
Written on 09 April 2021

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News

Fundamental Research

At IFP School, as in any Graduate School, teaching and research activities are mutually enriching. However, the School has a unique feature linked to its nature as a school of specialization: it is an outward-looking organization with a strong focus on the corporate and professional issues. As such, it hosts a diversity of international publics (students, professors, experts, industry representatives, researchers), all passionate about the same industrial and societal issues. By providing the opportunity for original and close interactions between academia and industry, the School is a fertile breeding ground conducive to the development of new ideas.

This issue of Science@ifpen presents the diversity of themes tackled at the School, primarily within the framework of research and educational chairs. It highlights the dynamism and plurality of its research activities, which cover a broad spectrum of scientific fields. The aspect that also emerges from this issue is that the School is not only a place where knowledge is passed on but also one where it is produced, thereby illustrating our ambition to develop educational programs of outstanding quality that are relevant and adapted to the challenges of today and tomorrow.

I hope you enjoy reading this issue.

**Christine Travers**
IFP School Dean

# LES BRÈVES

**Tackling climate change necessarily involves reducing greenhouse gas emissions resulting from human activities, primarily carbon dioxide and methane**. The problem is global and the actions required must be implemented within the framework of a systemic approach, with scale effects that are difficult to fully understand. Nevertheless, **the Paris Agreement reflects the determination of nations to correct the current trajectory while respecting the legitimate aspirations of emerging countries to raise their living standards**.

In addition to reducing emissions at source, **one lever available to limit climate impact is to extract $CO_2$ from the atmosphere** (i.e. negative emissions), using solutions that are environmentally-friendly, that protect biodiversity and that are both deployable and accepted by our societies. **The main difficulties lie in the complexity and interdependence of the phenomena to be considered**, requiring expertise and tools in a variety of fields, such as energy, land use planning and forest management, as well as human sciences. Although such expertise exists in all these fields, partial and poor solutions may emerge if there are not sufficient interactions to solve the problem in a global way.

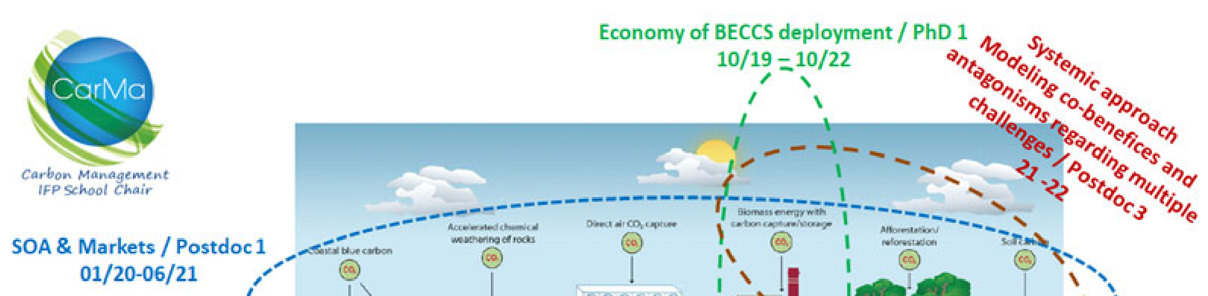
**The ambition of CarMa**[1], a teaching and research Chair sponsored by Total, **is to explore and analyze the field of negative $CO_2$ emissions**, using a very broad approach, **in order to identify which options could be deployed by 2050**. **In line with the principle of sustainable development** , the approach adopted focuses on **three solutions that may increase $CO_2$ sequestration capacities:** direct capture of $CO_2$ in the atmosphere (DACCS), soil sequestration and biomass energy extraction combined with $CO_2$ capture, storage and utilization (BECCS).

**These topics are already being examined** from a regulatory and economic perspective, including a "carbon life cycle analysis (LCA)", **in two post-doctoral research projects and one thesis**. Three additional young researchers will be recruited in 2021 to work on the societal aspects of BECCS deployment and on the antagonisms and co-benefits of land allocation in the context of biomass energy use. The research areas addressed during the first two years (some in partnership[2]) lie within the perimeters illustrated in the diagram.

**The very first results**, currently being published[1] [3], **present the economic analysis of a concrete case** in Sweden involving the collection, transport and use of biomass, combined with the capture, transport and storage of the $CO_2$ produced by its combustion. In this analysis, the concepts of cooperative game theory are mobilized in order to identify conditions for cooperation between different emitters connected to a common infrastructure, a pre-requisite considered essential for the large-scale deployment of this combination of technologies.

**In order to raise awareness** of this crucial issue for the 21st century, **a website has been set up to facilitate the dissemination of the Chair's results**. The "BECCS" theme has also been included in the 2020 edition of the "***Energy Transition***" MOOC offered by IFP School.

*Click on the picture to enlarge*



CarMa Chair: research perimeters (years 1 and 2) concerning negative CO2 emissions approaches

1- CarMa: “Carbon Management and negative emissions technologies towards a low carbon future”, created in July 2019 in partnership with the Tuck Foundation.
2- For example with the CNRS, the University of Pau and Pays de l’Adour and INRAE.
3- The article currently submitted[1] can be accessed on City Research Online and in Les Cahiers de l’économie, published by IFPEN - IFP School (issue 135 – August 2020).

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*[1] E. Jagu et O. Massol.* ***Building infrastructures for Fossil- and Bio-energy with Carbon Capture and Storage: insights from a cooperative game-theoretic perspective****, 2020, submitted to Environmental and Resource Economics.*
>> https://openaccess.city.ac.uk/id/eprint/25034/

**Scientific contact: Jean-Pierre Deflandre**

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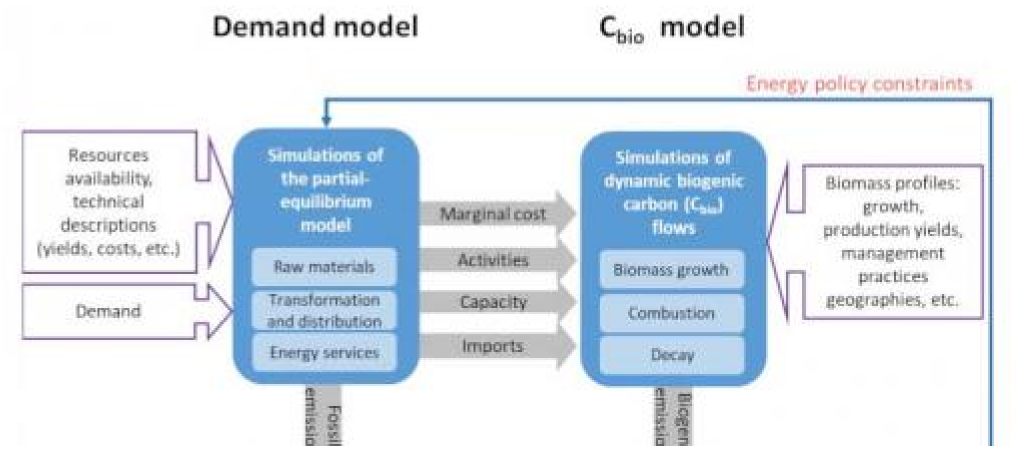
Training and Careers

News June 2020

## Launch of the new CarMa Chair website




storage

Fundamental Research

News April 2020

## Dynamic modeling to help achieve genuine carbon neutrality

Climate, environment and circular economy | Environmental monitoring | Life cycle analysis (LCA)

Economics | Environmental impact evaluation & LCA

CarMa Chair: negative CO2 emissions by 2050

**In 2016, IFP School joined forces with Mines ParisTech, Toulouse School of Economics and Paris Dauphine-PSL University to launch an original scientific initiative: the ”Economics of Natural Gas” Chair.**

The creation of this Chair resulted from **a series of observations concerning the scientific and societal relevance of questions related to gas** (particularly in the context of the energy transition and the rapid development of new technologies) **and the opportunities offered by the complementary nature of the expertise present.**

Accordingly, the chair set itself the following objectives:

- to advance scientific knowledge in energy economics on gas issues;
- to support an ambitious research program, the results of which are intended to be published in top-field journals;
- to empower talented researchers by providing them with the opportunity to broaden their research practice and to facilitate their presence in international networks;
- to educate the next generation of energy economists and experts by developing a set of modernized courses on contemporary gas issues.

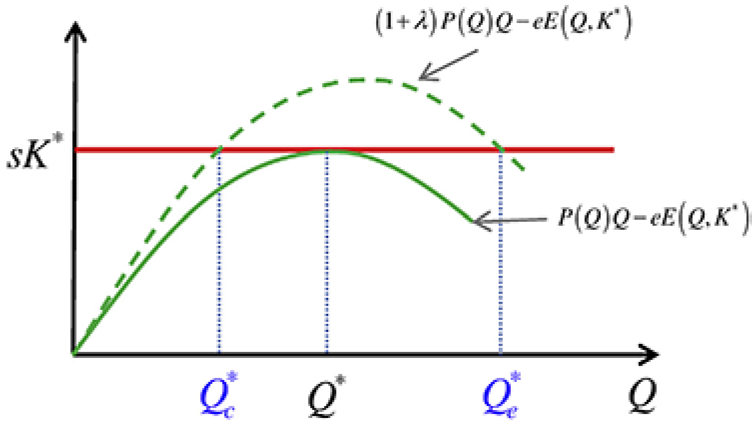
**Supported by industry** (EDF, GRTGaz and Total) **via the Fondation des Mines, the Chair has a lean organizational structure and a governance that complies with international academic standards**. Identification of the themes tackled and evaluation of the research carried out are overseen by **an independent scientific committee that gathers a group of eminent scholars**[1].

To date, **the Chair has initiated five doctoral projects**.

**Four of these PhD dissertations have just been defended** and offer a series of original contributions on various issues including:

- the spatial integration of gas markets[2];
- the flexibility of the gas supply chain[3];
- the econometrics of energy demand[4];
- and the application of network theory to model the transition to low-carbon societies[5].

In parallel, **the Chair's researchers have also worked on a range of other themes**, such as **the technical and economic representation of gas transport**, **the behavior of regulated operators** (figure) and **the detection of market power in a liberalized gas industry**.




Behavior of a regulated pipeline operator
subject to an increase in demand [3]

*The solid line depicts the situation envisaged in the absence of an increase: the volume Q* is such that the book profit (in green) reaches the authorized level of capital remuneration (red constraint).*

*The dotted line depicts the situation given an increase in demand: satisfying the regulation constraint requires a production adjustment either up (expansion to Qe) or down (contraction to Qc).*

**The Chair also organized two international conferences in Paris and invited foreign scholars to lead dedicated seminars.** So far, the research conducted at the Chair has resulted in **14 scientific publications** (e.g., [1-4]) **and more than fifty papers** at conferences and academic seminars.

For **IFPEN**, the momentum created by the Chair directly contributes to advances in the **fundamental research** conducted within the context of Scientific Challenge No. 9 “Assessing the economic and environmental challenges of the energy transition”.

At **IFP School**, the initiatives promoted by the Chair have made it possible to modernize the teaching of energy economics and thus better prepare students for current and upcoming challenges. For example, they now get some exposure to the modern tools and methodologies (based on game theory concepts, for instance) required to model and analyze price formation in a network industry in the presence of imperfect competition. **The Chair also made it possible to develop new case studies inspired by contemporary industrial issues and energy policy debates**.

**Future research developments will concentrate on a variety of issues,** such as **the market design needed to foster the efficient coordination of low-carbon electricity and gas systems or the barriers hampering the deployment of new, gas-based, energy technologies**. Research targeting these areas will primarily be hinged around the implementation of methodological developments initiated over the last four years.

1-The scientific board consists of Professors Steven A. Gabriel (University of Maryland), Christian von Hirschhausen (TU Berlin and DIW (the German Institute for Economic Research)), Michele Polo (Bocconi University) and Robert Ritz (University of Cambridge, Chairman of the Board).
2- Ekaterina Dukhanina (2020), “***Integration of gas markets : Europe and beyond***”. Thesis defended at MinesParisTech.

3- Amina Baba (2020), “***La flexibilité sur le marché du gaz naturel*** ” (Natural Gas Market Flexibility). Thesis defended at Paris-Dauphine University.
4- Arthur Thomas (2020), “***La demande de gaz naturel dans la transition énergétique***” (The Demand for Natural Gas in the Energy Transition). Thesis defended at Nantes University.
5- Côme Billard (2020), “***Connections Vertes : Appliquer l'Economie des Réseaux à la Transition Energétique*** ” (Green Connections: Applying Network Economics to the Energy Transition). Thesis defended at Paris-Dauphine University.

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[1] *A. Thomas, O. Massol, B. Sévi (2021).* ***How are day-ahead prices informative for predicting the next day’s consumption of natural gas? Evidence from France****. The Energy Journal, (Accepted & Forthcoming).*
>> *DOI: 10.2139/ssrn.3388794*

[2] *A. Baba, A. Creti, O. Massol (2020).* ***What can be learned from the free destination option in the LNG imbroglio?*** *Energy Economics, Vol. 89: 104764.*
>> *DOI: 10.1016/j.eneco.2020.104764*

[3] *F. Perrotton, O. Massol (2020).* ***Rate-of-return regulation to unlock natural gas pipeline deployment: Insights from a Mozambican project****. Energy Economics, 85, 104537.*
>> *DOI: 10.1016/j.eneco.2019.104537*

[4] *O. Massol, A. Banal-Estañol (2018).* ***Market Power and Spatial Arbitrage between Interconnected Gas Hubs****. The Energy Journal, Vol. 39 (SI2), 67-95.*
>> *DOI: 10.5547/01956574.39.SI2.omas*


**Scientific contact: Olivier Massol**


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The “Economics of Natural Gas” Chair: results and outlook

**Electrification of the vehicle powertrain is one of the keys to sustainable mobility and hybridization with internal combustion engines is becoming increasingly common. In this context, the “48-volt” mild hybrid system is a low-cost, flexible and easy-to-integrate option, with reduced safety constraints and outstanding performances.**

However, **48-volts systems** tend to target relatively low power levels, **providing only assisting torque for propulsion and limited braking energy recovery**. These limitations are the result of the low voltage used for both the source (battery) and the load (electric motor).

**An innovative approach was conducted by a team** of lecturers-researchers and students **from the Powertrain Engineering program at IFP School**, as part of a final year project: **an optimization approach combining an enhanced powertrain structure and a dynamic energy management strategy**. This combination **allows to overcome the initial limitations** and operate with higher electric powers, thereby enabling all-electric propulsion in urban environment for a light hybrid vehicle [1].

**Supplying high levels of power at low voltage** imposes severe constraints on the battery and the electric motor: thermal stress and premature ageing, high currents and considerable losses. The in-depth analysis of these constraints allowed to separate their dynamics and to distribute them to the various components of the onboard energy system.

**Regarding the source**, it was decided to combine a power source (supercapacitor) to meet the requirements of high dynamics and an energy source (48-V battery) to meet the requirements of low dynamics. As for the load, it is provided by two judiciously scaled and positioned electric motors (figure 1).

**This configuration has been completed by the implementation of a dynamic energy management strategy during the driving cycle** (figure 2). Depending on the required performances, the consumption reduction objectives and the battery state of charge, the functional architecture of the powertrain self-adapts in real time. The energy management strategy can thus use the all-electric mode (MG1+MG2), the series hybrid mode (MG2), the parallel hybrid mode (ICE+MG2) or the conventional IC mode (ICE).

*Click on the picture to enlarge*

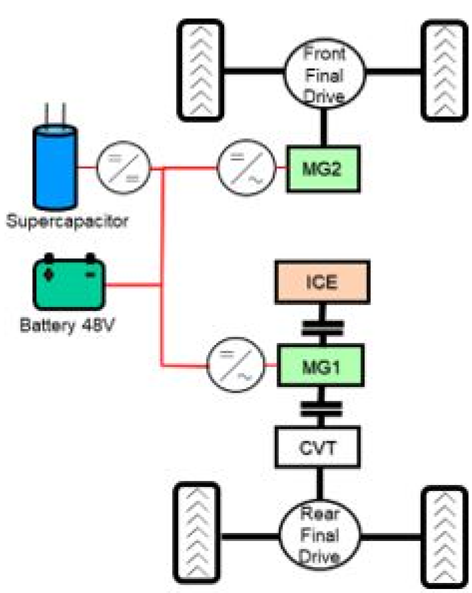

Figure 1: Proposed mild-hybrid architecture
MG: Motor/Generator
ICE: Internal Combustion Engine
CVT: Continuously variable transmission
CL: Clutch

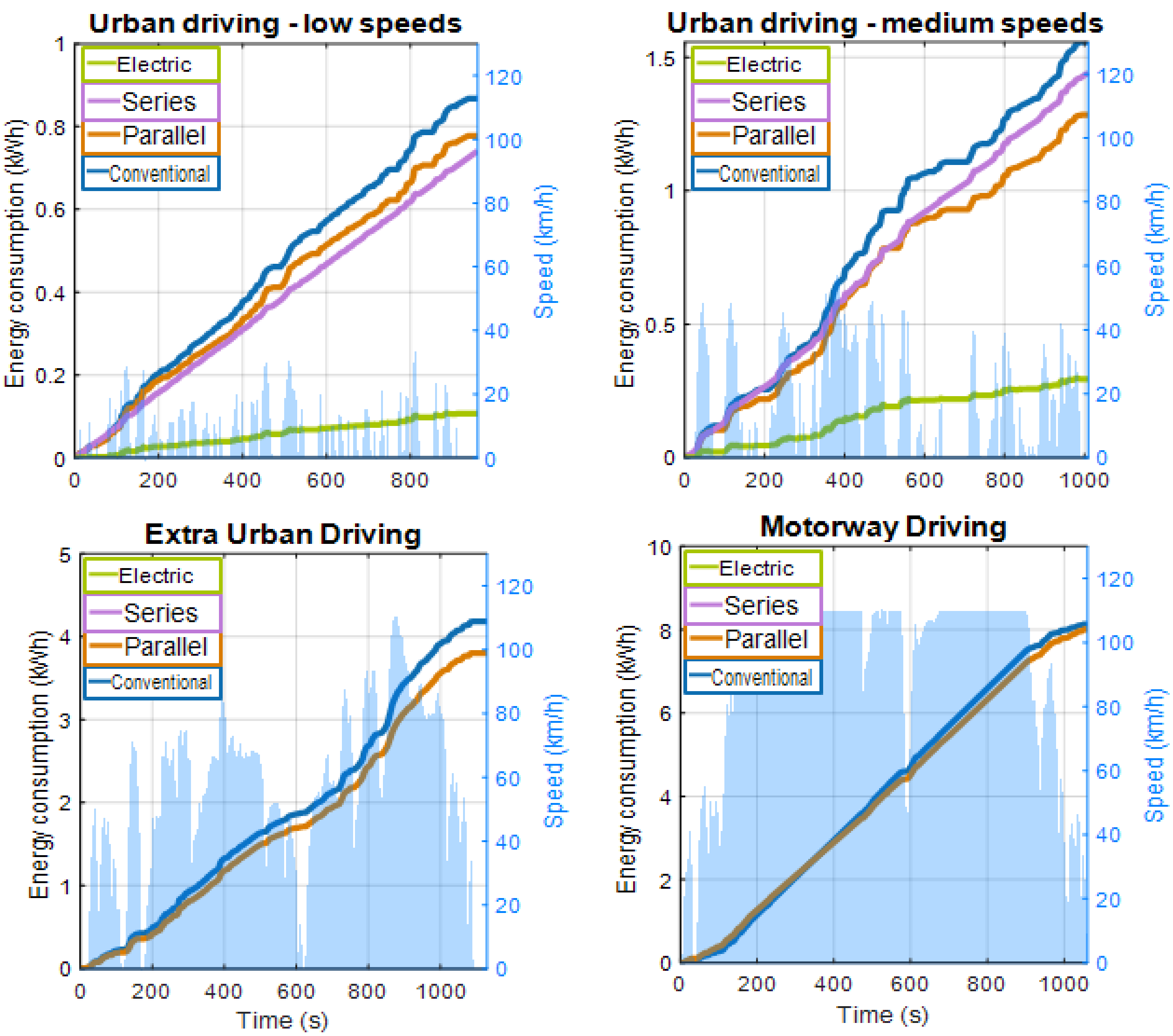


Figure 2: Energy consumed as a function of the mode activated

The proposed propulsion architecture and energy management strategy offer **very high operating flexibility with the potential to reduce fuel consumption and pollutant emissions at low cost,** with **simplified integration**.

Based on these results, **a new project is under way** to investigate **the possibility of using the 48-volts system for very high power levels, suitable for all-electric urban vehicles**.

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[1] *O. El Ganaoui-Mourlan, E. Miliani, D. Carlos Da Silva, M. Couillandeau et al.,* ***Design of a Flexible Hybrid Powertrain Using a 48 V-Battery and a Supercapacitor for Ultra-Light Urban Vehicles****, SAE Technical Paper 2020-01-0445, 2020*
>> *DOI: 10.4271/2020-01-0445*

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## IFPEN is banking on hydrogen mobility

Press release

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The 48-volts system: mild hybrid with significant potential

**The period 2012-2020, during which IFP School hosted the teaching and research Chair dedicated to this theme**[1] **was also a period of fundamental change in terms of economic analysis of the environment and energy, with an increased interest in issues related to sustainable development.**

**The questions addressed in the framework of the Chair concerned the interactions between**, on the one hand, **energy and environmental changes related to the ecological transition and**, on the other hand, **economic growth and energy markets.**

**The results of the Chair's activities highlighted the impact of market mechanisms on the energy mix**[2]. The use of Markov regime-switching models has made it possible to highlight the effect of the development of intermittent renewable electricity production on electricity prices[1].

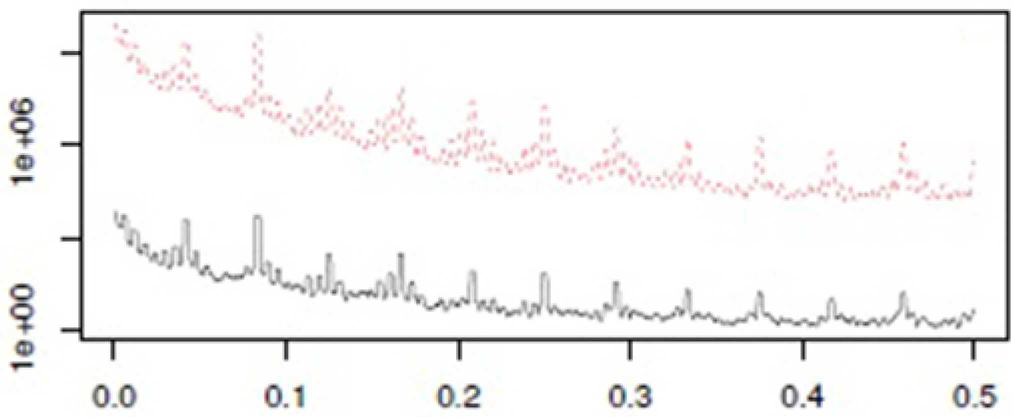
Thus, **a low price regime is identified when the share of renewables in the electricity mix is high and a high price regime when the opposite is true**. Consequently, increasing the proportion of wind and solar energies in the overall electricity production increases the probability of moving from a high price regime to a low price regime.

**The figure below** illustrates this phenomenon in two distinct ways using the German example, with:

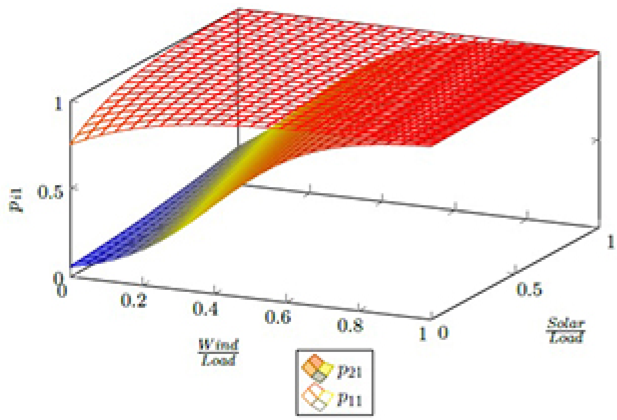
- on the left, the market price of electricity being in line with the distribution of the residual load curve (non-renewable generation compensating for the intermittence of renewables);
- on the right, the probability of switching to a low price regime (vertical axis) which depends on the share of renewable energies in the electricity mix.

**The Chair's activities** have been **carried out through seven PhD theses** and **have resulted in multiple articles in peer-reviewed journals**: for example, on **the decarbonization of the electricity mix in oil-exporting countries**[2] and on **economic growth** and **the development of renewable energy**[3].

These activities have also been reflected in the teaching programs offered at **IFP School** and have led to the organization of annual conferences to which foreign professors have been invited.




Periodogram of prices (in black, €/MWh)
and the residual load curve (in red, MWh) in Germany (2014-2015)




Probability of transition to a low-price regime
as a function of the share of renewable energies in the electricity mix

1- Chair financed by the **Tuck foundation**
2- For example those obtained by C. De Lagarde (2018) "***Promoting renewable energy : subssidies, diffusion, network price and market impacts***". Thesis defended at Paris Dauphine-PSL University.
3- Markov regime switching models are employed to describe business cycles, while allowing to identify shocks (crises, disruptions). Markov processes are those relating to random systems, whose future evolution depends on the past only on the basis of current information.

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[1] *C. de Lagarde , F. Lantz, 2018,* ***How renewable production depresses electricity prices: evidence from the German market****, Energy Policy, Vol 117, pp. 263-277*
>> *DOI: 10.1016/j.enpol.2018.02.048*

[2] *A. Farnoosh, F. Lantz, J. Percebois (2014),* ***Electricity generation analyses in an oil-exporting country: Transition to non-fossil fuel based power units in Saudi Arabia****. Energy 05/2014; 69.*
>> *DOI: 10.1016/j.energy.2014.03.017*

[3] *V. Court, P-A. Jouvet, F. Lantz, (2018),* ***Long-term endogenous economic growth and energy transitions****, The Energy Journal, Vol. 39, 1,*
>> *DOI: 10.5547/01956574.39.1.vcou*


**Scientific contact: Frédéric Lantz**

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Economic modeling applied to the environment and energies

**Seismic imaging remains an important tool in the characterization of geological reservoirs. In the case of carbonate reservoirs, the biological origin of the sediments, as well as their transformation over time through diagenesis[1], results in numerous structural heterogeneities.**

**The geological interpretation of seismic reflectors** observed in these reservoirs **can be extremely difficult due to the very small number of direct observations**, generally limited to the exploration wells. **Lateral variations in facies[2] can thus lead to misinterpretation and result**, for example, in the erroneous interpretation of fluid-rich zones.

**One way to establish the link between geological facies and seismic signature is to study**, at outcrop, **rocks similar to deep carbonate reservoirs**[1]. **IFPEN is currently involved in a research project to study a lacustrine carbonate formation** belonging to the Eocene Green River formation, **in southwestern Wyoming** (USA). An outcrop is being characterized at the metric scale, from a sedimentological and diagenetic point of view, **in order to convert the various carbonate facies into seismic images (figure A), by measuring acoustic P-wave velocities[3]** (figure B).

**A classical seismic modeling** was performed, **translating these velocities into seismic reflectors**. This modeling is first carried out in the time domain and then converted into depth equivalent, using a velocity law derived from outcrop measurements. The difference between the time image (figure C) and the depth image (figure D) is representative of what can be observed on a large scale, in reservoir seismic. **This time-to-depth conversion is of major importance**, especially for very heterogeneous environments of this type in terms of wave propagation velocities.

**Seismic reflectors are traditionally used** in basin and reservoir modeling as surfaces corresponding to a same geological age (deposition or erosion). **The study confirms**, on a small scale, **that this interpretation can prove to be erroneous**, as a seismic reflector may correspond to a change of facies within the same geological deposit. Without detailed sedimentological knowledge of the imaged carbonate rocks, it is therefore possible to misinterpret these geophysical objects.

**The study also demonstrates the importance of analog studies in the field**, as the only way to obtain all the information necessary to relate geophysical data to sedimentological reality.

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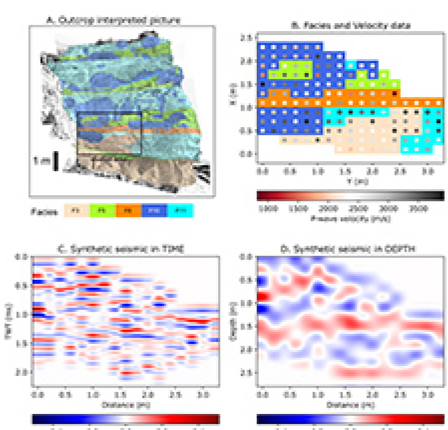

A: Interpreted outcrop in carbonate facies.
B: Discretization of the facies and outcrop speed measurements.

C: Synthetic seismic in time.
D: Synthetic seismic in depth.

1- Set of physicochemical and biochemical processes involved in the transformation of sediments into sedimentary rocks
2- The attributes of a sedimentary rock: set of lithological (mineralogy, geometry, sedimentary structure, etc.) or paleontological (fossil content) characteristics.
3- Elastic compression wave, the fastest propagating seismic wave in the rock.

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[1] *C. Bailly, J. Fortin, M. Adelinet, Y. Hamon. (2019).* ***Upscaling of Elastic Properties in Carbonates: A Modeling Approach Based on a Multiscale Geophysical Data Set****; Journal of Geophysical Research: Solid Earth, 124(12), 13021-13038.*
>> *DOI: 10.1029/2019JB018391*

**Scientific contact: Mathilde Adelinet**

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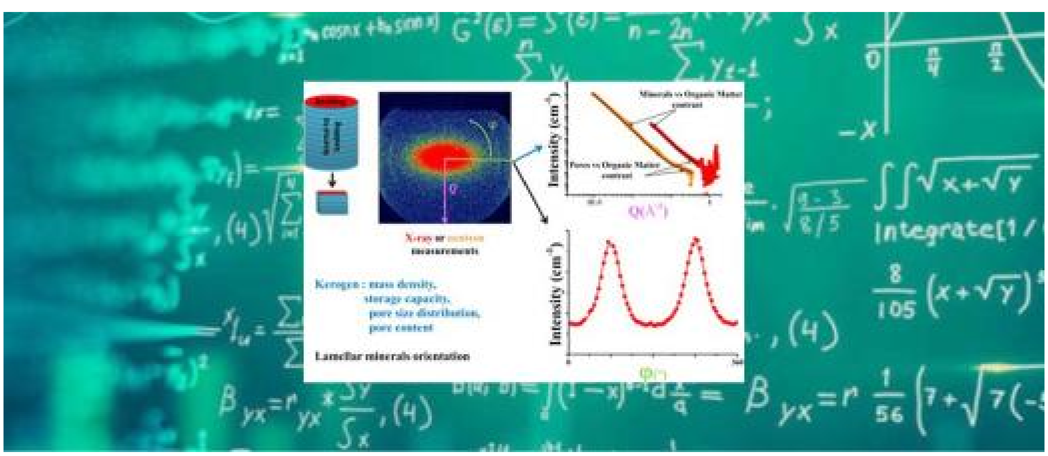
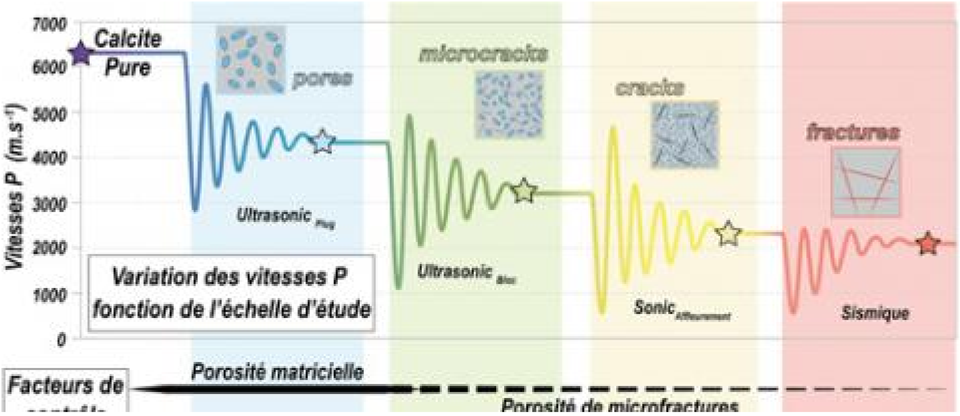


Fundamental Research

News December 2020

## New methods for characterizing source rock porosity

Geosciences | Geology - Sedimentology | Analysis and characterization




## Characterization and modeling of the facies(a)-eogenesis(b) couple, initial state of carbonate reservoirs (HDR 2017)

Carbonate reservoirs present significant heterogeneities (in terms of types and scales) associated with the biological origin of sediments[c], as well as t

Geosciences | Geology - Sedimentology | Geostatistics - Geological modeling

Petrophysics and transfers in porous media

From outcrop to reservoir: thanks to seismic waves!

**Unlike hydrocarbons of fossil origin, the molecules derived from biomass are polar, due to the heteroatoms they contain. This difference on a molecular scale induces a more complex macroscopic behavior that must be taken into account when designing the processes where such mixtures are encountered.**

**Moreover, while a significant variety of molecules is encountered in oil fluids, their diversity is still considerably larger in biomass. This makes it impossible to calibrate traditional thermodynamic models by conducting measurements on each molecule or each combination. It is therefore essential to have predictive tools**, based on theoretical considerations, **to calculate the properties of these mixtures from the molecular structures.**

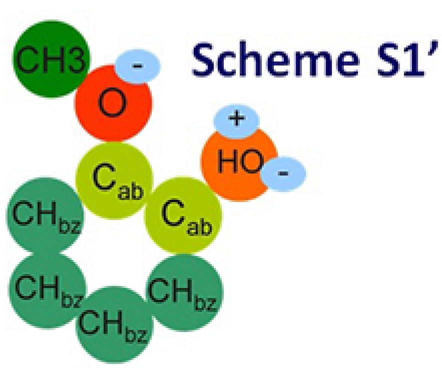
**The objective of the “Thermodynamics for biofuels”** teaching and research Chair **was to construct such a predictive method**.

To do so, researchers drew on academic research initiated in the 1990s, proposing methods based on statistical mechanics to construct thermodynamic models (SAFT equations of state).

**A non-exhaustive list of research projects conducted within the framework of the Chair**, particularly through PhD theses, illustrates the advances obtained:

- a method based on group contributions was used to calculate phase equilibria for mixtures of molecules identified in biomass[1]. The result is the GC-PPC-SAFT model, the name of which reflects its content[2,3];
- to compensate for the limits of the model for molecules with several oxygenated functionalities, a methodology was developed to extend group contributions, taking into account the distance between groups[4];
- for some biomass molecules with highly complex forms, such as guaiacol, the molecular description had to be adapted to the solvent containing the molecule (as illustrated in the diagram below)[5];
- the model developed was also compared to solvation measurements (interaction of a solute with a solvent) during joint research conducted with a team from Kazan University[6];
- GC-PPC-SAFT was also employed in the context of the esterification processes used to convert vegetable oils into fuel[7];
- finally, in order to dimension the hydrotreatment process for fluids derived from biomass, thereby making them compatible with oil fuels, the solubility of hydrogen in these fluids was studied[8].

*Click on the picture to enlarge*



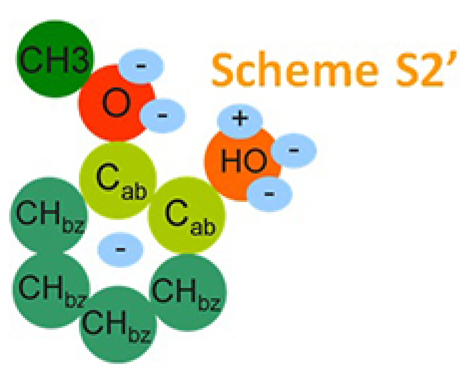



Illustration of the group-contribution principle for the guaiacol molecule: each bubble represents a group, with some able to carry a bonding site (positive or negative) enabling the molecule to create hydrogen bonds with its neighbors. Several distribution schemes for these sites were studied.

**Thanks to the work carried out within this research Chair, IFPEN has an "equation of state"-type tool available for better understanding and describing mixtures derived from biomass, with their oxygenated compounds. It is now widely used in applied research projects.**

1- **Tuck Foundation** chair, 2009 to 2018
2- Statistical Associating Fluid Theory
3- Consisting in dividing molecules into fragments, less numerous than the molecules (example illustrated), with each considered to partly contribute to the desired property
4- GC for group contributions and P for the polar term, all based on the Perturbed Chain SAFT variant

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[1] *D. Nguyen-Huynh, J.-C. de Hemptinne, R. Lugo, J.-P. Passarello, P. Tobaly,* ***Simultaneous liquid–liquid and vapour–liquid equilibria predictions of selected oxygenated aromatic molecules in mixtures with alkanes, alcohols, water, using the polar GC-PC-SAFT*** *(Prédictions simultanées d'équilibres liquide-liquide et vapeur-liquide de certaines molécules aromatiques oxygénées dans des mélanges avec des alcanes, des alcools et de l'eau, à l'aide du GC-PC-SAFT polaire), 92 (2014) 2912–2935.*
\>> *https://www.sciencedirect.com/science/article/pii/S0263876214002470*

[2] *T.-B. Nguyen, J.-C. de Hemptinne, B. Creton, G.-M. Kontogeorgis,* ***Characterization Scheme for Property Prediction of Fluid Fractions Originating from Biomass*** *(Schéma de caractérisation pour la prédiction des propriétés des fractions fluides issues de la biomasse), ENERG FUEL 29 (2015) 7230–7241.*
\>> *http://dx.doi.org/10.1021/acs.energyfuels.5b00782*

[3] *T.-B. Nguyen, J.-C. de Hemptinne, B. Creton, G.-M. Kontogeorgis,* ***Improving GC-PPC-SAFT equation of state for LLE of hydrocarbons and oxygenated compounds with water*** *(Amélioration de l'équation d'état GC-PPC-SAFT pour la LLE des hydrocarbures et des composés oxygénés avec de l'eau), Fluid Phase Equilib. 372 (2014) 113–125.*
\>> *http://www.sciencedirect.com/science/article/pii/S0378381214002064*

[4] *M. Jaber, W. Babe, E. Sauer, J. Gross, R. Lugo, J.-C. de Hemptinne,* ***An improved group contribution method for PC-SAFT applied to branched alkanes: Data analysis and parameterization*** *(Une méthode de contribution de groupe améliorée pour PC-SAFT appliquée aux alcanes ramifiés: analyse et paramétrage des données), Fluid Phase Equilib. 473 (2018) 183–191.*
\>> *https://www.sciencedirect.com/science/article/pii/S0378381218302504*

[5] *L. Grandjean, J.-C. de Hemptinne, R. Lugo,* ***Application of GC-PPC-SAFT EoS to ammonia and its mixtures*** *(Application de GC-PPC-SAFT EoS à l'ammoniac et ses mélanges), Fluid Phase Equilib. 367 (2014) 159–172.*
\>> *http://dx.doi.org/10.1016/j.fluid.2014.01.025*

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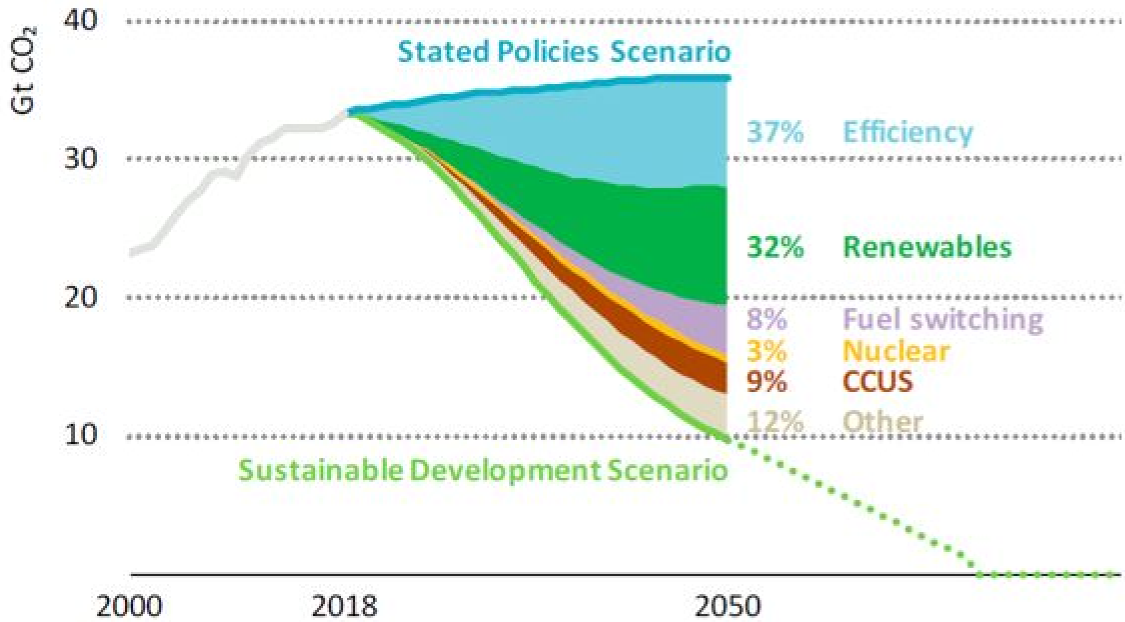
**In its “sustainable development” scenario, the International Energy Agency (IEA) considers energy efficiency to be the primary lever for reducing $CO_2$ emissions** (see diagram). The Intergovernmental Panel on Climate Change (IPCC) also considers energy efficiency as a key element of the ecological transition. This is also the case for all governments that have signed up to the Paris Agreement. **But this strategy could prove to be flawed in that it disregards a phenomenon that has long been at work to counteract the benefits of energy efficiency: the “rebound effect”.**




CO2 emission reduction factors linked to energy
to achieve the IEA’s “sustainable development” scenario [1]

**This results from the set of economic and behavioral mechanisms that cancel out all or part of the energy savings generated by efficiency gains**. The extents of the rebound effects are difficult to quantify, but a trend is emerging within the existing body of knowledge of this phenomenon.

**A recent study, to which IFPEN contributed**[2], unequivocally demonstrated **mounting evidence of a very significant rebound effect**: more than half of the energy savings resulting from improved energy efficiency do not appear to materialize in reality**. A key question is whether these rebound effects are properly taken into account in energy and climate models**.

**In the same study, four or the “integrated assessment models” used by the IPCC were examined, along with models used by BP, Shell, the IEA and the US Energy Information Administration** (EIA). It was found that **the majority of these models are unable to incorporate many of the mechanisms contributing to the rebound effect**. This analysis therefore suggests that **the models in question overestimate the energy savings that can actually be achieved**. In other words, **global energy demand appears to be significantly underestimated in the scenarios guiding political decision-making**.

Since it appears that around 50% of energy savings are eroded by the rebound effect, **there is an urgent need for the modeling community to take this phenomenon more seriously** and incorporate it better into their equations. If they do not, the credibility of global climate scenarios may have to be taken with some caution, especially those that rely on a significant decoupling between economic activity and energy consumption.

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*[1] International Energy Agency, World Energy Outlook 2019, Paris, p. 79.*

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*V. Court. The Conversation - 06/04/2021 :*
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