it developed electric powertrain technologies aimed at the emerging retrofit market. Our thriving partnership research activities also resulted in the development of a family of efficient electric powertrains, incorporating compact electronics and an original engine cooling solution. These solutions cover a broad range of applications, from the small low-voltage vehicle to vehicles requiring high power. In order to fuel these partnerships and boost the competitiveness of the industrial fabric, IFPEN designed two new machine topologies for which

patent applications have been submitted. These topologies reduce raw material consumption by 30% for equivalent state-of-the-art performances, thanks to improved performance densities.

## FOCUS

In 2021, IFPEN was selected to jointly manage, alongside Gustave Eiffel University, the PEPR related to the digitalization and decarbonization of mobility (see page 10).

## CONNECTED MOBILITY

### MOBILITY DATA HUB: TOWARDS A NATIONAL MOBILITY DATA PLATFORM

Placing mobility on an ambitious decarbonization trajectory while integrating changes in behavior depends on being able to better understand, analyze and even predict the movements of people and goods. Mobility data thus represent a key resource. While digital sector players are in possession of a significant proportion of the data, other national players have access to fragmented shares that are highly relevant once a synergy is created between them. Thus, because it now appears necessary to create a trusted third party bringing together these players and capable of processing this data, at the end of 2021, IFPEN, in collaboration with Inria and Cerema, launched the creation of a Mobility Data Hub, the aim of which is to provide all players with common tools making it possible to pool mobility data as well as analyze and anticipate the mobility of people and goods. The Mobility Data Hub was one of the projects selected for the Propulse program launched by the French Innovation for Transport Agency, announced on 17 December 2021.



## CONNECTED MOBILITY

### MODELING MOBILITY DATA IN THE ILE-DE-FRANCE REGION

In October 2021, the IFPEN Transports Energie Carnot Institute and Paris Ouest La Défense (POLD) launched their new collaborative partnership established within the framework of the Territoires d'innovation de grande ambition (TIGA, Ambitious Demonstrators and Innovative Territories) initiative for Ile-de-France, "Construire au futur, habiter au futur" (Building in the future, living in the future). Ambition: to capture, analyze and model mobility data for the Paris Ouest La Défense area in order to better understand and anticipate work-related journeys. IFPEN will construct its analyses primarily on the data provided by the Gecoair™ ecomobility application.

## CONVERSION OF IC POWERTRAINS



### Interview with:

**Cécile Cohas, innovation research mission manager, Voies navigables de France (VNF)**



*In order to meet our objective of establishing a green river fleet, we asked IFPEN to work with us. Our partnership takes the form of a research and innovation contract aimed at drawing up prospective scenarios for the establishment of a green fleet in the Rhône-Saône basin by 2050. IFPEN's teams are conducting an in-depth cross-functional study on the theme. In addition to the technical, technological and economic modeling of the solutions under consideration, the study also offers crucial life-cycle analyses to complete the sector-specific data provided by the European Commission. Ultimately, the objective is for these scenarios to be extended to all the basins covered by VNF and lead to the construction of new boats or the retrofit of existing vessels [...].*

## HYDROGEN MOBILITY

### HYDROGEN TO REDUCE THE ENVIRONMENTAL IMPACT OF MOBILITY

IFPEN is working on solutions for the use of renewable or low-carbon hydrogen to reduce the environmental impact of mobility: hydrogen used to power a fuel cell that generates on-board electricity for electric vehicles, hydrogen used as a fuel in an internal combustion engine, integration of low-carbon hydrogen in the production of advanced biofuels, in the form of e-biofuels that can be used by heavy transport (land or sea), off-road vehicles and the aviation sector. Its researchers have been contributing to the ECH2 project led by Vitesco Technologies since October 2021. Objective: to improve the control electronics of hydrogen fuel cell vehicles and facilitate their large-scale roll-out by reducing their costs and increasing their lifespan. In addition, a new fuel cell system test bench, which with a power of 210 kW is the most powerful in France, was commissioned at IFPEN's Lyon site.

# RESPONSIBLE OIL AND GAS

## UNDERSTANDING AND MODELING THE UNDERGROUND ENVIRONMENT

### IFPEN ORGANIZES AN INTERNATIONAL BASIN MODELING WORKSHOP

The second edition of the Basin Modeling workshop organized by the IFPEN RE Carnot Institute brought together around one hundred experts from some twenty countries to review the various research avenues in the field. There was a particular focus on new working methodologies, the themes of permeability and flows in faults and fractures, as well as multi-physical and multi-scale problems. A specific session was dedicated to the energy transition.

## ENHANCED RECOVERY

### A LOWER ENVIRONMENTAL IMPACT



Enhanced oil recovery (EOR) makes it possible to meet demand by increasing the production of existing reservoirs, while limiting drilling operations and optimizing produced water management. In this area, within the framework of the EOR Alliance, IFPEN, Beicip-Franlab and Solvay are developing technologies adapted to different types of reservoir and EOR processes, from formulation research in the laboratory to experimentation in the field.

The DOLPHIN 3 JIP, launched at the end of 2019 with six oil industry partners and focused on minimizing the environmental impact of EOR, is pursuing its activities with the conduct of water treatment unit tests on the IFPEN Gas Oil water Separation Platform (GOWSP).

## DIGITALIZATION

### DATA AND PROCESSES

IFPEN is reinforcing its activities in the field of the processing and capitalization of data generated by high-throughput experimentation as well as data related to the development of technologically complex processes. These activities are aimed, on the one hand, at developing tools for the transformation of research data, facilitating the work of R&I teams and contributing to the improvement in experimentation efficiency; and, on the other hand, proposing new digital services and technologies to accelerate the digital transition of the refining and petrochemicals sectors.

## CLEAN FUEL PRODUCTION

### NEW FCC GASOLINE HYDROTREATMENT CATALYSTS

IFPEN's research led to the development of two new catalysts, selective hydrogenation and selective hydrodesulfurization, for the Prime-G+® process marketed by Axens. These developments reinforce a range of solutions adapted to the needs of refining operators for the production of gasoline meeting the strictest environmental standards, as reflected in the 300<sup>th</sup> reference obtained by Prime G+® technology in 2021.

## PRODUCTION OF PETROCHEMICAL INTERMEDIATES

### DIMENE-B® : A NEW 1-BUTENE PRODUCTION PROCESS

IFPEN's teams developed a new homogeneous catalysis process, together with the associated catalyst, for the production of 1-butene via the dimerization of ethylene. 1-butene is a chemical intermediate used as a comonomer for the production of plastics. The process, marketed by Axens, also makes it possible to convert ethylene derived from biomass and thus contribute to the production of bioplastics. More energy efficient, its design makes it possible to increase 1-butene production capacity.



# FUNDAMENTAL RESEARCH SERVING INNOVATION

## COLLABORATIVE PROJECT

### BIFROST, AN INTERDISCIPLINARY COLLABORATIVE PROJECT

At the interface of analytical chemistry and data science for the analysis of complex mixtures, the BIFROST (Blind Identification, Filtering & Restoration On Spectral Techniques) project, launched in 2018 with the Marseille Institutes of Mathematics (I2M) and Molecular Sciences (ISM2) within the framework of the Aix-Marseille excellence initiative, was completed in 2021. Combining quantitative analysis and algorithm optimization in signal unmixing, it demonstrated the benefit of associating new NMR (nuclear magnetic resonance) data acquisition methods and applied mathematics.

## THERMODYNAMICS

### IFPEN ANTICIPATES INCREASING NEEDS IN THE FIELD OF RECYCLING

The objectives of the French Circular Economy law and the needs expressed by industry have established thermodynamics applied to recycling an active research field for which IFPEN's contributions have been significant. For example the EleTher teaching and research chair, launched by IFP School in 2021, is focused on the use of thermodynamic tools to improve the efficiency of recycling processes. To achieve this, it aims to acquire a better understanding of physicochemical phenomena in the aqueous phase. In this context, the 31<sup>st</sup> edition of the ESAT conference on applied thermodynamics, organized jointly with Mines ParisTech engineering school in July 2021, brought together numerous players in the field.



## + FOCUS

Nine projects were selected from the 33 proposals involving IFPEN that were submitted within the context of the ANR's 2021 generic call for projects. This number, in significant increase compared to previous years, illustrates the quality and relevance of the proposals drawn up. These projects will help overcome scientific challenges in a variety of fields including geothermal energy, artificial intelligence, biomass conversion and electric machines.



**Interview with:**  
**Sophie Violette,**  
**Lecturer-HDR**  
**(national accreditation**  
**to supervise research)**  
**Researcher, Sorbonne**  
**University – ENS**  
**Geology Laboratory-**  
**PSL University and**  
**member of IFPEN's**  
**scientific board**

*In the last few years, IFPEN has implemented a complete shift in focus in terms of its oil and gas research programs to encompass new energy and ecological themes. Organizing its fundamental research around scientific challenges has been tremendously beneficial to the reflection process surrounding this change, since it has made it possible to put into perspective the purpose of IFPEN's technologies and their applications. We should also pay tribute to the revamped Earth Sciences and Environmental Technologies division for the advances it has made in transferring its expertise to NETs, and IFPEN's teams in general for their capacity to adapt and make this shift a reality. The "climate/soil interactions and the water cycle" theme is a prime example of this: its flagship "Critical zone challenges" project required the expertise acquired in deep basins to be applied to surface-related themes, but it also demonstrated the efficiency with which IFPEN's long-established analytical tools have been transposed. One example is Rock-Eval®, capable of reliably, rapidly and cost-effectively characterizing the content of soil organic matter, as well as other numerical tools that will ultimately be able to quantify the anthropic impact on erosion processes.*

*The development of these themes at IFPEN has also been an opportunity to forge academic and industrial partnerships. For example, a new agreement with long-standing partner INRAE involves the pooling of expertise that paves the way for some equally fruitful collaborative projects in the future. Lastly, let's underline the contribution of scientific visitor David Sebag, whose complementary soil science expertise reinforced and galvanized the skills of IFPEN's teams.*



# ENCOURAGING AND SUPPORTING INNOVATION

## STARTUPS & SME

### SUPPORT FOR FUNCELL, A COMPANY THAT DEVELOPS BIO-BASED ADDITIVES FOR THE PAPER INDUSTRY

In 2021, IFPEN began supporting FunCell, a company founded in 2020 and located in Isère (south-east France), that develops bio-based additives for the paper industry. The additives improve the properties of cellulosic materials (paper, cardboard, packaging and hygiene products) and, notably, give them greater resistance to humidity. This innovation could therefore help promote the use of paper packaging as an alternative to plastics. The additives have already been successfully produced in the laboratory and IFPEN will now help FunCell to extrapolate and develop the process at the industrial pilot scale. "We are pleased to be teaming up with IFPEN. We will be able to benefit from their expertise in order to take our technology further and apply it on an industrial scale, since it has obvious potential as regards the ecoresponsible packaging market", explains Gilles du Sordet, CEO of FunCell. Awarded a Grand Prize in the i-Lab 2020 competition, the FunCell solution also meets the durability and toxicity criteria of the packaging market.



## + FOCUS

In 2021, IFPEN met more than 450 companies and more than doubled the number of contracts signed.

## PARTNERSHIP

### IFPEN AND BPIFRANCE JOIN FORCES TO SUPPORT GREENTECH STARTUPS

At the 2021 edition of Meet'Up Greentech, the annual event of the French Greentech ecosystem organized by the French Minister for the ecological transition, Pascale Ribon, Deeptech Director at Bpifrance, Catherine Rivière, Executive Vice-President of IFPEN and Nathalie Alazard-Toux, President of IFP Investissement, signed a partnership agreement. Under the terms of this agreement, Bpifrance and IFPEN will be mobilizing their resources and expertise to promote the transfer of research results through the creation of startups in four key energy transition fields: sustainable mobility, the circular economy, energy efficiency and air quality. Bpifrance and IFPEN want to converge their respective objectives, in line with the strategic priorities formalized in the Deeptech plan drawn up by the French public authorities: transfer of public research results and support for startups mobilizing disruptive technologies.



**Interview with:**  
**Guillaume Lepage,**  
**Technological Development Manager, Naturamole**



*We met IFPEN at a French R&D ecosystem event. Among the various SME support mechanisms available, the Boost&Link™ partnership offered by IFPEN appealed to us on various levels. On the technical side, due to its advanced expertise in the field of separation processes and distillation technologies, IFPEN helped us develop a high-yield purification process delivering a high level of purity from an active ingredient derived from renewable resources. Secondly, the service is structured in a straightforward manner, with each step explicitly and clearly defined. Thirdly, the successful revenue model is an undeniable asset: as an SME, we do not need to provide any cash upfront. Building on this success, we plan to turn to IFPEN again for future development projects.*





# TRAINING TALENTED YOUNG PEOPLE FOR THE ENERGY TRANSITION

## AWARD

### HAPPYATSCHOOL® LABEL 2022

At the end of 2021, the School was awarded the HappyAtSchool® label, which recognizes schools that provide a happy environment for students to live and study in. Five criteria are used: the quality of facilities and protection of the environment, academic teaching, student life, proximity with companies and confidence in the future. Recommended by 91.3% of students from the 2021 intake, IFP School is among the French engineering schools offering the best student experience.



## EVENT

### AN IFP SCHOOL STUDENT DELEGATION INVITED TO THE ÉLYSÉE

A student delegation attended the presentation of the France 2030 Investment Plan by Emmanuel Macron, at the Élysée Palace in October 2021. IFP School, as an active player in the energy and ecological transition, was asked to contribute to the debate. To this end, invited students prepared a summary of the intake's ideas and vision relating to the challenges to be overcome and the actions to be implemented, including, for example, the promotion of hydrogen as a "zero-emission" solution, a theme that is an integral component of various programs delivered by the School and developed by LAB e-NOV™ in an on-line training module available to a wider public.



## DEVELOPMENT

### A SUSTAINED DYNAMIC

In 2021, despite a challenging health context, off-site programs led by IFP School in partnership with IFP Training continued apace. The second intakes of the Petroleum Upstream Techniques & Economics and Petroleum Downstream Techniques & Economics masters' programs in partnership with Institut national polytechnique Félix Houphouët-Boigny (INPHB) were welcomed in Côte d'Ivoire. Also worthy of mention is the 19th edition of the Petroleum Engineering and Project Development master's program, one of IFP School's first spin-off programs, which is based in Nigeria. This development dynamic was also reflected in the broadening of industrial partnerships to include around twenty new companies operating in the energy transition, finance and consultancy sectors, among others. The development of IFP School also hinges around the promotion of research activities via the four teaching chairs it leads: Electricity and



Digital Transition (EDT); Electric, Connected and Autonomous Vehicles for Smart Mobility (ECAV); Carbon Management and Negative CO<sub>2</sub> Emissions Technologies Towards a Low-Carbon Future (CarMa) within the framework of which agreements were signed with the CNRS and INRAE; and Electrolyte Thermodynamics (EleTher) launched in 2021.



#### Interview with:

**Arash Farnoosh, IFP School, EDT chair holder,  
Executive Master of Management in Energy program head**



*It was against the backdrop of a rapidly evolving sector that we launched the Electricity and Digital Transition chair in 2018. It was becoming increasingly necessary to understand the changes taking place in the energy industry in terms of transport, distribution and production in a world under carbon constraints having recourse to intermittent and non-storable renewable resources. Its results are significant and students have benefitted from it within the framework of the teaching programs: the chair covered technical and economic aspects and management as well as the digitalization of electricity via the digitalization of its tools, in particular, big data, real-time information, artificial intelligence and machine learning methods, an increasingly important component of future electric systems. In addition, publications (12 scientific articles since its creation), conferences and workshops, thesis research on the technical and economic challenges associated with the integration of renewable energies into the network, and, lastly, the arrival of Professor Peter Cowling (University of York, UK), a specialist in optimization and algorithms, contributed further still to the preparation of our students to tackle the challenges facing the sector.*



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IFP Energies nouvelles  
1 et 4, avenue de Bois-Préau  
92852 Rueil-Malmaison Cedex  
Tel.: + 33 1 47 52 60 00

IFP Energies nouvelles Lyon  
Rond-point de l'Échangeur de Solaize  
BP 3 – 69360 Solaize  
Tel.: + 33 4 37 70 20 00



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# MEETING TOMORROW'S CHALLENGE TODAY

- + IFP Energies nouvelles (IFPEN) is a major research and training player in the fields of energy, transport and the environment. From scientific concepts within the framework of fundamental research, through to technological solutions in the context of applied research, innovation is central to its activities, hinged around four strategic directions: climate, environment and circular economy – renewable energies – sustainable mobility – responsible oil and gas.



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