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IFPEN, innovations to tackle the challenges of climate change

The constant increase in greenhouse gas emissions is rapidly reducing humanity's leeway when it comes to tackling climate change. The last IPCC (Intergovernmental Panel on Climate Change) report indicates that to have any chance of limiting the increase in global mean temperature to under 2°C (compared to pre-industrial values), it will be necessary to cut emissions by between 40 and 70% by 2050, allowing by the end of the century, to counterbalance all remaining emissions by carbon capture and sequestration techniques. This will require truly huge efforts, the extent of which has probably not been adequately appreciated yet.

Eliminating energy waste, which still remains significant, while simultaneously increasing the proportion of renewable energies, can help initiate a reduction in greenhouse gas emissions over the coming decades. But by the middle of the century, the easiest part of the job will have been done and any further progress of any significance will necessitate innovative energy solutions. Financial incentives related to carbon prices will not be sufficient to allow the emergence of new technologies and processes: substantial research work is also required and it needs to start right now.

Hervé Le Treut
Director of the Pierre-Simon Laplace Institute
Pierre et Marie Curie University
Member of the French Academy of Sciences

Advanced control of wind turbines

One of the major challenges for the development of the wind power sector is reducing the cost of the produced energy. The use of advanced control systems is one of the levers to optimize wind turbines performances and generate production increases.

The use of advanced sensors, such as Lidar (Light detection and ranging), to measure variations in wind speed before it reaches the wind turbine, constitutes a major advance. To turn these sensors into advanced control systems, it is necessary to firstly estimate the wind speed as it actually reaches the rotor on the basis of these measurements and, secondly, to use this information to control the wind turbine[1].

A first software solution developed by IFPEN provides a real-time estimate of the wind field reaching the turbine blades on the basis of upwind measurements. This is used to correlate the data supplied by the sensor with information that is useful for the wind turbine control system.

A second software solution concerns blade orientation control strategies. These strategies can be broken down into three sequential levels, each affecting the stability and mechanical stress of a wind turbine component (rotor, mast, blades).

Ultimately, the system can be used to make a complete correlation between the crude response of the sensor and the operation of the wind turbine, helping to reduce mechanical loads due to wind[2]. This limits maintenance requirements and increases the life span of the systems, with a positive impact on energy costs.

In the short term, this innovation will be trialled on a full-scale turbine at two test sites, located in France (ANR SmartEole project) and in Canada, to ensure experimental and long-term consolidation of all these developments.

Lidar sensor on a nacelle: Wind Iris from Avent Lidar Technology.

(1) ***J. Chauvin*** *and* ***Y. Creff,*** Nonlinear two-stage control strategy of a wind turbine for mechanical load and extreme moment reduction. *OMAE 2011.*

(2) *B. Bayon and* ***J. Chauvin,*** Investigating Lidar sensing errors for wind turbine loads reduction. *OMAE 2014.*

Scientific contact:
jonathan.chauvin@ifpen.fr

Saving the environment by good driving

To cut the fuel consumption – and hence CO_2 emissions – of road vehicles, one of the methods used involves adopting driving behavior that is as energy-efficient as possible.

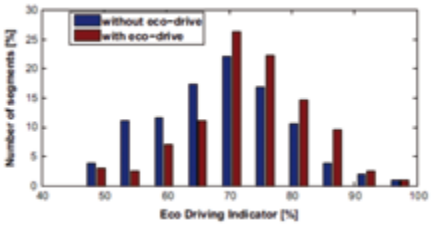
To fully exploit the potential offered by ecodriving, as opposed to just applying simple recommendations, it is necessary to optimize the driver's actions. This entails the online resolution of a mathematical problem, a complex task due to the limited computation resources generally available on board a vehicle (e.g. smartphone).

To overcome this obstacle, IFPEN has developed semi-analytical methods that can be used to calculate optimum speed profiles, without modifying the route or the journey time. They use simplified models of the vehicle and its powertrain system. These methods have been applied to electric and IC vehicles. Today, the corresponding algorithms are implemented within GECO™ real-time driving assessment software, offered by IFPEN to consumers in the form of a free smartphone application (www.geco-drive.fr).

The results of preliminary trials with GECO™, as well as data relating to the use of this service by the general public (see figure), demonstrate significant energy savings, without any effect on journey time.

Ongoing research aims to extend the service offered, by incorporating an eco-routing function (selection of the best route) using energy maps, cooperative multi-agent control and dialog with the road infrastructure.

These algorithms, which are remotely operated on a server, are the basis for new web services hinged around energy efficiency in the field of transport.



Effect of the use of an online driving optimizer for several road segments.

(1) ***W. Dib, A. Chasse, P. Moulin, A. Sciarretta, G. Corde,*** *Control Engineering Practice, 2014, 29, 299-307.*
DOI: 10.1016/j.conengprac.2014.01.005

(2) ***W. Dib, A. Chasse, D. Di Domenico, P. Moulin, A. Sciarretta,*** *Oil & Gas Science and Technology, 67(4), 589-600.*
DOI: 10.2516/ogst/2012023

Scientific contact:
antonio.sciarretta@ifpen.fr

H_2: from energy vector to primary energy?

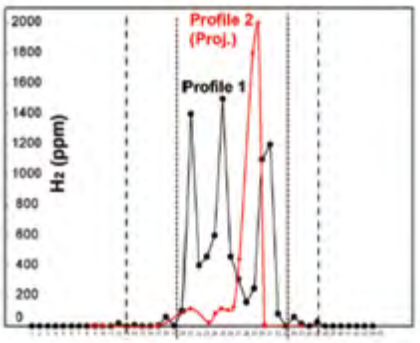
Could hydrogen be one of the clean, sustainable energy sources of the future? Today, di-hydrogen (H_2) is only an intermediate product, primarily obtained by hydrocarbon reforming and mainly used for chemicals. It is also an energy vector that is increasingly being considered for certain uses (transport, storage and intermittent renewable energies), but the costs – including environmental – remain high.

What if H_2 existed in its natural state in a usable form? What if it was a primary energy source, like oil or gas? This would be a genuine paradigm shift!

Until very recently, H_2 was considered to be non-existent in its native state, due to the oxidizing conditions that reign on the superficial layers of our planet. With exceptions confirming the rule, however, specific geological conditions exist, in which contact of meteoric water with rocks containing reducing elements – primarily ferrous iron – produces native H_2. These environments are inaccessible (mid-oceanic ridges) or rare (terrestrial mountain ranges containing peridotites).

The discovery in Western Russia, in the center of the Volga-Ural craton, of circular depressions emitting di-hydrogen raises hopes of a native H_2 that might be of real economic interest[1]. Cratons are the old, stable part of the continental lithosphere, located in the center of continents, and represent 50% of the earth's surface: a genuine mine! H_2 has also been detected inside other cratons, in North and South America, as well as in Africa.

IFPEN's research in this area is now focusing on production and transport mechanisms for the gas[2], in order to assess how this resource could contribute to the energy mix of the future.



H_2 concentration profile in the soil. Lake Podovoye, Russia.

(1) *N. Larin,* ***V. Zgonnik****, S. Rodina,* ***E. Deville, A. Prinzhofer*** *and V.N. Larin, Natural Resources Research, 2015.*
DOI: 10.1007/s11053-014-9257-5

(2) ***J. Guelard,*** Origin and dynamics of natural hydrogen flows in a continental environment: Rock/Water/Gas systems. The example of Eastern Kansas. *Ongoing doctoral research.*

Scientific contacts:
valerie.beaumont@ifpen.fr
eric.deville@ifpen.fr

Biofuels: what's new?

In the quest for sustainable alternatives to fossil fuels, the use of lignocellulosic biomass is a promising strategy that exploits a non-food resource.

In the context of bioproducts and biofuel production, the first step may consist in obtaining sorbitol, a glucose sugar-alcohol, via cellulose hydrolysis/hydrogenation. Sorbitol is then transformed into light alkanes, by aqueous-phase heterogeneous catalysis.

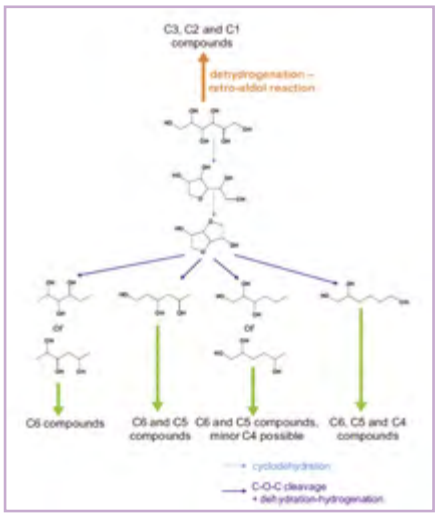
The reference catalytic system for this reaction, based on platinum nanoparticles deposited on a silica-alumina acidic support, presents a lack of stability and activity. Another problem concerns the multitude of unwanted products.

IFPEN's quest for more performant catalysts has led to an original application of a model reaction – the dehydration of cyclohexanol – to compare the aqueous phase acidity of different oxides. Hence, solids based on tungstated titanium oxide have been shown to be particularly stable and active. By combining this oxide with platinum, identified as the metal phase with the best performance, catalysts are obtained that improve C_5/C_6 alkane selectivity from sorbitol[1].

A general reaction scheme allowing to explain the formation of the various intermediate products observed on this new catalyst has also been proposed[2].

Since the final alkane yields are still insufficient at this stage for industrial application, attempts are being made to improve the process by adding metallic promoters. In parallel, the developed methodologies are already being used in other projects focusing on converting biomass into bioproducts.

Scientific contact:
amandine.cabiac@ifpen.fr



General reaction scheme for the transformation of sorbitol on a Pt/ZrO_2+TiO_2-WO_x catalyst.

(1) *L. Vilcocq, R. Koerin, **A. Cabiac,** C. Especel, **S. Lacombe,** D. Duprez,. Appl. Catal. B-Environ., 2014, 148, 499.*
DOI: 10.1016/j.apcatb.2013.11.016

(2) *L. Vilcocq, **A. Cabiac,** C. Especel, **S. Lacombe,** D. Duprez, J. Catal., 2014, 320, 16.*
DOI: 10.1016/j.jcat.2014.09.012

Engine knock: self-ignition gets the LES treatment

One solution envisaged to meet pollutant standards for gasoline IC engines, while at the same time reducing their fuel consumption and improving their performance, is downsizing. This technology, which combines downsizing with high-pressure turbocharging, increases engine efficiency and reduces CO_2 emissions.

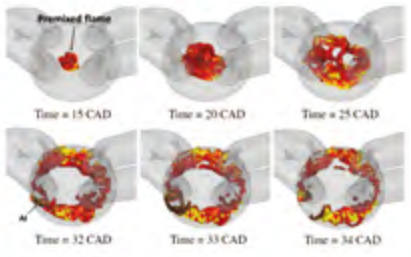
However, the more severe conditions encountered in these engines promote the development of abnormal combustion (knock and super-knock). The latter, due to areas of self-ignition of fresh gas upstream of the flame front, generate serious risks of mechanical breakdown and make them particularly difficult to study.

IFPEN recently studied this phenomenon by numerical simulation[1, 2] using the AVBP[1] 3D code developed in partnership with CERFACS[2]. These studies demonstrated the representativeness of the LES simulation compared to experimental results – also obtained at IFPEN – both in terms of "cycle-to-cycle" variability and in terms of knock frequency, its intensity and the moment at which it occurs during the cycle.

In addition, LES simulation enables detailed analysis of the physical phenomena occurring in the combustion chamber. It is thus possible to locate the main zones triggering self-ignition. It can also be used to monitor – for each engine cycle and at any time – the position of the flame and of uncontrolled self-ignition (see figure). The establishment of a transition towards detonation has thus been confirmed during certain cycles and appears to be the cause of very high-intensity, often destructive, knock.

LES has been shown to be a powerful tool to help powerchain engineers gain a better understanding of phenomena inside combustion chambers, with a view to improving their products.

Scientific contact:
anthony.robert@ifpen.fr



Location of the flame (red) and of self-ignition (black) during an engine cycle.

1 - Large Eddy Simulation (LES) calculation code
2 - European Centre for Research and Advanced Training in the field of Scientific Computation

(1) ***A. Robert,** S. Richard, **O. Colin, L. Martinez, L. De Francqueville,** Proc. Combust. Inst., 2014, 35 (3), 2941-2948.*
DOI: 10.1016/j.proci.2014.05.154

(2) ***A. Robert,** S. Richard, O. Colin, T. Poinsot, Combustion And Flame, In press, 2015.*

An industrial ecosystem optimization platform

Cutting industry's energy consumption increases competitiveness and reduces the sector's impact on the environment. Integrative and multiscale energy optimization approaches are more effective than juxtaposed interventions on one or more components of the system concerned.

Conventional methodologies and design tools operate on a process scale. However, on a plant – or even industrial territory – scale, the system becomes so complex that it reaches its limits.

This observation made by the Ancre[1] alliance led IFPEN to coordinate an R&I program aimed at designing and developing an "energy and materials" flow optimization digital tool on a plant and territory scale: Plate-form(E)3.

A prototype of this tool is under development, with the support of the ANR[2, (1)]. IFPEN, as the project's coordinator, is involved in the definition of the overall system architecture, modeling of input data and integration of the different elements.

The Plate-form(E)3 design and decision aid tool will ultimately make it possible to model identified or planned facilities from an energy point of view and on different scales, then to minimize the global costs and environmental impacts, while at the same time satisfying requirements in terms of materials.

The tool will combine a simulation and optimization engine with a graphic design, project edition and results analysis environment. It will also ensure interoperability with the industrial process simulators currently on the market[(2)].

The platform will be used by industrial players and design departments, as well as local authorities, in a regional development and industrial ecology context.

1 - French National Alliance for Energy Research Coordination
2 - French National Research Agency

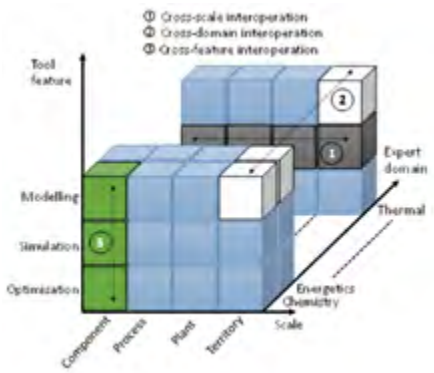


Diagram of interoperabilities taken into account in the platform.

(1) *A. Aubry, **J. Noel, D. Rahon,** H. Panetto,* Lecture Notes in Computer Science. *Springer, 2013, 8186, 57-61.*

(2) ***E. Lemaire, D. Rahon, Y. Creff, A. Gomez.** SFGP 2013 Congress.*

Scientific contact:
eric.lemaire@ifpen.fr

Appointment

Didier Houssin *took over from Olivier Appert as Chairman and CEO of IFPEN on 8 April 2015.*
A graduate of the Institut d'études politiques de Paris *(1977) and the* École nationale d'Administration *(1983), he worked in international roles at the French Ministry of Industry from 1983 to 1987, before being seconded to Total until 1990. He then served as Deputy Director of Economic and Financial Affairs at the Ministry of Industry, followed by Director of Energy and Mineral Resources from 1997 to 2004, before being appointed Managing Director of BRGM.*
From 2007 to 2012, he was Director of Energy Markets and Security at the International Energy Agency.
Since December 2012, he had been Director of Sustainable Energy Policy and Technology at the IEA.

HDR

• ***Fadi Nader,*** *HDR awarded by Pierre et Marie Curie University (Paris VI), for his work on multiscale diagenesis and its impacts on reservoir rock heterogeneities (19 March 2015).*

Awards

• ***Alain Méthivier*** *was one of three Marius Lavet prize finalists for his work on the development of the Eluxyl adsorbent and process between 1992 and 2014. He was involved in this project first as a research engineer, then as project manager and, finally, as head of department. This prize rewards an engineer who has had a distinguished career (23 March 2015).*

• ***Claire Derlot,*** *a PhD student within the Biotechnology Division, was awarded a prize for best poster at the 37th Symposium on Biotechnology for Fuels and Chemicals in San Diego (USA). She presented her thesis research on gene engineering to regulate the production of enzymes used for biomass decomposition (April 2015).*

• ***Cécile Plennevaux,*** *a former PhD student at IFPEN, was awarded the 2014 certificate of honor by Cefracor* (Centre français de la corrosion et de l'anticorrosion *– French corrosion and anticorrosion center), for her thesis entitled "Study of the risks of corrosion and delayed rupture of steels in the presence of H_2S in high-pressure and high-temperature oil and gas exploration conditions" (8 June 2015).*

Upcoming scientific events

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– Microfluidics –*** *4-5 November 2015, IFPEN Rueil-Malmaison - www.rs-microfluidics2015.com*

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– SimRace –*** *8-10 December 2015, IFPEN Rueil-Malmaison - www.rs-simrace.com*

Publication

• *OGST – IFP Energies nouvelles journal – Issue 2, volume 70 (2015). Issue focusing on fluid-polymer interactions: permeability, durability (http://ogst.ifpenergiesnouvelles.fr).*

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Editorial committee: Xavier Longaygue, Laurent Forti, Françoise Brucy
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To get in touch with IFPEN or receive Science@ifpen:
Institutional Relations and Communications Division:
Tel.: +33 1 47 52 51 34 - Science@ifpen.fr
1 et 4, avenue de Bois-Préau - 92852 Rueil-Malmaison Cedex - France
Press contact: A.-L. de Marignan - Tel.: +33 1 47 52 62 07 – **Institutional contact:** A. Sanière - Tel.: +33 1 47 52 69 19