

THE ESSENTIALS
2019

INNOVATING
FOR ENERGY

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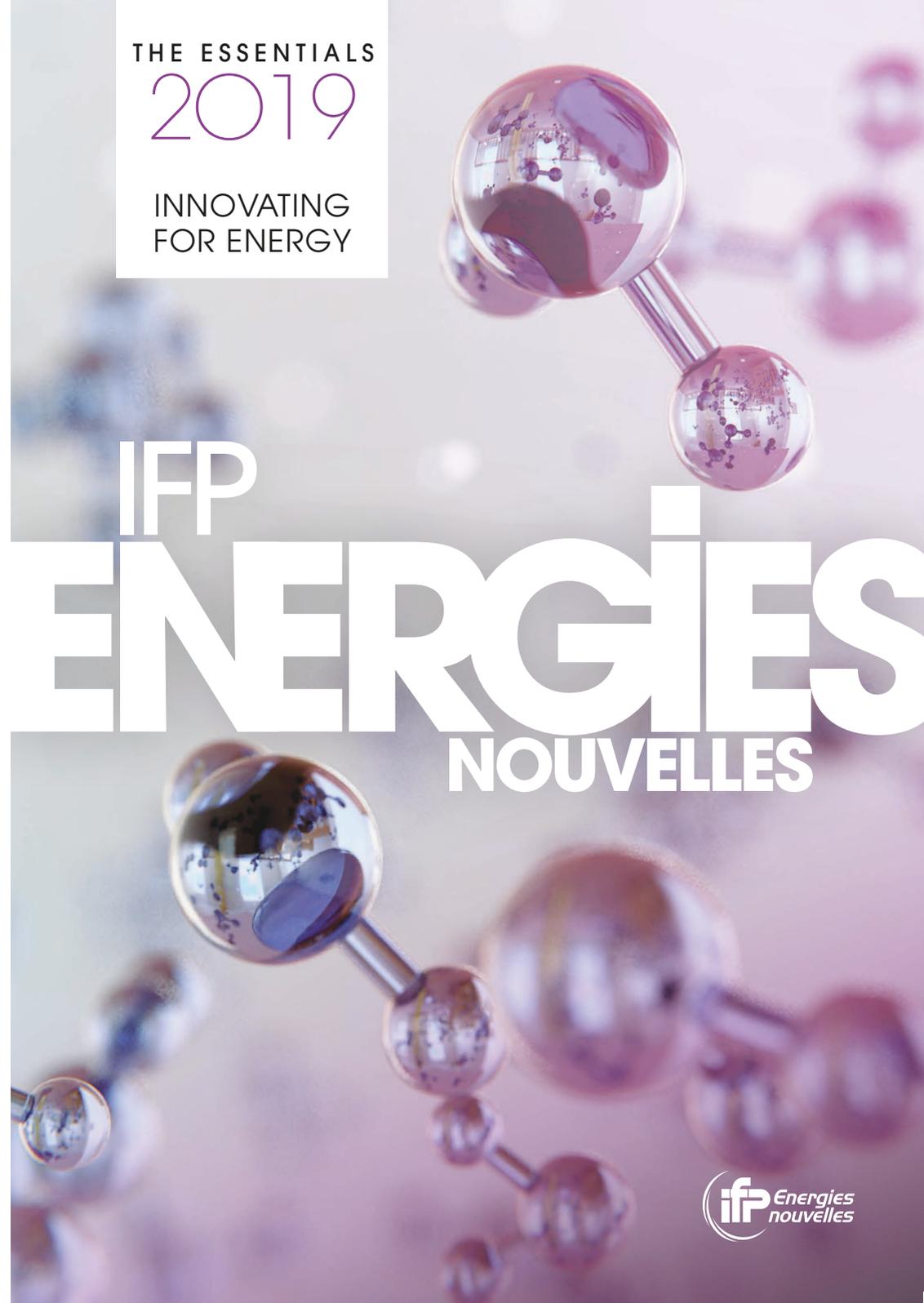
INNOVATING
FOR ENERGY

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MEETING TOMORROW'S CHALLENGE TODAY

IFP Energies nouvelles

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



IFP

ENERGIES

NOUVELLES



THE MESSAGE OF **DIDIER HOUSSIN**

Chairman and CEO of IFPEN

2019

IFPEN, DRIVING INNOVATION



IFPEN – resolutely committed to innovation to underpin a sustainable energy mix – supports the fundamental transformation of the energy sector. Accordingly, in 2019 – a year marked by advances in a number of areas – we adjusted our research perimeter, with a reinforcement of activities related to sustainable mobility and new energies.



IFP ENERGIES NOUVELLES (IFPEN) 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.

Consisting of world-leading industrial players and small to medium-sized companies with strong growth potential, this policy of valorisation is illustrated by the portfolio of subsidiaries and stakeholdings of the IFP Group.

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

Created in 1944, IFPEN is a state-owned industrial and commercial establishment.

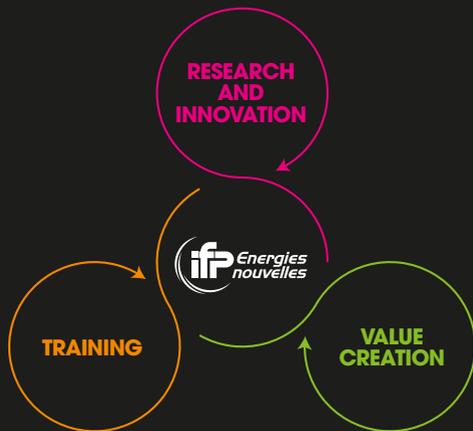
OUR MISSION

A CONTEXT

CLIMATE CHANGE AND THE ENERGY TRANSITION



THREE PRIORITY AREAS



KEY FIGURES 2019



€283.3 million 
Operating expenses
 including **€236.2 million**
 for R&I
60% 
of budget dedicated to NETs

1,633 
Total full-time equivalent workforce for 2019
 including **1,136** researchers
Nearly 200 research grant holders, post-doctoral researchers and placement students 

185 
patent applications
 including **94** in the field of new energy technologies

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

Around **500** 
IFP School graduates

ISO 
9001 certified for R&I activities

26,000 
participants, from 130 countries, enrolled on IFP School's MOOC on the energy transition

38 
contractual research projects involving international partners, of the 71 launched in 2019

DEVELOPING THE INNOVATIONS OF TODAY AND TOMORROW

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. To achieve this objective, IFPEN has hinged its R&I activities around three strategic priorities supported by fundamental research.

SUSTAINABLE MOBILITY

Taking into account evolving transport modes, boosting energy efficiency in transport and diversifying energy sources are the major challenges associated with sustainable mobility. IFPEN channels its expertise into addressing these challenges, via its IFPEN Transports Energie Carnot Institute, to come up with innovations that can be used by industry, are competitive from an economic, energy and environmental point of view, and are of benefit to the community and citizens. Three complementary themes are being explored: electric mobility, from the hybrid vehicle to all-electric, connected mobility, with the development of services and applications, and mobility with a low environmental impact, with the improvement of IC engines in a context of hybridization and the optimization of fuel use, particularly low-carbon.



NEW ENERGIES



Tackling climate change and moving the energy sector to a sustainable, low-carbon and cost-effective energy mix depend on technological innovations. IFPEN is contributing to this transformation by developing production processes for advanced biofuels, bio-based products and plastics recycling processes. IFPEN is also working on solutions for CO₂ capture and storage, ocean energies and energy storage.



RESPONSIBLE OIL AND GAS

Against the backdrop of the reduction in the environmental footprint and decrease in energy consumption, IFPEN develops eco-efficient and flexible processes for the production of fuels and chemical intermediates meeting the strictest standards. To make better use of reserves, IFPEN also proposes increasingly efficient, cutting-edge modeling tools and technologies for oil and gas exploration and production.

FUNDAMENTAL RESEARCH SERVING INNOVATION

In order to support its innovation ambitions and ensure the scientific excellence of its research activities, IFPEN draws on a solid fundamental research program, organized around nine scientific challenges. Launched four years ago, this program reached maturity in 2019. It has provided a platform for more efficiently addressing scientific questions raised by the development of new products and processes and reinforcing the collaborative research strategy implemented with its network of partners.



ENCOURAGING AND SUPPORTING INNOVATION

IFPEN's ambition is to contribute to the development of green industrial sectors and sustainable mobility, and speed up the detection of new energy technology opportunities. To this end, a diversification process is under way concerning industrial partnerships, innovation support for SMEs and start-ups, and the development of IFPEN Group subsidiaries.



START-UP AND SME SUPPORT

IFPEN has been actively supporting SMEs and intermediate-sized companies for nearly 30 years. Today, this support extends to start-up companies and is primarily focused on the energy transition and the environment. To improve the detection of opportunities, IFPEN draws on an extensive network of partners.

STIMULATING INTERNAL INNOVATION IN THE NET FIELD

IFPEN has created the internal conditions required to express a genuine innovation culture. A project incubator, an innovation challenge and a “free creativity” initiative focusing on the development of new methods and tools are examples of the types of initiatives proposed to stimulate creativity supporting new energy technologies (NETs).

MOVING TOWARDS NETS: SUPPORTING THE GROUP SUBSIDIARIES AND STAKEHOLDINGS

IFPEN's technology transfer policy is underpinned by its dynamic portfolio of subsidiaries and stakeholdings, today bringing together reference global industrial players and newly-created innovative companies. This model addresses the current need for the creation of sectors in the fields of new energies, the environment and sustainable mobility. Hence, in line with R&I activities, the group's subsidiaries are pursuing their NET development.

TRAINING THE KEY PLAYERS IN THE ENERGY TRANSITION

Against the backdrop of the energy transition, IFP School and IFP Training provide industry with the highly qualified personnel it requires. IFP School offers young graduate engineers advanced graduate programs in the fields of energy and sustainable mobility. Over 500 students from throughout the world graduate from the school each year. IFP Training, an IFPEN subsidiary, offers professional training programs to almost 15,000 employees from industry every year, reinforcing their competitiveness.

IFP SCHOOL

IFP School's ambition is two-fold: 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 academic and industrial partners, offering its students a resolutely innovative teaching model. IFP School graduates are immediately operational and already prepared for the jobs of the future in the field of new energy technologies.



IFP TRAINING

IFP Training trains the operators, technicians, managers, engineers and leaders of the oil and gas, chemicals and powertrains sectors. A shareholder in Corys, the global dynamic process simulation leader, IFP Training provides a unique global solution combining dynamic simulators and programs leading to a qualification, aimed at improving the performance and safety of teams in the field.

IFPEN 2019 NEWS IN BRIEF

TWO CARNOT INSTITUTES WITHIN IFPEN!

In addition to the renewal of the IFPEN Transports Energie Carnot Institute, at the beginning of 2020, the French Ministry for Higher Education, Research and Innovation announced that IFPEN had been awarded a new Carnot label relating to its energy resources activities.

The IFPEN Transports Energie Carnot Institute coordinates Carnauto, dedicated to the vehicle and mobility sector. It contributes to AirCar, dedicated to aviation, as well as to collaborative structures specializing in technological research and innovation, bringing together industrial players.

The role of the new IFPEN Ressources Énergétiques Carnot Institute, which brings together 14 laboratories, is to address scientific, technological and digital challenges in order to support the transition to a low-carbon energy mix.



IFPEN RESEARCHERS GO OUT TO MEET SCHOOL PUPILS AND THE PUBLIC

In May 2019, researchers from IFPEN went out to schools in Rueil-Malmaison to raise pupils' awareness of air pollution related to human activity. Interactive presentations gave pupils the opportunity to immerse themselves in the subject, tackling the themes of greenhouse gases and mobility. And in October, as part of the French Science Festival, IFPEN joined forces with 13 other research organizations at the Forum des Halles in Paris to present "Science en Direct", a public event providing an original and entertaining take on the themes of energy, the environment, climate, space, biodiversity and health.

JECHANGEMAVOITURE.GOUV.FR

In 2019, the French Ministry for the Ecological and Inclusive Transition launched the jchangemavoiture.gouv.fr platform, for which the calculation core was developed by IFPEN's teams. Aimed at the general public, the site allows people to compare several vehicles of varying degrees of electrification on the basis of their own particular mobility usages, guiding them in their choice of a new vehicle and ultimately helping them to make savings and reduce their environmental footprint.

IFP SCHOOL : ACCREDITATIONS TO AWARD QUALIFICATIONS

In September 2019, the French National Engineering Accreditation Board renewed IFP School's accreditation to award specialized engineering degrees for a period of five years (the maximum period). The accreditation covers all ten engineering degrees awarded by the school. In January 2019, the French Ministry for Higher Education, Research and Innovation had also issued a decree granting IFP School the right to award Master's-level applied graduate degrees. These two qualifications cover all of the school's student profiles.



SUCCESS FOR IFPEN'S ENERGY INNOVATION EVENTS

IFPEN's Energy Innovation events, inaugurated in 2019, hosted three round tables in Paris over the course of the year: the theme of the first of these was "Transport electrification: what potential for what usages?". Grenoble-Alpes Métropole, ADEME and Enedis took part in the session. The second such event focused on the future of second-generation (2G) biofuels, also known as "advanced biofuels". The French Ministry for the Ecological and Inclusive Transition, Safran and the Innovations Institute in Ecomaterials, Ecoproducts and Ecoenergies (Canada) were present at the event. Finally, the third edition, dedicated to CO₂ capture, storage and utilization, brought together the IEA, Air Liquide and Total. Around one hundred people, including numerous journalists, attended these events hosted by IFPEN.



SUSTAINABLE MOBILITY



LAUNCH OF THE MODALIS² PROJECT FOR THE MODELING OF ADVANCED BATTERIES

In 2019, via the IFPEN Transports Energie Carnot Institute, IFPEN led the Modalis² project for the “Advanced Batteries” call for proposals within the Horizon 2020 program. This project brings together Saft, Siemens Digital Industries Software, Siemens Corporate Technologies, Umicore, Solvay, K&S, CRF, Gemmate Technologies and the University of Turin, alongside IFPEN. Modalis² is aimed at developing a chain of numerical tools for the purposes of modeling and designing battery systems using new materials. This research will support the development of advanced battery systems while optimizing development and production costs.

IFPEN'S EXPERTISE APPLIED TO MOBILITY IN HOSPITALS

For the last internal innovation challenge, an IFPEN engineer proposed a removable support solution for transporting heavy wheeled loads to make life easier for hospital porters. From genesis to proof of concept, all those involved at IFPEN rallied together, continuing the dynamic approach synonymous with this challenge. The proposed solution was developed thanks to a combination of mechanical know-how and expertise in the control of electric powertrains adapted to load elimination. Drawing on the broad range of expertise present at IFPEN, researchers also pondered appropriate alternative applications, leading to the opening up



of new market opportunities in the hospital sector. After the winning proposal in mid-2018 and the proof of concept in 2019, industrialization is set for 2020.

AN ONBOARD KIT TO MEASURE REAL-TIME POLLUTANTS

In 2018, IFPEN joined forces with SME Capelec to begin the development of REAL-e, a smart and connected onboard analyzer that measures real-time pollutant emissions from the exhaust of light vehicles. REAL-e is a simpler, more economical and faster system than those currently employed. In 2019, REAL-e won one of the three “Coups de cœur” (jury’s favorite) innovation awards at the Equip Auto tradeshow (dedicated to automotive after-sales and mobility services) in Paris.



MEASURING ULTRAFINE PARTICLE EMISSIONS

The Horizon 2020 Sureal-23 “Understanding, measuring and regulating sub-23 nm particle emissions from direct injection engines including real driving conditions” project concerned the development of new onboard technologies capable of measuring ultrafine (up to a diameter of 10 nm) particle emissions from gasoline and diesel engines, in real use conditions. This provides the European regulator with a scientific basis for a potential reduction in the regulatory particle measurement threshold from 23 nm to 10 nm.

IFPEN'S RECOGNIZED EXPERTISE IN THE MEASUREMENT OF VEHICLE EMISSIONS



In 2019, IFPEN, as an expert in the characterization of vehicle pollutant emissions, and the French Ministry for the Ecological and Inclusive Transition launched a study to evaluate real-use pollutant and greenhouse gas emissions for vehicles complying with the Euro 6d-TEMP standard. This study, the results of which will be published in the last quarter of 2020, will make it possible to provide citizens with a transparent picture of the environmental performances of currently available gasoline, diesel and hybrid vehicles.

NEW ENERGIES

BIOBUTADIENE: LAUNCH OF THE 1ST INDUSTRIAL DEMONSTRATOR

In September 2019, Michelin, IFPEN and Axens announced the construction of the first industrial demonstrator in France for the production of butadiene using ethanol extracted from biomass, as an alternative to petrochemical-based butadiene. Objective: to manufacture innovative and more environmentally-friendly synthetic rubbers. Work to construct the industrial demonstrator began at the start of 2020 and will be completed at the start of 2021 on Michelin's Bassens site (Gironde, southwestern France). This demonstrator will be used to test ethanol derived from various types of biomass, including forestry and agricultural waste. The idea is to validate the process developed by IFPEN, which will ultimately consolidate the portfolio of green technologies marketed by Axens.

TOWARDS THE MANUFACTURE OF 100% RENEWABLE PLASTIC BOTTLES

In February 2019, Anellotech, IFPEN and Axens announced they had successfully produced bio-based aromatics at Anellotech's TCat-8[®] pilot plant in Texas, and extracted ultra-pure bio-based paraxylene. This success represents an important step in the project, which will lead to the production of 100% bio-based PET bottles. The next step will be the purification of a larger quantity of paraxylene, which will enable Anellotech to produce renewable PET resin to manufacture 100% bio-based bottle prototypes. This will be the first industrial unit dedicated to the production of bio-PET from the continuous treatment of non-food biomass. With this project, IFPEN is contributing to the development of innovative solutions in the field of bio-aromatics, in line with its strategy aimed at developing renewable chemicals and fuels from non-food biomass.



WIND TURBINE CONTROL USING LIDAR: RESEARCH AGREEMENT BETWEEN IFPEN AND LEOSPHERE



Leosphere, the global leader in wind measurement using lidar technology, is an SME based in Saclay. Following the joint work conducted within the framework of the ANR SmartEole project with Engie Green, the company signed an exclusive bilateral research agreement with IFPEN relating to the development of several technological building blocks geared to wind turbine control using lidar. This partnership led to the development by IFPEN of a beta version of the WiSE-Windfield software solution that incorporates some major advances. The software makes it possible to accurately reproduce

the wind field measured by a lidar placed on the nacelle of a wind turbine and will be integrated into systems within the WindCube[®] Nacelle range aimed at active wind turbine control. A licensing agreement has been drawn up and the software is set to be tested with target customers.

INDUSTRIAL-SCALE CO₂ CAPTURE AND STORAGE: LAUNCH OF THE 3D PROJECT

In June 2019, a consortium bringing together 11 European players, including ArcelorMittal, Axens, IFPEN and Total, launched a demonstration project concerning the innovative CO₂ capture process of industrial origin DMX[™]. The "3D" project (DMX[™] Demonstration in Dunkirk), which is part of the European Union's Horizon 2020 research and innovation program, targets three objectives:

- demonstrate the efficiency of the DMX[™] process on an industrial pilot scale;
 - prepare for the development of a first industrial unit that could be operational from 2025;
 - design the future European Dunkirk - North Sea cluster, which should be able to capture, process, transport and store 10 Mt of CO₂ per year and be operational by 2035.
- 3D, which aims to validate reproducible technical solutions and enable the industrial roll-out of capture-storage technology around the world, is an essential lever in terms of meeting the objectives of the Paris Climate Agreement.



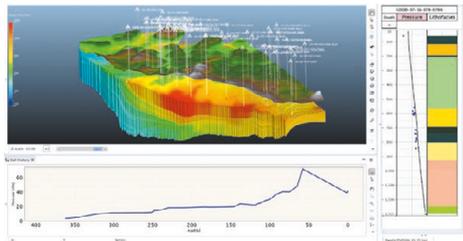
RESPONSIBLE OIL AND GAS

5

**new JIPs with
15 industrial partners
launched in 2019**

MODELING AS A TOOL FOR UNDERSTANDING EXPLORATION RISKS

Basin modeling is vital in order to identify drilling opportunities, estimate the oil and gas potential of sedimentary basins, locate future fields in increasingly complex environments and reduce exploration risks. Thus, within the framework of the NOMBA project conducted with Total and finalized in 2019, IFPEN developed the first calculator combining dynamic oil system simulation (ArcTem code integrated in the TemisFlow™ suite) with open-access geomechanics software (EDF's Aster code). This technology, evaluated on case studies provided by Total, proposes increasingly predictive



models while maintaining good calculation performances. Among other aspects, it addresses the problem of predicting excess pressure and natural fracturing regimes in sedimentary basins, decisive for the evaluation of their economic potential, drilling dimensioning and well safety.

A NEW FRAMEWORK AGREEMENT LAUNCHED WITH TECHNIPFMC ON NEW ENERGY TECHNOLOGIES

The framework agreement between IFPEN and TechnipFMC was renewed at the start of 2019 for a period of five years. The objective: to pursue the development of technologies relating to reeled flexible and rigid hoses, umbilicals and composite hybrid flexible pipelines. This new agreement places the focus on technological innovation to meet the requirements of deep offshore markets in response to the development of fields with increasingly restrictive characteristics.

It will also make it possible to explore new technologies in the energy transition and renewable energy fields, including CO₂ capture and energy storage, with a view to anticipating and supporting industrial evolutions.

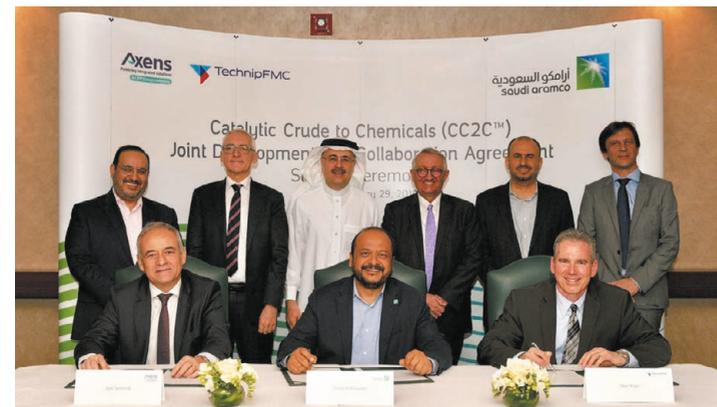
TOWARDS ENHANCED PROCESS PERFORMANCE IN THE DIGITAL ERA

Data acquisition and exploitation have become essential improvement and performance levers for the refining and petrochemicals sectors. Aware of this, IFPEN has reinforced its R&I activities aimed at developing a digital offer enabling end users to better exploit and model information generated by industrial units in order to maximize their operational performance. This new digital twin offer is hinged around Connect'In™, Axens' digital process performance monitoring platform. IFPEN's research to support the industry's digital transition continues in 2020.

40 TO 60%
**of chemical intermediates produced
from crude oil**

CATALYTIC CONVERSION OF CRUDE OIL INTO CHEMICALS

At the start of 2019, Axens, Saudi Aramco and TechnipFMC signed a collaboration agreement aimed at accelerating the development of Catalytic Crude to Chemicals (CC2C) technology and bringing it to market by 2021. IFPEN's teams have contributed their expertise in the fields of process modeling and technology extrapolation. This innovative technology for the catalytic conversion of crude oil into chemicals is aimed at increasing efficiency and chemical intermediate yields, converting more than 60% of the crude oil into petrochemicals, while minimizing emissions.



FUNDAMENTAL RESEARCH SERVING INNOVATION

CARMEN: THE NEW JOINT RESEARCH LABORATORY WITH THE CNRS



In 2019, a joint research laboratory called Carmen (*CARactérisation des Matériaux pour les Énergies Nouvelles* or characterization of materials for new energies) was created, bringing together, alongside the CNRS and IFPEN, ENS Lyon, Sorbonne University, Claude Bernard Lyon 1 University and Strasbourg University. The purpose of this new and unique international consortium is to reinforce knowledge on molecular and/or colloidal transport in complex porous substrates and develop new methodologies for the detailed analysis of these materials in order to support the development of innovations for the energy transition.

CORROSION RESISTANCE: CREATION OF A RESEARCH ALLIANCE



IFPEN and seven partners (Axel'One, Institut de la corrosion, CNRS, École des mines engineering school in Saint-Étienne, INSA Lyon, MECM and the University of Lyon), together making up the CorRTEX "Corrosion Research, Technology and Expertise" alliance, are working on the development of a corrosion test loop to test the corrosion resistance of various materials, predict operating performances, detect corrosion at an early stage and understand its origin. This experimental tool may be pooled as part of an open innovation approach to meet the needs of industry and SMEs.

ENCOURAGING DIALOG BETWEEN SPECIALISTS ON SCIENTIFIC PROBLEMS SUPPORTED BY INNOVATION

The scientific events organized by IFPEN are aimed at promoting exchange between international experts on themes of interest for the R&I community. In 2019, the Microfluidics Rencontre scientifique event and the Scienc'Innov e3CAV workshop related respectively to the contribution of microfluidics, from laboratory activities through to process development, and the contribution of CAVs (Connected and Automated Vehicles) to mobility sustainability. IFPEN also joined forces with INRAE for the joint organization of the 3rd European bioeconomy conference and hosted the annual Mascot - Num conference, covering data assimilation, uncertainty quantification, statistical techniques for machine learning and numerical analysis.

3
projects supported by the ANR launched by IFPEN in 2019

3
new ITN* /H2020 projects



*Innovative Training Networks

AI AND NUMERICAL SIMULATION TO OPTIMIZE RESEARCH

In 2018, IFPEN launched an ambitious action plan to drive its digital transformation. In particular, within the framework of the ACAI (Acceleration of Computations through Artificial Intelligence) project, IFPEN and INRIA are cataloging and categorizing the numerous existing approaches that hybridize AI and simulation. Evaluated on models similar to their own, they will be used to develop new deep learning methodologies in order to improve modeling and accelerate the simulation of the physical processes at work in porous media, engines, wind turbines, processes and thermodynamics.

ENCOURAGING AND SUPPORTING INNOVATION

200 IDEAS EMERGE IN THE INTERNAL INNOVATION CHALLENGE

A new edition of the internal innovation challenge was launched in October 2019. Objective: to generate projects covering all activities relating to IFPEN's new fields. For this challenge, dedicated to the environment and the climate, more than 200 innovation ideas were submitted. The final jury will select five or six winners.



IFPEN, PARTNER OF NATURAMOLE

IFPEN signed a partnership agreement with Naturamole, an SME specializing in the development of bioprocesses and the production of natural molecules via enzymatic biocatalysis and microbiological fermentation. Within the framework of this partnership, IFPEN will be helping the SME identify and validate a process for producing two highly pure lactones for a launch to market as natural ingredients carrying EC 1334/2008 and COSMOS certification for the formulation of flavorings and perfumes.

MORE THAN 250

new innovative start-ups and SMEs were identified by the Incubation and SME division's team in 2019. Around 50 of these held further discussions with an IFPEN Business Unit. These discussions resulted in around 10 R&D partnership contracts.

IFPEN ACQUIRES A STAKE IN THE SMART ELECTRIC TRAILERS AND TROLLEYS SPECIALIST

IFPEN acquired a 10% stake in K-Ryole, a company specializing in smart electric trailers and trolleys. K-Ryole™ effortless traction technology enables professionals to transport heavy loads by bicycle or on foot. This investment will be accompanied by a technological partnership with IFPEN enabling K-Ryole to develop its range.





TRAINING THE KEY PLAYERS

IN THE ENERGY TRANSITION

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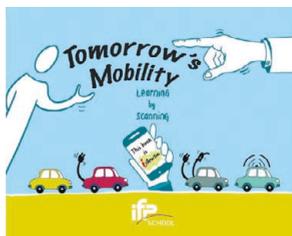
prizes awarded
to IFP School students
in 2019

FOUR TEACHING AND RESEARCH CHAIRS

IFP School promotes its research activities, particularly via teaching chairs, four of which are currently active: “Economic Modeling Applied to the Environment and Energy”, “Electricity Economics and the Digital Transition”, “Electric, Connected and Autonomous Vehicles for Smart Mobility”, and “Carbon Management and Negative CO₂ Emissions Technologies towards a Low Carbon Future”. The latter, created with the support of Total and the Tuck Foundation, concerns the development of innovative solutions to reduce atmospheric CO₂ emissions caused by human activities.

MOOCS: A CONFIRMED SUCCESS

The two new MOOCs organized by IFP School: “Tomorrow’s Mobility” and “Energy Transition: Innovation Towards a Low Carbon Future” attracted more than 30,000 participants from more than 100 countries. Around 20% of students who began their course in 2019 at IFP School stated that the MOOCs were a factor that encouraged them to apply to the school. An enhanced version of these modules is proposed in 2020.



INNOV'ACTION CHALLENGE



For IFP School’s 1st Innov’Action challenge, 18 teams of students tackled challenges set by partners companies including Air Liquide, Arkema, Axens, Renault Sport Racing, Technip and Total. The event, forming part of the Experience Sharing Module, enabled students from the class of 2019 to work on the themes of innovation, digital technology and the intercultural dimension within companies.



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