

ACTIVITY REPORT

2017

INNOVATING
FOR ENERGY

IFP ENERGIES NOUVELLES



OUR MISSION

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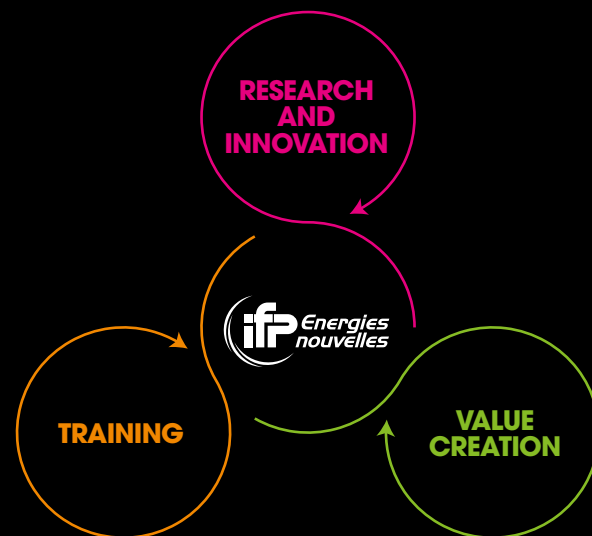
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A CONTEXT CLIMATE CHANGE AND THE ENERGY TRANSITION



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.

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 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 postgraduate 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 programs to almost 15,000 employees from industry every year, securing their competitiveness.

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 quasi 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.

INTERVIEW WITH **DIDIER HOUSSIN**

Chairman and CEO of IFPEN

**PREPARING
FOR THE
FUTURE
BY BUILDING
ON IFPEN'S
SUCCESSSES**

There is a determination to accelerate and reinforce IFPEN's focus on new energies and to move towards the complete self-funding of activities conducted within the context of the responsible oil and gas strategic priority, in line with our objectives and performance contract.



The national priorities concerning the energy transition are clear. The presentation of the French Climate Plan in July 2017 set out the roadmap that will make France a carbon-neutral country by 2050. Reflecting ambitions on a European level and the commitments of COP 21, this plan reinforces the objectives defined by the law relative to the energy transition for green growth. IFPEN is fully in step with these objectives and is in the process of a radical change.

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Reflecting this commitment, the creation of an Open Innovation and Incubation division at IFPEN in 2017 is aimed at increasing the company's diversification into new energy technologies, via a more open approach to innovation and the reinforced transfer of our R&I results in this field. This new division is currently overseeing the in-house participative innovation challenge launched in September to "reinvent energies". The 167 ideas submitted illustrate the creativity and mobilization of IFPEN's employees to help us develop and grow in new sectors. These forward-looking ideas will enable IFPEN to contribute to the construction of new industrial sectors in the fields of new energies and sustainable mobility.

There were numerous highlights for IFPEN Group in 2017, including the creation of two new players. Firstly, IFPEN launched DriveQuant, a start-up company marketing a range of connected mobility services, stemming from its research activities. Secondly, Mavel edt was created by IFPEN and its partners Mavel and Weisa Automobile Technology Limited to launch short production runs of innovative electric engines for private vehicles. Inaugurated in April, its production line is already supplying its first customers. IFPEN is also helping to maintain the group's technological competitiveness. For example, the merger between Axens, Heurtey Petrochem and Eurecat, finalized in 2017, provides a platform for positioning the new entity across all segments covering refining, petrochemicals, gas, biofuels and biochemistry. The new group will achieve a turnover of €1 billion in 2018. IFPEN Group's other companies are beginning to fare better, with clear signs of an upturn, heralding an improved outlook.

Another challenge for IFPEN – and one that is particularly important to me – is that of the digital transformation. A major reflection process was conducted throughout 2017 covering all of the company's sectors; it culminated in the definition of an ambitious action plan. Digital technology will allow IFPEN to reach new levels of performance in terms of collective efficiency, agility and reactivity. It represents a cultural change as well as an opportunity to expand our R&I offer in our various fields of activity, with new tools, methods and services focused, in particular, on data and data-processing, to address the needs of industry.

2017 also marked the fiftieth anniversary of our Lyon site. It was an opportunity to join together with our supervisory authorities and main industrial and academic partners to celebrate half a century of successful human adventure, which began with some thirty or so people and is still continuing today with more than 800 employees. Partners who emphasized the special nature of the IFPEN model, i.e., our capacity to establish useful bridges between fundamental research, applied research and industrial development to serve innovation. Today, IFPEN-Lyon is a benchmark player in a number of fields, including catalysis and eco-efficient processes, and contributes to the creation of value and jobs across the territory. We will continue to support local SMEs and start-ups and help drive the growth of new energy transition and sustainable mobility sectors.

Proud of its past successes, IFPEN is now resolutely focused on the future. At this point, I invite you to discover the priorities, challenges and highlights of 2017 as presented in this document. Whether they concern vehicle electrification, bio-based chemistry, biogas, wave energy or water cycle management, IFPEN's researchers have made major advances in numerous fields.

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**
Training
- 8 Nathalie Alazard-Toux**
Industrial Development

OTHER MEMBERS OF THE EXECUTIVE COMMITTEE

- 9 Yves Boscher**
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 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 at 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 Director for 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 of the Gas, Renewables & Power branch, President of the Strategy-Innovation Division, Member of the Executive Committee, Total

Raphaël Schoentgen

Research and Technology Director for the Engie group

STAFF REPRESENTATIVES

Michel Castagné

Marie Velly

WITH THE ATTENDANCE OF

Nathalie Deguen

Economic and Financial General Controller, Ministry of the Economy

Philippe Geiger

Government Commissioner to IFPEN, Deputy Director of Energy, Ministry of the Ecological and Inclusive Transition

Guillaume Gougeul

Secretary of the Central Works Committee

Grant Thornton et Deloitte & Associés

Statutory auditors

* as of 4 April 2018

THE SCIENTIFIC BOARD*

Grégoire Allaire

Chairman, Professor of Applied Mathematics at the École polytechnique, Senior University Professor

Janne Blichert-Toft

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 (Spain)

Christophe Coperet

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

Marc-Olivier Coppens

Ramsay Memorial Professor and Head of the Chemical Engineering Department at University College London (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 (Austria), 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 nationale 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, IEA Clean and Efficient Combustion TCP Delegate

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 (France)

Luc Vervisch

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

* as of 4 April 2018

IFPEN NEWS IN 2017: IN BRIEF



IFPEN APPOINTMENTS

Éric Lafargue takes over from Georges Picard as Executive Vice-President responsible for industrial development, subsidiary management and legal, economic and financial affairs. Nathalie Alazard-Toux was appointed Director of the Industrial Development Business Unit, taking over from Éric Lafargue. Christine Travers was appointed Dean of IFP School, taking over from Philippe Pinchon. Cécile Barrère-Tricca (photo) was appointed Site Director of IFPEN-Lyon, taking over from Pierre Beccat. Lastly, Nathalie Schildknecht replaces Cécile Barrère-Tricca as Director of the Physics and Analysis division.



A ROADMAP TO SUPPORT THE DIGITAL TRANSFORMATION

IFPEN conducted a major reflection process concerning the digital transformation, a veritable strategic priority for the years to come. The resulting roadmap will guide the evolution of the company's operating tools and methods with a view to achieving greater efficiency, as well as - and above all - the evolution of its R&I services to address new market needs.

AN EVOLVING PORTFOLIO OF SUBSIDIARIES AND STAKEHOLDINGS

2017 saw the finalization of Axens' takeover of Heurtey Petrochem. The merger led to the creation of a benchmark global group for clean fuels and eco-efficient processes, the principal vector for the industrial development of IFPEN's innovations. 2017 also saw the creation of DriveQuant, a start-up company in the field of connected mobility, and Mavel edt, a company jointly owned by Mavel and Weisa Automobile Technology Limited, specializing in the production of electric powertrains for the motor vehicle market.

PANORAMA 2017 CONFERENCE

Digital technologies are central to the energy transition. They will play a fundamental role in the integration of renewable energies, improved energy efficiency and consumption reduction. It is for this reason that IFPEN dedicated its Panorama 2017 conference to the theme "A digital industrial revolution: what impact for the energy and transport sectors?". The event, bringing together 280 participants on site and 500 more via the Internet, saw contributions from digital technology experts, all major players in the fields of energy, transport, engineering and consultancy.



See technical reports and videos of speakers



RISE IN THE NUMBER OF PATENTS FILED

With 187 first patents filed in 2017, IFPEN broke its previous record from 2016. Of these 187 patents, 79 relate to new energy technologies (NETs). These figures reflect the quality of IFPEN's innovation policy and the priority given to the industrial development of its R&I results. In total, it currently has a portfolio of more than 11,000 active patents.

AN IN-HOUSE INNOVATION CHALLENGE

In 2017, IFPEN launched a major in-house innovation challenge. The goal: to help reinforce IFPEN's activities in the field of new energy technologies (NETs), providing research programs with new projects. In total, 167 proposals were evaluated with a view to selecting 6 winning projects in 2018.



A SEMINAR DEVOTED TO SPATIALIZATION IN LIFE-CYCLE ANALYSIS (LCA)

LCA is a key tool for quantifying a sector's environmental externalities, from the resource to be mobilized through to product launch. IFPEN's expertise in this field now incorporates the geographical dimension, an essential approach when it comes to addressing territoriality issues inherent to the decentralization of production resources related to new energies. The potential of spatialization in LCA was illustrated at the EcoSD* network's theme day, held at IFPEN in March 2017. Co-organized with IRSTEA (French National Research Institute of Science and Technology for the Environment and Agriculture), INRA (French National Institute for Agricultural Research) and the school of Environmental Management and Engineering, the event brought together around one hundred academic, industrial and institutional representatives.

* Eco-design of systems for sustainable development

13th ranked patent filer in France according to the INPI*



More than **600** scientific publications and conference papers



Around **500** IFP School graduates of which almost 50% are foreign students



ISO 9001 certified for R&I activities



* French National Industrial Property Institute

IFPEN-LYON 50 YEARS OF INNOVATION

In 1967, IFPEN opened its design and industrial development center in Solaize, near Lyon, to expand its testing facilities. The site houses pilot units and large-scale equipment used to extrapolate laboratory research to an industrial scale. Over the decades, IFPEN has thus contributed to the development of new products, processes and industrial sectors, in the fields of energy, transport and eco-industries. Half a century of innovation.

www.50ansifpenlyon.com



Key figures

(end 2017)

841
employees

34,045 m²
of buildings

2,600th
license sold

A few key dates

1971

CREATION OF COFLEXIP

IFPEN created Coflexip to develop and market flexible pipelines for the subsea transportation of oil and gas. An innovative concept, in a market previously dominated by rigid pipes. Following significant international expansion, in 2002, Coflexip merged with Technip, another company created by IFPEN, in 1958.



2001

CREATION OF AXENS

IFPEN creates Axens to propose industry an integrated offer of technologies and services aimed at reducing the environmental footprint of oil products and fuel production activities. Now with a workforce of more than 2,300 employees, Axens Group is a world-class player for processes and catalysts aimed at the refining, petrochemicals, gas, alternative fuels and bio-based products markets.

1981

LAUNCH OF BIOFUEL RESEARCH

It has been known since the earliest days of the car industry that the fermentation of beetroot produces ethanol that can be used as a fuel. It was an alternative that came back to the table after the second oil crisis. IFPEN began developing so-called 1st-generation biofuel production processes. In the 2000s, research focused on the development of 2nd-generation processes, using non-food biomass. In particular, it developed Diester[®], used in numerous diesel vehicles today.

1990

EXTENSION OF THE ENGINE ACTIVITY AT SOLAIZE

While IFPEN's powertrain research activities began in the 1960s on the Rueil-Malmaison site, it was not until 1990 that they started at the Lyon site. The aim of this research is to obtain a better performance/emissions compromise. In the previous year, IFPEN took part in the Clean and fuel-efficient program developed by the French government and the car industry.

2016

FIRST SUCCESS IN THE FLOATING OFFSHORE WIND POWER SECTOR

The floating and anchoring technology developed by IFPEN and SBM Offshore was chosen by EDF Energies Nouvelles within the context of the ADEME (French Environment and Energy Management Agency) call for projects concerning floating wind turbine farms. Some of the research was conducted at the Lyon site.



What they have to say about IFPEN...

ALAIN BERETZ

General Director for Research and Innovation, French Ministry of Higher Education, Research and Innovation

"IFPEN clearly illustrates the importance of coherence between education, research and innovation. IFPEN owes its success to the genuine coherence of these three roles."

LUC BENOÎT-CATTIN

Vice-President for Industry, Arkema

"IFPEN is capable of building a solid bridge between academic and applied research, to reach a commercial dimension."

JEAN-FRANÇOIS PINTON

President of the ENS Lyon

"IFPEN plays the role of facilitator at the center of the research, training and innovation triptych within the chemistry sector in the Rhône valley."



Discover the speeches made at IFPEN-Lyon's 50th anniversary conference



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.



1,638 
Total full-time equivalent workforce for 2017

including **1,115** researchers (R&I engineers and technicians) and **+210** research grant holders, post-doctoral researchers and placement students



450 employees have been mobile since 2014



72% of employees benefited from at least one training initiative in 2017



4.89% Proportion of disabled workers in 2017



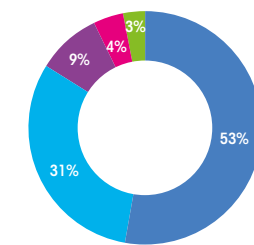
FINANCIAL DATA

Budget implementation in 2017 was marked by a sharp increase in royalties, largely due to the excellent commercial performance of IFPEN's Axens subsidiary. Overall, there was a drop in operating expenses, due to a payroll that has been stable for the last two financial years and a rigorous external spending policy.

As a result, there was an improvement in IFPEN's EBIT compared to the initial budget, despite the loan cancellations recorded over the course of the financial year relating to the budget allocation from the French Ministry for the Ecological and Inclusive Transition.

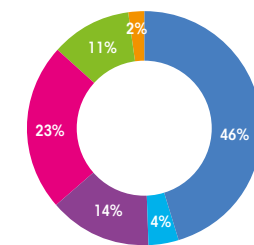
The objective for 2018 and thereafter is to maintain the trajectory initiated in 2017, seeking a sustainable balance in EBIT, via a continued increase in the group's own resources and the maintenance of its operating expenses at current levels, along with a stabilization in budget allocation. Since the budget allocation is currently dedicated to funding research in the field of NETs, its stabilization will be a major factor in terms of speeding up the transformation of IFPEN's economic model for the coming years.

BREAKDOWN OF CURRENT EXPENDITURE
Financial end 2017





■ Personnel costs
■ Current operating costs
■ Amortization, Provision
■ Taxes
■ Others

BREAKDOWN OF CURRENT REVENUE
Financial end 2017



■ Net budget allocation
■ Royalties
■ Collaborative research payments
■ Dividends
■ Public Funds
■ Others

€278.2 million 
Operating expenses
including **€232.9 million** 
for R&I

€125.1 million
Budget allocation

€150.1 million
Own resources

50% of budget dedicated to NETs 

WEIGHT OF NETS IN IFPEN R&I (IN %)	2017
Total NETs	50
New energies	13
Sustainable mobility	16
Cross-disciplinary fundamental research	21

IFPEN GROUP CONSOLIDATED ACCOUNTS (IN € MILLION)	2017
Turnover	1 055,6
EBIT	51.8
Net profits group share	23.7

DEVELOPING THE

INNOVATIONS

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 themes: 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. This research represents a cross-functional bedrock the purpose of which is to address scientific questions associated with the development of new products, as well as to anticipate future requirements.

In total, some 1,200 researchers covering more than 50 fields of expertise are mobilized day to day at IFPEN's two sites, representing the driving force behind a research strategy serving innovation and the energy transition.

More and more services for connected vehicles - p. 16
 Launch of a wave energy conversion demonstrator project - p. 23
 Gas treatment: reducing costs and increasing performance - p. 28
 A new "asset" for IFPEN - p. 32

2017 HIGHLIGHTS: THE ESSENTIALS

AND OF TODAY TOMORROW

- 14 **Sustainable mobility**
- 20 **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 (IC IFPEN TE). The Institute is exploring four complementary technological avenues, namely vehicle electrification, the development of services and software for connected vehicles, the improvement of the energy efficiency of IC engines and their pollution control and, lastly, the optimization and use of low-carbon fuels.

The IFPEN Transports Energie Carnot Institute

Since it received its label in 2006, IFPEN's activities in the field of transport and mobility have been conducted within the framework of the IC IFPEN TE. Renewed in July 2016 as part of Carnot 3, this label is recognition of IFPEN's capacity to conduct joint research programs and support company innovation. IC IFPEN TE is an active member of the Carnot Institute network. Contributing to Carnot Institute projects for industrial sectors, 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



IC IFPEN TE forges relations with micro-companies, 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&I support

specific to their innovation need. For example, in 2017, IC IFPEN TE:

- organized the first "17-20 Carnauto" event, held in May, at IFPEN-Lyon, on the theme of vehicle electrification. The event was an opportunity for the some twenty companies present to discuss the Carnauto offer and potential R&I funding solutions with Bpifrance;
- took part in the 10th edition of the Carnot Events, held in Paris in October. It met numerous project leaders at its stand who will now be followed up with a view to potential collaboration.

HIGHLIGHT

IFPEN RESEARCHERS CONTRIBUTE TO THE CARNOT INSTITUTE'S PROJECTS

In order to promote technological and behavioral changes in the field of mobility through new concepts and services, in early 2017, IC IFPEN TE launched its second internal call for projects on sustainable mobility. The aim of this initiative was to reinforce research and innovation capacity by mobilizing the IFPEN researchers concerned. Along the 30 proposals submitted and evaluated, two were selected for a preliminary analysis.



HIGHLIGHT

TOWARDS FUEL-EFFICIENT HEAVY TRUCKS



IFPEN is contributing to the Falcon (Flexible & Aerodynamic truck for Low CONsumption) project, the aim of which is to develop a complete, fuel-efficient heavy truck for goods transport.

The three-month project is being led by Renault Trucks with 12 industrial, academic and research partners. Labeled by the Cara, Mov'eo, Capenergies and Véhicule du futur (Vehicle of the Future) competitiveness clusters, it was selected within the context of the 23rd call for projects of the French Interministerial Fund (FUI). Working in partnership with Enogia, IFPEN is responsible for developing the ORC thermal energy recovery system prototype and evaluating component performance.

Developing vehicle electrification

Vehicle electrification is crucial for reducing fuel consumption and limiting the impact of transport on the environment and health. Already enjoying significant growth, it will initially rely on different hybridization solutions adapted to usages. IFPEN's research in this field covers the development of innovative, efficient electric machines with a high specific power, along with their power electronics. IFPEN also designs technological solutions targeting lost thermal energy recovery. Lastly, due to the complex architecture of electric vehicles, researchers are also working on the optimization of onboard energy management.

HIGHLIGHTS

E-TURBO: A TURBOCHARGER THAT PRODUCES ELECTRICITY



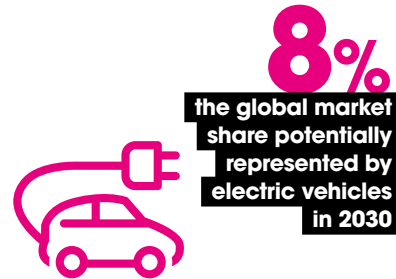
Most current IC engines use a turbocharger to improve the vehicle's performance and fuel consumption, recovering some of the energy lost via exhaust gases. IFPEN and its partner Mavel are pushing back the boundaries, developing an original electrified turbocharger solution, the e-turbo. The objective: to improve acceleration

and drivability aspects, but also reduce fuel consumption by optimizing engine performance and recovering more of the exhaust energy.

A demonstrator, designed and tested in 2017, was used to validate the concept of the innovative electric motor adapted to this application, which is extremely demanding in mechanical and electrical terms due to the very high turbocharger speed. It confirms IFPEN's capacity to develop complex, energy-efficient electrical systems. Initially developed for sports cars, the e-turbo is also aimed at mid-range vehicles, goods transport trucks and construction site machinery.

FIRST SUCCESSFUL TESTS FOR AN ORC MODULE APPLIED TO TRAWLERS

Launched in 2014, the European EfficientShip project is aimed at lowering the fuel consumption of trawlers by 5% and raising awareness within the shipping sector of the importance of reducing CO₂ emissions. Project partners Enogia, IFPEN and CNR-Ismar adapted an ORC (Organic Rankine Cycle) thermal engine recovery system to fishing boats. The system is used to convert the heat lost in engine exhaust gases into electricity. In 2017, the first tests of the module on a pilot trawler proved successful, delivering the first kilowatts of electricity. Prototype testing will now continue over a period of a few months in order to power the onboard auxiliary components, including the high energy-consuming ice machines, essential for the conservation of fish. Extrapolation of results will allow the potential benefits of ORC technology to be evaluated for other types of ship.



Towards connected mobility

Like many economic sectors, the transport sector is undergoing a revolution on two fronts: technological and usage, with the appearance of new forms of mobility. In this context, digital technologies represent an interesting lever to facilitate the transition to cleaner, safer “eco-mobility”. Since a vehicle’s energy and environmental impact depend on its use in real conditions, IFPEN develops services and software solutions dedicated to energy analysis, eco-driving, the monitoring of pollutant emissions and driving analysis from a safety point of view.

HIGHLIGHT

MORE AND MORE SERVICES FOR CONNECTED VEHICLES

IFPEN exploits the possibilities offered by connected mobility to develop new innovative services. In 2017, the focus was on two areas: car repairs and air quality. The first solution developed concerns the use of telediagnosics for the wear and tear of parts such as brake pads, tires and batteries. The second solution relates to the quantification and monitoring of pollutant emissions associated with a vehicle’s journey, recorded via a smartphone application or telematic device. These stand-out solutions on the market now form part of the service range offered by DriveQuant, the start-up created in February 2017 by IFPEN. They supplement those already proposed for energy analysis, safety at the wheel and eco-coaching.

Recovering low-temperature thermal energy

IFPEN and its partner Enogia, the heat recovery specialist, are developing an ORC system capable of recovering the thermal energy of an engine’s cooling system. An original approach that reduces constraints, thereby making it possible to make the system lighter, more compact, cheaper, more reliable and easier to integrate. Adaptable to both heavy trucks and light vehicles – gasoline and Diesel powertrains –, this solution makes it possible to reduce fuel consumption and CO₂ emissions by between 2 and 3% in standard operating conditions.

The contribution of life cycle analyses to sustainable mobility

In order to achieve carbon neutrality in the transport sector by 2050, several solutions are emerging, including various forms of vehicle electrification (battery, light hybridization, plug-in hybridization), powertrain performance and after-treatment improvements and the incorporation of biofuels. IFPEN uses the life cycle analysis (LCA) method to study the environmental performance of various powertrains under consideration, taking into account the vehicle’s life cycle and associated energy vectors (fossil fuels, biofuels, electricity). This approach thus makes it possible to compare various sustainable mobility deployment scenarios and identify those that are most beneficial to the environment.

For a global approach to connected mobility

From bicycles through to heavy trucks via private cars, IFPEN offers eco-mobility solutions adapted to various types of transport:

- via the Geco air smartphone app, which analyzes pollutant and CO₂ emissions associated with the journeys undertaken by its users, irrespective of the type of transport used, to help them reduce their environmental impact;
- with La Compagnie des Mobilités, to integrate into the Geovelo bicycle GPS smartphone app modules to evaluate the energy expenditure relating to a specific journey and to qualify the conditions of cycle paths in real time;
- with Michelin Solutions, via the development of the Mybestroute offer launched in 2017, which heavy truck sector professionals can use to identify the best routes in terms of fuel consumption, time and costs.



HIGHLIGHT

TURNING MOTORISTS INTO “ECO-MOBILITY DRIVERS” WITH GECO AIR

Developed by IFPEN, the Geco air app provides a real-time analysis of pollutant and CO₂ emissions associated with a journey. Launched in early 2017, Geco air has already caught the attention of numerous private users as well as local authorities and air quality players. Reflecting this momentum, the Lyon region’s 4th inter-company eco-driving challenge, which, this year, was hinged around the use of this app, proved highly successful. Organized with Greater Lyon and the ADDVC (Association for the sustainable development of Chemistry Valley), this challenge is aimed at raising motorists’ awareness of a more fuel-efficient and eco-friendly driving approach, while enabling their company to evaluate and contribute to the reduction of the environmental footprint of their employees. In total, 61 companies took part in the challenge – a record – and 204,000 km were traveled in eco-mobility mode.

±20%

Variation in CO₂ emissions depending on the individual driver for the same urban journey



ALEXANDRE CHASSE

Head of the Telediagnosics and fleet management project at IFPEN

“In July 2017, IFPEN and Michelin Solutions signed a five-year partnership agreement to continue research under way since 2015 aimed at reducing the fuel consumption of heavy trucks and associated fuel spending, which can account for as much as 30% of a fleet manager’s total costs. Initial research led to the marketing of Michelin Solutions’ Mybestroute offer. Its added value lies in the accuracy and reliability of heavy truck fuel consumption predictions, made possible by the approach adopted based on journey modeling and the incorporation of parameters such as the vehicle load and gradients encountered along the route. Other areas for collaboration, such as eco-driving and energy diagnosis, are being considered.”



Improving IC powertrains

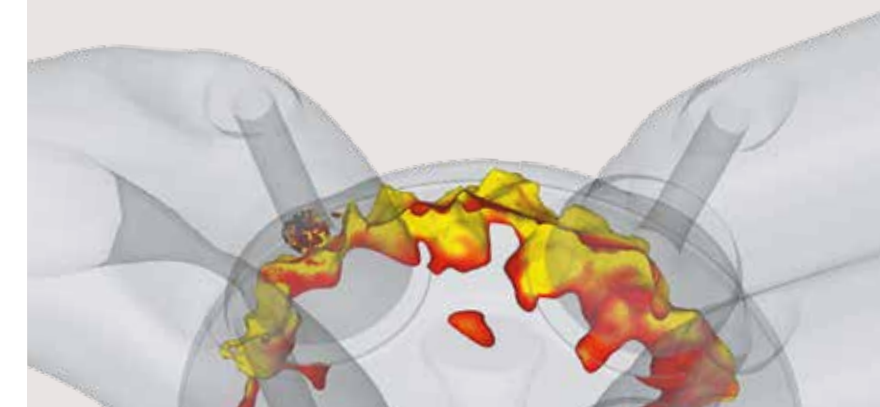
In a context marked by the priorities of the French Climate Plan, with the scheduled end of greenhouse gas-emitting powertrains by 2040, the effects of “Dieselgate” and the tightening up of global environmental standards, today’s industrial offer is evolving rapidly. In this transition, gasoline engines, integrated into hybrid powertrains, will play an essential role in the short and medium terms for the majority of road vehicles. And diesel will remain the reference fuel for industrial vehicles and heavy trucks, while kerosene will continue to be used in the aviation sector. In line with market reality, IFPEN is conducting research aimed at improving the efficiency of IC engines while reducing pollutant emissions, via the optimization of existing technologies and the introduction of breakthrough solutions.

HIGHLIGHT

MODELING AND SIMULATION SOFTWARE: CONTINUED TRUST OF IFPEN’S PARTNERS

Within the context of its R&I activities, IFPEN develops software tools for the design of powertrains, marketed by various partners. Two major partnership contracts were renewed in 2017:

- the first is a five-year agreement with partner Convergent Science Inc., a global leader in the field of 3D engine combustion modeling software. This new deal extends the scope of the partnership to large eddy simulation (LES) in particular;
- the second is a four-year agreement with partner Siemens PLM Software, a global leader in the field of system simulation tools. The result of a collaboration initiated by IFPEN with the French SME Imagine more than 15 years ago, in 2017, Siemens PLM Software’s LMS Imagine.Lab Amesim platform integrated the HOT (Hybrid Optimization Tool) stemming from IFPEN’s R&I activities. The purpose of this tool is to facilitate the design and optimization of hybrid powertrains, by making it possible to identify the advantages and disadvantages of an architecture or a component with respect to another.



HIGHLIGHT**TOWARDS HIGHLY-EFFICIENT GASOLINE ENGINES**

Significantly improving the thermodynamic efficiency of gasoline powertrains is one of IFPEN's research avenues. Optimized combustion systems based on an original internal aerodynamic approach were identified and developed in 2017. Presented at the Aix-la-Chapelle conference in October, a demonstration on a 1 liter – 3 cylinders – 2 valves per cylinder engine delivered a maximum effective efficiency of 42.5% and efficiencies in excess of 40% over a broad operating range. The other project in this field, Eagle (Efficient Additivated Gasoline Lean Engine) was launched in 2016 within the context of the European Horizon 2020 framework program. Led by IFPEN, this project, lasting three and half years, brings together nine partners. The aim is to develop a gasoline powertrain for a hybrid application delivering peak efficiencies of 50%. Various technologies are being evaluated to this end, including an intelligent thermal insulation solution for the combustion chamber, an innovative ignition system, the use of hydrogen as a gasoline additive and a pollution control system adapted to lean burn operation.

“Dieselgate”: IFPEN, a member of the commission for pollutant emission control

Following the Volkswagen scandal, at the end of 2015, the French Ministry for the Environment, Energy and Marine Affairs launched a comprehensive survey of 86 Diesel vehicles marketed in France. They were tested on a chassis dynamometer and on the track with a view to detecting anomalies in the pollution control systems. IFPEN, a member of the independent commission, was tasked with analyzing the results and making recommendations in a report published in July 2016. Ten vehicles with particularly high emissions levels were also the subject of an in-depth study conducted by IFPEN, the results of which appeared in a report published in April 2017.



Read supplementary report of April 2017 (in French)

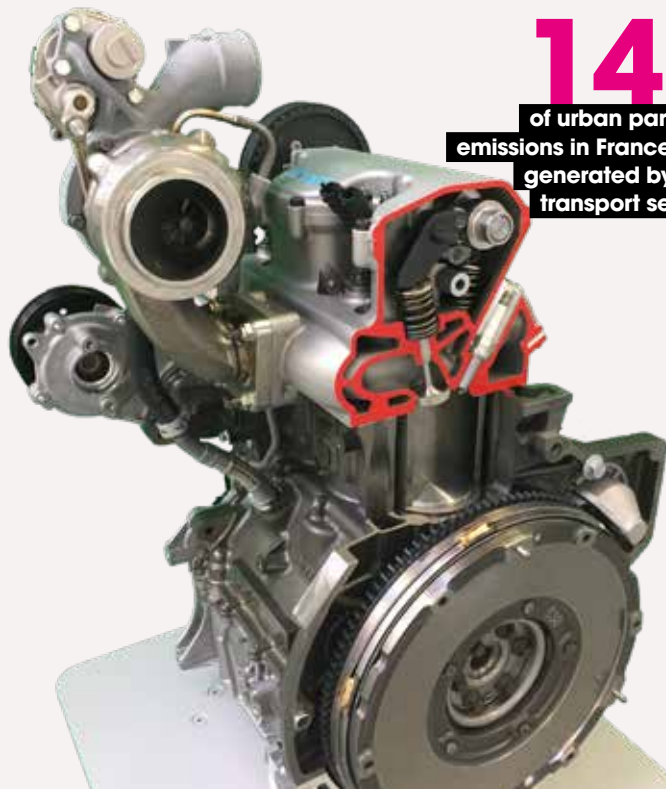
66 g/km 

Average CO₂ emissions objective set by the European Union for new cars by 2030

HIGHLIGHT**NEW ADVANCES IN THE FIELD OF VEHICLE AFTER-TREATMENT**

IFPEN is pursuing research aimed at improving the performance of its pollution control solutions. In 2017, a zeolite that can be used to increase the conversion of low-temperature nitrogen oxides during selective catalytic reduction (SCR) was identified. Further research is under way to verify its capacity to increase catalyst selectivity and minimize exhaust gas ammonia emissions. In the field of particle emissions, a multi-function fluid that can be used to supply the ammonia required for SCR and improve the regeneration of the particle filter by lowering the soot combustion temperature was developed. The target: a simplified after-treatment system and reduced fuel consumption. Lastly, IFPEN is taking part in the European Sureal-23 project, aimed at characterizing measurement devices for particle sizes below 23 nanometers.

14%
of urban particle emissions in France are generated by the transport sector

**Optimizing fuel use**

Irrespective of the type of fuel used, conventional or alternative, engine and fuel compatibility makes it possible to optimize energy and environmental performances. In particular, the introduction of low-carbon fuels (natural gas, biofuel, hydrogen, etc.) requires specific technologies. IFPEN is working on the development of new, low-emission, highly energy-efficient engine/fuel pairings, with a particular focus on natural gas, which opens up avenues of potential interest. The issue of alternative fuel production is examined in the «New Energies» chapter of this report (see page 20).



Partner Interview
ARTHUR LEROUX, Chairman of Enogia

Created in 2009, Enogia is a French start-up specializing in ORC thermal energy recovery systems. It has been working with IFPEN since 2014 to extend its range of applications.*

What are your target markets?

To begin with, we focused on stationary applications, primarily in the field of renewable energies: biomass and biogas cogeneration installations, geothermal power plants, etc. Our aim is to be the market leader in this segment but we also want to expand our perimeter to the transport market, via miniaturization in particular.

Why a partnership with IFPEN?

IFPEN's researchers are already working on heat recovery from a system point of view. We're contributing a component approach aimed at feeding the joint reflection process. Moreover, IFPEN's test benches are far better than ours, enabling us to bring our products to market much faster. Lastly, IFPEN's teams have a forward-looking intelligence capacity that we don't have as a start-up. It was they who advised us to turn our attention to transport applications. I would also add that we felt IFPEN had a thorough understanding of the challenges facing a start-up company, something that is rare and invaluable.

What projects are you working on together?

We are looking at several applications in the vehicle, rail and shipping sectors. We're also developing a 100 kW turbine for stationary applications, in order to target markets with power needs greater than those covered by our current product range.

* Organic Rankine Cycle.

NEW ENERGIES

The energy transition and tackling climate change depend on the development of new resources such as lignocellulosic biomass and ocean energies, the potential of which is set to expand. IFPEN develops sustainable fuel production processes based on biomass that can be used in conventional engines, as well as production processes targeting bio-based chemical intermediates. Its activities are also aimed at proposing technological solutions for the development of ocean energies. In parallel with this field of expertise, IFPEN is also interested in energy storage technologies. Lastly, with a view to reducing CO₂ emissions, IFPEN is taking part in research dedicated to CO₂ capture process improvements.

Biofuel production

2020-2030

the decade during which 2G biofuels will enjoy an industrial boom

Most of the R&I work taking place around the world in the field of biofuel production focuses on the development of so-called 2nd generation (2G) technologies, using lignocellulosic resources such as agricultural and forestry waste, without competing with food for human consumption. IFPEN is studying two main processes for the conversion of biomass into fuel: biochemical conversion (bioethanol production) and thermochemical conversion (biodiesel and biokerosene production), also known as BtL (Biomass to Liquid) technology. Its research covers the entire process chain, from pre-treatment of lignocellulose to fuel production, via the optimization and integration of the different steps, in economic and environmental terms.

HIGHLIGHT

FINAL STEPS PRIOR TO THE MARKETING OF THE FUTUROL PROCESS

In the field of biochemical conversion, IFPEN is contributing to the Futurol collaborative project, aimed at developing and launching to market a complete chain for the production of 2nd-generation bioethanol, which is economically competitive. Following the commissioning of the industrial biomass pre-treatment prototype in 2016, installed at the Tereos sugar plant in Bucy-le-Long (Aisne, northern France), the project reached another key milestone in 2017. A series of tests conducted on this prototype delivered the technical parameters required to validate the industrial scale-up of this technology. Further tests will be conducted in 2018 at the Pomacle (Marne, France) pilot unit in order to qualify a broad range of biomass and complete the process file. Axens is responsible for marketing the process.



HIGHLIGHT

SUCCESSFUL COLD START FOR THE BIOTFUEL PROJECT PILOT UNITS

In the field of thermochemical conversion, IFPEN is a key partner in the BioTfuel project, the objective of which is to develop and launch to market a production chain for 2nd-generation biodiesel and biokerosene by 2020. In 2017, construction work was completed on 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 (Oise area); the other for the gasification of the torrefied biomass at Total's site near Dunkirk. The two pilot units were brought into service at the end of the year, with the cold test phase and first R&I test due to be launched in 2018. They will be used to validate the sequence of technologies retained and guarantee industrial-scale scale-up, as well as the overall efficiency of the process chain.

IFPEN, co-manager of the New Resources solution



Working alongside Veolia, IFPEN is managing the New Resources solution, one of the nine solutions in the New Industrial France program, following on from the Green Chemistry and Biofuels and Recycling and Green Materials Plans. Within this, IFPEN is responsible for managing the Advanced Biofuels working group and contributes to the Biobased Chemistry Group. As such, in April 2017, IFPEN contributed to the organization of a seminar with the General Directorate for Enterprise (DGE) focusing on the conditions for the emergence in France of an industrial lignocellulosic biomass production sector.

HIGHLIGHT

VALIDATION OF A PILOT UNIT FOR THE PRODUCTION OF BIO-AROMATICS

IFPEN, Axens and American company Anellotech joined forces in 2015 to develop Bio-TCat, a process for the thermocatalytic conversion of lignocellulosic biomass with a view to the production of bio-aromatics (BTX, for benzene, toluene and xylenes). In 2017, an important milestone was reached with the commissioning of the pilot unit installed at the Southampton resources site in Silbee (Texas), aimed at testing the viability of the process on an industrial scale. The first tests were very positive, validating the technologies and the pilot unit's process control. A major testing program is scheduled for 2018 and 2019 in order to acquire the operational data required for the industrial scale-up of the process. Once the development phase has been completed, the industrialization and marketing of the process will be handled by Axens.

Towards plant-based chemistry

Bio-based chemistry is now considered to represent a realistic option for producing the majority of the main chemical intermediates currently derived from fossil resources, particularly for the production of plastics. It will also be possible to produce new molecules with new functionalities. This trend fits squarely with the growing demand on the part of consumers for bio-based products and a deficit in the global supply of some aromatics and olefins. IFPEN is working on the development of processes, catalysts and biocatalysts for the transformation of biomass into alcohols, olefins and aromatics.



HIGHLIGHT

BIO-BUTADIENE PRODUCTION: THE BIOBUTTERFLY PROJECT HOLDS ITS PROMISES

In 2017, research conducted by IFPEN, Michelin and Axens within the framework of the BioButterfly project culminated in the first experiments on pilot units, installed at IFPEN's Lyon site. The objective of this project supported by ADEME: to test different catalysis and separation operations, which, once integrated, will make it possible to produce butadiene (a chemical intermediate used in the manufacture of synthetic rubbers) from biomass. The experimental data acquired confirmed the economic and environmental performance of the process compared to the fossil option. A pre-industrial demonstrator was also defined and a decision will be taken in 2018 regarding its construction. If it does go ahead, the demonstrator will be used to validate the operation of the process and the quality of the butadiene produced. The partners are targeting commercialization of the technology by 2020.

10%

estimated average annual growth in the production of bio-based plastics over the period 2017-2030

**Investing in emerging markets related to new energies**

New R&I themes, stimulated by the energy transition and circular economy markets, are beginning to emerge. IFPEN's research activities include processes for the conversion of used materials, such as plastics, to major chemical intermediates, as well as biogas and aqueous effluent purification technologies, with a view to industrial water recycling.

HIGHLIGHTS

BIOGAS PURIFICATION: THE WORLD'S FIRST DEMONSTRATION OF A NEW TECHNOLOGY

In 2015, IFPEN joined forces with the SME Arol Energy for the Biomet project - supported by ADEME -, targeting the energy recovery of biogas produced by methanization. Biogas is purified using gas sweetening technology developed by IFPEN, which makes it possible to both reduce the carbon footprint and increase the economic profitability of the process. This purification technology was demonstrated in 2017 at the Terragr'Eau methanization site in Évian (France). Biogas was purified beyond regulatory specifications and injected into the natural gas network managed by GRDF. Early results obtained confirm the performance of the technology - called AE-Amine - now ready for industrial roll-out.



10%

the objective for the incorporation of green gas in overall gas consumption in France by 2030*

* Objective specified by the energy transition and green growth law

A NEW ADSORBENT FOR LITHIUM EXTRACTION

IFPEN and its partner Eramet have developed an innovative direct extraction process based on a selective adsorbent to valorize lithium from Argentinian brines from salars to compete with the conventional process based on naturel evaporation. It will optimize the use of existing resources, favoring a reduced environmental footprint. A new adsorbent formulation was validated in 2017 in operating conditions, demonstrating solid performances in terms of yield, mechanical resistance and selectivity. The individual operations of the process were also tested. The goal of this research is to pave the way for industrial implementation at Eramet's extraction site in Argentina by 2020.

Offshore wind and ocean energy development

Offshore wind, tidal and wave energies represent an emerging - yet to date little exploited - alternative in the field of renewable energies. 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. Thanks to this expertise, IFPEN is positioned across several segments of the value chain, from resource evaluation through to the design of efficient control systems for land and offshore wind turbines. IFPEN is also contributing to the development of efficient wave energy technology that can be used by industry.

HIGHLIGHT

LAUNCH OF A WAVE ENERGY CONVERSION DEMONSTRATOR PROJECT

While a few demonstrators are currently being tested around the world, wave energy conversion systems are currently at a very early stage of development. In this field, IFPEN is taking part in the four-year S3 project, launched in early 2017, in collaboration with SBM Offshore (project leader) and the École centrale de Nantes. Supported by ADEME, the aim of this project is to develop and test, in real operating conditions, a wave energy conversion demonstrator based on an innovative machine system designed by SBM Offshore. The system uses electroactive polymers that change shape under the action of the swell, thereby converting wave energy directly into electricity. IFPEN is responsible for the development of short-term swell prediction strategies, which will enable active control of the machine and increase its electricity production capacity.

Digital technologies serving NETs

The wind energy, ocean energy and energy storage sectors are fields in which the use of digital technologies is relatively widespread. For example, IFPEN's solutions - including Wise-Lidar and Wise-Control software - are already based on approaches focusing on measurements. IFPEN's goal is now to further develop this digital offer with its partners, making maximum use of the possibilities provided by digital technology.

**Software "with the wind in its sails"**

Working in partnership with Leosphere, IFPEN is developing solutions designed to use wind measurements provided by lidar sensors to increase the energy productivity and reduce the operating costs of wind turbines. The first part of the collaboration is dedicated to the processing of lidar measurement data. This work led to the development of the Wise-Lidar software solution, which is used to fine-tune wind predictions and thus more accurately evaluate a wind energy project's profitability. The second part concerns the development of control solutions to manage the orientation of wind turbines as a function of the wind (Wise-Control system tested within the framework of the ANR SmartEole project).



HIGHLIGHT

NEW LIDAR MEASUREMENTS FOR THE SMARTEOLE PROJECT

Within the context of the ANR SmartEole project aimed at improving the productivity and life-span of wind turbines using advanced control technologies, IFPEN is working with Avent Lidar Technology (Leosphere group) to develop and test an innovative software and hardware solution known as Wise-Control. Based on lidar wind measurements, it allows the estimation of the wind field in real time with a view to optimizing the orientation of the nacelle and blades. In 2017, a series of tests conducted on a land wind turbine demonstrated the relevance of this solution: considerable potential production gains and reduced mechanical stresses were identified. Increased production efficiency and reduced maintenance costs are major levers for the development of wind energy.





5 to 20%

Share of global electricity consumption represented by wave energy potential



Interview with
ANTOINE LE COTTY
Technical Director,
Renewable Energies,
SBM Offshore

SBM Offshore, one of the world leaders in floating systems for the energy industry, has developed a floater and anchoring solution for offshore wind turbines with the collaboration of IFPEN.

What is your view of the ocean renewable energy (ORE) market?

The energy sector is changing, with a move towards an energy mix in which OREs will play an integral role. Following the acceleration in fixed offshore wind power seen over the last decade, the industrial development of floating offshore wind power will be complementary. Wave energy will also have a role to play, as long as operationally efficient systems can be developed. Generally speaking, customers are seeking players with experience and the capacity to grasp the issues involved in the execution of offshore projects and operations.

How does the partnership signed with IFPEN in 2015 work?

Floating wind turbines demand knowledge of energy, offshore operations and wind power, as well as new analysis tools. Our expertise, combined with that of IFPEN, cover the entire scope of this field. The cooperation is going remarkably well and we work together very naturally, demonstrating that the partnership is based on genuine synergy.

What challenges have you faced in your various projects?

We have put together a very promising technical proposal, led by credible and complementary partners. The main challenge is the technological development of a complete combined floater/turbine solution. At the same time, we need to prepare the evolution towards applications for commercial wind farms.

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. Potential options include the increased densification and inter-connection of transport and distribution networks, but also stationary electrical energy storage. IFPEN's research focuses on the latter segment. Furthermore, IFPEN is also interested in the problem of underground storage, particularly concerning natural gas. The major challenge for this type of storage is to ensure confinement and, if necessary, to be able to implement any appropriate remediation measures in time.

HIGHLIGHTS

FLOW BATTERIES: A PROMISING TECHNOLOGY UNDER INVESTIGATION

In the field of stationary energy storage, IFPEN is targeting the development of alternative technologies to Li-ion batteries – the current market standard –, focusing more specifically on redox flow batteries. In batteries of this type, liquid electrolytes store energy in electrochemical form and circulate through ion-exchange membranes, thereby generating electricity via an oxidation-reduction (redox) reaction. There are two advantages with these batteries: they can be scaled to the desired power and energy, and tolerate an extremely high number of recharging cycles. The major challenge concerns the development of new, cheaper, more energy-efficient electrolytes, and this is an area IFPEN is working on. Its research activities focus on aspects ranging from the understanding of mechanisms through to multi-physical and multi-scale modeling of the technology, with a view to its optimization.

INDUSTRY FIRST FOR THE GASMAP METHANE DETECTOR

In the field of underground natural gas storage, IFPEN and its partner Aerovia designed the GasMap mobile air sampling solution, to help operators better detect any methane leaks on their geological storage sites. Onboard a vehicle, it provides real-time measurements of the methane concentration at ground level and in the atmosphere. In the event of an anomaly, additional tracers make it possible to identify a biogenic waste leak. A series of measurements taken in 2017 at an industrial operator's storage site demonstrated the performance of the system in terms of identifying and mapping leaks, both below ground and in the atmosphere. Gas dispersion modeling work based on wind data will eventually make it possible to further fine-tune detection accuracy and incorporate emission flows. This air quality monitoring system may well find applications in other fields.

CO₂ storage

Despite a context that has not been conducive to its industrial development so far, CO₂ capture and storage is still considered to be a major potential contributor to the reduction in CO₂ emissions and the achievement 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 companies to develop technologies aimed at significantly reducing CO₂ emissions via carbon capture, utilization and storage (CCUS) is a step in this direction. The research conducted by IFPEN consists in developing technologies and processes capable of capturing the CO₂ emitted by energy-intensive industries (steelmaking, cement plants, refining or petrochemicals). Two research priorities have been identified: post-combustion capture by solvents, and oxycombustion via chemical looping combustion.



HIGHLIGHT

CHEMICAL LOOPING COMBUSTION, THE FOCUS OF A NEW PROJECT

Alongside Sintef and Total, IFPEN is among the nine industrial, university and institutional partners of the Cheers project, launched in early October 2017 for a five-year period. Funded by the European Horizon 2020 program and China, this project is aimed at further improving CO₂ capture technology via the chemical looping combustion (CLC) process developed by IFPEN and Total. The industrial pilot built in China will be used to evaluate the efficiency of the process through to the production of a “pure” CO₂ flow that may either be stored underground, used for enhanced oil recovery or recycled by the chemicals industry.



STÉPHANE BERTHOLIN
Project manager of Cheers, for IFPEN

“IFPEN, in partnership with Total since 2008, is developing a chemical looping combustion (CLC) process to produce energy while capturing the CO₂ emitted. CLC is a disruptive process consisting in using the oxygen contained in a solid oxygen carrier for the purposes of combustion. The solid takes on oxygen via oxidation on contact with air in a first reactor and releases this oxygen to burn the combustible fuel in a second reactor. The absence of nitrogen in the flue gases generated during combustion facilitates CO₂ capture after steam condensation. Research conducted by IFPEN and Total has led to the development of innovative technological building blocks and the identification of synthetic oxygen-carrying materials with significant technical and economic potential. Within the context of the Sino-European Cheers project, IFPEN is responsible for designing the demonstration pilot unit and selecting a solid oxygen carrier suitable for the process.”



RESPONSIBLE OIL AND GAS

Today, the oil and related industries have to meet the sustained demand for oil and gas, while significantly reducing their environmental footprint and consuming less energy. IFPEN develops eco-efficient processes for the production of fuel, hydrogen and chemical intermediates meeting the strictest standards. IFPEN develops cutting-edge technologies in target fields, such as exploration or enhanced oil recovery, in order to improve the production of existing reserves.

2035

The date by which the global demand for fuel should have stabilized*



HIGHLIGHT

TOWARDS IMPROVEMENTS IN THE DEEP CONVERSION OF RESIDUES

The tightening up of IMO (International Maritime Organization) bunker fuel specifications reinforces the need for heavy fraction deep conversion processes. IFPEN is supporting the refining industry as it adapts to this market evolution by improving the performance of the ebullated bed hydrocracking technology, which has been marketed by Axens since 2016 for deep conversion and already offers unprecedented conversion rates (more than 90%). In 2017, for example, research work was continued to develop an optimized version making it possible to process more resistant feeds from a variety of sources, focus conversion as a function of local constraints and improve the economic and environmental performance of the process.

Heavy crude and residue conversion and purification

While, in the short term, low crude oil prices are not conducive to the conversion of residues and heavy crudes into lighter products, this is likely to be a growth market in the medium and long terms due, firstly, to the gradual disappearance of 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, with a view to improving flexibility, energy efficiency and the environmental footprint.

* With a sharp reduction in fuels associated with individual mobility, offset by the continued development of goods and aviation transport.

Deep desulfurization: pushing back the boundaries

The IMO's new standards will lead to a tightening-up of global specifications relating to the sulfur content of marine fuels by 2020. Anticipating their introduction, IFPEN has already been working for several years to improve its deep conversion and desulfurization processes. This research has led to the development of an innovative process making it possible to simultaneously produce bunker fuel with a very low sulfur content and high added-value distillates, while ensuring the quality of the heavy fraction. Thanks to the integration of desulfurization and conversion operations, its energy and economic efficiency have also been optimized.



0,1%

Maximum sulfur content in marine fuels authorized by the IMO in ECA zones (Baltic Sea, North Sea and North American coasts) since 2015

HIGHLIGHT

FCC ALLIANCE: THE END OF ONE CYCLE AND THE START OF ANOTHER

In the field of heavy feed conversion, IFPEN is conducting research to improve the eco-efficiency of the FCC (Fluid Catalytic Cracking) cluster, which includes the pre-treatment of FCC feeds and the FCC process itself. The latter is being developed as part of the FCC Alliance, established 35 years ago by IFPEN, Axens, Total and TechnipFMC. Research conducted within the framework of the FCC Alliance's 2015-2017 cycle led to the development of new technological approaches concerning this key process, improving its flexibility in terms of the targeted products (petrochemical intermediates or fuels), while reducing its environmental footprint. A new three-year cycle begins in 2018, focusing on innovative technologies and greater consideration of crude to chemical specific demands.

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 this, IFPEN is working on the development of hydrotreatment, catalytic reforming and paraffin isomerization catalysts and processes for gasoline production, as well as hydrodesulfurization catalysts and processes for the production of diesels and kerosene. IFPEN is also developing technologies aimed at offering operators greater flexibility with respect to the fuels produced, in order to address the gasoline/diesel imbalance in some geographic areas.



HIGHLIGHT

CATALYSTS CONTAINING ADDITIVES FOR THE HYDROTREATMENT OF MIDDLE DISTILLATES

Against a background of stricter environmental standards and feeds that are increasingly difficult to treat, the desulfurization of diesel cuts requires catalysts that are correspondingly more active. In 2017, IFPEN developed a new additivation technology for catalysts used in the Prime-D hydrotreatment process marketed by Axens, making it possible to improve their performance while reducing production costs. The objective is to apply this technology to all hydrotreatment catalysts developed by IFPEN.

HIGHLIGHTS

**NEW PRIME-G+ PROCESS:
LESS SULFUR, MORE OCTANE**

A new version of the Prime-G+ gasoline hydrodesulfurization process was finalized by IFPEN, in partnership with Axens, in 2017. It is aimed at two main markets. Firstly, the USA, where the tightening-up of specifications governing sulfur (US Tier 3 standard reduced from 30 to 10 ppm) means that there is a need for higher performance. This improvement developed by IFPEN makes it possible to minimize the investments required to adapt existing units to meet these more severe specifications. Secondly, Asia, and more specifically China, where compliance with the new standard (10 ppm) sits alongside a significant octane constraint. This process addresses this specific need, because it offers maximum octane retention. To date, more than 250 Prime-G+ units have been licensed by Axens around the world, making it a reference process in the field of clean gasoline production.

**MINI FORMAT, MAXIMUM EFFICIENCY
FOR HYDROCRACKING PACKINGS**

A new ultra-compact reactor packing for hydrocracking units was developed by IFPEN in 2017, in partnership with Axens, responsible for marketing the solution. Its innovative concept means the height of the distributor platforms can be reduced three-fold, while delivering the same mixture and distribution quality as previous generations. The result is increased catalytic efficiency, giving refiners the option to treat a bigger volume of feedstock, thereby increasing the competitiveness of their facilities. This new packing also reduces the environmental footprint of hydrocracking processes.

Natural gas treatment and conversion

IFPEN is studying natural gas conversion, firstly for centralized hydrogen production via the development of highly energy-efficient, low CO₂-emitting processes and, secondly, for liquid fuel production. 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, offering services ranging from process design through to solvent development, and the creation of new packings for absorption columns.

HIGHLIGHT

**GAS TREATMENT: REDUCING COSTS
AND INCREASING PERFORMANCE**

In 2017, IFPEN developed a new gas distributor. The new distributor is delivering improved distribution within absorption columns, which means that the height of these columns can be reduced by more than 10%, thereby lowering the investment costs for industry. It adapts to packings designed by IFPEN as well as other references on the market. In addition, a methodology aimed at precisely characterizing packing performance was developed and tested on a latest-generation commercial packing. This methodology should enable IFPEN's subsidiary Prosernat to formulate optimized solutions for its customers. Lastly, in the field of sweetening processes, IFPEN is working on the development of a new solvent.

40%
the approximate volume
of commercial gas reserves
that are sour and hence
require treatment

**Paving the way for the digital
transformation of refineries**

In many activity sectors, data acquisition and analysis have become performance improvement levers. Conscious of the stakes, IFPEN launched a reflection process regarding the potential of digital technologies for optimizing the operation of industrial units. Connected sensors, artificial intelligence, machine learning and clouds are just some of the concepts being explored. They will give rise to feasibility demonstrations, initially focusing on catalytic reforming and gasoline desulfurization processes. Ultimately, this approach may be applied to all refinery, petrochemical and bio-refinery processes.

**Petrochemical intermediates
production**

Petrochemical intermediates are used in the production of numerous everyday products, such as plastics and synthetic textile fibers, the demand for which is strong globally. Growth in the petrochemicals sector is thus an underlying trend. IFPEN's research is aimed at developing new olefin (ethylene, propylene, butadiene, etc.) and aromatic (benzene, toluene, xylenes) production processes and improving the performances of existing processes, while increasing product purity and consuming less energy.



ANNE-AGATHE QUINEAUD
Project manager New process
for ethylene purification by selective
hydrogenation, at IFPEN

HIGHLIGHT

A NEW, HIGH-EFFICIENCY SIEVE FOR THE ELUXYL PROCESS

In 2017, IFPEN and Arkema finalized a new molecular sieve to be employed in the Eluxyl separation process for paraxylene, a major product in the formulation of a polymer used to make plastic bottles and synthetic textile fibers. It delivers 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 thus addresses a strong market demand. It also consolidates Axens' leading position in the segment as the company that markets the Eluxyl process: it has more than 30 references around the world. As a result of these successes, Arkema set up a new production unit at its Honfleur (France) plant, where the molecular sieves for the Eluxyl process are manufactured. Inaugurated in April 2017, this unit has doubled the plant's production capacity and created local jobs.

"The ethylene market is enjoying strong growth, with demand driven by the need for polymers. In order to be used, ethylene, which is mainly produced by hydrocarbon steam cracking, has to be ultra-pure: the acetylene content must be reduced to less than 1 ppm at all times. It's a scientific and technical challenge, which requires the use of a selective hydrogenation catalyst offering an excellent performance. In 2017, IFPEN developed a catalyst enabling a very high level of purity to be obtained and demonstrated its considerable operating flexibility. This knowledge will allow Axens to optimize its commercial offer to players in the petrochemicals sector."

+3% 
Average annual growth in the demand for
chemical intermediates over the period 2018-2035

**Understanding and modeling
underground environments**

Sedimentary basins and oil and gas reserves under exploration by the oil industry are increasingly complex in nature from a geological point of view. Yet a thorough understanding is essential in order to reduce risks and ensure high exploration success rates. 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.

**Towards data processing
for exploration-
production**

The exploration-production sector today is undergoing a profound transformation associated with the contribution of digital technology, both in terms of working tools and methods. Using POC (proof of concepts), IFPEN intends to support industrial players through this transformation. The aim is to be able to build offers that can be integrated into this new environment, focused on data in our partners' possession.





Interview with
OLIVIER HOUZÉ, CEO of KAPPA
JEAN BURRUS, CEO of Beicip-Franlab

In December 2017, IFPEN, Beicip-Franlab and KAPPA signed a partnership contract to offer industrial players an advanced and complete reservoir simulation solution. This contract follows on from an existing collaboration initiated in 2016 between Beicip-Franlab and KAPPA relating to the marketing of the PumaFlow dynamic reservoir simulation software.

What are the expectations of the reservoir simulation market?

O. H.: It's an extremely competitive market, with long-established players and new arrivals who are relatively aggressive. The cards are being reshuffled and the sector is undergoing radical technological changes (cloud, automation, big data), the impact of which will be substantial, albeit still unclear at the moment. There are also "endemic" expectations: faster, more reliable, more models, etc.

J. B.: In addition to these major technological changes, there is an absolute need, when it comes to reservoir simulation, to establish a better integration between well engineering and reservoir engineering. This stems from the strategic importance for our customers to increase and optimize short-term production, without losing sight of the importance of the reservoir context. New workflows are needed to address these requirements.

Why a KAPPA/Beicip-Franlab/IPFEN partnership?

O. H.: The 2015 crisis led us all to rethink our model. This partnership allows KAPPA to extend the scope of its activity to reservoir simulation for which we did not have the critical mass required. This is all about capitalizing on the respective strengths of the partners: KAPPA in the field of software; IFPEN in the technical field; Beicip-Franlab as a reservoir specialist.

J. B.: Initially, the idea was to forge a partnership that was merely commercial. But dialog with our respective customers convinced us that together we could deliver new solutions making better use of our respective strengths. Hence the idea for a new product incorporating the best of each partner and providing a solution that is more attractive for users. It was important for Beicip-Franlab not only to continue to provide a reservoir simulation solution for its existing customers, but also, and above all, to deliver a competitive edge over the market standard.

To what extent does the 2017 partnership go beyond that of 2016?

O. H.: There is no comparison. The 2016 partnership amounted to using KAPPA as a commercial vector for IFPEN's software solutions, with the creation of a number of technical bridges at the margin. In this new partnership, KAPPA will re-write the application component of these software solutions and connect to IFPEN's calculation modules. The results will be KAPPA products powered by IFPEN.

J. B.: We're now aiming at creating a new reservoir simulation platform. This platform will offer the performance and quality of the current PumaFlow simulator in the fields of the physics and numerical computing, as well as an enhanced capacity to integrate well interpretations, dynamic and monitoring data, as well as the potential offered by the cloud. Beicip-Franlab will continue to share its professional expertise in the definition of product and support services for its long-standing customers.

HIGHLIGHTS

GEOANALOG: A NEW WEB SERVICE FOR THE OIL INDUSTRY

In December, IFPEN launched its GeoAnalog web service. This training and decision-making tool, which has already caught the eye of several major oil industry players, contributes to a better understanding of the deformation of complex geological structures, which in turn, will help guide exploration strategies. With a simple Internet connection, the tool provides access to a database of structural analogical models, the fruit of 30 years of expertise and some 1,500 analogical experiments conducted by IFPEN. Whether in the office or out in the field, some of the data can be accessed by everyone in SaaS (Software as a Service) mode. The complete catalog of analogical models can be consulted free of charge and, for GeoAnalog customers, models are analyzed and visualized via interactive and intuitive technologies.

To find out more: <https://geoanalog.ifpen.fr>

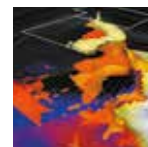


THE NEW VERSION OF OPENFLOW SUITE LAUNCHED TO MARKET

The 2017 version of OpenFlow Suite has just been launched to market by Beicip-Franlab. Teams from IFPEN, Beicip-Franlab and Tech'advantage spent almost a year working on the industrial development phase of the process. This version consolidates the significant efforts made since the 2016 version to address customer expectations in terms of the ergonomics, robustness and performance of the TemisFlow, DionisosFlow, FracaFlow, PVTFlow, PumaFlow, CougarFlow and EasyTrace applications. It also incorporates new functionalities, such as consideration of Inflow Control Devices (ICDs), within the PumaFlow reservoir simulator.

HIGHLIGHT

OPTIMIZING THE PREDICTION OF EXCESS PRESSURES AND STRESS FIELDS IN OIL BASINS



The modeling of pressure regimes in oil basins is crucial for drilling dimensioning and well safety. As oil exploration begins to move into increasingly complex geological environments, more accurate predictive models are required. To address this problem, in 2015, IFPEN and Total launched the Nomba project, within which IFPEN is responsible for developing a calculator combining the ArcTem basin simulator (integrated into the TemisFlow oil system modeling suite) with free geomechanical simulation software. In 2017, the world's first combined 3D hydromechanical modeling conducted on a basin operated by Total demonstrated the control exerted by tectonic constraints on the amplitude of excess pressures. The aim of future developments will be to apply this methodology to increasingly complex 2D and 3D faulted tectonic contexts in order to estimate the evolution of excess pressures and stress fields over the history of sedimentary basins.

Producing better with enhanced recovery

Enhanced Oil Recovery (EOR) is now of considerable strategic importance for the majority of oil companies in order to access new reserves. 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.

HIGHLIGHTS

WATER CYCLE MANAGEMENT IN THE FIELD OF EOR: SUCCESS OF THE DOLPHIN 2 JIP

The Dolphin 1 JIP (Joint Industry Project), which ended in late 2016, studied the impact of additives used by chemical EOR technology on oil production water management. Dolphin 2, launched in early 2017 for a period of three years, is primarily aimed at extrapolating Dolphin 1 on a semi-industrial scale and testing new water treatment technologies specifically developed for the EOR context. This second phase of the JIP involves ten partners, including four new arrivals in comparison to Dolphin 1. The advances stemming from the Dolphin JIP are also contributing to the expansion of the integrated offer developed by IFPEN in partnership with Beicip-Franlab and Solvay within the context of the EOR Alliance.

FIVE PILOT AGREEMENTS FOR THE EOR ALLIANCE

The EOR pilot tests are a first crucial step for the validation of the solutions tailor-made for each oil field at the laboratory scale. The purpose of the pilot tests is to verify the performance of the EOR solution and evaluate potential risks prior to any large-scale deployment. In 2017, the EOR Alliance signed contracts with oil companies concerning five pilot tests on five fields around the world.

18

oil companies in the Dolphin JIP community

Chemical EOR: a third successful workshop

In May 2017, IFPEN organized the third Chemical EOR workshop: Key Success Factors. It brought together EOR managers and experts representing more than 30 oil companies in 20 countries. The workshop was an opportunity for those attending to share concrete field cases and discover the latest innovations to emerge from IFPEN's workshops, at the cutting-edge of EOR research.



FUNDAMENTAL RESEARCH SERVING INNOVATION

IFPEN's scientific policy is hinged around two objectives: to support the company's innovation ambitions and ensure the scientific excellence of its research activities. In order to reinforce the transparency and coherence of all its activities, IFPEN has structured its fundamental research around nine scientific challenges. By focusing research efforts and pooling common issues, this approach is aimed at accelerating the acquisition and dissemination of missing building blocks of knowledge in order to advance innovation. It also makes it easier to mobilize the best scientific communities, by developing an appropriate strategy of academic partnerships, and through participation in national and European collaborative projects. Lastly, this approach makes it possible to steer the evolution of fundamental research over time, identifying emerging research themes.

Overcoming the scientific challenges

The "scientific challenges" approach formalizes the major multidisciplinary reasoning processes 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 needs to be overcome. Each specific scientific issue is associated with a long-term road map hinged around projects, theses and postdoctoral work, as well as pivotal academic partnerships. The specific scientific issues are thus tools for steering IFPEN's fundamental research programs.

HIGHLIGHT

A NEW "ASSET" FOR IFPEN



Digital optimization is a feature of many of IFPEN's research activities and delivers added value in terms of accuracy, robustness and speed. In particular, it is essential for the calibration of digital simulators with respect to experimental data and as a support tool for technology design. Within the context

of scientific challenge 7 "the control and optimization of complex systems", IFPEN developed a cross-functional platform, called Atout*, dedicated to the optimization and analysis of uncertainties, capitalizing on different algorithms and methods developed by researchers in-house, with a view to their broad roll-out to teams. Capable of connecting to all internal and external expertise-specific software, Atout is used in a variety of fields of application, such as the design and reliability of floating wind turbines or the calibration of materials behavior laws and kinetic models.

* Advanced Tools for Optimization and Uncertainty Treatment, the word "Atout" translates as "Asset" in English

30%
Share of fundamental research in IFPEN's R&I activities

IFPEN'S SCIENTIFIC CHALLENGES: 2017 RESULTS

EXPERIMENTATION, DATA ACQUISITION, UNDERSTANDING

CHALLENGE 1: Material and fluid characterization for energy, on various scales

Local palladium concentration in catalyst grains for selective hydrogenation processes is a critical factor for the catalytic activity. IFPEN developed a new quantitative approach to high-resolution elementary analysis, from both the compositional (ppm scale) and geometric (micrometric resolution) points of view. This approach, based on LIBS (Laser Induced Breakdown Spectroscopy), is unique in terms of the simplicity of its implementation and speed of operation.

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

For the photocatalytic production of fuels from solar energy and a CO₂+H₂O mixture, promising alternative materials were identified, enabling the increased penetration of the incident photon flux within the catalytic bed. An improved intrinsic performance and a reduction in the installation's footprint are thus achieved. Additional kinetic modeling research led to a precise description of the phenomena involved.

CHALLENGE 3: Understanding the effect of confining fluids on their dynamics and their reactivity in porous media

The productivity of certain separation processes is limited by the diffusion time of fluids to the microporous structure of catalysts but it can be improved by creating an additional mesoporous network. In the case of zeolites used for xylene separation, different characterization methods (immersion calorimetry, infrared spectroscopy, gravimetric analysis, static adsorption, etc.) were employed to measure and better understand the impact on transport properties of introducing a new network, with an additional external surface generated.

CHALLENGE 4: Optimum processing of large volumes of experimentation and simulation data

The Plugim! platform, harnessing IFPEN's tools dedicated to the processing and analysis of 3D signals, images and volumes, has evolved with a view to making it open access in 2018. It integrates numerous algorithms stemming from recent developments: an innovative 3D reconstruction approach for the surface representation of catalysts and a robust chromatogram calibration tool, delivering a ten-fold reduction in processing time.

PHYSICAL MODELS AND DESCRIPTORS FOR SIMULATION

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

In the context of increasing electrification in the transport sector, research is under way focusing on the identification of magnetic field distribution descriptors. These will make it possible to identify the principal magnitudes involved in combined

thermal and electromagnetic phenomena, and thereby optimize the design and efficiency of synchronous reluctance motors in order to improve the cost/performance compromise of electric vehicles.

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

Within the context of the ANR MORE4LESS project, thermal transfers in a fixed and fluidized particle bed were studied using the PeliGRIFF digital tool, developed by IFPEN. The tool is designed to simulate a fluid/particle flow on two scales: the micro scale, where fluid/particle interactions are calculated directly, and the meso scale, where fluid/particle interactions are averaged and modeled using analytical and empirical correlation techniques. By comparing the two results, it was possible to evaluate and validate the correlations used and improve the laws governing thermal transfers between fluid and particles, which is an important advance for process engineering as well as for energy storage applications.

SYSTEM SIMULATION, OPTIMIZATION AND CONTROL

CHALLENGE 7: Control and optimization of complex systems

A method was developed to calculate the speed profiles of a vehicle enabling the reduction of its fuel consumption, while respecting constraints imposed by the route and surrounding vehicles. It is based on an estimation of the position of the preceding vehicle and on the semi-analytical – and hence fast – resolution of optimal control equations.

CHALLENGE 8: Achieving the best numerical and IT performance of our computational codes

Developed within the framework of the collaboration between IFPEN and the CEA concerning the Arcane platform, the new Alien linear algebra library is now available. As a unique software interface adapted to the demands of high-performance parallel computation, it gives access to the scientific community's principal linear solver libraries, such as Petsc and SuperLU, as well as IFPEN's own libraries (IFPSolver, MCGSolver). Alien has already been integrated into simulators based on Arcane as well as the PumaFlow reservoir simulator.

ECONOMIC AND ENVIRONMENTAL ISSUES

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

IFPEN designed an integrated road transport demand simulation model, making it possible to define development scenarios concerning the vehicle fleet in France and Europe to the year 2030. This model examines the dynamics of the private vehicle market by technology type or propulsion mode. It can also be used to study the effects of a wide range of instruments and government policies, and to evaluate the environmental impacts (CO₂, particles, etc.) of these policies. It has been designed so that it can connect directly to the TIMES family of energy scenario models developed by IFPEN.

**BENJAMIN HERZHAFT**

Program manager, responsible for the coordination of fundamental research in IFPEN's Scientific division

"ANCRE* is currently conducting a reflection process concerning fundamental research, aimed at facilitating the emergence of an interdisciplinary research community looking into basic sciences for energy. IFPEN is a member of the working group set up at the end of 2016 in order to build a national research program based on shared objectives, with a view to driving innovations in the different energy fields. An approach based on the identification of scientific challenges and specific scientific issues, similar to that deployed at IFPEN, was implemented. Working seminars were organized at the end of 2017 focusing on the first two challenges, each bringing together some twenty academic and industrial experts to identify priority research avenues."

* French National Alliance for Energy Research Coordination

45
specific scientific issues
formalized in 2017

Digital tools: towards 4.0 research Lab?

The experimentation, modeling and simulation of physical phenomena lie at the heart of IFPEN's fundamental research. These activities produce data that can then be exploited to advance knowledge and develop innovations. But given the volume and diversity of the data generated, there is increasing awareness of the importance of issues surrounding the sharing, analysis and visualization of these data. How can the processing of such large volumes of data be optimized?

For their part, digital technologies now offer new capabilities in terms of optimizing the analysis of large volumes of data. Having transformed entire swathes of the services sector and industry, can they now do the same for research in the field of the energy transition?

To address these issues, IFPEN is studying the potential of the digital transformation. Objective: to accelerate the research and innovation process in its areas of expertise. This reflection process falls within the framework of IFPEN's scientific challenge 4, the "optimum processing of large volumes of experimentation and simulation data". In 2017, two fields of application in the process development sector were identified:

- **the connected unit**

The idea is to use connected objects and new digital platforms to generate more data and facilitate their decompartmentalization in order to reinforce pilot testing. RFID chips, miniaturized sensors, short-range networks, clouds, etc. these are just some of the technologies that can be used to enhance the acquisition and analysis of data, and thus optimize pilot experimentation.

- **augmented model**

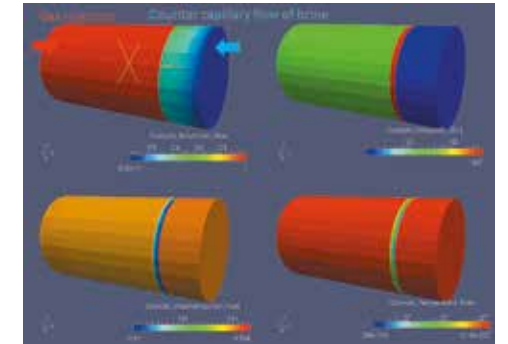
Digital transformation tools (artificial intelligence, machine learning, big data, etc.) can accelerate the establishment of structure/property relationships, thereby making it possible to conceive innovations and better predict the behavior of the processes and catalysts developed by IFPEN.

Feasibility demonstrations will be conducted in both of these fields in order to validate their capacity to drive IFPEN's research forward towards a 4.0 dimension.

The implementation of a partnership research strategy

IFPEN maintains a dynamic ecosystem of French and European academic partnerships, supporting its fundamental research activities. These partnerships, focusing on issues relating to the scientific challenges, mainly take the form of doctoral theses and collaborative projects with public support, funded, in particular, by the ANR or the European Horizon 2020 framework program. In 2017, IFPEN submitted 19 proposals in response to the ANR's 2018 generic call for projects, doubling the number submitted in previous years. IFPEN is 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. Lastly, IFPEN builds long-term strategic partnerships with public research players and industry. These partners include the CNRS (French National Center for Scientific Research), and the CEA (French Alternative Energies and Atomic Energy Commission), with whom a partnership agreement was signed in June 2017 in order to reinforce collaborative initiatives to support the energy transition and sustainable mobility.

20
projects supported by the ANR
involving IFPEN under way in 2017



HIGHLIGHT

LAUNCH OF THE DATAIA CONVERGENCE INSTITUTE

IFPEN is a founding member of DATAIA, a Convergence institute dedicated to data sciences. Supported by the ANR and led by Paris-Saclay University, this interdisciplinary institute brings together 12 partners (universities, research institutes and graduate schools) to focus on the scientific and technical challenges related to data sciences and associated socio-economic issues. In line with the digital transformation under way at IFPEN, this participation falls within the framework of challenge 4, the "optimum processing of large volumes of experimentation and simulation data", and will give rise to several theses.

HIGHLIGHT

POOLING AND SHARING IN THE AUVERGNE-RHÔNE-ALPES REGION

Reflecting its deep-rooted presence in the Auvergne-Rhône-Alpes region, IFPEN reinforced its links with two key players: the ENS de Lyon and Lyon University. Ratified in February 2017 for a period of four years (photo), the scientific collaboration framework agreement with the ENS de Lyon extends a scientific partnership dating back more than 20 years. The aim is to reinforce research, knowledge transfer and innovation capacities to address the challenges of tomorrow's chemistry and the energy transition, with a particular focus on modeling applied to catalysis. The partnership agreement between IFPEN and Lyon University was signed in April 2017. It is aimed at strengthening links between higher education, research and industry. Among its objectives: to facilitate the emergence of new themes in the fields of energy, sustainable mobility and eco-industries, and raise the profile and international influence of R&I in these areas.



See interviews with the presidents of the ENS de Lyon and Lyon University conducted for the 50th anniversary of IFPEN-Lyon

15

active academic collaboration
framework agreements at
the end of 2017

Fundamental research and industry

IFPEN forges relations with industrial players in order to pool fundamental research efforts in various fields. In 2017, IFPEN and Michelin initiated a collaboration focusing on materials and processes, hinged around three areas of common interest: the activation of catalytic systems, molecular reconstruction methods and the economic evaluation of processes. Part of this collaboration is centered on a jointly-supervised thesis in the field of homogeneous catalysis. Elsewhere, IFPEN continues to work with PSA and Renault on pre-competitive research in the field of powertrains within the Groupement Scientifique Moteurs (GSM). The new long-term program now under way is targeting affordable and competitive sustainable mobility.



ZLATKO SOLOMENKO
Winner of IFPEN's 2017
Yves Chauvin prize

"My thesis concerned the study of dual-phase flows and wetting in structured packings used for gas purification. I proposed and validated a digital simulation methodology for wetting phenomena that could be used for the development of optimal geometries for gas/liquid contactors. This subject gave me the opportunity to broaden my digital simulation and experimentation knowledge, under the supervision of recognized scientists in their respective fields. I particularly appreciated the availability of my supervisors and the fact that I had access to cutting-edge experimental facilities. Being awarded this prize was a source of considerable pride and recognition of research that I hope will help lead to an improvement in the performances of gas purification and CO₂ capture units."



Interview with
JEAN DAILLANT
CEO of SOLEIL

The renewal in 2017 of the research framework agreement between IFPEN and SOLEIL synchrotron reflects the determination of the two partners to reinforce their collaboration.

What is SOLEIL's partnership policy?

Our purpose is to produce synchrotron radiation and use it to carry out our research. But this tool covers so many disciplines that we cannot possibly tackle them all. That's why we make it available to scientific, academic and industrial players. We do this within the framework of targeted partnerships, such as the one we have had with IFPEN for the last ten years or so.

How would you qualify the relationship between IFPEN and SOLEIL?

It has always been excellent and of an outstanding quality. The challenge today is to take it a step further and get to know each other even better. By working together more closely, we will be able to enhance our collaboration and more precisely integrate IFPEN's needs into our programs by having IFPEN involved in our new developments: ambient pressure photoemission, infrared, etc.

Have your partnership themes evolved over time?

Yes, and that is actually another aspect we are working together on. Historically, our partnership primarily concerned catalysis. This remains an active component and one that has benefited from the improvement in our facilities, such as the ROCK line. Over the past few years, our collaboration has also been extended to other fields, such as catalyst characterization during reactions and, more recently, the study of rock morphology using tomography. And this is a trend that is set to continue in the context of new energy technologies, particularly in the fields of chemical looping combustion (CLC) for CO₂ capture, the conversion of biomass into bioproducts, or batteries.

The importance of theses at IFPEN



Covering all of IFPEN's scientific challenges, doctoral theses represent one of its principal fundamental research tools. While their underlying purpose is to drive advances in scientific knowledge, they are also an effective way of mobilizing the expertise of partner laboratories. Theses are also a way of contributing to the emergence of new ideas and the development of new concepts. Each year, the Yves Chauvin prize is awarded in recognition of research excellence and the originality of the approach employed by a PhD researcher. The 2017 prize was awarded to Zlatko Solomenko for his thesis entitled "Study of dual-phase flows and wetting in structured packings". Conducted and supervised at IFPEN, this thesis was directed by the École Centrale de Lyon. It falls within the framework of challenge 6, the "modeling of closely-coupled phenomena with a view to scale change", with potential applications in the fields of gas treatment and CO₂ capture.



«My thesis in 3 minutes»: watch videos of two of IFPEN's PhD students from 2017

135

theses under way each
year on average

Exchange with the scientific community

Alongside an active partnership research strategy, IFPEN also promotes exchange between researchers and the scientific community in order to remain positioned at the highest level of scientific excellence and foster knowledge-sharing. These exchanges take a number of forms: the hosting and organization of events on themes associated with IFPEN's scientific challenges, involvement in scientific networks 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 scientific papers is another way used by IFPEN to make its R&I accessible and allow the scientific community to harness it.

159

publications by IFPEN researchers
in peer-reviewed international
scientific journals in 2017

OGST, IFPEN's journal is made open access

IFPEN leads the editorial committee of the peer-reviewed journal Oil & Gas Science and Technology (OGST). Published in digital format and indexed in the major international databases, OGST covers all the disciplines and fields of activity within the scope of IFPEN. Six issues were published in 2017, including themed reports dedicated to three Rencontres scientifiques events, relating to the themes of "Flow dynamics at fluid interfaces"; "Digital and high-performance computing methods for complex flow simulation"; and lastly, "Large-eddy simulation for internal combustion engines". Moreover, in 2016, the journal notched up more than 1,500 article quotations, giving it a two-year impact factor published in Web of Science (WoS) of 1.184; up compared to 2015 (1.087). OGST articles and special reports are freely available at: <http://ogst.ifpenouvelles.fr>.



HIGHLIGHT

2017 RENCONTRES SCIENTIFIQUES EVENTS

Under the aegis of the French Academy of Sciences, the IFPEN Rencontres scientifiques events bring together international experts from academia and industry around a specific theme. These experts present their research work and discuss the progress made, possible applications and future challenges to be addressed. In 2017, two Rencontres scientifiques events were organized, associated with IFPEN's research interests:

- the first, in March, dedicated to computational chemistry for combustion pollutants mitigation;
- the second, in December, dedicated to colloids and complex fluids for energies, co-organized with the CEA.



Award winners in 2017...

- **Kim Larmier**, former IFPEN PhD researcher, 2017 thesis prize of the European Federation of Catalysis Societies ;
- **Charles-Philippe Lienemann**, the SCF's (French Chemistry Society) 2017 Innovation Research prize;
- **Bertrand Paul**, former IFPEN PhD researcher, the French Rock Mechanics Committee's 2017 Pierre Londe thesis prize.

CREATING

WEALTH AND JOBS

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 IFPEN group. The broad influence and high profile of the group's companies (including Axens, Beicip-Franlab, Heurtey Petrochem,

IFP Training, etc.), along with the promising potential of the latest companies created or supported (such as Mavel and DriveQuant), 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 IFPEN group's subsidiaries are the focus of reinforced efforts.

ANCRE Alliance: positive assessment of IFPEN's chairmanship - p. 40

Outstanding success for the 2017 internal innovation challenge - p. 41

Conversion of water-treatment plant sludge with Cleef System - p. 45

Successful start for DriveQuant - p. 47

2017 HIGHLIGHTS: THE ESSENTIALS

A CULTURE OF INNOVATION

The success of IFPEN's value creation model depends on its capacity to deliver innovations, via the development of a forward-looking vision of its activities and the production of research in line with the needs of its customers and partners. 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 right from the outset of projects. Lastly, IFPEN contributes to 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 is its capacity to anticipate R&I needs. It does this by adopting a forward-looking approach to identify the themes that it should be targeting. IFPEN also supports the public authorities in their strategic reflection concerning future energy scenarios and contributes to the drawing-up of the French national and European research program. IFPEN is heavily involved in the ANCRE alliance¹, of which it is one of the founding members alongside the CEA, CNRS and CPU². It is also an associate member of the AllEnvi³. In addition, the «scientific challenges» approach implemented by IFPEN contributes to the identification of a forward-looking vision of fundamental research activities. These forward-looking studies are supported by the Scientific Board, with active contributions from partnerships forged by IFPEN.

¹ French National Alliance for Energy Research Coordination

² French Conference of University Vice-Chancellors

³ French National Alliance for Environment Research

HIGHLIGHT

ANCRE ALLIANCE: POSITIVE ASSESSMENT OF IFPEN'S CHAIRMANSHIP



Didier Houssin, Chairman and CEO of IFPEN, chaired ANCRE from September 2015 to September 2017, before handing over the reins to the CEA. This was a particularly active period from an energy perspective (COP 21, 2030 Energy-Climate package, enactment of legislation relating to the energy transition for green growth, etc.), with significant contributions from ANCRE:

identification of future challenges, contribution to public policy-making, research program guidance and the production of high added value knowledge. There are plenty of reasons to be satisfied with the achievements so far: ANCRE's technical and economic forecasting study scenarios in the field of energy are an authority; its contributions to the drawing-up of French national energy research strategy (SNRE), developments at the ANR, national and European research program guidance have been decisive; the creation of a scientific community looking into "basic sciences for energy" is well under way; collaboration initiatives with the AllEnvi (environment), Athena (human and social sciences) and Allistene (digital) alliances have been reinforced; the development of the theme-based technology transfer consortium (CVT) has been successful.

12

strategic studies carried out by CVT ANCRE since December 2012

Energy Scenario to 2050: complementary technologies

In February 2017, ANCRE published its technological forecasting scenario "French law relating to the energy transition for green growth" to 2050. The purpose of this scenario was to identify the key technologies, principal challenges to overcome and preferred solutions to achieve the main objectives set out in the French law relating to the energy transition for green growth, as well as in the long-term energy research program. It demonstrates that these technologies are complementary and not exclusive and should all be implemented, some of them as an immediate priority. IFPEN was actively involved in coordinating this work, which mobilized all of ANCRE's program groups.



Download the ANCRE scenario (in French)

The role of industrial committees

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. These committees, which meet twice a year, bring together around ten French industry representatives, major players in the energy, chemicals and transport sectors. They discuss the energy context and the changes taking place in these sectors and, each year, express an opinion on IFPEN's research program.



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 system 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. This internal incubator pools expertise in the fields of strategic marketing and business model development. Its portfolio of projects is currently structured around four topics: stationary energy storage, the circular economy, industrial ecology and CO₂ conversion.



HIGHLIGHT

OUTSTANDING SUCCESS FOR THE 2017 INTERNAL INNOVATION CHALLENGE

Following the success of the 2016 call for projects, a company-wide participative innovation challenge was launched in 2017, with a view to reinforcing IFPEN's activities in the NET field, in line with the French Climate Plan and the French law relating to the energy transition for green growth. The challenge was a great success: 167 ideas were submitted, covering the challenge's 8 themes and led by multi-disciplinary teams. The ambition is to provide IFPEN's programs, including those of the internal incubator, with new projects and, in the medium term, to increase value creation and employment in these fields. At the end of the selection process, six projects were retained in 2018.



BENOIST THIROUARD,
Director of the IFPEN's Open
Innovation and Incubation division

"In an accelerating and constantly evolving environment, open innovation has become an absolute necessity. Created at the end of 2017, the Open Innovation and Incubation division plays a key role in driving IFPEN's open innovation process improvements. The objective is to reinforce our innovation capacity in the field of NETs, improving our reflection processes and drawing inspiration from outside the company. The aim is also to be more agile, to identify opportunities at an earlier stage and share them faster in order to establish a position more quickly. IFPEN's internal innovation challenge is an excellent vector: its format is such that the projects identified can immediately be discussed with key opinion leaders, partners and potential customers, an essential step in securing and accelerating value creation for IFPEN. In order to take things a step further, IFPEN is considering the possibility of opening up the challenge to external players and working to reinforce its integration within the French national and European ecosystem of innovation."

6 to 8 
projects incubated
at IFPEN each year

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, since 2014, a working format based on "innovation task forces" has been 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 from the sectors concerned. An innovation task force and collaboration in platform mode are behind the creation of DriveQuant by IFPEN in 2017, in order to market the web services developed by researchers in the field of the connected vehicle.

A partnership 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 favors collaborative research via strategic partnerships with academia and industry, throughout the innovation chain.

A network of partners

IFPEN has built up an ecosystem of collaborations with universities, research bodies, industrial players and SMEs in both France and Europe. Examples include the scientific collaboration framework agreement signed in 2017 with Utrecht University concerning geosciences and renewable energies, the agreement signed with Italian SME Mavel to co-develop and market innovative electric powertrains and the Franco-German BioTfuel collaborative project aimed at developing an end-to-end chain of 2nd-generation biodiesel and biokerosene production technologies, bringing together Axens, the CEA, IFPEN, Avril, ThyssenKrupp Industrial Solutions and Total.



66
collaborative projects with public
support involving IFPEN under way in 2017

At the heart of the French Research and Innovation System

In addition to the fundamental research projects supported by players such as the ANR (see page 35), IFPEN contributes to collaborative technological research and innovation structures, in partnership with industry. For example, it is active in seven competitiveness clusters – including the Rhône-Alpes clusters Axelera (chemistry and the environment) and Cara (urban transport), of which it is a founding member – 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. Three new projects coordinated by IFPEN were selected within the context of ADEME's 2017 call for projects. 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 Inter-ministerial Fund (FUI).

IFPEN, a leading European research player

IFPEN has worked for many years alongside industrial and academic research partners in various European structures, such as the ETIP Bionenergy and Ertrac (road transport) technological platforms, and the European Energy Research Alliance (EERA). IFPEN also contributes to several projects supported by the European Union, particularly within the framework of the Horizon 2020 program.

European networks and emerging themes

IFPEN joined ETP4HPC, an industrial association promoting the development of competitive, high-performance computing (HPC) services in Europe, and, more generally, an ecosystem covering the entire simulation/computing value chain. IFPEN is also a member of the CO2ValueEurope association, launched in November 2017 with the aim of promoting the development and commercial roll-out of sustainable industrial solutions targeting the conversion of CO₂ into other usable substances.

A variety of industrial collaborations

When IFPEN identifies complementarity with an industrial player in terms of expertise and technological building blocks, it considers forming a bilateral research partnership 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: FOUR PROPOSALS SELECTED IN 2017

In 2017, IFPEN stepped up its participation in calls for proposals associated with the Horizon 2020 program, 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, 17 proposals were submitted, compared to 10 in 2014, 9 in 2015 and 12 in 2016. Among them, four proposals were accepted in the fields of vehicle electrification and CO₂, representing more than €3.5 million of funding requested for IFPEN. IFPEN's success rate with respect to Horizon 2020 calls for proposals for the years 2014 to 2017 is 41%. A satisfactory result that demonstrates the excellent fit between IFPEN's strategic directions and European R&I priorities.*

* European Research Council

** Innovative Training Networks

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 make-up. The transfer from laboratory to industry takes a variety of forms, on a case by case basis, depending on the context: 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. Another form of collaboration concerns joint service offers: in 2010, IFPEN, Beicip-Franlab and Solvay created the EOR Alliance in order to market together a joint 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, 13TH RANKED PATENT FILER IN FRANCE

IFPEN was ranked 13th by the INPI in terms of the number of patent applications published in 2017. That puts IFPEN among the top 3 research bodies in France, with the French Alternative Energies and Atomic Energy Commission (CEA) and the French National Scientific Research center (CNRS). When adjusted to account for workforce, IFPEN climbs to number one. In addition, IFPEN filed 187 first patents (primarily French) in 2017 – a record – including 79 relating to new energy technologies (NETs). IFPEN is also one of the top patent filers outside France, with 1,140 rights created in 2017.

11 000

active patents in IFPEN's portfolio globally



HIGHLIGHT

IFPEN TAKES A STAKE IN LA COMPAGNIE DES MOBILITÉS

In January 2018, IFPEN became a 20% stakeholder in the start-up company La Compagnie des Mobilités. The newly-created company designs and markets mobile and Internet applications dedicated to soft journeys in urban and tourist zones.

It developed the Geovelo navigation aid system for bicycles, singled out for an award by the Île-de-France region in the Viva Technology Challenge. This stakeholding reinforces IFPEN's positioning in the connected mobility market and consolidates the R&I partnership established in 2017 with La Compagnie des Mobilités to contribute to the development of the Geovelo application.



Watch the video highlighting the Geovelo application rolled out by the city of Orléans

Supporting innovative companies

SMEs and start-ups, IFPEN's innovation and transfer partners

IFPEN has been actively supporting SMEs for nearly 30 years. Today, this support extends to start-up companies and is primarily focused on new energy technologies. The objective: to accelerate innovation projects and co-develop new products and services in the fields of transport, energy and eco-industries. The partnership takes a variety of forms: more often than not, R&I, but also access to expertise and technical resources, support for transfer to industry and funding. The acquisition of stakeholdings is also an option. IFPEN thus contributes to the consolidation of a fabric of SMEs and start-ups in its fields of activity.


HIGHLIGHT

CONVERSION OF WATER-TREATMENT PLANT SLUDGE WITH CLEEF SYSTEM

Cleef System offers sites – urban or industrial – with a water-treatment plant, an innovative process for converting sludge into an eco-fuel with a high calorific value. In October 2017, the SME inaugurated its first industrial demonstrator at the Roussillon chemicals platform (Isère, France). With a capacity of 200 kg/h, the facility is the fruit of four years of development activities conducted with technological support provided by IFPEN. It is used to convert some of the platform's water-treatment plant sludge into eco-fuels, which then supply a biomass power plant that produce high-pressure steam for industrial players operating on the site, thereby creating a short circular economy loop. Present alongside the company from the outset, IFPEN helped it acquire a better understanding of the phenomena governing the process and supported it through the industrial scale-up phase.



300 ...
new SMEs met each year
on average by IFPEN


**HIGHLIGHT****IFPEN RECEIVES THE AWARD FOR THE MOST FREQUENTLY APPROACHED R&D CENTER DURING TECHINNOV**

In February 2017, IFPEN took part in the Techinnov business conference, organized by the Essonne Chamber of Commerce and Industry. This annual event contributes to more than 10,000 meetings between SMEs, start-ups, industrial partners, research centers, technology transfer specialists and financial bodies. Taking part for the 11th time, IFPEN was highly solicited, with nearly 70 contact requests and 40 meetings. IFPEN thus won the award for the most frequently approached R&D center during the event. These meetings were an opportunity for IFPEN to enter into contact with SMEs, and subsequently guide some of them towards the Carnauto technological platform.

Carnauto, AirCar, Axel'One: adapted support

The launch of a new company requires support, in terms of both hosting and made-to-measure facilities (laboratories, experimental facilities). IFPEN provides logistics support via the Axel'One collaborative innovation platform, dedicated to chemistry and the environment, in the Auvergne-Rhône-Alpes region. These resources include the Innovative Processes platform at IFPEN's Lyon site, and IFPEN's supercomputer. IFPEN also supports SMEs via partnership structures with other research centers. In particular, it invests in inter-Carnot projects providing access to technological platforms, such as the "Carnot Institute projects for industrial sectors" actions Carnauto (motor vehicle and mobility) and AirCar (aviation).

Contribution to the capital funding of innovative companies

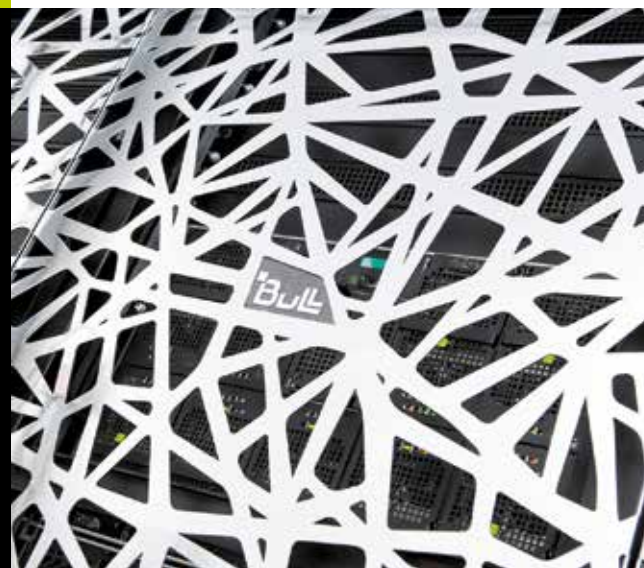
Sometimes, within its fields of interest – eco-industries, eco-energies and mobility – IFPEN takes a stake in a company, either directly or indirectly via funds. For example, IFPEN has been working from the outset with Demeter Partners, a leading European energy transition investment capital player, actively investing in funds launched in this field. These funds cover the entire equity chain, from start-up through to infrastructures dedicated to the environment and the energy transition. Within these funds, IFPEN also contributes its expertise to the screening of the companies to be supported.

HIGHLIGHT**INVOLVEMENT IN THE NEW DEMETER 6 FUND**

In November 2017, Demeter launched a fund dedicated to start-ups operating in the smart city and smart energy sectors, two sectors favorable to the emergence of new champions addressing the challenges associated with climate change. This new fund will provide long-term finance and support for around twenty European start-ups in France, Spain and Germany. By participating in the Demeter 6 fund, IFPEN will be co-investing in innovative companies operating in the NET sector.

120

companies given financial support
by Demeter over the past 12 years

**Supporting company creation****A capacity to uncover gold nuggets**

Identifying new products and services stemming from its 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.

Business setting-up assistance policy

IFPEN supports its employees wishing to start a company, irrespective of the target field. This policy is hinged around an incubation period of 6 to 18 months, during which time IFPEN shares its business start-up experience with the employee.

IFP Group

IFPEN's technology transfer policy is underpinned by its portfolio of subsidiaries and stakeholdings, today bringing together reference industrial players at global level (Axens, Heurtey Petrochem, Beicip-Franlab, IFP Training, etc.) and newly-created innovative companies such as Mavel edt and DriveQuant. 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 and sustainable mobility. Today, IFPEN is channeling its efforts in this direction, with the creation of companies and acquisition of stakeholdings in the NET sector.

HIGHLIGHT**SUCCESSFUL START FOR DRIVEQUANT**

Illustrating IFPEN's company creation policy, the start-up DriveQuant was launched in February 2017, adopting a position in the emerging – yet already competitive – connected mobility market. DriveQuant markets a range of services in the field of mobile technologies applied to connected transport and mobility, ranging from driving analysis to vehicle safety, via coaching, energy and pollutant emissions analysis. A number of major insurance companies and fleet managers have already been won over by these services, with joint projects under way.



Interview with
DAVIDE BETTONI
Chairman and CEO of Mavel

Italian company Mavel has been supplying electric motors and high-performance electronics for targeted applications for nearly 20 years. Working in partnership with IFPEN, it is broadening the scope of its activities to the vehicle market.

What does the partnership with IFPEN bring to your company?

Technically, we have benefited from the complementary nature of our activities: firstly, our experience in motors and inverters. Secondly, IFPEN's R&D capacity and its vast pool of testing resources. The benefits of being able to rely on a structured partner are also considerable. Financially, the fact that IFPEN took a stake in Mavel gave a clear boost to our growth.

Together, you established Mavel edt: what does the company do?

The company is dedicated to the mass production of electric powertrains for small vehicles aimed at the Chinese market. It is a jointly-owned company between IFPEN and investor Weisa Automobile Technology Ltd. Having industrialized our processes in Italy, we are going to transfer the production line to China in 2018. Small-scale production and Mavel's engineering expertise will remain in Europe.

Are there any other projects in the pipeline with IFPEN?

Launching a development project in the vehicle sector represents a considerable investment. We are therefore exploring several avenues, particularly in the field of turbochargers, but no specific project has yet been launched. One thing is clear: our technology really stands out in the electric powertrain market. In the current economic environment, we are confident about the future!

> 50%

of IFPEN resources come from
the industrial development of its research



PRINCIPAL HIGHLIGHTS CONCERNING IFP GROUP SUBSIDIARIES AND STAKEHOLDINGS



Axens Group: catalytic processes, refining and petrochemicals, alternative fuels

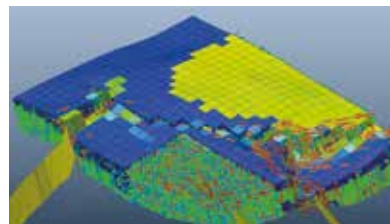
In 2017, Axens Group pursued its development, driven by its licensing, catalyst and adsorbent activities. There were several notable successes in the field of clean fuel and aromatic production processes, with the commissioning of numerous licensed units. This demand is being sustained by several regions around the world, particularly the Middle East, India and China. New processes were also either marketed or developed in the fields of chemicals and biofuels, in particular. The market success of the Impulse (hydrotreatment), Prime-G+ (hydrodesulfurization), Symphony (catalytic reforming) and Craken (hydrocracking) 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 launch of Connect'In, an online digital support offer for the monitoring and optimization of unit performances.

Axens Group now owns a 92.4% stake in Heurtey Petrochem and its subsidiary Prosernat. This acquisition, at

the end of 2016, enables the group to reinforce its position in the fields of gas treatment, furnaces, process equipment and technological modules, with a significantly expanded range of services. It was a difficult year for this activity, marked by the bottoming-out of the market. It was reorganized, bringing together project and engineering teams with a view to increasing competitiveness. The group's objective is to develop it with a view to being able to operate on third markets, while reinforcing synergies with Axens' other divisions.

AxensGroup now owns 50% of Eurecat, the catalyst regeneration and conditioning specialists.

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



In 2017, in a context that remained challenging for exploration-production activities, Beicip-Franlab maintained a sustained level of activity enabling it to deliver solid results for the financial year. The activity was driven by contracts in the Middle East and Iran, in particular, where several integrated studies relating to major fields were conducted. Demand in this region of the world is increasingly shifting towards studies combining an understanding of the reservoir and well and surface network optimization. The year was also marked by a sharp recovery in Beicip-Franlab's market share in North Africa, particularly Algeria, where some major exploration projects were initiated for both conventional and unconvention-

nal reservoirs. There was sustained activity in Europe too, underpinned by technical support and the implementation of several projects. Following a difficult year in 2016 in Asia, several projects on the theme of karst reservoirs were conducted, leading to technical successes. In the field of software, there were several sales to Beicip-Franlab's major customers, covering both exploration and reservoir technologies.

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

In 2017, Tech'advantage developed its third-party application maintenance activities in the upstream oil sector. In addition to research conducted on the Flow range of geoscience software, the company extended its expertise in the field of new technologies, launching its EDC (EasyDoc-Contents) embedded contextualized user help application in SaaS mode.

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

In 2017, 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: professional training

In 2017, in an extremely sluggish market, IFP Training continued to deploy its training programs leading to a qualification in numerous countries (Algeria, Congo, United Arab Emirates, France, Gabon, Iran, Kuwait, Mexico, Nigeria, etc.) to address its customers' requirements regarding the development and certi-

fication of skills. The second half of the year was marked by a number of major successes, particularly in Mexico, with new training center accreditation services, in Oman concerning training on real personnel units in the field of petrochemicals, and in Chad following a World Bank call for tenders.

In July 2017, IFP Training transferred the shares it had in its subsidiary RSI to Corys. Following the deal, RSI merged with Corys to create a global dynamic simulation leader in the field of energy and transport. IFP Training currently has a 25% share in Corys.

DriveQuant: services for connected vehicles and drivers

During its first year of activity, DriveQuant consolidated its technical and market positioning, with the acquisition of a dozen

or so customers, including insurance companies, fleet managers and spare parts distributors. The company starts 2018 with an excellent outlook and rapidly expanding technical and sales teams.

Mavel: powertrain engineering

In April 2017, in Pont-Saint-Martin, Italy, Mavel edt, a new company created by Mavel, Weisa Automobile Technology Limited and IFPEN, inaugurated its facility dedicated to short production runs of the range of innovative, efficient, low-power electric motors developed by IFPEN and Mavel.

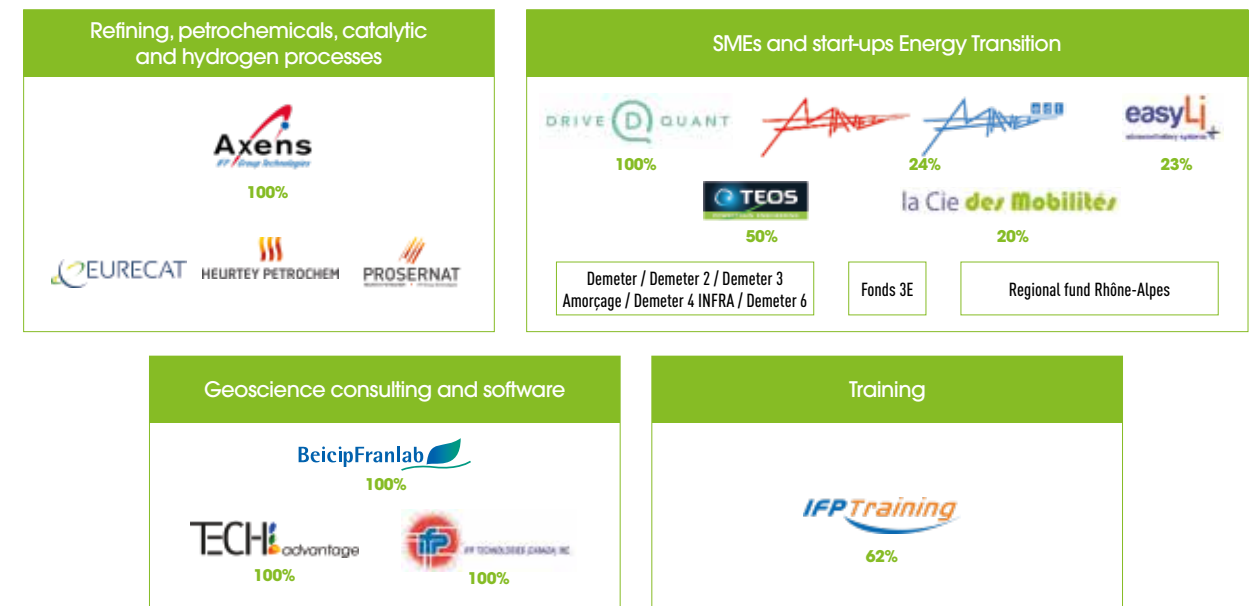
easyLi: powertrain engineering

In 2017, easyLi, which designs, produces and markets turnkey electric energy storage solutions, secured



the contract to supply the battery and recharging kit to start-up company CityScoot. CityScoot supplies the city of Paris with electric scooters on a free floating basis, i.e., the scooters do not have to be picked up or left at a specific pick-up/recharging station. EasyLi had a solid year, enjoying growth driven by a dual energy storage offer, in the field of light electric mobility, and stationary technology.

PORTFOLIO OF INDUSTRIAL STAKEHOLDINGS at 30 April 2018



New "Innovation and Entrepreneurship" module - p. 52
 IFP School students rewarded by their peers - p. 53
 First Petroleum Data Management program graduates - p. 54

2017 HIGHLIGHTS: THE ESSENTIALS

TRAINING

THE KEY PLAYERS IN THE ENERGY TRANSITION

Training is one of IFPEN's statutory missions. IFP School, its applied graduate training institution, trains the experts who will drive the energy transition and meet current industrial and societal expectations in the fields of energy and powertrains.

Not only are IFP School graduates immediately operational, they are also equipped for the professions of tomorrow associated with the energy transition. The School has already adapted its graduate program provision, changing the content of existing programs and creating some new ones.

IFP School maintains close links with industry and offers programs that meet its needs. Its partnership model - company sponsorship or work-study contracts - is tried and tested. On the international stage, IFP School offers joint graduate programs with high-profile universities, often leading to a double degree.

In order to maintain its established position as a world-class training center in the fields of energy and transport, IFP School attaches significant importance to its recruitment process and selecting the very best students. It constantly improves its programs, particularly by increasing the exposure of its students to environmental and ethical aspects.

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 for the energy and transport sectors 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 current energy revolution, IFP School is accelerating the evolution of its programs content via the introduction of new themes directly linked to new energy technologies. A strategy that allows it to remain in step with the needs of both industry and society, and to train outstanding engineers who are not only immediately available for companies, but who, above all, are 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: vehicle electrification, ex-biomass processes, CO₂ capture, 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;
- digital transformation, or how to understand and mobilize big data to manage new energy production constraints;
- 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

NEW "INNOVATION AND ENTREPRENEURSHIP" MODULE

The first session of the "Innovation and Entrepreneurship" module organized on the theme of mobility, brought together more than thirty students from various programs in January 2017. With this cross-functional program, IFP School encourages students to discover every aspect of setting up a company: the proposal of innovative ideas using creativity techniques (design thinking), drawing up of a business model, definition of a marketing plan, prototyping in a fablab and a pitch to win over potential investors. Buoyed by the success of this first session, which addresses the needs for agility inherent in energy innovation and student aspirations, a second session was organized in January 2018.

HIGHLIGHT

A SUSTAINABLE CAMPUS INITIATIVE

Created in September 2017, the Sustainable Campus Initiative is aimed at launching and supporting, on the IFP School campus, initiatives to disseminate exemplary behavior and practices concerning sustainable development. Projects tackle issues as diverse as energy consumption, transport, food and even health. In addition to campus-specific actions, IFP School also draws on IFPEN's CSR policy to improve efficiency. Early initiatives included an eco-gesture campaign and the installation of centralized waste recycling points.



CHRISTINE TRAVERS
IFP School Dean

"IFP School's ambition is to train talented young people able to work straight away in businesses involved in energy innovation, and who are equipped with the broad range of skills that prepare them for their future professions. To give substance to what we are in the process of becoming: the school for energy innovation and sustainable mobility, through the success of our students, to contribute to the construction of a world that supports sustainable and accessible energy."

13

industry-oriented programs,
including 7 delivered in English

HIGHLIGHTS

IFP SCHOOL STUDENTS REWARDED BY THEIR PEERS

In June 2017, a team of five IFP School students won first prize in the international Field Challenge competition organized by the European Association of Geoscientists & Engineers. They simulated the development of an oil and gas field in the North Sea using data provided by Total. The competition final brought together eight teams from Europe and Asia. IFP School students had already won the competition previously in 2011, 2014 and 2016: an award that underlines the recognition, by the sector's industrial players, of the relevance and quality of the programs delivered by the School

A NEW GRADUATE PROGRAM WITH SINGAPORE

In March 2017, IFP School signed a cooperation agreement with the National University of Singapore. It lays the foundations for the creation of a new graduate program offer in the energy field. An initial joint masters program, entitled Petroleum Projects and Offshore Technology, represents the first building block in this offer. It is due to be launched in 2019.

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 available to companies:

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

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 are endorsed by 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 because it is through interaction with representatives from industry on its advisory board that IFP School adjusts the number of students on its programs as a function of estimated future recruitment opportunities.



SYLVAIN CALISTI

Product Manager at Kayros,
Petroleum Economics
and Management graduate, 2012

“What is it that really stands out from my time at IFP School? Undoubtedly the people! Wherever I am in the world, I always come across a former student from the Petroleum Economics and Management program and we reminisce about everything we learned and the good times spent at IFP School!”

> 80%

of IFP School students are supported by companies throughout their studies

An international network in more than 100 countries

Today, more than 18,000 IFP School alumni are working in the energy and transport industries, in over 100 different countries. This network forms an important link for France's influence on the international stage. IFP School's graduate program activities play an essential role in IFPEN's partnerships around the world. By training high-potential employees in French and foreign companies, IFP School forges strong ties with the people destined to become the future industrial and political elite in their own sectors and 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 and improving their employability. IFP School develops and uses methods promoting knowledge and learning by experimentation: flipped classrooms, serious games, virtual reality and mobile learning are just some of the tools that help make IFP School students operational immediately after graduating.

350



teachers from the industry



LARISSA HOUSE

Former Petroleum Economics
and Management student 2017

“The teaching at IFP School, with visiting lecturers from industry and case studies, is extremely applied in nature, complementing the more theoretical course programs delivered by the Colorado School of Mines, which I'm following as part of my double degree. This operational approach is a big plus for my future career.”

HIGHLIGHT

SPONSORSHIP OF 2017 INTAKE

Thierry Pilenko, CEO of TechnipFMC (in the center of the photo) sponsored IFP School's 2017 intake.



HIGHLIGHTS

FIRST PETROLEUM DATA MANAGEMENT PROGRAM GRADUATES

Sixteen students from the first Specialized Master's Petroleum Data Management program graduated in October 2017. The objective of this program is to address the challenges associated with the energy sector and big data, by training the specialists capable of managing all the data acquired in the field of the exploration and use of natural resources, in particular oil, natural gas and water.

LEARNING BY DOING: IN STEP WITH THE PROFESSIONS OF TOMORROW



IFP School uses cutting-edge teaching methods (flipped classroom, learner community, MOOCs, virtual reality, serious games, mentoring, etc.). A previous award winner in 2015, in June, the School won first prize in the Digital Learning Excellence Awards, given by Cegos and AEF Groups, for its graduate program module entitled “Industrial

Unit Inspection”. The module, taken by students on the Energy and Processes program, includes exercises for the drawing up of anomaly detection procedures, via a virtual reality tour with headsets, paving the way for a real field visit. This fun approach enables students to immerse themselves in an industrial environment, true to the School's spirit of learning by doing.



Learning for all through MOOCs

In 2017, IFP School organized its third MOOC (Massive Online Open Course) sessions on sustainable mobility and the Oil & Gas chain. In total, more than 80,000 people have taken part in the various online course sessions since they were launched in 2014. Free and delivered in English with French subtitles, IFP School's MOOCs break down borders and reach learner populations from a variety of countries and environments. A successful experiment that will give rise to MOOCs focusing on new themes during 2018 and 2019.

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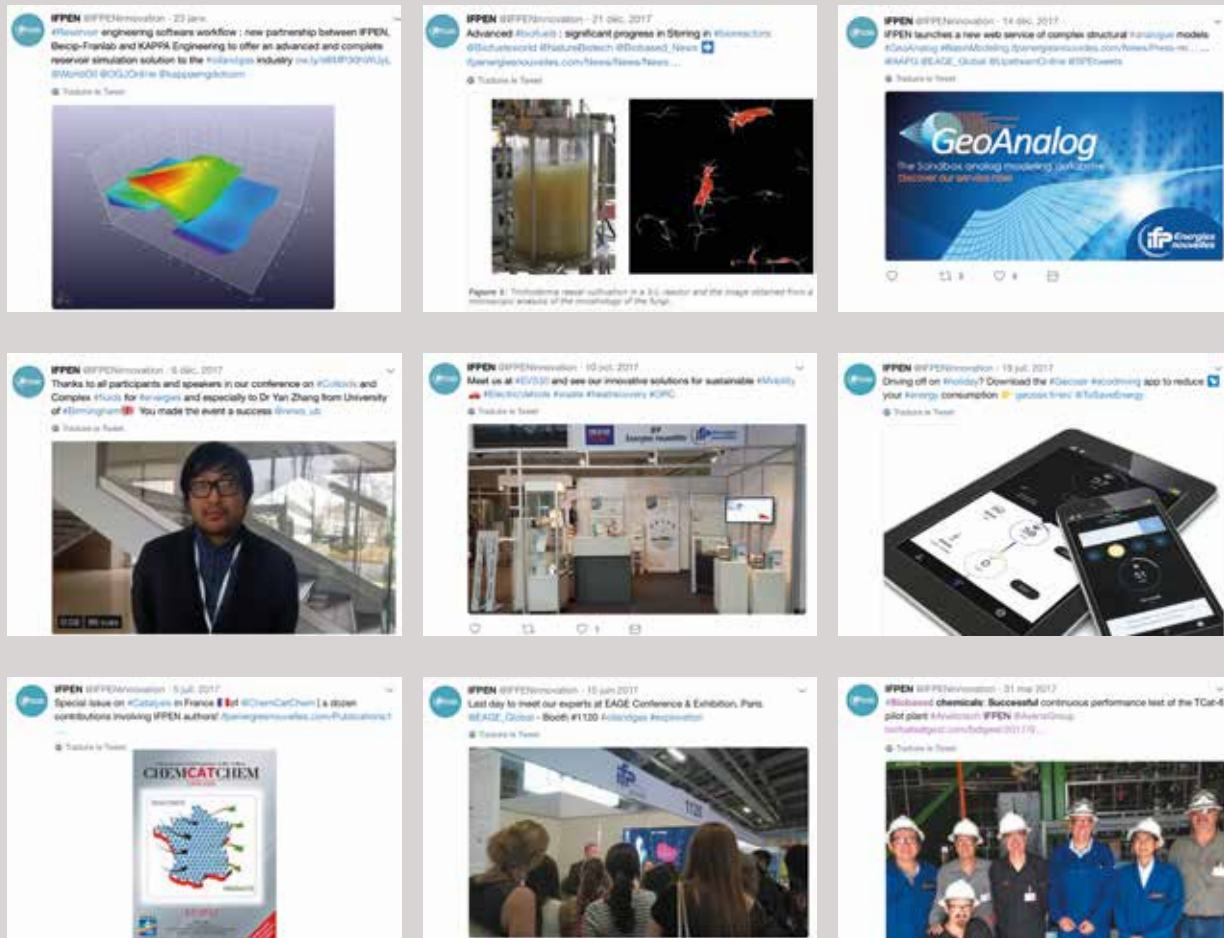
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REVIEW OF 2017

of @IFPENinnovation



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ACTIVITY REPORT

2017

INNOVATING
FOR ENERGY

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MEETING TOMORROW'S CHALLENGE TODAY

IFP Energies nouvelles

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.

