

ACTIVITY REPORT

2018

INNOVATING
FOR ENERGY

IFP
ENERGIES
NOUVELLES



OUR MISSION

CONTENTS

01 IFPEN, THE ESSENTIALS

01 Profile

Interview with Didier Houssin,
Chairman and CEO of IFPEN

04 Corporate governance

06 IFPEN news in 2018

08 2018 social and financial data

10 DEVELOPING THE INNOVATIONS OF TODAY AND TOMORROW

12 Sustainable mobility

18 New energies

26 Responsible oil and gas

32 Fundamental research serving innovation

38 CREATING WEALTH AND JOBS

40 A culture of innovation

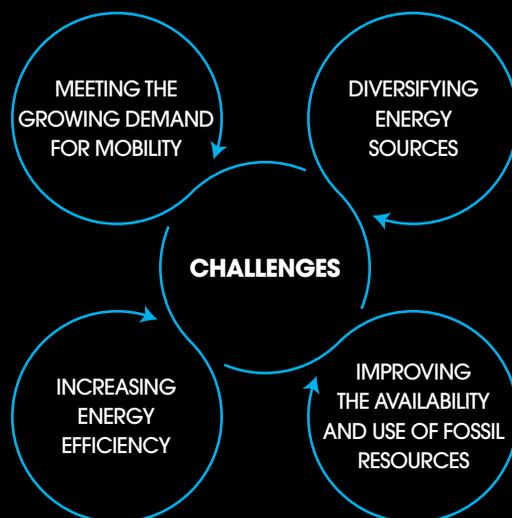
44 From research to industry

50 TRAINING THE KEY PLAYERS IN THE ENERGY TRANSITION

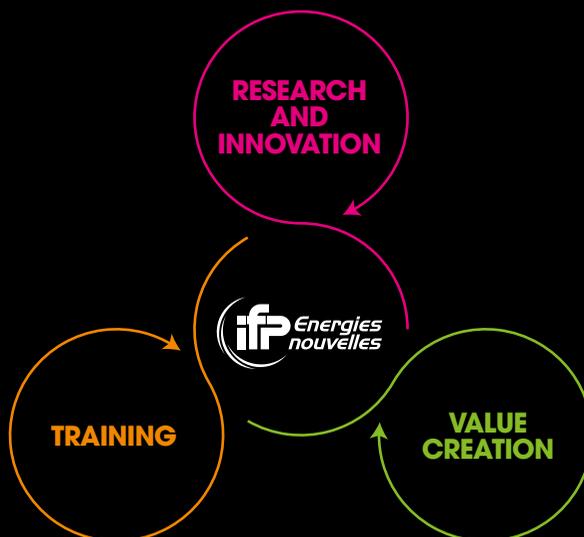
52 IFP School

A CONTEXT

CLIMATE CHANGE AND THE ENERGY TRANSITION



THREE PRIORITY AREAS



IFP Energies nouvelles

is a major research and training player in the fields of energy, transport and the environment. From research to industry, technological innovation is central to all its activities, structured around three strategic priorities: sustainable mobility, new energies and responsible oil and gas.

AS PART OF THE PUBLIC-INTEREST MISSION WITH WHICH IT HAS BEEN TASKED BY THE PUBLIC AUTHORITIES, IFPEN FOCUSES ON:

- > providing solutions to take up the challenges facing society in terms of energy and the climate, promoting the transition towards sustainable mobility and the emergence of a more diversified energy mix;
- > creating wealth and jobs by supporting French and European economic activity, and the competitiveness of related industrial sectors.

An integral part of IFPEN, its graduate engineering school – IFP School – prepares future generations to take up these challenges.

PUBLIC/PRIVATE FUNDING

IFPEN has proven expertise across the entire value chain, from fundamental research to innovation. It is funded both by a state budget and by its own resources provided by industrial partners. The latter account for over 50% of IFPEN's total budget, a configuration that is almost unique in France.

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.

FUNDAMENTAL RESEARCH, THE BUILDING BLOCK FOR FUTURE INNOVATION

IFPEN's fundamental research program aims to create a bedrock of knowledge essential for the development of innovations. The scientific expertise of IFPEN's researchers is internationally recognized and they are regularly consulted by the public authorities to provide their insight in their specific fields to inform the decision-making process.

THE CREATION OF WEALTH AND JOBS

IFPEN's economic model is based on the transfer to industry of the technologies developed by its researchers. This technology transfer to industry generates jobs and business, fostering the economic development of fields and approaches related to the mobility, energy and eco-industry sectors. IFPEN's innovations are brought to market through close partnerships with industrial players and IFP Group subsidiaries. In both emerging and mature markets, IFPEN creates companies or acquires stakeholdings in companies of significant potential, either directly or via capital funds. In addition, and as part of collaboration agreements, IFPEN supports the development of SMEs and SMLs which in turn benefit from its technical and legal expertise.

INTERNATIONAL SCOPE

IFPEN is an active player in numerous projects, technological platforms and networks within the context of the European Horizon 2020 Framework Program, and is contributing to the emergence of a European vision of research in the fields of mobility and energy. IFPEN works with over 100 academic and industrial partners, international companies and SMEs around the globe, through collaborative projects, consortiums or bilateral contracts.

TRAINING, A VECTOR FOR COMPETITIVENESS

Against the backdrop of the energy transition, IFP School and IFP Training provide industry with the highly qualified personnel it requires to take up current and future technological, economic and environmental challenges. IFP School operates within a highly international environment and provides young graduate engineers with advanced graduate programs in the fields of energy, motor vehicles and the environment. Over 500 students from throughout the world graduate from IFP School each year. IFP Training, an IFPEN subsidiary, offers training courses to almost 15,000 employees from industry every year, securing their competitiveness.

INTERVIEW WITH **DIDIER HOUSSIN**

Chairman and CEO of IFPEN

2018, A KEY YEAR FOR THE TRANSFORMATION OF IFPEN

“

Today, new energy and mobility technologies account for more than 50% of our research programs, which are supported by a solid bedrock of fundamental research. This rapid transformation reflects our capacity to look forward to the future, drawing on our experience and our strengths.

”



As is the case throughout the energy sector, IFPEN is engaged in a major transformation process. The objective is to make IFPEN a leading research center for new mobilities and new energy technologies.

Over the decades, we have developed expertise to turn our research results into industrial and technological innovations. This specific characteristic of IFPEN is made possible by the bridges we have built between fundamental research, applied research and industrial technologies. We currently channel our knowledge and expertise into supporting the energy and ecological transition. Today, new energy and mobility technologies account for more than 50% of our research programs, which are supported by a solid bedrock of fundamental research. This rapid transformation reflects our capacity to look forward to the future, drawing on our experience and our strengths.

IFPEN's priorities are in line with the French Government's objectives concerning the energy and ecological transition. 2018 was an opportunity for IFPEN to contribute to the development of public policies, within the context of both the French long-term energy program (PPE) and the drafting of framework legislation governing French mobility.

In 2018, our expertise covering the evolution of the transport and mobility sector was also reflected in the E4T study (Economic, Energy and Environmental Study for French Road Transport Technologies) conducted with ADEME on vehicle electrification. In particular, this study demonstrated the contribution of the life cycle analysis (LCA) method used by IFPEN for its projects. In parallel, the profile of our research in the field of electric, connected and low-environmental impact mobility was reinforced, with, for example, the development of an electric machine for mid-category cars and a smartphone application aimed at reducing vehicle pollutant emissions.

In the field of new energies, in 2018, we launched a number of projects, with the support of our administrators, industrial committee members and the Scientific Board. These concern, for example: CO₂ storage, plastics recycling, a field in which IFPEN's teams are working on the chemical recycling of colored and opaque bottles and thermoformed PET, lithium production and stationary electricity storage, a segment in which IFPEN is developing alternative technologies to lithium-ion batteries.

In the field of responsible oil and gas, our programs are aimed at helping our subsidiaries and industrial partners to develop their markets. Our main activities relate to the

development of clean fuels and the energy efficiency of refining and petrochemicals processes. Today, this long-established field of activity is entirely financed by our industrial partners. As a result, the objective, set for 2020, in our 2016-2020 Objectives and Performance Contract was attained in 2018, which is something we can all be very proud of.

In the transition phase that we have begun, proposals for new ideas and new concepts have been encouraged more than ever before. In fact, this was the aim of the internal participative innovation challenge finalized in 2018, which demonstrated the creativity, motivation and mobilization of teams to reinforce our portfolio of innovative projects. The past year also saw the introduction of an ambitious action plan to support IFPEN's digital transformation, the objective being to improve our operational efficiency and develop new products with a view to enriching our digital offer.

The transfer of our research results to industry lies at the heart of our strategy. Hence, in 2018, we filed 188 patents, almost half of which concerned new energy technologies, placing us 12th in the 2018 ranking of French patent filers and 3rd in the ranking of leading public research centers. Our research was once again widely recognized across the scientific community, as reflected in the prizes and awards won by our researchers and PhD students. For example, the French Chemistry Society (Catalysis Division) chose Céline Chizallet as the recipient of its young researcher award and the 2018 L'Oréal-Unesco "For Women in Science" fellowship was awarded to Céline Pagis. In 2018, we also submitted nearly 60 project proposals to funding agencies such as ANR and ADEME, as well as within the context of the H2020 European program.

In order to foster the emergence of the technologies of the future and new energy transition players, IFPEN implements a proactive company support and spin-off policy, and encourages the creation of start-ups. By way of illustration, two start-ups, Galanck and Geovelo, joined IFP Group in 2018 in the field of new mobilities, following DriveQuant, a company created in 2017 and now thriving.

2018 was thus a pivotal year for our transformation, with numerous challenges to be met as well as some impressive collective successes. They are the proof of the dynamic capabilities of IFPEN's employees and their commitment to the development of technologies for the energy transition and sustainable mobility.

I hope you enjoy reading this report!

CORPORATE GOVERNANCE

THE EXECUTIVE

COMMITTEE



GENERAL MANAGEMENT

- 1 Didier Houssin**
Chairman and CEO
- 2 Pierre-Henri Bigeard**
Executive Vice-President Research and Innovation
- 3 Éric Lafargue**
Executive Vice-President Administration and Management of Subsidiaries

BUSINESS UNIT DIRECTORS

- 4 Catherine Rivière**
Energy Resources
- 5 Jean-Pierre Burzynski**
Processes
- 6 Gaëtan Monnier**
Transport
- 7 Christine Travers**
Education and Training
- 8 Nathalie Alazard-Toux**
Industrial Development

OTHER MEMBERS OF THE EXECUTIVE COMMITTEE

- 9 Véronique Ruffier-Meray**
Human Resources Director

THE BOARD OF DIRECTORS*

STATE REPRESENTATIVES

Adrien Bichet

Head of the Energy, Stakeholdings, Industry and Innovation bureau at the Budget Directorate, representing the Minister of Budget

Frédéric Ravel

Scientific Director of the Energy, Sustainable Development, Chemistry and Processes sector at the Research and Innovation Strategy Service at the General Directorate for Research and Innovation, representing the Minister of Research

Franck Tarrier

Deputy Director of the Transport Equipment, Machinery and Energy Division at the General Directorate for Enterprise, representing the Minister of Industry

Marie-Solange Tissier

President of the Regulation-Resources section at the High Council for the Economy, Industry, Energy and Technology, representing the Minister of Energy

QUALIFIED MEMBERS

Didier Houssin

Chairman and CEO

Carla Gohin

Director of Research, Innovation and Advanced Technologies of PSA Group

Hélène Jacquot-Guimbal

Managing Director of IFSTTAR (French Institute of Sciences and Technology for Transport, Development and Networks)

Bruno Jarry

President of the Académie des technologies (French Academy of Technologies)

Hervé Le Treut

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

Claude Nahon

Sustainable Development and Environment Director of the EDF group

Sophie Paturle-Guesnerot

Managing Partner of Demeter Partners

Axel Plasse

Deputy-Director, Engine and Gearbox Development Strategy, Renault-Nissan-Mitsubishi Alliance

Philippe Sauquet

President Gas, Renewables & Power, and President, Group Strategy-Innovation, Total

Raphaël Schoentgen

CEO, Hydrogen Advisors

STAFF REPRESENTATIVES

Michel Castagné

Marie Velly

WITH THE ATTENDANCE OF

Nathalie Deguen

Economic and Financial General Controller, Ministry of the Economy

Philippe Geiger

Deputy Director of Energy, Ministry for Ecological and Inclusive Transition

Guillaume Gougeul

Secretary of the Central Works Committee

Grant Thornton et Deloitte & Associés

Statutory Auditors

* As of 17 April 2019

THE SCIENTIFIC BOARD*

Grégoire Allaire

Chairman of IFPEN's Scientific Board, Professor of Applied Mathematics at the École polytechnique, Senior University Professor

Janne Blicher-Toff

Director of Research at the CNRS and Professor of Geosciences at the École normale supérieure de Lyon

Carmen Claver

Professor of Inorganic Chemistry at Rovira i Virgili University, Tarragona

Christophe Coperet

Professor of Molecular Chemistry and holder of the surface and interface chemistry chair at the École polytechnique fédérale, Zürich

Marc-Olivier Coppens

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

Patrick Criqui

Director of research at the CNRS, head of the Sustainable Development and Energy Economy team at the GAEL Laboratory of the CNRS and Grenoble-Alpes University

Luigi Del Re

Professor at Johannes Kepler University, Linz, Head of the Institute for Design and Control of Mechatronical Systems

Jocelyne Erhel

Director of Research at INRIA (French Institute for Research in Computer Science and Automation)

Mohamed Gabsi

Professor and Head of the Electronics-Electrical Engineering Department at the École normale supérieure de Paris-Saclay

Anke Lindner

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

Michèle Marin

President of the INRA Occitanie Center in Toulouse

Jean-François Minster

President of the Île-de-France Photovoltaic Institute

Christine Rousselle

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

Michel Sardin

Emeritus Professor at the University of Lorraine – National Polytechnical Institute of Lorraine – Chemical Industry Engineering School (INPL-ENSIC), Advisor at the ICEEL Carnot Institute, Nancy

Luc Vervisch

University Professor at the Institute of Applied Sciences (INSA), Rouen

* As of 17 April 2019

IFPEN NEWS IN 2018: IN BRIEF

IFPEN'S CONTRIBUTIONS TO PUBLIC POLICIES

IFPEN took part in the reflection processes and helped to draft the French Energy and Climate Strategy, presented at the end of 2018 by the Government. In particular, its contribution related to biofuels, clean mobility and carbon pricing. IFPEN also took part in the public debate organized within the context of the French long-term energy program (PPE) via several workshops and the publication of a guide relating to lignocellulosic biofuels (see p. 40).

In addition, in anticipation of the review of France's draft framework legislation on mobility, IFPEN's experts were called upon by various National Assembly and Senate bodies to provide insights relating to themes such as clean mobility, advanced biofuels and the end of IC vehicles by 2040.



2018 GECO AIR CHALLENGE: A 1ST NATIONAL EDITION

After four editions organized in the Greater Lyon metropolitan area, IFPEN, supported by ADEME, introduced an international dimension to the 5th edition of the inter-company eco-driving challenge. Several cities, air quality players, associations and public bodies mobilized to deliver concrete improvements to air quality. Participants in the challenge were able to help reduce emissions related to their journeys, using just a smartphone and the Geco air app, by adopting a smoother driving style and favoring soft transport modes.

IFPEN SERVING THE TERRITORY

At the end of 2018, IFPEN joined forces with the town of Rueil-Malmaison and Paris Ouest La Défense public local body to sign a framework partnership agreement aimed at serving the local territory and its residents through development and innovation. This agreement consolidates existing partnerships and defines strategic development priorities with a view to making the region an innovation pioneer. Joint projects will be conducted in the fields of the energy and ecological transition, sustainable mobility, entrepreneurship and digital technology.





THE DIGITAL TRANSFORMATION AT IFPEN: A STRATEGIC PRIORITY

The digital transformation, one of the strategic priorities underpinning IFPEN's development policy, is the focus of an ambitious action plan launched in 2018. It is hinged around a functional dimension, aimed at improving the organization's overall performance, and a dimension concerning the structuring of R&I programs to develop new products and reinforce IFPEN's digital offer. For example, the plug im! platform, providing non-expert users with access to 2D and 3D signal and image processing, was launched on an open access basis aimed at the scientific community. In addition to the fields already covered by IFPEN's R&I activities, such as services for connected vehicles, numerous proofs of concept (POC) and projects were developed incorporating cross-disciplinary digital tools, methodologies and approaches. Examples include the wind turbine digital twin (see p. 21) in the field of new energies; or, in the field of processes, the new monitoring platforms making it possible to improve the predictive capabilities of simulators.



ENER220: A SUPERCOMPUTER SERVING INNOVATION

In August 2018, IFPEN commissioned a new supercomputer to address the fast-evolving needs of R&I teams in the fields of numerical simulation and high-performance computing. Replacing ENER110 at the IFPEN-Lyon site, this major piece of scientific equipment has doubled the power of its predecessor and complements the external computing resources researchers have access to through partnerships with leading French bodies.

NEW FORESIGHT STUDIES

IFPEN's expertise in the fields of energy geopolitics and transport was used within the context of two foresight studies conducted in 2018:

- The first concerned the evolution of energy geopolitics in the context of the low-carbon energy transition, the results of which were published at the end of the year. Conducted by IFPEN and its partner IRIS* within the framework of the ANR Generate (Geopolitics of Renewable Energies and Prospective Analysis of the Energy Transition) project, the study underlines the evolution from reliance on fossil resources towards other types of resources. It also highlights the strategic role of innovation in renewable energy technologies. Lastly, it reveals the impact of the price of fossil energies on the development of these technologies and, consequently, the influence of oil and gas-producing countries on the energy transition;
- the second study, called E4T, evaluates the various electric and hybrid vehicle technologies, their investment and operating costs and their environmental impact (see p. 15).

* French Institute for International and Strategic Relations

KEY FIGURES

(end of 2018)



SOCIAL & FINANCIAL DATA

SOCIAL DATA

To address the national priorities concerning the energy transition, making efficient use of the company's resources is an objective that depends on the implementation of a dynamic human resources policy. This policy makes the identification and anticipation of the skills required to develop high-level scientific and technical expertise a priority.



1,622 

Total full-time equivalent workforce for 2018

including **1,119** researchers

Nearly 200 research grant holders, post-doctoral researchers and trainees



400

employees have been mobile since 2015



76%

of employees benefited from at least one training initiative in 2018



4.86%

Proportion of disabled workers in 2018



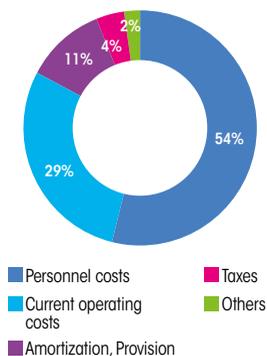
FINANCIAL DATA

There was an improvement in EBIT in 2018 compared to 2017, buoyed by an increase in the group’s own resources and nearly stable operating expenses, a significant share of which was diverted from some upstream oil activities to NETs, in line with IFPEN’s R&I redeployment strategy. It was against this backdrop that IFPEN’s oil and gas activities became self-financing in 2018, two years ahead of the commitments contained in the 2016–2020 Objectives and Performance Contract.

In 2018, the budget allocation was in line with the figure initially stated in the budget, due to the absence of loan cancellations during the financial year, which provided considerable visibility relating to the forecast-based management of R&I programs. It is now entirely dedicated to the funding of IFPEN’s NET activities.

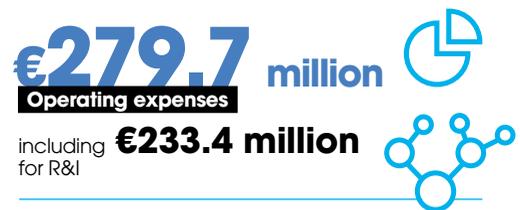
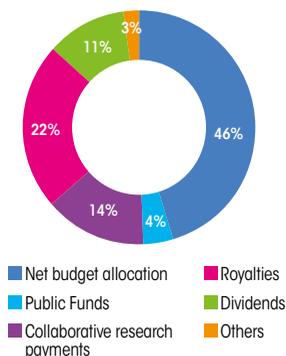
BREAKDOWN OF CURRENT EXPENDITURE

Financial end 2018



BREAKDOWN OF CURRENT REVENUE

Financial end 2018



WEIGHT OF NETS IN IFPEN R&I	%
Total NETs	55
New energies	17
Sustainable mobility	17
Cross-disciplinary fundamental research	21

IFP GROUP CONSOLIDATED ACCOUNTS	M€
Turnover	1,243.1
State Subsidy	128.3
EBIT	65.4
Net Profits Group share	35.3



DEVELOPING THE INNOVATION

IFPEN's commitment to the development of a sustainable energy mix is reflected in actions aimed at increasing energy efficiency, reducing CO₂ emissions and improving the environmental footprint of industry and transport, while meeting the global demand for mobility, energy and products for the chemicals sector.

With these objectives in mind, IFPEN develops solutions making it possible, firstly, to use alternative energy sources and, secondly, to improve existing technologies associated with the use of fossil energies. The aim of its research is to overcome existing scientific and technological challenges in order to develop economically competitive and energy-efficient innovations that can be used by industry. Its researchers develop processes, equipment, software and services as part of ambitious R&I programs, hinged around three main strategic priorities: sustainable mobility, new energies and responsible oil and gas.

In order to facilitate the emergence of its innovations, IFPEN draws on a solid fundamental research program. A veritable cross-functional bedrock, its purpose is to address scientific questions relating to the obstacles hampering the development of new products.

In total, more than 1,100 researchers, covering more than 50 professions, are mobilized day-to-day at IFPEN's two sites, representing the driving force behind a research strategy serving innovation and the energy transition.

Towards a new range of electric motors
without rare earth - p. 14

Futural process: market launch - p. 19

ArcoDES, new DionisoFlow
calculator - p. 30

Plug Im! : signal and image
processing available on an open
access basis - p. 32

2018 HIGHLIGHTS: THE ESSENTIALS >>>

INNOVATIONS

OF TODAY AND TOMORROW

- 12 **Sustainable mobility**
- 18 **New energies**
- 26 **Responsible oil and gas**
- 32 **Fundamental research
serving innovation**



SUSTAINABLE MOBILITY

25%
of global energy
demand is related to
the transport sector

Reducing CO₂ and pollutant emissions, diversifying energy sources and incorporating the evolution in transport modes: these are the challenges associated with sustainable mobility. IFPEN channels its expertise into addressing this triple challenge via the IFPEN Transports Energie Carnot Institute. This Institute is exploring three complementary technological avenues, namely vehicle electrification (from the hybrid to the electric vehicle), the development of services and applications for connected vehicles and, lastly, the improvement of IC engines, all with a view to improving energy efficiency, reducing emissions and optimizing the use of fuels, particularly low-carbon fuels.

The IFPEN Transports Energie Carnot Institute

Since 2006, IFPEN's activities in the field of transport and mobility have been conducted within the framework of the IFPEN Transports Energie Carnot Institute (IFPEN TE). Renewed in July 2016, this label is recognition of IFPEN's capacity to conduct joint research programs and support company innovation. The IFPEN TE Carnot Institute is an active member of the Carnot Institute network. It coordinates the Carnauto action dedicated to the car and mobility sector, and participates in the AirCar action, dedicated to the aviation sector.



HIGHLIGHT

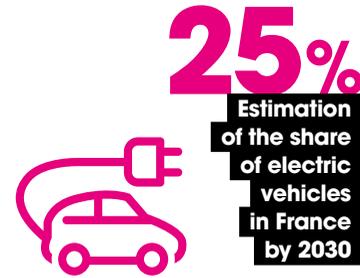
MEETING MOBILITY SECTOR PLAYERS

The IFPEN TE Carnot Institute forges relations with start-ups, SMEs and intermediate-sized companies operating in the car and mobility sectors at various events it either organizes or takes part in. The objective: to help these companies gain access to R&D support specific to their innovation need. For example, in 2018, the IFPEN TE Carnot Institute took part in:

- the Global Industrie Conference in March 2018, in Paris, bringing together more than 50,000 visitors and 2,700 exhibitors. At the Carnot pavilion, the IFPEN TE Carnot Institute presented its latest innovations in the motor vehicle sector, as well as its expertise in the aeronautics field;
- the annual "17-20 Carnot" event, in May in Paris, on the theme "Carnot: an international ambition." This was an opportunity to present the IFPEN TE Carnot Institute's international strategy and discuss the theme with the companies, organizations and institutional players attending the event;
- the 11th edition of the Carnot Events held in Lyon in October, where it met, at its booth, project leaders interested in its sustainable mobility services and solutions. The IFPEN TE Carnot Institute was also present in the area dedicated to the Carnauto action, where several of its developments were showcased.

Developing vehicle electrification

Vehicle electrification is crucial for significantly reducing CO₂ emissions in the transport sector and improving local air quality. Already enjoying significant growth, it will initially rely on different hybridization solutions adapted to usages. IFPEN's research is aimed at developing optimized and energy-efficient electrical systems. It concerns the development of innovative electric and hybrid machines, as well as the electrification of powertrain functions. IFPEN also designs technological solutions targeting waste thermal energy recovery. Lastly, in the field of batteries, IFPEN is focusing on the behavior of systems as well as aging and thermal runaway mechanisms.



WISSAM DIB
Electric Powertrains project
manager, IFPEN

“IFPEN aims to develop a range of electric motors with their power electronics, covering the needs of every market segment. Following a first version for small, no-license vehicles and a second one for urban cars, in 2018, we developed a synchronous reluctance electric machine prototype for compact cars requiring higher torque and power, of up to 140 kW. We introduced innovations with respect to the active parts of the machine and the mechanical integration of the system, with an inverter and a DC/DC converter directly incorporated in the motor housing. Advanced control laws were also developed for this application. The result is improved system efficiency and a significant reduction in costs. In parallel, we are working on a motor solution with a lower battery voltage (48 V), aimed, in particular, at hybrid vehicle applications.”

Recovering the thermal energy lost by vehicles

In order to improve the energy footprint of vehicles, IFPEN is working on onboard mechanical energy or electricity generation systems based on the recovery of waste thermal energy, both in the exhaust and in the engine cooling system. Objective: to reduce fuel consumption, increase engine performance and cover some of the onboard electricity requirements. The original solutions proposed by IFPEN include:

- an electric turbocharger making it possible to recover more exhaust energy than with a standard system;
- low-temperature energy recovery solutions based on Organic Rankine Cycles (ORC), capable of recovering the thermal energy lost in the engine cooling system. Developed in partnership with SME Enogia, these solutions can be adapted to both heavy trucks and light vehicles.



Watch video presenting
IFPEN's ORC solutions
for transport



HIGHLIGHT**TOWARDS ELECTRIC MOTORS WITHOUT RARE EARTHS**

The use of rare earths for magnets represents a major obstacle for the development of electric powertrains at a reasonable cost. IFPEN is actively involved in the European H2020 ReFreeDrive project, which brings together 12 partners to develop a concept for an electric machine capable of operating without rare earths, and explore a new generation of inverters integrated in the motors. Within the project, launched in 2017, IFPEN is responsible for designing the electric machine, the inverter and the control strategy. A first version of a ferrite-based synchronous reluctance electric machine was thus developed in 2018 for medium-powered (75 kW) and high-powered (200 kW) electric powertrain applications. Find out more about the project: www.refreedrives.eu.

**HIGHLIGHT****A MICROTURBINE FOR ONBOARD ELECTRICITY GENERATION**

A microturbine is an electricity generator with a turbine that rotates at high speeds and can provide up to 100 kW of power. IFPEN focuses its efforts on a low-powered (less than 35 kW) microturbine technology, addressing electric vehicles' onboard electricity generation requirements (range extension, for example), as well as needs in other market segments such as yachting. In 2018, IFPEN developed and commissioned a demonstrator with a view to testing a complete electricity generation system incorporating a microturbine entirely designed by IFPEN (combustion chamber and exchangers), initially targeting low-powered (<8 kW) and low-voltage (48 V) applications.

95 g/km

Average CO₂ emissions objective set by the European Union for new vehicles by 2021

Modeling the thermal runaway of batteries

Controlling aging and thermal runaway mechanisms of lithium-ion batteries represents a major challenge in terms of ensuring the safety and maintaining the performance of electrified vehicles. For the past few years, IFPEN has been conducting research aimed at understanding and modeling these phenomena, using 3D and 0D/1D approaches. The research is being conducted jointly with Ineris and the LRCS*, as well as within the framework of the European H2020 Demobase** project. Launched in 2017 and coordinated by Saft, the 3-year Demobase project brings together 11 partners to conduct research aimed at reducing electric powertrain design efforts and improving battery efficiency and safety. IFPEN is responsible for developing thermal runaway models for the various lithium-ion battery cells, as well as evaluating the benefit of these models in the battery pre-design phases, taking safety into account.

* Solid Reactivity and Chemistry Laboratory

** Design and Modelling for improved BAttery Safety and Efficiency



Battery consortium: enrollments are now open!

Predict battery life-span with a view to improving dimensioning and integration: that is the objective of Comutes²*, a consortium created at the end of 2018 on the initiative of IFPEN and bringing together CEA Liten**, IFSTTAR***, IMS****, EIGSI***** and UTC*****. The partners' objective is to organize battery aging test campaigns, pooling data and testing facilities and sharing the costs and ownership of results with outside members. The first campaign, lasting two years, concerns low-temperature lithium-ion battery aging.

* Consortium for the pooling of electric tests on storage systems

** CEA Liten: European Institute Driving the Development of the Sustainable Energy Technologies of the Future

*** IFSTTAR: French Institute of Science and Technology for Transport, Development and Networks

**** IMS: Laboratory dedicated to Integration: from Material to Systems (CNRS UMR 5218)

***** EIGSI: General Engineering school - La Rochelle

***** UTC: University of Technology of Compiègne



HIGHLIGHT

INSIGHT CONCERNING VEHICLE ELECTRIFICATION

Working in partnership with ADEME, IFPEN analyzed the major trends and potential relating to vehicle electrification in France from three angles: energy, economics and the environment. Published in July 2018, the aim of the E4T* study was to identify the best technological choices as a function of usages by 2030. The key points to emerge from the study include:

- the significant slowdown expected in the production of gasoline and diesel vehicles by 2030 (excluding long haul trucks);
- the relevance from an ecological point of view of plug-in hybrid vehicles for private individuals in the medium term;
- the efficiency of electric vehicles in terms of reducing local pollution and CO₂ emissions, particularly if they are widely used, like buses.

A follow-up to this study, projecting forward to 2040, will be launched in 2019. This study will evaluate hydrogen, biofuel and natural-gas based energy systems.

* Economic, Energy and Environmental Study for French Road Transport Technologies



Download the summary of the main results of the E4T study (in French)

Towards connected mobility

The transport sector is currently undergoing a revolution on two fronts: technologies and usage, with the appearance of new forms of mobility. For several years, IFPEN has been exploiting the potential offered by digital technology to reduce the environmental impact of transport, proposing web services and apps for connected vehicles, from eco-driving to the evaluation of pollutant emissions, via energy analysis. Targeting ever cleaner and safer mobility, IFPEN is now reinforcing its initiatives in the fields of air quality, with the creation of new tools and software services for pollutant emission monitoring, and soft mobility options.





HIGHLIGHT

GECO AIR, AN APPLICATION TO SUPPORT AIR QUALITY

Two years after its launch, *Geco air*, the smartphone app that estimates a vehicle's real-time pollutant and CO₂ emissions, continues to be enhanced and is gaining in popularity among private individuals, local authorities and air quality players. In addition to major functional developments, trials with major cities are under way.

An increasingly powerful algorithm

Since 2018, *Geco air* has integrated new algorithms used to estimate the total fine particle emissions associated with a journey, including non-exhaust emissions, those for example associated with worn tires and brake pads. Depending on driving style (braking, sudden accelerations, etc.), pollutant emission levels from wear and tear can increase by 100%! In addition, *Geco air* now includes a model of fine and ultra-fine particles specific to direct-injection gasoline vehicles. Lastly, the *Geco air* eco-driving challenge, organized nationally for the first time in 2018, generated new real data further reinforcing the relevance of the app.

A public decision-making tool

While *Geco air* was initially designed to help users become "eco-mobility drivers", the possibilities offered by the application are much broader. By analyzing the data provided by users, it is possible to draw up real-time local maps of pollutant emissions across a region. In 2018, two such experiments were launched:

- in the Auvergne-Rhône-Alpes region, as part of the *Airmap* project. Selected by Lyon Metropolis within the framework of its [R]Challenge, this project brings together IFPEN, Vinci Autoroutes (French highways operator) and the Direction interdépartementale des routes Centre-Est (Center-East regional roads and highways Directorate);
- in the Provence-Alpes-Côte d'Azur, as part of the *Airmes* project. Winner of the Primequal* call for projects, *Airmes* is being conducted with Aria Technologies and AtmoSud, the local air quality network, in the Euromed district of Marseille.

By making it possible to visualize and understand the impact of urban infrastructure on vehicle pollution, *Geco air* facilitates local authority decision-making concerning urban planning, road development and traffic management.

* A French inter-body research program for improved air quality, implemented by the Ministry for Ecological and Inclusive Transition and ADEME

MORE THAN

30 MILLION

km traveled with the Geco air application

Solutions for the connected bicycle

As part of its partnership with the start-up La Compagnie des Mobilités, IFPEN is developing modules for the Geovelo app used to evaluate the energy expenditure relating to a specific journey and qualify the conditions of cycle paths in real time. The objective: to promote the safe and secure use of bicycles in urban zones.



Watch a video showing how IFPEN and Geovelo are facilitating the use of bicycles in towns (in French)

Efficient models for battery dimensioning

With more than ten years of experience, IFPEN is now recognized as a leading player in battery modeling and simulation. Reflecting this successful positioning, IFPEN co-develops models integrated in the Electric Storage library of the Simcenter Amesim™ system simulation platform marketed by Siemens PLM Software. This library is enjoying growing success with industrial players, for the battery pack dimensioning and pre-design phases. Constantly enhanced and updated, these models are capable of representing the electrothermal behavior of batteries and their aging, as well as thermal runaway phenomena affecting lithium-ion batteries.

Developing low-impact IC powertrains

In the context of the tightening up of global regulations and the increasing restrictions placed on IC vehicles – particularly diesel – in towns and cities, industrial players are rapidly evolving their offers. To meet ambitious objectives relating to pollutant and CO₂ emissions by 2030, improvements in IC powertrains are required. The gasoline engine, integrated into a hybrid powertrain, will remain the dominant technology during this period for the majority of light vehicles. And diesel will be the reference fuel for industrial vehicles and heavy trucks, while kerosene will continue to be used in the aviation sector. In line with these forecasts, IFPEN is conducting research to increase the efficiency of IC engines and reduce pollutant emissions. Its research is also aimed at identifying low-carbon fuels (natural gas, biofuel, hydrogen) presenting more favorable energy and environmental footprints, and optimizing their use in engines.

14%

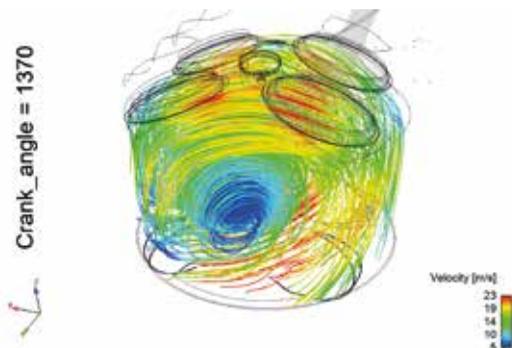
The minimum share of renewable energy* in road and rail fuels by 2030 (European REDII directive)

* 1st and 2nd generation biofuels and synthetic fuels produced from green electricity, known as e-fuels

HIGHLIGHT

TOWARDS HIGHLY-EFFICIENT GASOLINE ENGINES

In order to improve the thermodynamic efficiency of gasoline powertrains operating with a stoichiometric mixture, IFPEN has developed and optimized a new generation of combustion systems using an original swumble-type internal aerodynamic approach. Having been demonstrated on a 1 liter – 3 cylinders – 2 valves per cylinder powertrain in 2017, this approach was successfully transferred to a 4 valves per cylinder engine in 2018. A maximum effective efficiency of 43% and efficiencies in excess of 37% over a broad operating range were achieved, while significantly reducing particulate emissions across the emission spectrum.



Measuring and understanding unregulated pollutant emissions

IFPEN continues its research aimed at qualifying emissions of ultra-fine particles – with a diameter of below 23 nanometers – and pollutants not yet subject to European regulations. There are two objectives: firstly, to be capable of identifying development avenues for the design of future pollution control systems and, secondly, to help legislators define the best emission reduction regulatory mechanisms. IFPEN contributed to the CAPPNOR 2 project, supported by ADEME, resulting in the acquisition of new knowledge concerning French vehicle emissions in urban zones, particularly particulates yet to be regulated. It is currently taking part in the European H2020 SUREAL-23* project, with a view to developing new onboard measurement technologies for ultra-fine particulates. Responsible for testing different technologies, in 2018, IFPEN conducted test bench experiments to measure ultra-fine particulates resulting from combustion in a direct injection gasoline engine. Lastly, within the context of the ADEME RHAPSODIE project, in 2018, IFPEN conducted a campaign to measure soot precursors emitted by Euro 6 gasoline and diesel vehicles.

* Understanding, measuring and regulating sub-23 nm particle emissions from direct injection engines including real driving conditions

HIGHLIGHT

NEW TOOL FOR MEASURING THE THERMAL STABILITY OF JET FUELS

IFPEN and AD Systems, an SME specializing in test equipment for the evaluation of oil product properties and performances, co-developed a device used to characterize the thermal stability of fuels for the aviation industry, a major problem stemming from the use of new combustion systems and fuel diversification (introduction of biofuels, for example). Called TO10 and marketed by AD Systems, the instrument was approved by the ASTM in 2018. It incorporates models developed by IFPEN describing the thermal stability of jet fuels. IFPEN is pursuing its collaboration with AD Systems with the development of a new instrument dedicated to qualifying the thermal stability of diesel.





NEW ENERGIES

The energy transition and tackling climate change depend, among others, on the use of new resources such as lignocellulosic biomass and offshore wind energy, the potential of which is set to expand. IFPEN develops sustainable fuel and chemical intermediate production processes based on the use of biomass, as well as technological solutions for the development of ocean energies. IFPEN also proposes energy storage technologies. In addition, with a view to reducing greenhouse gas emissions at source, IFPEN is conducting research to improve CO₂ capture and storage processes. Lastly, IFPEN is investing in new themes, with projects in fields as varied as geothermal energy, rare earths and critical metals, as well as environmental monitoring.

Biofuel production

The R&I work taking place around the world in the field of biofuel production focuses on the development of so-called 2nd generation (“advanced” biofuel) technologies, using lignocellulosic resources such as agricultural and forestry waste. While requiring processes that are technologically more complex than for conventional (or 1st generation) biofuels, these biofuels benefit from a resource that is more widely available, as well as a more favorable environmental footprint. They are set to enjoy their industrial boom in the decade from 2020-2030. IFPEN’s activities cover the two main processes for the conversion of biomass into fuel: biotechnological conversion (bioethanol production) and thermochemical conversion (biodiesel and biokerosene production), also known as BtL (Biomass to Liquid) technology. The research covers the entire process chain, from pre-treatment of lignocellulose to fuel production, via the optimization and integration of the different steps, in both economic and environmental terms.

ALMOST
1/3

**of the total energy consumed in Europe
should come from renewable sources
by 2030 (REDII directive)**

REDII, a key directive for advanced biofuels in Europe

Since the publication in the OJEU on 21 December 2018 of the definitive text pertaining to the agreement of European Union member states revising the renewable energy directive (REDII), the European advanced biofuels market is now governed by a clarified regulatory framework. In particular, the new directive sets a ceiling for the incorporation of conventional biofuels (1st generation) in the transport sector of a maximum of 7% in European Union countries from 2021 and an incorporation target for advanced biofuels of 3.5% in 2030. In line with these priorities, IFPEN is actively involved in the development of advanced biofuels processes, using all types of non-food lignocellulosic biomass.

HIGHLIGHT**FUTUROL PROCESS: MARKET LAUNCH!**

After 10 years of research, the French Futurol project targeting the development of a 2nd generation bioethanol production technology was successfully completed at the end of 2018. IFPEN was a key player in this collaborative project, which brought together 11 partners*. The process base set was finalized in 2018, after a last series of tests conducted on the Pomacle-Bazancourt (Marne, France) pilot to qualify a broader spectrum of biomass than the straw used previously. Futurol technology has now entered the marketing phase, which will be handled by Axens. Presenting a more favorable environmental footprint than that of 1st generation processes, this technology is also economically competitive and adapted to different types of biomass, ensuring it can be continuously used anywhere in the world. The Pomacle-Bazancourt pilot facility will be available over the next few years for trials to support the commercialization phase.

* ARD, IFPEN, INRA, Lesaffre, Office national des forêts, Tereos, Total, Vivescia, Crédit Agricole Nord Est, CGB, Unigrains

Vehicle emissions: proposals contained in the New Resources solutions

IFPEN leads the Advanced Biofuels working group of the French New Resources solution. Within this context, IFPEN contributed to the drawing up of a paper on "Regulations governing emissions for new private cars and for new light commercial vehicles", currently being revised at European level. Conscious of the crucial role that biofuels already play and will continue to play in the future for the decarbonization of transport (and road transport, in particular), the working group conducted a reflection process over a period of several months, the results of which were summarized in a position paper at the end of 2018. It proposes an original approach to rewarding the development efforts of manufacturers who market vehicles compatible with the incorporation of high proportions of biofuels. The greater the extent to which manufacturers anticipate the proportions imposed by regulations, the more credits they will receive in the form of a CO₂ reduction.

HIGHLIGHT**BIOTFUEL PROJECT: FINAL STAGES PRIOR TO MARKETING**

In the field of thermochemical conversion, IFPEN is one of the leading players in the BioTfuel project, supported by ADEME, the objective of which is to develop and launch to market an advanced biofuel (biodiesel and biokerosene) production process chain by 2020. The two demonstration pilot units (one for the pre-treatment of biomass by torrefaction at Avril Group's site in the northern French town of Venette in the Oise area (France); the other for the gasification of the torrefied biomass at Total's site near Dunkirk) have been started-up in 2018, paving the way for R&D tests in 2019. They will be used to validate the sequence of technologies retained and guarantee industrial-scale extrapolation, as well as the overall efficiency of the process chain, the final steps prior to marketing.



Supporting biobased chemistry

Bio-based chemistry is now considered to represent a realistic option for producing the majority of the main intermediates currently derived from fossil resources, and used particularly for the production of plastics and synthetic textiles. This trend fits squarely with the growing demand on the part of consumers for more sustainable consumer goods and the threat of a deficit in the global supply of some olefins and aromatics. IFPEN is working on the development of processes, catalysts and biocatalysts for the transformation of biomass into bases for the chemicals sector: alcohols, olefins and diolefins, oxygenated platform molecules and aromatics.



10%

Estimated average annual growth rate of bioplastics through to 2035

Bio-butadiene production: towards large-scale experimentation

Within the framework of the BioButterfly project, Axens, IFPEN and Michelin are developing a butadiene production process using fermented ethanol of plant origin. Supported by ADEME, the project is being conducted as part of a strategy to create a French bio-based synthetic rubber sector for the manufacture of tires. IFPEN conducted the first experiments on pilot units installed at the IFPEN Lyon site in 2017. The experimental data acquired confirmed the targeted economic and environmental performance of the process. Research has continued with the definition of an extrapolation pilot unit, the construction of which is being examined and could be launched in 2019. If it does go ahead, this pre-industrial demonstrator will enable IFPEN to validate the operation of the process and the quality of the butadiene produced. The partners are targeting validation of the technology by 2022.

Recycling colored and opaque plastics

While mechanical recycling works well for transparent, colorless PET plastic bottles, limitations exist when it comes to treating colored and opaque bottles and thermoformed PET. In order to make it possible to reuse these materials for the production of new containers that can, in turn, be subsequently recycled, IFPEN is working on chemical recycling. Its teams are conducting research aimed at developing a solution that can be used to convert colored, opaque or thermoformed PET flakes into a pure monomer, via depolymerization, depigmentation and decolorization. The research conducted so far has already resulted in the validation of the proof of concept regarding key elements of the process in the laboratory. Moreover, a pure monomer was obtained from dozens of kilos of opaque PET flakes, confirming the technical and economic feasibility of the options retained.

HIGHLIGHT

PRODUCTION OF BIO-AROMATICS: EXCELLENT RESULTS FOR THE BIO-TCAT™ PROCESS PILOT UNIT

In 2015, IFPEN and Axens joined forces with American company Anellotech to develop Bio-TCat™, a process for the thermocatalytic conversion of lignocellulosic biomass with a view to the competitive production of bio-aromatics. In March 2018, a continuous test was conducted over a period of 14 days on the TCat-8® pilot unit installed at Anellotech's Silsbee site in Texas. Since then, the unit has notched up a cumulative total of more than 5,000 hours of operation; during this period, the technologies and the pilot unit's process control have been validated and its efficient operation demonstrated. In addition, research focusing on biomass pre-treatment continued throughout the year. Once the development phase has been completed, the industrialization and marketing of Bio-TCat™ technology will be handled by Axens.

Offshore wind and ocean energy development

In the field of renewable energies, offshore wind energy and wave energy represent emerging – yet hitherto little exploited – alternatives for the future. IFPEN is contributing to their growth, drawing on long-established expertise in the fields of offshore oil production and advanced control for the automobile sector. Its efforts focus on three main areas: the development of technologies for floating wind turbines, the design of more efficient control systems for wind turbines and the integrated simulation of the behavior of wind turbines in their environment. IFPEN is also contributing to the development of efficient wave energy technology that can be used by industry.

Wind turbine 4.0: promoting innovative solutions

In June 2018, IFPEN hosted a design thinking workshop on the theme “wind turbine digital twin”. The digital twin is the virtual version, developed on a computer, of a product or object, used to simulate and predict its operation. The purpose of this two-day creative process was to work with customers and potential partners to design a digital solution for wind turbines aimed at optimizing their operation and maintenance. More than twenty participants were mobilized: energy companies, sensor suppliers, turbine suppliers, maintenance and safety specialists, as well as IT professionals. The workshop was brought to a successful conclusion with a collective pitch before a panel of investors. Following the considerable interest shown in this initiative, IFPEN will host another workshop dedicated to digital twin applications in 2019.



18.5 GW

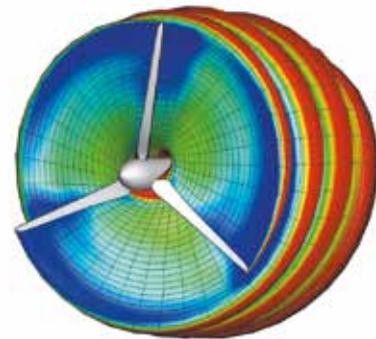
of installed capacity for offshore wind energy at the end of 2018 in Europe



PAULINE BOZONNET

DeepLines Wind™ project manager

“IFPEN developed DeepLines Wind™ software in order to simulate the dynamic behavior of floating offshore wind turbines, in partnership with Principia, the company responsible for marketing the solution since 2015. Some of the features were taken from the DeepLines™ solution dedicated to the dynamic analysis of seabed-surface links, such as the calculation of the force of the waves and current on a floating body and the calculation of structural deformations. Alongside these, aerodynamic calculation capacities developed by IFPEN were incorporated to analyze the effects of wind on wind turbine blades, as were features associated with command control. IFPEN’s R&I contribution is now being used to perform combined mechanical simulations of all of the wind turbine’s components using the same software. In 2018, we also developed new simulation methods, particularly concerning wake effects between wind turbines. The performance of DeepLines Wind™ has been demonstrated within the framework of projects conducted by IEA-Wind, the international wind energy cooperation network. We are also using it to design an innovative floater solution with SBM Offshore.”



CO₂ capture and storage

Despite a context that has not been conducive to its industrial development so far, CCUS, or Carbon Capture, Utilization and Storage, is still considered to be a key contributor to the reduction in CO₂ emissions and the attainment of objectives defined by COP21. The creation, at the end of 2016, of a one-billion dollar fund – the Oil & Gas Climate Initiative – by ten major companies, dedicated to the development of technologies, such as CCUS, aimed at significantly reducing CO₂ emissions, is a step in this direction. In terms of capturing the CO₂ emitted by energy-intensive industries, IFPEN is focusing its research efforts on two priority areas: oxycombustion with chemical looping combustion and post-combustion capture by solvents. Research concerning CO₂ storage relates, in particular, to the development of storage site modeling and monitoring tools.

14%

The potential contribution of CCUS to the reduction in CO₂ emissions by 2060 (the IEA Blue Map scenario)

HIGHLIGHT

DEVELOPMENT OF A TECHNOLOGY TO MONITOR THE INTEGRITY OF CO₂ STORAGE FACILITIES

Working in partnership with Ensegid* and five industrial players, IFPEN is actively involved in the AquiferCO₂leak project, to develop a technology used to monitor the integrity of CO₂ storage facilities in potable surface water and aquifers. Launched in April 2018 for a period of four years, the project, requested by ADEME, its primary backer, enjoys additional funding from the Aquitaine region and has been labeled by the Avenia competitiveness cluster. IFPEN's researchers are contributing their expertise for the implementation of methodologies stemming from their R&I, the development of technological tools and the acquisition and processing of data with a view to real-time on-site interpretation. Ultimately, the project will enable the development of solutions for monitoring geological CO₂ storage as well as surface natural gas storage.

* Graduate school of environmental, geological and sustainable development engineering (University of Bordeaux INP), project coordinator



Post-combustion capture: reduced energy consumption

The DMX™ process developed by IFPEN is a second-generation process making it possible to reduce the energy consumption associated with post-combustion capture. Dedicated to capturing the CO₂ in the emissions of industrial facilities (coal-fired power plants, cement plants, steel works, etc.), the solution makes it possible to improve the performance of traditional amine-based processes, which require a significant amount of energy for solvent regeneration. The target energy saving is between 30 and 40%. The solution hinges around a high cyclic capacity demixing solvent that is chemically stable. The tests conducted on a mini-pilot facility at IFPEN Lyon demonstrated the efficiency of the process on a small scale and on synthetic gas. Its demonstration is scheduled on an industrial pilot unit at a site in Dunkirk within the framework of an H2020 project due to be launched in 2019, in partnership with ArcelorMittal, Total and Axens.

HIGHLIGHT

THE USE OF UNDERGROUND ENVIRONMENTS: LAUNCH OF A PROJECT ON SOCIAL ACCEPTABILITY



IFPEN is actively involved in the four-year GEFISS (Gouvernance élargie des filières d'ingénierie du sous-sol - wider governance for underground engineering sectors) project, launched in July 2018 and led by the Géodénergies SIG*. While the deployment of underground engineering projects (CO₂ storage, geothermal energy, energy storage, oil and gas production) is fundamentally important to the energy transition, such projects raise questions and, indeed, opposition, among stakeholders from civil society. The aim of GEFISS is to propose new forms of exchange in order to construct informed dialog surrounding projects involving the use of underground resources and the conditions for their implementation. Backed by ADEME and coordinated by Actys-Bee, this project is being conducted in partnership with the Commission nationale du débat public (French national public debate commission), the consultancy sector, research centers, universities and think tanks and is supported by service and energy providers.

* Scientific interest Group

Developing energy storage

The emergence of variable renewable energies, such as solar and wind power, requires the provision of solutions to compensate for production variations, guaranteeing the stability of the supply network and smoothing out consumption peaks that will result from the development of electrification in new sectors, such as transport. To guarantee this balance, several solutions exist, including the increased densification and interconnection of transport and distribution networks, consumption management as a function of production and stationary electrical energy storage. IFPEN's research efforts are focused on the latter, targeting the development of alternative technologies to lithium-ion batteries.

HIGHLIGHT

IFPEN MICROGRID: ELECTRICITY STORAGE SYSTEM TESTING

For the purposes of its research concerning stationary energy storage systems, IFPEN has installed a Redox flow battery demonstrator integrated in a microgrid at its Lyon site. Launched in August 2018, this demonstrator consists of a photovoltaic panel, an electric vehicle charging point and an electricity storage system. The objectives are, firstly, to be able to test the properties and battery use limits in a representative environment and, secondly, to validate energy management systems (EMS) that manage and optimize the storage operation and make it possible to integrate variable amounts of electricity of solar or wind origin into the network.



Energy management solutions to support the energy mix

As part of its commitment to supporting a sustainable energy mix, IFPEN designs tools dedicated to the insertion of variable renewable energies in electricity networks. Research areas relate in particular to EMS (Energy Management Systems), IT systems and equipment integrated into smart grids, on a building, district or town scale. An EMS makes it possible to fully exploit a storage system within a specific network. Such systems are designed to optimize energy consumption and cost by quantifying its use, evaluating needs in predictive mode and making it possible to manage stocks as well as supply sources. Thanks to their expertise in the field of data science and the testing facilities available at the Lyon site, such as the microgrid, IFPEN's teams are focused in particular on the development of energy cost optimization systems including the incorporation of storage battery aging, and smart energy consumption prediction models.

Spotlight on Redox flow batteries :



Interview of
Joseph Martin
(in French)



Interview of
David Pasquier
(in French)

Investing in new markets serving the energy transition

Complementary R&I themes are emerging today to support the industrial development of new energy transition sectors. The fields covered by IFPEN include eco-efficient critical metal and rare earth production technologies, biogas purification solutions, hydrogen production and storage, geothermal energy and tools and equipment dedicated to the environmental monitoring of underground storage and usages.

HIGHLIGHT

TOWARDS NEW LITHIUM EXTRACTION AND CAPTURE SOLUTIONS

In order to optimize the use of existing lithium resources with a reduced environmental footprint, IFPEN and its partner Eramet developed an innovative and competitive direct extraction process, adapted to the waters of the Argentinian salt flats. The selective adsorbent on which the technology is based was validated in conditions representative of the process in July 2018, following six months of continuous operation of a semi-industrial pilot unit at Eramet's Trappes site. The pilot unit is currently being transferred to a site close to Eramet's concession (at an altitude of 4,000 m). The lithium that could be produced there from 2021 will meet the needs of the battery market for electric vehicles and mobile devices as well as those of the glass and ceramics production sectors. IFPEN is pursuing its partnership with Eramet within the framework of the European* EuGeLi (European Geothermal brines Lithium) project, launched at the start of 2019 and bringing together eight partners. The objective: adapt the sieve in order to capture lithium from the geothermal waters of the Rhine basin.

* Funded by the European Commission within the framework of the EIT Raw Materials KIC



HIGHLIGHT

VALIDATION OF A NEW SOLVENT FOR BIOGAS PURIFICATION

IFPEN joined forces with SME Arol Energy for the Biomet project, supported by ADEME. The project, which ended in May 2018, targeted the energy recovery of biogas produced by methanization. For nearly a year, biogas was purified continuously using gas sweetening technology developed by IFPEN, and then injected into the GRDF gas network. The performance of this new solvent, called AE-Amine, was validated. The objective: a reduction in the carbon footprint and an increase in the economic profitability of the biogas purification step.

55 g 

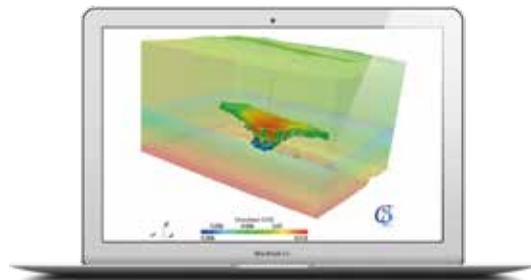
of CO₂ per kWh emitted on average by geothermal power plants, i.e., around 10 times less than a power plant operating using natural gas

(source : ENR.fr)



HIGHLIGHT**COORESFLOW: AN INTEGRATED SOLUTION FOR CO₂ STORAGE MODELING**

Today, IFPEN is taking its expertise acquired in oil and gas reservoir characterization and modeling and using it to provide solutions to the problems of environmental monitoring. For example, in 2018, in the field of the modeling of underground energy storage behavior, IFPEN finalized the first version of the CooresFlow prototype, a new generation software for the combined simulation of fluid-rock interactions from basin to well scale, particularly adapted to problems associated with CO₂ storage. CooresFlow incorporates features making it possible to predict risks during the storage site selection and design phases, simulate the future of the CO₂ stored, help position monitoring tools during the surveillance phase and adapt the measurement protocol.

**HIGHLIGHT****LAUNCH OF THE GECO PROJECT FOR THE REDUCTION IN NON-CONDENSABLE GAS (CO₂) EMISSIONS FROM GEOTHERMAL POWER PLANTS**

In the field of geothermal energy, IFPEN and its partner Storengy are participating in the H2020 GECO (Geothermal Emission Gas Control) project, launched in October 2018 for a period of four years. Coordinated by Icelandic company Reykjavik Energy and bringing together 16 other industrial and academic partners, the aim of this project is to considerably reduce gas emissions from geothermal power plants via the complete reinjection of non-condensable gases such as CO₂ in geothermal fluids. Various technological approaches will be tested on four pilot units in four countries: Iceland, Italy, Turkey and Germany. IFPEN is contributing its expertise for the definition of the optimal conditions for fluid mixing, flow simulation of fluids circulating in a drilling well and the integration of simulation models in a monitoring tool.

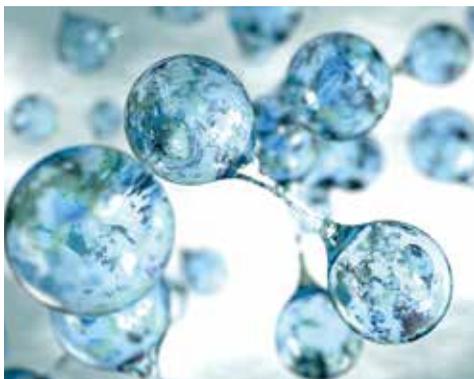
Reinforcement of synergies between IFPEN and Storengy

In June 2018, IFPEN and Storengy signed a framework agreement aimed at reinforcing existing R&I collaboration and developing new joint projects in the field of the energy transition. Five fields are concerned: energy storage, geothermal energy, hydrogen, the digital transformation and numerical tools. The objective is to develop innovative technologies to address the challenges associated with clean energy production and

storage. With this agreement, Storengy and IFPEN are exploiting their synergies with a view to contributing to the rapid development of new stand-out industrial sectors for the energy transition.

HIGHLIGHT**TOWARDS THE AUTOMATIC DETECTION OF HYDROGEN SEEP ZONES**

For several years now, IFPEN has been examining the potential of naturally occurring hydrogen seeps on the earth's surface. For example, IFPEN is actively involved in the sen4H2 (Sentinel Data for the Detection of Naturally Occurring Hydrogen Emanations) project, backed by the European Space Agency (ESA), led by Italian SME Terradue and supported by ENGIE and Storengy. The one-year project, launched at the end of 2018, is aimed at developing an automatic satellite image interpretation method for detecting and qualifying natural hydrogen seeps on the earth's surface. In this project, IFPEN's teams are contributing their expertise in the understanding of natural hydrogen generation and migration processes, as well as in data processing. Sen4H2 will focus on known areas of superficial hydrogen emissions, in Russia and the USA.





RESPONSIBLE OIL AND GAS

Today, the oil and related industries are undergoing some profound transformations. Against the backdrop of the accelerating energy transition, the sectors must significantly reduce their environmental footprint while continuing to meet sustained demand in the short and medium terms. IFPEN develops eco-efficient and flexible processes for the production of fuel, hydrogen and chemical intermediates meeting the strictest standards. In addition, in order to make better use of reserves, IFPEN develops increasingly efficient and cleaner, cutting-edge technologies for oil and gas exploration and production.



HIGHLIGHT

A NEW CATALYST FOR FCC PRETREATMENT

For a number of years now, IFPEN has been conducting research in the field of heavy feed conversion, leading to the optimization of the FCC (Fluid Catalytic Cracking) cluster, its greater flexibility in terms of the target products and an improvement in its energy efficiency. The research is conducted within the FCC Alliance, established 35 years ago by IFPEN, Axens, Total and TechnipFMC. In the field of the pre-treatment of feeds for FCC, a new generation vacuum distillate hydrotreatment catalyst was developed in 2018 by IFPEN's teams. The new catalyst, marketed by Axens in 2019, presents an enhanced hydrodesulfurization and denitrogenation performance compared to the previous generation.*

* The FCC cluster, the essential building block for refining, comprises the pre-treatment of FCC feeds and the FCC process itself

Heavy crude and residue conversion and purification

Even against the backdrop of the long-term decline in fossil energies, the conversion of residues and heavy crudes into lighter products remains necessary due, firstly, to the sustained demand for light products and the gradual disappearance of the market for low-quality heavy fuels and other final residues and, secondly, the increase in the proportion of heavy and extra heavy oils in the global oil supply. In this field, IFPEN is pursuing the development of processes and catalysts for the conversion and purification of increasingly heavy feeds to obtain cleaner products meeting increasingly stringent specifications.

25%

**of a refinery's flow is treated
by the FCC process**

Objective: to reduce the sulfur content of marine fuels

The new standards imposed by the International Maritime Organization (IMO) will lead to a tightening up of the specifications relating to marine fuels across the world by 2020. Their sulfur content will have to be below 0.5% in order to limit sulfur oxide emissions, which are harmful to health. Anticipating their introduction, IFPEN has been working for several years to improve deep residue conversion and desulfurization processes.

HIGHLIGHT

PROGRESS IN THE FIELD OF EBULLATED BED HYDROCONVERSION

Deep conversion consists in converting a maximum of heavy feeds into lighter products, for fuel and chemical intermediate production. In this field, IFPEN improved the H-Oil™ ebullated bed hydroconversion process to reduce operating costs and reduce its environmental footprint.

With more than 20 licenses held around the world, Axens is successfully marketing this process and currently has a 50% market share. In 2018, research activities focused, firstly, on improving the technology via numerical simulation and experimentation on a cold model and, secondly, on improving the performance of the process thanks to innovative design features and new catalytic systems. As a result of the research, conversion rates of up to 98% were validated for some feeds, with significant savings in terms of investment costs.



Fuel production and purification

Global standards and regulations relating to fuels continue to be tightened up with a view to improving air quality. The allowable sulfur content of gasolines and diesels is now 10 ppm across the board and there has been a reduction in the olefin and benzene content of gasolines. To address these requirements, IFPEN's research activities are focused on developing catalysts and eco-efficient processes for the production of clean, sustainable fuels, meeting increasingly stringent standards. Its researchers are developing hydrotreatment, catalytic reforming and paraffin isomerization technologies for gasoline production, as well as hydrodesulfurization technologies for the production of diesels and kerosene. The solutions developed by IFPEN are also aimed at providing operators with flexibility with respect to the fuel bases produced and fostering the coupling of refining with competitiveness of refining sites.



EMMANUELLE GUILLON

Hydrocracking project manager,
IFPEN

“In June 2018, an innovation which hinges around an intensification of the process design, with a view to improving its performance and the environmental footprint has been delivered to Axens for industrial upscaling. This innovation addresses the flexibility requirements of the hydrocracking market, in that the process can be adapted depending on the target products: diesel fuel, kerosene or petrochemical bases. We have managed to gain a much more thorough understanding of the sequence of catalytic hydrotreatment and cracking functions in order to achieve target parameters, such as total conversion, middle distillate selectivity and product quality. The new process also makes it possible to more effectively take into account constraints in terms of feeds, operating conditions and cycle time. In addition, we have developed simulation tools that can be used to rapidly integrate future catalysts and their sequences .”

HIGHLIGHT**NEW MIDDLE DISTILLATE HYDROTREATMENT CATALYSTS**

Foresight studies conducted by the IEA highlight an increasing global demand for diesel through to 2040, in the line with economic growth in emerging countries. Against the backdrop of the tightening-up of fuel specifications, feeds that are increasingly difficult to treat and the reduction in the environmental footprint of industry, meeting this demand requires the development of increasingly efficient middle distillate hydrotreatment processes and catalysts. In 2018, IFPEN's teams developed a 7th generation of low-pressure cobalt- and molybdenum (CoMo)-based hydrotreatment catalysts, as well as a 6th generation of high-pressure nickel and molybdenum (NiMo)-based catalysts. These catalysts, marketed by Axens, are based on a new additivation method and are associated with significant gains in terms of the elimination of sulfur derivatives and the improvement in diesel properties.

**Impulse® catalysts: a success story!**

Six years after the launch of its Impulse® catalyst range, used for the hydrotreatment of diesel and the hydrocracking of vacuum distillates, Axens boasts more than 100 references around the world. A major commercial success, which is testimony to the outstanding performance of the range, in line with market requirements in terms of complying with increasingly stringent regulations. In parallel, IFPEN is pursuing research aimed at enhancing the performance of hydrorefining catalysts in terms of activity and selectivity. This constant optimization of efficiency is made possible through innovation with respect to materials and the active phases of heterogeneous catalysts.

HIGHLIGHT**NEW CONTINUOUS CATALYTIC REFORMING PROCESS**

Technological innovations designed to improve the operability and performance of the continuous catalytic reforming process for the equivalent cost were developed by IFPEN in 2018 in partnership with Axens. These advances were made possible thanks to in-depth studies leading to a better understanding and control of the catalyst flow within the reactor, the mechanical resistance of the reactors and the energy efficiency of the process. The benefits of incorporating an additional reactor and the relevance of potential modifications in the design of the reactors and the recontacting section were validated.

Digital era processes

In many activity sectors, data acquisition and analysis have become performance improvement levers. Aware of the stakes, IFPEN has launched several initiatives aimed at identifying the potential of digital tools and technologies to support the digital transition of the refining and petrochemicals industry. Connected sensors, artificial intelligence and machine learning are some of the avenues explored. For example, IFPEN is testing the use of data analytics and machine learning for the prediction of hydrotreatment catalyst performance. A digital platform enabling the creation of a digital twin of a unit has also been developed in order to visualize monitoring and performance aspects and be able to conduct virtually real-time comparisons with process simulators.

Petrochemical intermediate production

Petrochemical intermediates are used in the production of numerous everyday products, such as plastic packaging and bottles and synthetic textile fibers. Driven by the increase in demand for consumer goods, particularly in emerging countries, growth in the petrochemicals sector is an underlying trend. IFPEN's research is aimed at developing new catalysts, adsorbents and olefin and aromatic production processes while increasing the purity of the products obtained and consuming less energy.

+3% 

Estimated average annual growth in ethylene consumption through to 2035

HIGHLIGHT

NEW GENERATIONS OF CATALYSTS FOR SELECTIVE HYDROGENATION PROCESSES



The steam cracking process is a key element for the production of olefins such as ethylene (C2 cut) and propylene (C3 cut), for which global demand has risen significantly, and naphtha (pyrolysis gasoline cut). In order to be used, these cuts have to be purified; specific processes and catalysts developed by IFPEN in partnership with Axens make it possible to selectively hydrogenate them in order to achieve impurity contents of less than 1 ppm.

In 2018, thanks to the development of a new palladium-based catalytic phase and optimized support preparation, IFPEN created two new generations of more

effective selective hydrogenation catalysts:

- for the “pyrolysis gasoline” cut, a new catalyst that offers improvements in terms of activity, stability and lifespan. This makes it possible to obtain the same performance as the previous generation but at a lower temperature, significantly reducing the unit's energy consumption, with longer life cycles and lifespans;
- for the “propylene” cut, a new catalyst presenting enhanced activity and selectivity as well as improved stability with respect to operating condition variations, and a broader range of operating conditions.

This new generation of catalysts will enable Axens, which is handling industrial development and marketing, to optimize its offer and consolidate its position as selective hydrogenation market leader.

Increasingly efficient paraxylene production with Eluxyl®

In the context of a long-standing partnership with Arkema, IFPEN is working on the formulation of high-performance adsorbents for the Eluxyl® paraxylene separation process, marketed by Axens as part of the ParamaX® paraxylene production complex. In 2017, IFPEN and Arkema finalized a new molecular sieve delivering a 140% increase in productivity compared to the previous generation, while enabling the production of ultra-pure paraxylene, highly sought-after by the chemicals industry. This innovation enabled Axens to consolidate its position as market leader with more than 20 units operating around the world, including two new ones in 2018. Today, IFPEN is pursuing research to optimize Eluxyl® technology, which will make it possible to use new, more effective xylene separation molecular sieves. IFPEN is also working to optimize the overall paraxylene production complex from an energy and economic point of view. In 2018, new equipment was installed at its Lyon site in order to develop this technology and future generations of sieves.

Natural gas treatment and conversion

IFPEN is studying the conversion of natural gas, particularly for the production of liquid fuel. The latter conversion is conducted using the Fischer-Tropsch process. This is known as GtL (Gas to Liquid) technology. IFPEN's GtL research is aimed at finding new catalysts and increasing the productivity of the process, in order to bring down the costs of the technology and limit its impact on the environment. IFPEN is also focusing some of its efforts on natural gas sweetening and offers a comprehensive range of services ranging from process design through to solvent development, via the creation of new packings for absorption columns.

40%

of the world's natural gas reserves are sour gases that have to be treated before they can be used

HIGHLIGHT**SOLVENTS FOR NATURAL GAS SWEETENING**

Natural gas sweetening consists in removing carbon and sulfur from the crude gas in order to meet the required specifications for its use and to be able to transport or liquefy it. While gas sweetening processes using amines are fully mastered today, IFPEN is now studying a new substance capable of improving their performance. The objective: to reduce the flow rate of the solvent used in order to improve the economic competitiveness and optimize the energy consumption of the process. Research to acquire the operational characteristics of this new solvent is ongoing, alongside associated modeling work. The next step will involve testing the solvent on a demonstration unit.

Understanding and modeling underground environments

Global reliance on fossil fuels is set to remain high through to the period 2030–2040, necessitating the development of more advanced exploration technologies. Sedimentary basins and oil and gas reserves under exploration by the oil industry are increasingly complex in nature from a geological point of view. So a thorough understanding is essential in order to reduce risks, ensure high exploration success rates and reduce the number of drilling operations. Such is the aim of the technologies developed by IFPEN, the only national research body with geoscientific expertise ranging from the understanding of the phenomena involved at the nano and microscopic scale to modeling on a basin scale.

HIGHLIGHT**ARCADES, NEW DIONISOSFLOW CALCULATOR**

Resulting from IFPEN's research and marketed by Beicip-Franlab, the DionisosFlow stratigraphic modeling software solution is designed to more accurately describe sedimentary layer deposits on a regional scale, thereby reducing exploration or delineation risks. In the longer term, the solution will contribute to the evaluation of the impact of climate

change on sedimentary systems, particularly on soils and coasts. The 2018 version of DionisosFlow incorporates a new calculator, ArcaDES, developed by IFPEN. The innovation improves the robustness and accuracy of calculations, and improves overall performance (parallel version). ArcaDES will now be used within the framework of future JIPs and collaborative projects, such as the DORS2 JIP on the modeling of organic matter production, decomposition and preservation, and the CarDIO JIP, set up to model the transformation of sediments (carbonaceous) in rocks under the effect of diagenetic processes.

JIPs: a productive form of collaboration with industry

IFPEN reinforces its links with industry via JIPs (Joint Industry Projects), an original form of collaboration that addresses its own needs and those of industry. JIPs make it possible for IFPEN teams to develop and validate methodologies and technologies in line with concrete industrial problems. For their part, industrial partners benefit from IFPEN's expertise and the results of its research. Recent successes in the field of energy resources include: the CATS2* JIP, closed in 2018 with the delivery of a software prototype used to simulate turbidite flows, and the DORS** JIP, the first phase of which closed in 2017 and now in a two-year extension period. Supported by Total, Chevron, ENI, ENGIE and Repsol, its objective is to develop new numerical modeling approaches on various scales concerning geological processes, integrated into the DionisosFlow software tool. The modules stemming from this research make it possible to take greater account of organic matter in marine, land and lacustrine environments. In 2019, IFPEN plans to launch new JIPs, particularly concerning sedimentary process modeling and complex reservoir characterization.

* Cellular Automata for Turbidite Systems

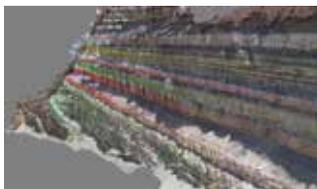
** Dionisos Organic Rich Sediments

HIGHLIGHT**KRONOSFLOW, A KINEMATIC ANALYSIS TOOL FOR COMPLEX GEOLOGIES**

In the field of oil system modeling, the KronosFlow application, developed by IFPEN, working closely with Beicip-Franlab and with the support of industrial partners, reinforces the 2018 version of the TemisFlow basin modeling software, thereby combining dynamic structural evolution modeling with that of oil systems. This first commercial version of KronosFlow is used to define the kinematics of geological layer deformation as accurately as possible with associated meshes, in order to better reflect oil fluid genesis and accumulation. The tool is used to provide a 2D evaluation of basins and oil systems in complex geological configurations. TemisFlow is marketed by Beicip-Franlab.

HIGHLIGHT

TOWARDS THE 3D INTERPRETATION OF GEOLOGICAL OUTCROPS



For several years now, IFPEN has been active in the digitalization of geosciences via a package of technologies integrated in the SmartAnalog workflow. SmartAnalog is used to work on geological outcrops comparable to buried reservoirs, containing energy resources

(water, CO₂, hydrocarbons, etc.). One of the technologies associated with the workflow and stemming from IFPEN's R&I, Virtuoso, is used to analyze and interpret models of outcrops reconstructed in 3D from photos taken on the ground. It is a prototype of an application under development since 2013 and validated via a series of tests conducted with academic partners. A stabilized version was integrated in the SmartAnalog workflow in 2018. This technology addresses three objectives: propose a didactic tool for field geology, calibrate the parameters for reservoir simulation and conduct 3D virtual tours of outcrops.

Find out more: <https://www.smartanalog.eu>.

Producing better with enhanced recovery

Enhanced Oil Recovery (EOR) has become strategically important for oil companies as they seek to increase oil field potential and lifespan. It helps meet existing demand for oil and gas in an energy transition context, producing more from existing reservoirs, while increasing the recycling of produced water and reducing the number of drilling operations. To address this need, IFPEN, Beicip-Franlab and Solvay joined forces to form the EOR Alliance. This alliance develops solutions tailored to the various specific reservoir conditions and for all types of EOR processes. The solutions developed provide complete coverage of the chain, from laboratory-scale EOR formulation development through to field application and monitoring. IFPEN is also focusing a significant amount of research on the issue of water cycle optimization in an EOR context, with a view to promoting its eco-responsible development.

CAL-X, a new generation of smart lab

In 2016, IFPEN introduced a pioneering technology stemming from its R&I within the framework of the joint offer of the EOR Alliance. It supplements the laboratory of 18 traditional coreflood* test systems IFPEN has at its disposal to study, in real conditions, formulations created for a given field. CAL-X, a miniaturized high-throughput experimentation test bench, makes it possible to characterize rock properties while reducing the time involved in coreflood testing from several weeks to just a few days, and using smaller samples than those used with a traditional test bench. This innovative equipment and the associated automation allow for a broader spectrum of products tested and an increase in sample volume, while maintaining the robustness of results. Continuously updated on the basis of feedback, in 2019, CAL-X, which addresses the EOR market's need for efficiency, will see its applications extended, particularly to cover new energy technologies.

* Coreflood systems are used to study fluid displacement in porous media

Offshore production

Representing almost one third of global production by 2030 and half of potential reserves yet to be discovered (according to current forecasts), offshore oil production continues to be of considerable strategic importance for oil and gas companies. However, the challenges facing industry in this field are numerous: producing in deep underwater environments, transporting fluids without forming hydrate and paraffin plugs, pumping a mixture of water, oil and gas with highly variable gas contents and separating effluents on the sea bed. IFPEN supports the sector's leading players in all of these areas, developing efficient solutions for offshore drilling and production, as well as for flow assurance and production risk management.

HIGHLIGHT

OFFSHORE FIELD DEVELOPMENT: AVAILABILITY OF THE I-CLIP RISER 1.0



In the field of offshore drilling, IFPEN finalized the development of a new generation of risers, the i-Clip Riser. Version 1.0, in which the connector can be inspected, allows for easier and quicker maintenance, while maintaining the characteristics of the previous generation of Clip Riser (water depth

of below 3,600 m, service pressure of 1,000 bars). Developed on the basis of feedback, this technology underwent tests on a traction test bench that resulted in certification by Bureau Veritas in 2018, thus paving the way for the roll-out of this new generation by a commercial partner from 2019. IFPEN also guarantees a constant level of service for the maintenance and inspection of the former generation of Clip Risers, through partnerships with AFGlobal and ExpertRiser Solutions.

35%

The average recovery rate from fields globally



30%

Share of fundamental
research in IFPEN's
R&I activities

FUNDAMENTAL RESEARCH SERVING INNOVATION

In order to support its ambitions in the field of innovation while ensuring scientific excellence, IFPEN implements a fundamental research strategy within the framework of a long-term program. Organized around nine scientific challenges, the program represents a cross-functional bedrock aimed at addressing scientific questions associated with the development of new products and processes. To this end, IFPEN maintains a dynamic ecosystem of academic partnerships and is involved in numerous French and European collaborative research projects.

Overcoming the scientific challenges

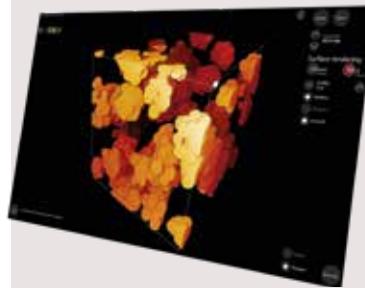
The “scientific challenges” approach formalizes the major multidisciplinary issues associated with IFPEN’s activities, ranging from the understanding of mechanisms on an atomic scale, through to the evaluation of the economic and environmental impact of its processes and products. Its implementation is based on “specific scientific issues”. Within the context of each broad challenge, a specific scientific issue identifies a scientific hurdle that is hampering the development of IFPEN’s innovations and that needs to be overcome. Each specific scientific issue is associated with a long-term road map, incorporating several research actions which are structured within various projects. The latter are conducted within the framework of strategic academic partnerships, supported in particular by PhD theses and post-doctoral research work. The challenges and their associated specific scientific issues are thus tools for steering IFPEN’s fundamental research.



Watch a video
on IFPEN's fundamental
research strategy

HIGHLIGHT

PLUG IM: SIGNAL AND IMAGE PROCESSING AVAILABLE ON AN OPEN ACCESS BASIS



Designed by IFPEN and freely available to the scientific community and industry, plug im! is a modular platform providing non-expert users with access to 2D and 3D signal and image processing. In particular, this user-friendly platform enables automatic processing of several pieces of data without the need to code a single line. It brings together data processing modules developed

by IFPEN, as well as those of industrial and academic partners, and can be enhanced over time by the scientific community. Specific developments can also be accommodated by IFPEN when requested by industrial partners, to support their innovation projects.

Find out more: <https://www.plugin.fr>.



Watch a video on the
plug im! platform

IFPEN'S SCIENTIFIC CHALLENGES: PROGRESS IN 2018

EXPERIMENTATION, DATA ACQUISITION, UNDERSTANDING

CHALLENGE 1: material and fluid multi-scales characterization for energy

The development of new analytical pre-treatment systems, based on centrifugal partition chromatography, enables the controlled fractionation of the complex aqueous matrices produced by lignocellulosic biomass conversion processes. By coupling these with high-performance analytical methods, it is now possible to characterize effluents more precisely. This approach is perfectly suited to the presence of heat-sensitive molecules and/or high molecular masses, such as sugars or phenolic oligomers. It also opens up new avenues for isolating and identifying enzymatic reaction inhibitors, these reactions being crucial to the biochemical conversion of biomass, with a view to producing advanced biofuels and bio-based chemical products.

CHALLENGE 2: understanding chemical, catalytic and enzymatic reaction mechanisms on a molecular or adapted scale

In processes such as biofuel production and sour gas treatment, metal equipment can come into contact with aqueous mixtures containing hydrogen sulfide (H₂S) and oxygen. When H₂S dissolves in water, it allows hydrogen to penetrate carbon steel, leading to blistering and premature rupturing due to stress corrosion cracking. Research conducted as part of a PhD thesis and within the framework of the Oxygen JIP (see p. 35) resulted in a better understanding of the role of oxygen traces on these mechanisms of hydrogen embrittlement, thereby making it easier to manage the damage generated. The work carried out demonstrated that, unlike surface corrosion, which is accelerated by the presence of oxygen, the specific nature of the products of corrosion in these sulfur-containing media slows down the penetration of hydrogen in steels.

CHALLENGE 3: understanding the effect of fluid containment on their dynamics and their reactivity in porous media

Molecular modeling is of vital importance to the understanding of fluid transport processes in confined media, such as nanopores. The method is used to define laws, which can differ from traditional hydrodynamic descriptions. This approach was used for a PhD thesis in the field of geosciences to study clay interface diffusion. However, the limited size of simulation volumes introduces systemic biases that have to be rectified in order to have tools that are genuinely predictive. A theoretical approach making it possible to correct them with a high degree of accuracy was thus developed and validated. It has been the subject of several publications.

CHALLENGE 4: the optimum processing of large volumes of experimentation and simulation data

At the start of 2018, IFPEN and INRIA organized in Rueil, the Scienc'Innov "DataSciEn2018" workshop dedicated to data science in the energy field, one of IFPEN's key fundamental research areas. The workshop brought together 110 academic and industrial participants for three plenary sessions (Frameworks and platforms, Advances in algorithms and Industry) and two practical work sessions hosted by NVIDIA and INRIA. A challenge concerning a predictive approach in the field of geosciences, based on data provided by IFPEN, was also launched on the ENS platform, with some thirty teams taking part.

PHYSICAL MODELS AND DESCRIPTORS FOR SIMULATION

CHALLENGE 5: the identification of descriptors for the design of materials, processes and simulators.

Within the framework of the ANR Slimcat project, quantum simulation of gamma-alumina/water interfaces, such as those involved during the catalysts preparation steps, provided a better understanding of the nature of the interactions between organic oxygen molecules and a metallic precursor containing cobalt with alumina sites. Structural and energy descriptors were thus identified that can be used to help us understand the behavior of these molecules in biomass conversion processes.

CHALLENGE 6: modeling of closely coupled phenomena with a view to scale change

In wind farms, the relative positioning of turbines needs to be optimized in order to avoid wake-related power loss and the risks of damage caused by turbulence. To do so, it is necessary to precisely simulate wind flows through the farm, taking into account representative weather conditions, particularly at the atmospheric boundary layer. To this end, a wind turbine model was combined with the Meso-NH weather model designed by Météo France and the Laboratoire d'aérodynamique (French Aerology Laboratory). Different options of variable complexity were integrated to represent the stresses on the turbine rotor (also see p. 21). Comparison with wind tunnel tests conducted for a configuration involving five wind turbines on a hill, provided highly conclusive results, including for the simplest model requiring short calculation times. This combined approach also made it possible to explain and digitally reproduce a spontaneous, fog-generating condensation phenomenon, as observed at a Danish offshore wind farm.

SYSTEM SIMULATION, OPTIMIZATION AND CONTROL

CHALLENGE 7: the control and optimization of complex systems

The H2020 Advice project concerned the original theme of route optimization, from an energy point of view, for a hybrid vehicle. IFPEN developed an eco-routing system designed to minimize fuel consumption for a set battery charge at destination, taking into account real-time traffic conditions. It required the resolution of a complex optimization problem with several levels involved (optimal command, route optimization on a graph), an operation made possible by the simplification of the models used. Fuel reductions, validated for simulated traffic conditions, can be as high as 10%.

CHALLENGE 8: achieving the best digital and IT performance of our computational codes

Stratigraphic modeling, which simulates sedimentary processes in geological basins over large scales of time and space, can help predict the impact of climate change on a region's geomorphology. In this field, a new numerical resolution method allows non-linear slope-dependent sediment flow, while respecting a maximum erosion rate constraint. It also combines sedimentation with surface water flow calculated using a new differential equation. This method, which uses an implicit numerical process that is both efficient and adapted to the strong correlation between erosion and water flow, is used to more accurately simulate the interaction of these natural phenomena.

ECONOMIC AND ENVIRONMENTAL ISSUES

CHALLENGE 9: assessing the economic and environmental impacts of innovations relating to the energy transition

Within the context of the ANR Generate (Geopolitics of Renewable Energies and Prospective Analysis of the Energy Transition) project, launched in 2018 and conducted in partnership with IRIS*, IFPEN is studying the criticality of energy transition materials and developing a geographic analysis of low-carbon innovations. Several raw materials markets (copper, lithium, etc.) have been modeled using the TIMES family of energy forecasting models developed by IFPEN in order to evaluate the demand for materials by 2050 in a variety of climate scenarios.

* French Institute for International and Strategic Relations



AUDREY BONDUELLE
Cataphot project manager

“For the past few years, to address the challenges of the energy transition, IFPEN has been conducting research to develop and optimize catalysts dedicated to the production of “green” energy, from low-carbon energy sources. Several options are being examined within the Cataphot project. IFPEN is working with several partners to develop catalytic materials for solar fuel production. These catalysts make it possible to convert CO₂ emitted by industrial sites, for example, into usable molecules via solar radiation, which is inexhaustible and abundant on the earth’s surface. Another example is the MoSHy project, which concerns the development of a method for identifying electrocatalysts for hydrogen production via the electrolysis of water. Selected by the Auvergne-Rhône-Alpes region within the context of the 2018 Pack Ambition Recherche call for projects, this project is being conducted in partnership with ENS Lyon and the Grenoble LEPMI (laboratory of electrochemistry and physical chemistry of materials and interfaces).”

Deploying an open and collaborative research strategy

IFPEN develops and implements a dynamic strategy of French and European academic partnerships, supporting its fundamental research activities. These partnerships, focusing on IFPEN’s scientific challenges, mainly take the form of doctoral theses and collaborative projects with public support, funded, in particular, by the ANR (French National Research Agency) or the European Horizon 2020 framework program. Since 2017, IFPEN has been proactively reinforcing its participation in research funding agencies calls for projects, with a doubling of proposals submitted between 2016 and 2018. In addition, at the end of 2018 IFPEN was also involved in two excellence laboratories, iMust in the Auvergne-Rhône-Alpes region and Matisse in the Île-de-France region. Additionally, it is a partner in the NanoimagesX “facility for excellence”. IFPEN is also a founding member of the Dataia Convergence Institute dedicated to data sciences. Lastly, IFPEN builds strategic partnerships relating to targeted themes with public research players as well as industrial ones, with a view to pooling fundamental research efforts.

13 
projects supported by the ANR
involving IFPEN under way in 2018



HIGHLIGHT

RENEWAL OF THE FRAMEWORK AGREEMENT WITH THE CNRS

In September 2018, IFPEN and the CNRS signed a new five-year framework agreement defining the general principles governing their collaboration, particularly research projects and the conduct of joint theses and post-doctoral activities. This renewal reflects the determination of the two organizations to ensure the long-term continuation of a successful collaboration dating back nearly 40 years and strengthen their links in shared areas of interest. Today, IFPEN and the CNRS launch between 20 and 30 theses and post-doctoral fellowships together per year. In addition, IFPEN’s teams are actively involved in around twenty CNRS research groups, including three new ones launched in 2018, giving rise to regular events bringing together researchers from the two organizations. One major objective of the new framework agreement is to further reinforce the collaboration, with the creation of a joint research laboratory dedicated to the characterization and analysis of materials for energy (CARMEN laboratory: CARactérisation des Matériaux pour les Énergies Nouvelles, characterization of materials for new energies).

HIGHLIGHT**EXTENSION OF THE COLLABORATION BETWEEN ANDRA AND IFPEN**

Partners for the last 20 years, ANDRA* and IFPEN signed, in May 2018, a new four-year collaboration framework agreement. Under the terms of the agreement, the two bodies will share their expertise on joint research topics relating to geological storage. Four research areas are covered: geological modeling of the underground environment; geological storage monitoring, instrumentation and analysis; numerical simulation of fluid flows; steel corrosion. Initiatives are already under way or being examined within the framework of post-doctoral internships, theses and joint studies.

* French National Radioactive Waste Management Agency

HIGHLIGHT**LAUNCH OF THE ROAD4CAT CHAIR IN THE FIELD OF CATALYSIS**

The agreement for the ROAD4CAT (RatiOnAl Design for CATalysis), IDEXLyon's* first industrial chair, was signed in June 2018. Awarded to Pascal Raybaud (IFPEN), this chair brings together IFPEN and the chemistry laboratory at ENS Lyon, whose other supervisory authorities are the CNRS and Claude Bernard Lyon 1 University. It proposes an innovative research approach applied to the rational design of heterogeneous catalysts. Its purpose is to develop fundamental research projects aimed, on the one hand, at identifying new concepts governing the transformation of fossil carbon into clean fuels and, on the other hand, at exploring new approaches in the fields of biomass conversion and photocatalysis. This chair will help reinforce the long-standing links between IFPEN, Lyon University and ENS Lyon, and will also lead to the recruitment of four PhD students and five post-doctoral researchers.

* Winner of the IDEX call for projects as part of the French Investments for the Future program, led by Lyon University

**Joint fundamental research with industrial players**

IFPEN forges relations with industrial players in order to pool fundamental research efforts in various fields. For example, IFPEN and Safran Tech have joined forces for a thesis concerning the development of optimization methods for costly mechanical system design simulators. Another example is the partnership between IFPEN and Michelin relating to materials and processes, in the form of a jointly supervised thesis in the field of homogeneous catalysis. A Cifre (industrial agreement for training through research) thesis project has also been launched with PSA, concerning the development of atomistic calculation methodologies aimed at understanding the reactivity of battery electrodes. Lastly, IFPEN continues to work with PSA and Renault on pre-competitive research in the field of powertrains within the Groupement scientifique moteurs (GSM).

18

active academic collaboration framework agreements at the end of 2018

HIGHLIGHT**CORROSION CONSORTIUM: PROMISING RESULTS**

IFPEN, the Institut de la Corrosion de Saint-Étienne (French Corrosion Institute in Saint-Étienne) and six industrial partners joined forces for the Oxygen JIP (Joint Industry Project), which was completed at the beginning of 2019. The consortium evaluated the impact of oxygen traces on steel corrosion in the presence of H_2S , a fundamental issue for operators concerning the reliability of materials' selection for oil and gas transport. The research also enabled IFPEN to anticipate steel corrosion and fracture risks in fields such as geothermal energy and biogas. The JIP's success has given rise to two new research proposals in partnership with the Corrosion Institute. The first, due to be launched in the first quarter of 2019, is aimed at understanding the effects of high pressures on steel fracture risks in the presence of H_2S (fugacity effects).

The importance of theses at IFPEN

Covering all of its scientific challenges, doctoral theses represent a major component of IFPEN's fundamental research. While their underlying purpose is to train young researchers and drive advances in scientific knowledge, their interest also lies in the interactions they generate with the academic world. The original questioning and contributions of PhD students help reinforce teams' expertise and introduce fresh ideas, with a view to developing new concepts. Each year, the Yves Chauvin prize is awarded to a PhD researcher in recognition of research excellence and the originality of the approach employed. The 2018 prize was awarded to Aurélie Pirayre for her thesis entitled "Reconstruction and Clustering with Graph Optimization and Priors on Gene Networks and Images". Her work represents an advance in the adaptation of image processing methods for the purpose of representing biological data in graph form. It was conducted and supervised at IFPEN, and directed by Professor Jean-Christophe Pesquet at Paris-Est Marne-la-Vallée University.



AURÉLIE PIRAYRE

Winner of IFPEN's 2018 Yves Chauvin thesis prize

*"The aim of my research was to improve our understanding of the mechanisms involved in the production of enzymes using a fungus, *Trichoderma reesei*. These enzymes are used as biocatalysts in certain 2nd generation bioethanol production processes. My research generated an approach and tools enabling improved analysis of biological data using mathematics. By integrating these data in image processing models, the team was able to show the reaction cascades between *Trichoderma reesei* genes in graph form. New biological data acquisition technologies generate large volumes of heterogeneous data: mathematics and IT have become essential tools when it comes to processing them. The BRANE (Biologically-Related A priori for Network Enhancement) suite of tools we developed makes this possible and biologists can now use it in their day-to-day research."*



Aurélie Pirayre presents her thesis in a video

135 
theses under way each year on average

Exchange with the scientific community

Alongside an active partnership research strategy, IFPEN also encourages exchange between researchers and the scientific community in order to promote knowledge-sharing. These exchanges take a number of forms: the hosting and organization of events on themes associated with IFPEN's research fields, active involvement in scientific networks (research groups, learned societies, etc.) and the hosting of scientific visitors. Such exchanges are beneficial for both sides, providing food for thought for researchers and contributing to research advances. The dissemination of knowledge via the publication of open-access scientific articles is another way used by IFPEN to make its R&I accessible and allow the scientific community to harness it.

166 
publications by IFPEN researchers in peer-reviewed international scientific journals in 2018

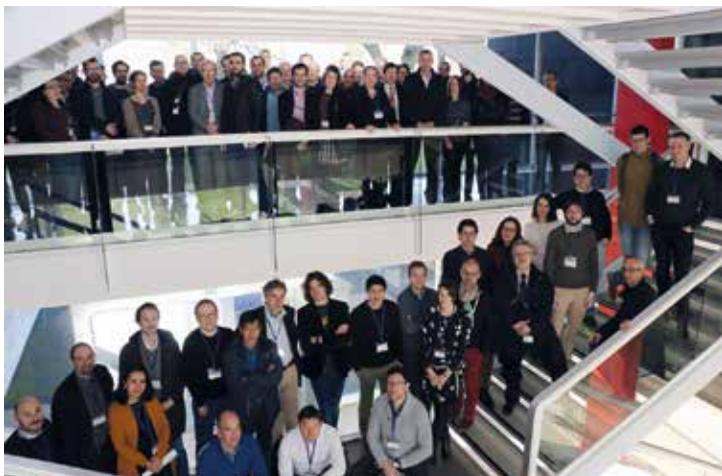
HIGHLIGHT

IFPEN'S OPEN ACCESS PUBLICATIONS

In order to raise the profile and influence of its research, in 2018, IFPEN introduced a policy of open, free and unlimited access (open access) to its researchers' publications and associated data. This initiative is in line with a French and European drive to encourage the sharing of research results and help speed up innovation. IFPEN's publications have been available for consultation on the HAL-IFPEN platform since 2012.



Access IFPEN publications (in French)



HIGHLIGHT

SCIENTIFIC WORKSHOPS SUPPORTING IFPEN'S FUNDAMENTAL RESEARCH

In 2018, IFPEN launched a new and free scientific event format: the *Scienc'Innov workshops*. Structured around a central and/or emerging theme within IFPEN's fundamental research, these workshops bring together a community of academic and industrial experts to discuss the scientific challenges to be overcome and identify concrete research and collaboration avenues. The first such events were the *DataSciEn'2018* workshop held in January and jointly organized with INRIA on the theme of data science for energy (see p. 33) and the *Energy Markets workshop (EM 2018)* in June, dedicated to the new organization of the commodity and energy markets in the context of the energy transition.

OGST, IFPEN's journal is made open access

IFPEN leads the editorial committee of the peer-reviewed journal OGST (Oil & Gas Science and Technology). Indexed in the major international databases, OGST covers all the disciplines and fields of activity within the scope of IFPEN. Its open access status and its circulation in digital format only mean that articles can be published throughout the course of the year, as part of an entirely dematerialized reviewing and production process. Each issue contains themed reports; two were published in 2018:

- *Numerical methods and HPC;*
- *Dynamics of sedimentary basins and underlying lithosphere at plate boundaries: The Eastern Mediterranean*

Moreover, in 2017, the journal notched up more than 1,600 article quotations, giving it a two-year impact factor published in Web of Science (WoS) of 1.399, an increase compared to 2016 (1.184). The number of article submissions and publications doubled in 2018 compared to 2017, with 400 submissions and 80 publications. OGST articles and special reports are freely available at: <http://ogst.ifpenergiesnouvelles.fr>.



Award winners in 2018...

• **Céline Pagis**, recipient of the 2018 L'Oréal-UNESCO "For Women in Science" fellowship;

• **Xavier Mangent**, former IFPEN PhD student, Van Straelen thesis prize, awarded by the French Geological Society.

• **Céline Chizallet**, young researcher prize awarded by the Catalysis Division of the Société chimique de France (French Chemistry Society);

In addition, **Hélène Olivier-Bourbigou**, women scientist of the year in 2014, was elected member of the Académie des technologies (French Academy of Technologies).

• **Olga Vizika-Kavvadias**, 2018 Darcy prize awarded by the Society of Core Analysts;

• **Alexandre Letteron**, former IFPEN PhD student, thesis prize from the Association des géologues du Sud-Est (South-East Geologists Association);



Watch video with Céline Pagis (in French)



CREATE WEALTH AND JOBS

Public debate on the PPE (French long-term energy program): an active contribution from IFFEN - p. 40
Interview: launch of an air pollution abatement theme - p. 41
IFFEN takes a stake in Galanck - p. 47

2018 HIGHLIGHTS: THE ESSENTIALS 



ING

40

**A culture
of innovation**

44

**From research
to industry**

IFPEN is committed to driving technological innovation and supporting economic activity in France and Europe. Its economic model is based on the transfer to industry of the solutions it develops, both in its traditional sectors of activity and in the new energy technologies (NET) sector.

IFPEN has created the in-house conditions required for the development of a genuine culture of innovation and has a permanent focus on reinforcing its integration and partnerships with structures within the innovation ecosystem, both in France and around the world.

One of IFPEN's strengths is its capacity to transfer to industry the results of its R&I, to major groups as well as start-ups, SMEs and intermediate-sized companies. This capacity is reflected in an ambitious patent filing policy and comes into its own via the IFP Group. The broad influence and high profile of the Group's companies (Axens, Beicip-Franlab, IFP Training), along with the dynamism and

promising potential of the latest companies created or supported, reflect the success of this technology transfer policy, which creates both wealth and jobs.

IFPEN's ambition now is to reinforce its innovation capacity concerning new energy technologies and its contribution to the development of green industrial sectors and sustainable mobility. To this end, industrial partnerships, innovation support for SMEs and start-ups and the growth of IFP group's subsidiaries are the focus of reinforced efforts.

A CULTURE OF INNOVATION

The success of IFPEN's value creation model depends on its capacity to deliver innovations, based on the development of a forward-looking vision of its activities and on the production of research in line with the needs of the energy market. IFPEN has also equipped itself with the organizational structure, methods and tools it needs to detect new opportunities and to take into account the potential for the market development of the targeted products and services right from the outset of projects. Lastly, IFPEN invests in collaborative research projects: by pooling research efforts, these projects make it possible to bring innovations to market much faster and speed up the emergence of energy transition industrial sectors.

A forward-looking approach

One of IFPEN's strengths lies in its capacity to anticipate R&I needs. IFPEN does this by adopting a forward-looking approach to identify future energy challenges and the themes that it should be targeting. This forward-looking approach benefits from the contribution of IFPEN's scientific board and industrial committees, and is enriched by the partnerships established, both academic and industrial. IFPEN also assists the public authorities in their strategic forward-looking reflection processes in the area of energy. It contributes to the drawing up of road maps and provides research and innovation program guidance on a national and European level. IFPEN fulfills these missions within the context of the ANCRE* alliance, of which it is one of the founding members alongside the CEA, CNRS and CPU**. IFPEN is also an associate member of the AllEnvi*** alliance and, in this capacity, it actively contributes to reflection processes in the fields of sustainable chemistry, water sciences and environmental assessment.

* French National Alliance for Energy Research Coordination

** French Conference of University Vice-Chancellors

*** French National Alliance for Environment Research

HIGHLIGHT

PUBLIC DEBATE ON THE PPE (FRENCH LONG-TERM ENERGY PROGRAM): AN ACTIVE CONTRIBUTION FROM IFPEN

Within the context of the national public debate on the French long-term energy program (PPE), a veritable energy road map for the next ten years, IFPEN has invested in several initiatives aimed at illustrating the role of R&I in meeting the objectives set out in the French energy transition and green growth law. These include:

- *the hosting on 30 May 2018 of a workshop dedicated to new technologies for renewable energies and energy storage, jointly organized with the CNDP* and the ANCRE alliance, which brought together 100 participants representing industry, academia and the public authorities. IFPEN's representatives made contributions in the fields of ocean energies, energy storage and biofuels;*
- *the publication of a guide relating to lignocellulosic biofuels;*
- *as part of an ANCRE working group, the conduct of a prospective study and drawing up of a road map for the development of aviation biofuels in France, presented in June 2018 as part of the French public debate on the PPE.*

* French National Public Debate Commission



Download IFPEN's
guide on biofuels
(in French)



Download ANCRE's
documents on aviation
biofuels
(in French)

Towards “agile” innovation

Dynamic project management

Innovation is IFPEN’s core business; its organizational structure is entirely geared towards its innovation strategy. R&I programs are led by business units responsible for developing and advancing projects and identifying industrial applications for them. Projects are managed dynamically, from their examination phase through to their development phase, via different steps punctuated by decisions taken on the basis of the benefit of the innovation and the target market appeal.

Detecting and incubating radically new ideas

An internal incubation program promotes the emergence and maturation of innovations marking a radical shift from IFPEN’s traditional activities, to support the energy transition and associated new markets. The system pools expertise in the fields of strategic marketing and business model development. Its product portfolio is currently structured around five areas: the circular economy, air pollution abatement, industrial efficiency, stationary energy storage and CO₂ conversion.



HIGHLIGHT

TIRE RECYCLING AT THE HEART OF A NEW PROJECT

 In the field of the circular economy, IFPEN is investigating different options within the framework of its incubator. These include tire recycling. The objective of the Stock project, launched in 2018, is to evaluate the interest of a solvolysis process to convert the different products resulting from the chemical recycling of tires. Having analyzed the worn tire sector on the basis of interviews conducted with industrial players, IFPEN’s teams are conducting tests aimed at verifying the feasibility of solvolysis on different representative samples. The aim of these tests is to recover the carbon black and oils produced in the optimum conditions, and then analyze them. A review of the process and a technical and economic evaluation will then be conducted to assess the relevance of solvolysis compared to traditional pyrolysis, in terms of product quality and the cost of the process.



SÉBASTIEN MAGAND,

“Air pollution abatement”
theme manager within IFPEN’s
Incubation and SME Department

“Air pollution has significant impacts on health and the environment, and generates considerable economic costs for society as a whole. Improving air quality is thus a major priority for the public authorities. IFPEN decided to open a new theme within its internal incubator in July 2018, dedicated to improving inside and outside air quality. The objective is to identify new innovation opportunities in a field of the future in which IFPEN has not really been an active player to date. An initial analysis phase was conducted in 2018 to precisely segment the different markets. Our research was supported by numerous interviews conducted with stakeholders and industrial players as well as local authorities and the institutional sector. This phase will enable us to determine unmet or poorly met technological needs over the next five to ten years, as well as the associated technological challenges, all of which represent potential innovation opportunities for IFPEN. The most promising and relevant of them with respect to our expertise will be examined in 2019 within the framework of the incubator.”

HIGHLIGHT

INTERNAL INNOVATION CHALLENGE: SOME PROMISING PROJECTS!

In 2017, IFPEN launched a major internal innovation challenge aimed at bolstering and extending its activities in the field of new energy technologies. Selected in April 2018 from 167 proposals, the six winning projects cover topics as diverse as biofuels, biogas, air pollution abatement, soil pollution and electrification of mobility. Over the course of the year, these projects were closely scrutinized and analyzed from a market point of view, the entire process underpinned by dialog with key opinion leaders, partners and potential customers. Projects with the highest levels of technical and economic maturity should result in the first demonstrations in 2019.

HIGHLIGHT**GIVING FREE REIN TO CREATIVITY, THE OTHER INNOVATION ROUTE**

Foster its researchers' creativity in order to drive innovation, such is the philosophy behind the "free creativity" approach launched by IFPEN. The principle: to select initiatives focusing on the development of new expertise, methodologies and tools. A trial began in September 2018 in three pilot research divisions. A total of 21 proposals were chosen in November for inclusion in IFPEN's 2019 program. The researchers selected have 1,200 days to develop their ideas!

**Concentrating efforts**

In order to reduce the time necessary to take its innovations to market, IFPEN is able to bring together, for a short period of time, a close-knit multidisciplinary team around a working «platform», to channel their energies into the development of a technological product. In addition, a working format based on «innovation task forces» is also being tested to reinforce the innovation process in high-potential market segments. These two initiatives are outward-looking in nature, with the emphasis on exchange with industrial players. By way of illustration, collaboration in platform mode was behind the KronosFlow software tool, the first version of which was integrated, in 2018, into TemisFlow software marketed by Beicip-Franlab, to provide a 2D evaluation of basins and oil systems in complex geological configurations (see p. 30).

6 to 8 
projects incubated at IFPEN each year

A collaborative research strategy

Since the challenges of the energy transition go far beyond the scientific and technological expertise of a single body, because pooling knowledge, know-how and costs creates synergies and accelerates the innovation process, because developing new industrial processes depends on the involvement of all the players, IFPEN builds strategic partnerships with academia and industry, throughout the innovation chain.

At the heart of the French Research and Innovation System

In addition to the fundamental research projects supported by players such as the ANR, IFPEN contributes to collaborative technological research and innovation structures, in partnership with industry. For example, it is active in seven competitiveness clusters – including the Axelera (chemistry and the environment), Cara (urban transport) and Mov'eo (environmentally-friendly cars and public transport) clusters – it is a founding member of the latter – and energy transition institutes Vedecom (mobility) and Pivert (plant-based chemistry). It is also a Carnot Institute for its transport activities. IFPEN is also a stakeholder in projects supported by ADEME in the fields of sustainable mobility and new energies, including several research demonstrators. Lastly, with a view to reinforcing both its territorial presence and industrial partnerships, IFPEN takes part in collaborative projects supported by the Auvergne-Rhône-Alpes region and the French Interministerial Fund (FUI).

Open innovation, at the heart of our corporate culture

In a constantly changing environment, and in order to reinforce its innovation capacity to support the energy transition, IFPEN conducts open research, i.e. connected to its partners and customers, at all stages of the innovation cycle. The idea is for IFPEN to enrich its thinking and breathe new life into its ideas externally, but also to identify opportunities earlier and share them more quickly in order to carve out a position more quickly. To do so, IFPEN is constantly working to strengthen its integration into the innovation ecosystem in France and Europe. Its involvement in collaborative research projects such as BioFuel (2nd generation biodiesel and biokerosene) and Cheers (CO₂ storage), and its strategy of co-developing innovative technologies with start-ups and SMEs are examples of this.



66 collaborative projects with government backing involving IFPEN under way in 2018

IFPEN, a leading European research player

IFPEN has worked for many years alongside industrial and academic research partners within the European Energy Research Alliance (EERA), as well as in different European associations and technological platforms. IFPEN also contributes to several projects supported by the European Union, particularly within the framework of the Horizon 2020 program.

Supporting emerging themes on a European level

IFPEN is actively contributing to the reflection process on an energy-climate theme with a view to formalizing the Sunrise – Solar Energy for a Circular Economy – project, one of the six CSA (Coordination and Support Action) projects selected by the European Commission in February 2019 following the FETFLAG-01-2018 call for projects. The objective is to build a large-scale research initiative focusing on the use of solar energy for the production of fuels and chemicals, within the framework of the future Horizon Europe program (2021-2027) currently being negotiated with Member States.

A variety of industrial collaborations

When IFPEN identifies complementarity with an industrial player in terms of expertise and technological building blocks, a bilateral research partnership may be established with a view to pooling resources and know-how. IFPEN works with over 100 industrial players in France or internationally on this basis. These collaborative arrangements also give IFPEN the opportunity to access industrial data, work on concrete case studies and ensure that its R&I is in line with industrial challenges.

HIGHLIGHT

HORIZON 2020: IFPEN INCREASINGLY ACTIVE

In recent years, IFPEN has stepped up its participation in European calls for proposals, adopting a position in new themes, such as high-performance computing, and seizing new opportunities for its fundamental research (ERC* project submissions and PhD student ITNs**). In total, 15 proposals were submitted in 2018 for the Horizon 2020 program. Of these, five proposals were accepted in the fields of connected electric vehicles, geothermal energy, CO₂ capture/storage and high-performance computing. IFPEN's success rate with respect to Horizon 2020 calls for proposals for the years 2014 to 2018 is 39%. A satisfactory result that demonstrates the excellent fit between IFPEN's strategic directions and European R&I priorities. Since the start of Horizon 2020, IFPEN has led 21 projects funded by this program.

* European Research Council

** Innovative Training Networks

Three industrial committees are responsible for examining IFPEN's R&I programs in order to evaluate their relevance in terms of the needs of industry. They bring together leading industry representatives from the energy, chemicals and transport sectors. Jean-Michel Noé, Philippe Gœbel and Philippe Bernet are chairmen of the Upstream, Downstream and Transport industrial committees, respectively. Below they share their vision of IFPEN's capacity to capitalize on long-standing expertise while positioning itself as a key energy transition player.

JEAN-MICHEL NOÉ, Chairman of the Upstream industrial committee

Over recent years, I've seen many changes at IFPEN, particularly with the emergence of new energies. 2019 will be a pivotal year, with the energy transition increasingly taking center stage. IFPEN will be able to invest in original themes and channel its long-standing expertise into activities supporting new energies. IFPEN's program for 2019 is coherent: it is open enough to enable investigation of fields that are still immature at present. It is a question of knowing which doors to open and which doors to close with full knowledge of the facts. IFPEN has all the strengths required to navigate this change successfully: scientific curiosity, expertise, creativity, the aptitude to evolve and motivation. There is no doubt in my mind that IFPEN will enjoy continued success.

PHILIPPE GÖEBEL, Chairman of the Downstream industrial committee

The worlds of industry and energy are driven by the long term. The Downstream committee's approach reflects this continuity, as well as a gradual shift towards the energy transition. One of IFPEN's strengths is its capacity to draw on its traditional expertise and know-how to support its subsidiaries and industrial partners in the development of their respective markets while limiting the environmental impact. IFPEN employs its expertise in research programs concerning conversion, distillates, gasolines and petrochemicals aimed at optimizing processes and increasing energy efficiency. IFPEN also draws on its expertise and know-how to diversify into new energy sectors in line with its resources and current positions. This evolution will enable IFPEN to take advantage of the new market opportunities generated by the energy transition.

PHILIPPE BERNET, Chairman of the Transport industrial committee

IFPEN's activities in the field of transport are characterized by their durability, enabling it to draw on its traditional professions along with its powertrain and energy expertise to navigate the evolution towards vehicle electrification. But what is also remarkable is the work conducted within IFPEN to diversify and address, for example, connected mobility technologies, which represent a major change with respect to traditional business lines. The chosen approach is interesting since it makes it possible to embrace a whole new field while drawing on recognized knowledge. Today, the issues and challenges in the transport sector, particularly in environmental terms, are global in nature; they cover the entire vehicle life cycle rather than merely usage. IFPEN is uniquely placed to tackle these issues as a whole within a cross-functional approach, thanks to its broad range of knowledge, expertise and tools.



FROM RESEARCH TO INDUSTRY

A key player in the energy transition, IFPEN implements a policy aimed at supporting the competitiveness of companies and facilitating the economic development of the energy, mobility and environment sectors. The transfer to industry of the technology it develops is an integral part of IFPEN's DNA. The transfer from laboratory to industry takes a variety of forms, depending on the context and needs: R&I partnerships, licensing out, support for SMEs and innovative young companies, the acquisition of stakeholdings and the creation of subsidiaries within IFP Group. Through all these actions, IFPEN helps create wealth and jobs.

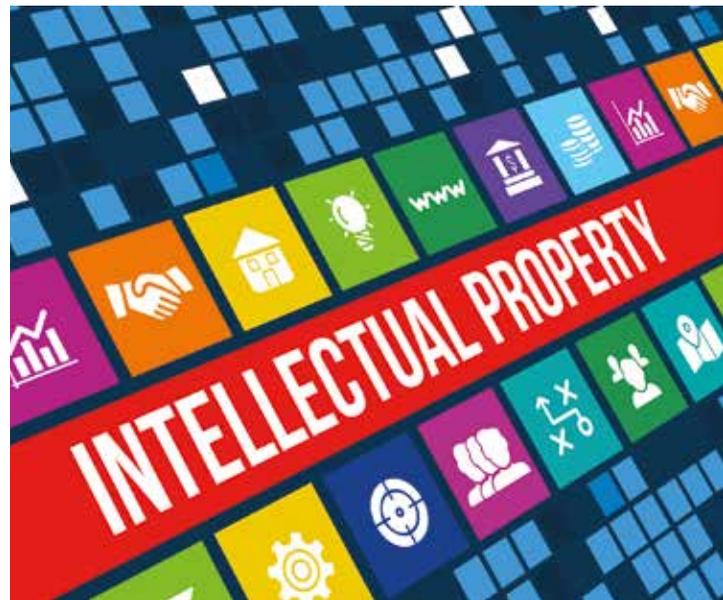
Protecting and transferring innovation

R&I transfer in partnership with industry

IFPEN works closely with industrial partners at the earliest possible stage of a project in order, firstly, to ensure the products of its R&I activities match market needs and, secondly, have access to a marketing vector. When IFPEN establishes a partnership, it gives rise to various forms of intellectual property sharing and transfer. For bilateral research contracts, for example, IFPEN and its partner define the rules regarding the ownership of results. Joint Industry Projects (JIPs) bring together several partners around an R&I program led by IFPEN. On completion of the project, the companies use the results, but IFPEN retains industrial ownership. Joint offers represent another form of collaboration: in 2010, IFPEN, Beicip-Franlab and Solvay created the EOR Alliance in order to market together a service and consultancy offer aimed at the oil industry for enhanced oil recovery.

An ambitious patent filing policy

Patent filing is a key component of IFPEN's research development strategy. Industrial property issues are taken into account from the time a project is launched, not only to protect the results of R&I work, but also to ensure technology transfer. IFPEN is therefore ranked amongst the top 15 national patent applicants in France, alongside major industrial groups. IFPEN's presence among the leading R&I players illustrates its determination to support the industrial sectors of today and the future through innovation.



HIGHLIGHT**IFPEN, 12TH RANKED PATENT FILER IN FRANCE**

IFPEN was ranked 12th by the INPI* in terms of the number of patent applications published in 2018. That puts IFPEN among the top three research bodies in France, with the CEA and the CNRS. When adjusted to account for workforce, IFPEN climbs to number one. In addition, IFPEN filed 188 first patents (primarily French) in 2018 – a record – including 88 relating to new energy technologies (NETs). IFPEN is also one of the top patent filers outside France, with 1,404 rights created in 2018.

* French National Industrial Property Institute

11,800

active patents in IFPEN's portfolio globally



IFPEN, innovation support ecosystem partner

In 2018, IFPEN reinforced its collaborative activities with several innovation support structures – incubators, accelerators, technology hubs – including the Axelera Chemistry and Environment cluster, of which it is a founding member, SATT Pulsalys* and the Bordeaux Technowest incubator. The decision to back such structures is aimed at further boosting the visibility of IFPEN's support for start-ups and SMEs and enabling it to reach new company profiles.

* Lyon Saint-Étienne technology transfer acceleration network

Supporting innovative companies

SMEs and start-ups, IFPEN's innovation partners

IFPEN has been actively supporting SMEs and intermediate-sized companies for nearly 30 years. Today, this support extends to start-up companies and is primarily focused on the energy transition and the environment. The objective: to create wealth and jobs in the regions by supporting the economic activity and competitiveness of companies driving an innovation project. Not only do IFPEN's partners have access to its technical resources and the skills and expertise of its researchers in more than 50 disciplines, but also to its entire ecosystem and network of academic and industrial players and innovation support structures. To reinforce a long-term partnership, the acquisition of a stakeholding may also be considered.

400

companies supported by IFPEN since 1989

HIGHLIGHT**A REDEFINED SUPPORT OFFER**

In 2018, IFPEN restructured its support offer aimed at start-ups, SMEs and intermediate-sized companies, hinged around open innovation and founded on an underlying principle: to speed up the innovation projects and development of the companies supported. IFPEN now proposes two partnership formats, adapted to project needs and maturity:

- a Corporate R&D project: to become strategic partners for the co-development and marketing of an innovation in IFPEN's market segments of interest;
- a Boost & Link partnership: aimed at providing a company with access to IFPEN's facilities and expertise to develop its solution.

The first such partnerships were formalized in 2018 and others are being discussed. In total, IFPEN is targeting twenty such projects through to 2020.



Find out more about the mechanism

MORE THAN
400
new companies met by IFPEN in 2018

Axel'One, Carnauto, AirCar: adapted support

The launch of a new business often requires support, in terms of both hosting and made-to-measure facilities (laboratories, experimental facilities, etc.). Companies can find such support in the form of Axel'One, the collaborative innovation platform dedicated to chemistry and environment located in the Auvergne-Rhône-Alpes region, of which IFPEN is one of the founding members. The resources companies can access include the Innovative Processes platform at IFPEN's Lyon site, and IFPEN's new supercomputer. IFPEN also promotes innovation through partnership initiatives, such as the Carnot Institute network, which facilitates partnerships between SMEs and public research players. In particular, the IFPEN Transports Energie Carnot Institute invests in projects providing access to technological platforms, such as the «Carnot Institute projects for industrial sectors» actions Carnauto (motor vehicle and mobility) and AirCar (aviation).



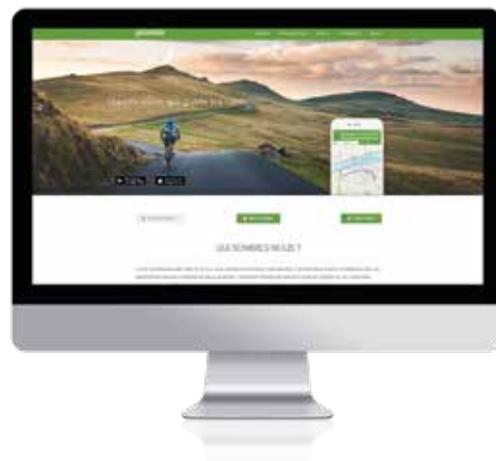
GAËL SAUVANET,

Co-founder and Technical Director,
La Compagnie des Mobilités

In January 2018, IFPEN acquired a stake in start-up La Compagnie des Mobilités, which designs and markets mobile and internet applications dedicated to soft journeys. Teams are working together within the framework of an R&D partnership.

“We began working with IFPEN within the context of the European Veco project aimed at developing mobile and web services for the connected bicycle. Together we came up with a solution based on our Geovelo app, making it possible to make bicycles “smart” by connecting them to a smartphone.

This first collaborative project led us to consider a research partnership, and having IFPEN acquire a stake in our company. With IFPEN's financial and R&D support, we are going to accelerate the development of Geovelo services aimed at local authorities and various players providing route planning data. One of the things we are considering is a tool to automatically detect the quality of cycle paths using smartphone accelerometer sensors. Lastly, IFPEN's support will give us a better platform from which to position ourselves with respect to new customers and partners.”



Supporting job creation

A capacity to uncover gold nuggets

Identifying new products and services stemming from R&I that can be marketed through the creation of start-ups is one of IFPEN's ambitions. The objective is to develop greater agility in order to be able to meet the needs of customers more quickly in rapidly evolving markets. IFPEN thus supports the creation of companies and fosters their development by providing a significant share of the start-up capital required. An example of this business creation policy is DriveQuant, a start-up launched by IFPEN in 2017 in the field of connected mobility.

Entrepreneurship policy

IFPEN supports its employees wishing to start a company, irrespective of the target field. Once the project has been examined, this entrepreneurship policy is hinged around an incubation period of several months, during which time IFPEN shares its business start-up experience with the employee.

> 50%
of IFPEN resources come from
the industrial development of its research



IFP Group

IFPEN's technology transfer policy is underpinned by its dynamic portfolio of subsidiaries and stakeholdings, today bringing together reference industrial players at global level (Axens, Beicip-Franlab, IFP Training, etc.) and newly-created innovative companies such as DriveQuant and La Compagnie des Mobilités. This model, which has proved its worth in the field of oil and gas, is also perfectly capable of addressing the current need for the creation of sectors in the fields of new energies, the environment and sustainable mobility. Today, IFPEN is channeling its efforts in this direction, with the creation of companies and acquisition of stakeholdings in companies operating in these sectors.

HIGHLIGHT

IFPEN TAKES A STAKE IN GALANCK

In October 2018, IFPEN became a 23% stakeholder in the start-up company Galanck. Founded in 2017, Galanck designs, produces and markets connected objects related to soft mobility. The start-up developed an intelligent backpack, the Galuchon, designed for the safety and comfort of cyclists and fans of new urban transport modes (scooters, personal transporters). This stakeholding reinforces IFPEN's positioning in the connected mobility and IoT (Internet of Things) markets. Several joint development priorities have also been identified. In addition, alongside Geovelo and the start-up K-Ryole, IFPEN and Galanck submitted a project proposal within the context of an Île-de-France regional call for projects to develop the use of bicycles in urban areas.



Discover the Galuchon,
Galanck's connected
backpack (in French)

PRINCIPAL HIGHLIGHTS CONCERNING IFP GROUP SUBSIDIARIES AND STAKEHOLDINGS



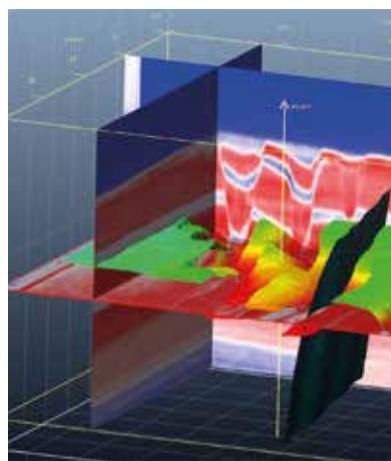
Axens Group: refining, petrochemicals, gas, renewable and alternative energies, water

In 2018, Axens Group pursued its development, driven by its licensing, catalyst, adsorbent and process equipment activities, including furnaces and modules. There were several notable successes in the fields of clean fuel (meeting new standards), petrochemical and gas production processes, with the signing of numerous contracts and the commissioning of a number of licensed units. Demand is being sustained by several regions around the world, particularly the Middle East, India and China. New processes were also either marketed or developed in the fields of chemicals and bio-fuels, in particular. The market success of the Impulse (hydrotreatment), Prime-G+ (hydrodesulfurization), Symphony (catalytic reforming) and Craken (hydro-cracking) catalyst ranges led to the initiation of or decisions to initiate new investments in France, the USA and Saudi Arabia. It is also worth noting the development of Connect'In, an online digital support offer for the monitoring and optimization of unit performances.

Axens, Heurtey Petrochem and Prosernat have now merged to form one company with an expanded range of activities. Axens Group now also owns 50% of Eurecat, the catalyst regeneration and conditioning specialists. Axens has thus broadened its portfolio of solutions and, since the end of 2018, it has boasted a new brand architecture, new identity and new logo.

Beicip-Franlab: geoscientific studies, consulting and software for the oil and gas industry

In a context that remained challenging for exploration-production activities, marked by considerable sales price pressures, Beicip-Franlab enjoyed a profitable year in 2018, with results showing a considerable improvement on 2017. The business was driven by markets in Europe, North Africa and Sub-Saharan Africa, and concerned regional exploration, field and production optimization studies, as well as software sales. On the technical front, new results were obtained with the successful application of stratigraphic modeling methods (DionisosFlow software), both with respect to regional oil evaluation and small-scale field characterization, in carbonaceous and clastic environments. Research conducted by the EOR Alliance, of which Beicip-Franlab is a founding member, reinforced the group's experience in enhanced recovery methods such as steam foam and screening methods. In the oil field sector, integrated reservoir/surface optimization activities continued, with large-scale applications in giant fields, particularly in Algeria. This research has led to the development of innovative thermodynamic fluid modeling methods, from well through to surface installations.



Tech'advantage: an IT consulting and digital services company supporting the energy sector

In 2018, Tech'advantage, in partnership with one of the leading IT consulting and digital services companies in France, won a call for bids concerning the support and maintenance of a chain of applications in the field of exploration-production. Building on the experience it has acquired in recent years working in partnership with France's top 10 IT consulting and digital services companies, Tech'advantage added to its network of partners by signing a commercial partnership agreement with Halias, a Grenoble-based SME specializing in scientific data management and monitoring software. In addition, 2018 was the year that saw the launch of various agile-type projects on behalf of companies in the field of oil engineering software development.

IFP Technologies Canada: development of exploration-production and environmental technologies

In 2018, IFP Technologies Canada primarily focused on the promotion of the EOR Alliance (IFPEN, Beicip-Franlab, Solvay), as well as consulting activities related to enhanced oil and gas recovery.

IFP Training Group: vocational training

In 2018, despite a context that remained challenging for vocational training in the oil and gas sector, IFP Training enjoyed numerous successes with a high level of customer satisfaction. The activity enjoyed a considerable recovery that benefited all the divisions (exploration-production, refining-chemicals, engines-lubricants and economics-management) and can be explained, in particular, by the skills development needs of IFP Training Group's customers. Numerous large-scale projects were conducted, primarily for national institutions and companies, in the following countries: Algeria, Angola, Brazil, Chad, Congo, Gabon, Kuwait, Mexico, Nigeria, Oman, Russia, Saudi Arabia, Senegal, Uganda.



DriveQuant: services for connected vehicles and drivers

In 2018, the insurance sector was in the spotlight with the launch of the first insurance by the minute contract with MAIF (winner of two insurance industry awards) and the first connected offer aimed at motorcyclists with April Moto (Allianz). For 2019, DriveQuant has a portfolio of mature products and a solid technical infrastructure, and will be accelerating the commercial development of its solution, particularly on the international stage. The marked growth in turnover confirms the relevance of its positioning.

Mavel: powertrain engineering

In 2018, Mavel Power Control (Shanghai) Co and Mavel TZ were created, with Chinese investors, for the production of electric motors in the country.

easyLi: lithium-ion energy storage solution engineering

This specialist in the design and industrial development of innovative energy storage solutions enjoyed excellent financial results in 2018. The solution developed for Cityscoot was a complete success. The fleets of scooters available on a free floating basis was deployed in French cities in 2018; Italy will follow suit in 2019, with Rome and Milan. The Storelio residential stationary storage solution is evolving towards a modular system with four storage capacities, ranging from 2.5 kWh to 10 kWh. This new version will be launched to market in 2019. easyLi continued to enjoy growth, driven by a dual energy storage offer, in the fields of light electric mobility and stationary technology.

La Compagnie des Mobilités: connected mobility

In January 2018, IFPEN acquired a stake in La Compagnie des Mobilités. A pioneer in the field of bicycle route planning, La Compagnie des Mobilités proposes a GPS application, called Geovelo, aimed at users and customizable. Geovelo also proposes soft mobility services for major cities. As an R&I partners, IFPEN is supporting the development of Geovelo. In 2018, the application was extended to a further five cities in France. In 2019, it will be rolled out internationally, with offers currently being assembled for Switzerland and Spain, and it will be extended to other market segments.

Galanck: connected objects for mobility

At the end of 2018, IFPEN acquired a stake in the innovative young start-up company Galanck. Winner of the 2018 Techninov award, Galanck designs, develops and markets smart accessories aimed at improving safety for cyclists, and all soft mobility users more generally. Their first product is an illuminated, "smart" backpack with Bluetooth connection to a GPS application with integrated signaling (indicators, brakes, warning lights) guiding users along their route and keeping them safe. Present at CES in Las Vegas in January 2019, Galanck attracted high-profile brands to distribute its product around the globe. IFPEN is working in partnership with Galanck on several R&I developments.

PORTFOLIO OF INDUSTRIAL STAKEHOLDINGS at 30 April 2019





THE KEY PLAYERS TRANSITION

Evolving programs with an increasing
focus on tomorrow's mobility - p. 52

New international programs - p. 53

Success of the new
Tomorrow's mobility MOOC - p. 54

2018 HIGHLIGHTS: THE ESSENTIALS





WINNING IN THE ENERGY

Training is one of IFPEN's statutory missions. IFP School, its applied graduate engineering school, trains the experts who will drive the energy transition and meet current industrial and societal expectations in the energy and transport sectors.

Not only are IFP School graduates immediately operational, they are also equipped for the professions of tomorrow associated with the new energy mix. The School constantly adapts its training provision, changing the content of existing programs and creating new ones to match the needs of industry, with which it maintains close links.

Its partnership model — company sponsorship or apprenticeship contracts — is solid, contributing to the applied nature of the programs. On the international stage, IFP School offers joint graduate programs with high-profile universities, with some leading to a double degree.

A world-class graduate school in the fields of energy and transport, IFP School attaches significant importance to its recruitment process, selecting and preparing the best talented young people and encouraging them to embrace the environmental and ethical aspect of their future professions. The School trains engineers with a global vision of their sector, who are outward-looking and capable of thriving in multicultural environments.



IFP SCHOOL

IFP School provides young engineers with advanced graduate programs leading to professional qualifications in the fields of energy and transport. It has a dual ambition: to provide industry with the skills it needs today and to train the future energy transition players. For this, it is supported by a strategic ecosystem of leading academic and industrial partners, offering its students a cutting-edge teaching model, hinged around innovative materials and tools. Thanks to the skills acquired, IFP School graduates are immediately operational in their sector and already prepared for the jobs of the future in the field of new energy technologies (NETs).

Adapting graduate programs to industrial and societal needs

In order to address the challenges associated with the energy transition, IFP School is accelerating the evolution of its program provision via the introduction of new themes directly linked to NETs. This strategy allows it to remain in step with the needs of both industry and society, and to train outstanding engineers. Graduates not only have the skills companies need immediately, but are also capable of innovating for the future, since they are equipped for the professions of tomorrow.



New skills to address the need for innovative technologies

The energy transition demands new skills and expertise in a variety of fields. IFP School incorporates these into its graduate programs:

- new technologies: hybridization, vehicle electrification, ex-biomass processes, CO₂ capture, energy storage, offshore wind, smart grids and renewable energies for electricity production from an economic angle;
- energy efficiency, in order to optimize energy use throughout the production and consumption chain;
- big data, to optimize energy production and create value;
- cross-disciplinarity, to decompartmentalize disciplines and sectors, thereby creating bridges between specific areas of expertise through the increase in the number of cross-functional projects.



HIGHLIGHT

EVOLVING PROGRAMS WITH AN INCREASING FOCUS ON TOMORROW'S MOBILITY

In order to adapt its teaching provision to the acceleration in vehicle electrification and the development of connected and driverless vehicles, in 2018, IFP School analyzed the required changes in its sustainable mobility and powertrains programs. As a result, specific teaching on electric and hybrid powertrains has been increased within the Powertrain Engineering and Energy and Powertrain programs, now equivalent to the time devoted to IC powertrains. The Energy and Products program has seen the introduction of similar changes, with new teaching modules on batteries and electromobility, as well as on gas, electricity and the digitalization of energy in industry.



The IFP School website has had a makeover!

The site has been redesigned to support the school's new positioning, promote its training offer to potential applicants and better reflect students' needs, particularly in terms of sponsorship and work/study provision.



Discover the new IFP School website

HIGHLIGHT

A NEW OPTION DEDICATED TO ENGINE ELECTRIFICATION

In partnership with IFP Training and the Vedecom Institute, IFP School launched two new “IC and hybrid” and “hybrid and electric” options within the Powertrains specialized master’s program. This course, reserved for working professionals, meets the expectations of manufacturers and industrial players who have to adapt to the evolving market context. This specialized master’s thus offers a program that is relevant to today’s needs and in line with the training market.*

* Institute for the energy transition dedicated to individual, low-carbon and sustainable mobility

17

graduate programs, including 8 delivered in English



TIMOTHÉE JOUAN

Energy and Powertrain program student, apprentice at Renault Sport

“IFP School’s strength lies in the fact that it provides students with the technical and economic expertise relevant to current industrial challenges. The Energy and Powertrain program has enabled me to reinforce my scientific knowledge in order to develop a system and life-cycle approach to vehicle design, associated with the environmental and regulatory requirements of a rapidly evolving field.”

Drawing on a network of international partners

IFP School works with high-profile academic and industrial partners. Through its numerous collaborations with universities and graduate schools, in France and elsewhere, some programs lead to a double degree. Moreover, its close links with industry enable IFP School to remain in step with the needs – both current and future – of companies in terms of expertise and skills. This proximity also explains its students’ high placement level and the relevance of program content. It is through interaction with industry representatives on the school’s advisory board and its program steering committees that IFP School optimizes the number of students on its programs and program content.

HIGHLIGHT

NEW INTERNATIONAL PROGRAMS

IFP School offers a range of international programs. One example is the Petroleum Projects and Offshore Technology joint master’s program with the National University of Singapore, the content of which was finalized in 2018. Taught in English on the Singapore University campus from September 2019, this 16-month program will cover the fields of petroleum engineering and offshore technologies. In 2018, IFP School also renewed its agreement with the Petroleum and Petrochemical College of Chulalongkorn University for a period of three years. The two institutions will thus continue to collaborate within the framework of the Thai university’s Petroleum Technology and Energy master’s program, and the partnership may be extended to include petrochemicals. These collaborations fit squarely with IFP School’s international development strategy – particularly in Asia – via academic partnerships with prestigious universities to meet the needs of local industrial players.

HIGHLIGHT

**IFP SCHOOL AND THE SPE:
A SPECIAL RELATIONSHIP**

With its 168,000 member engineers active in the production of energy resources in 144 countries, the Society of Petroleum Engineers (SPE) represents a professional network of significant importance for IFP School students. The visit by SPE president Darcy Spady, in January 2018, was an opportunity for students to discuss the challenges of the oil and gas exploration-production sectors with him. In September, the SPE gave its Gold Standard Award to the Student Chapter of IFP School for its dynamism and exceptional commitment. It is the third time the SPE Student Chapter of IFP School has won the award, having already received it in 2013 and 2015. Created in 1996, the chapter primarily brings together students from the field of georesources and energy. It is aimed at promoting the exchange of technical knowledge via events organized with energy sector professionals.

+ 80%
of IFP School students
are supported by companies
throughout their studies

**A diversified partnership
offer for companies**

The graduate program model designed by IFP School is hinged around a high level of industrial integration. Numerous collaboration options are thus available to companies:

- student sponsorship or apprenticeship contracts;
- secondment of high-potential young professionals who are already active;
- lecturing and project tutoring;
- organization of industrial visits;
- provision of real data for case studies;
- funding of an industrial chair;
- sponsorship of events or campus spaces.

**A network of alumni in more
than 100 countries**

Today, 15,000 IFP School alumni are working in the energy and transport industries, in over 100 different countries. This network is important for France's influence around the world. IFP School's graduate education activities also play an essential role in IFPEN's international partnerships. By training high-potential employees, IFP School forges strong ties with the people destined to become the future energy transition leaders, in their industrial sector or as policy-makers in their countries.

A focus on innovative teaching methods

IFP School's teaching model hinges around an approach based on solving concrete problems, with a view to effectively preparing students to integrate the workplace. IFP School develops and uses teaching methods promoting knowledge acquisition and learning by experimentation: flipped classrooms, serious games, virtual and augmented reality and mobile/micro learning are just some of the tools that help make IFP School students operational immediately after graduating.

HIGHLIGHTS

SUCCESS OF THE NEW TOMORROW'S MOBILITY MOOC

Following the success of the third edition of its MOOC (Massive Online Open Course) on sustainable mobility, in November 2018, IFP School launched a new free MOOC, in partnership with IFP Training and Vedecom. Called Tomorrow's mobility: sustainable technologies for the automotive sector, this online course enabled participants to acquire knowledge about the legislative and environmental framework governing future technological evolutions, as well as the advantages and limitations of different electric and hybrid powertrains, thanks in particular to virtual reality and serious games. The MOOC enjoyed significant success, bringing together close to 5,000 participants, 65% of whom were international, from 106 countries, for a completion rate of 20%, well above the average for MOOCs in the world.

75%

of those taking part in IFP School's Tomorrow's mobility MOOC said they were "extremely satisfied"

**A TEAM FROM IFP SCHOOL WINS THE FINAL OF THE EUROPEAN
IBA COMPETITION**

In March 2018, a team of five IFP School students specializing in geology and geophysics won the European final of the Imperial Barrel Award (IBA) competition, organized annually by the American Association of Petroleum Geologists (AAPG). The 21 teams taking part had to analyze a set of data (3D seismic block, drilling data) from the Danish waters of the North Sea and propose prospects and an exploration strategy. This award, given by a jury of industry players from the sector, is recognition of the relevance and quality of the training delivered by IFP School.

A module to prepare for the world of work

Organized every year, the Professional Skills module enables IFP School students to acquire the specific soft skills and know-how (project management, social and environmental responsibility, etc.) required for their chosen professions. In particular, students have access to an innovation and entrepreneurship module, enabling them to discover all the aspects associated with setting up a company (design thinking, construction of a business model, experimentation prototyping, drawing up of a business plan, development of a pitch to win over potential investors).



CAROLINE LE NAIL

IFP School Energy and Markets program and École des Mines de Saint-Étienne graduate

“At IFP School, I found the most appropriate graduate program for my intended career specialization in energies, with comprehensive content covering applied economics and finance, from refining to the electricity market. IFP School offers an extremely rich international environment, modules delivered by outside lecturers and collective projects that build a solid bedrock, with the added appeal of periods spent working in a company setting.”

350



lecturers from industry



HIGHLIGHT

SPONSORSHIP OF THE 2018 CLASS

IFP School's 2018 class was sponsored by Patrick Pouyanné, Chairman and CEO of Total.



Facilitating the professional integration of future graduates

Supporting students on their journey to the workplace and helping them position themselves on the market is one of IFP School's priorities. As part of this, in 2018, the 12th "Partner Companies Event" was organized, enabling students to talk to 20 companies from the energy and transport sector (industrial players and consultancy, service and engineering companies). These companies were able to present their career opportunities and the profiles they were seeking. IFP School's future graduates are increasingly sought after, with the number of recruiters present at these events increasing with each event.

ADVISORY BOARD*

Philippe Geiger

Chairman of the Advisory Board, Deputy Director of Energy at the Ministry for Ecological and Inclusive Transition

Didier Houssin

Chairman and CEO of IFPEN

REPRESENTING INDUSTRY

Hélène Beuchot

Human Resources Director, Perenco

Bruno Covin

Director of Strategy and Advanced Powertrain & EV Engineering, Renault Nissan Alliance

Marie-Isabelle Filliette

HR Policy and Strategy Department, Holding, Total

Philippe Franza

Director of Human Resources, ExxonMobil France

Agnieszka Kmiecik

Executive Vice-President People & Culture, TechnipFMC

Stéphane Martinot

Product Marketing Director, Valeo

Olivier Peyret

Chairman and CEO, Schlumberger France

Sandra Roche-Vu Quang

Chief Business Development Officer & CEO of New Countries, ENGIE

Éric Zielinski

Plant Engineering Manager, Saipem

REPRESENTING HIGHER EDUCATION OR RESEARCH

Dominique Bonvin

Professor at the École polytechnique fédérale de Lausanne

Élisabeth Crépon

Director, ENSTA ParisTech

Bernard Leduc

Professor at the Free University of Brussels

Sophie Mougard

Director, École des Ponts ParisTech

REPRESENTING ALUMNI

Nathalie Brunelle

General Secretary - Senior Vice-President Corporate Affairs, Total

Christian Dupraz

Senior Vice-President Asia, Axens

Patrice Marez

Head of Powertrain System Design, PSA Group

Jean-Baptiste Renard

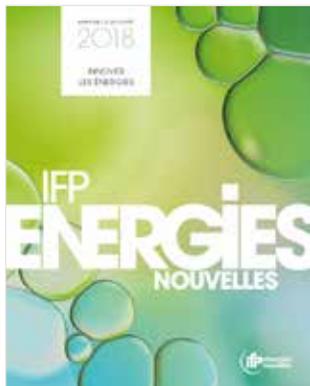
Consultant, Energy Expert

* as of 31 March 2019

REVIEW OF 2018

@IFPENinnovation





Only available in French



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

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

www.ifpenergiesnouvelles.com

Find IFPEN and IFP School on the social networks



Writing: IFPEN • **Design and layout:**  communication

Printing: this document has been printed on FSC®-certified paper 

Copyrights: Adobe Stock ; AD Systems ; Agence Contextes ; Axens ; Beicip-Franlab ; Carl Diner pour la Fondation L'Oréal ; Cyrille Dupont ; Éric Meurice / Objectif Images ; Éric Sutre / Andra ; Florian Grout / DP Multimédia ; Galanck ; Geovelo ; Happy Day ; IFPEN ; IFP School ; Joseph Melin / DP Multimédia ; La Compagnie des Mobilités ; Marc Roussel / ScOpimag ; Michel Haidar / DP Multimédia ; Patrick Chevrolat / Photo France ; Sabine Serrad ; Thierry Petit / Imag'In ; X

ISSN 2427-2973 - IFP Energies nouvelles

All rights reserved

ACTIVITY REPORT

2018

INNOVATING
FOR ENERGY

www.ifpenergiesnouvelles.com

MEETING TOMORROW'S CHALLENGE TODAY

IFP Energies nouvelles

is a major research and training player in the fields of energy, transport and the environment. From research to industry, technological innovation is central to all its activities.

