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*In a world subject to the uncertainties of climate change and forced to rethink its energy mix in the context of a controlled energy transition, the decisions of both private players (households, businesses) and public policy-makers must be assessed in order to optimize their industrial, economic (growth, jobs, etc.) and environmental consequences.*

*To meet these challenges, the Economics and Technology Intelligence Division of IFP Energies nouvelles is developing an analysis of scientific, technical and economic information, combined with territorial and time-related dimensions, along with the behavioral dynamics of users. This methodology enables it to produce prospective scenarios incorporating technological and environmental regulation-related changes and to perform market research, technical and economic assessments of industrial sectors and environmental impact studies. To do this, the Economics and Technology Intelligence Division draws on expertise in the field of prospective analysis, energy sector modeling, technical and economic assessment of industrial sectors and life cycle assessment.*

*The articles in this issue therefore illustrate a few of these approaches and demonstrate the potential they offer.*
*I hope you enjoy reading this issue.*

*François Kalaydjian,*
*Director of the Economics and Technology Intelligence Division*

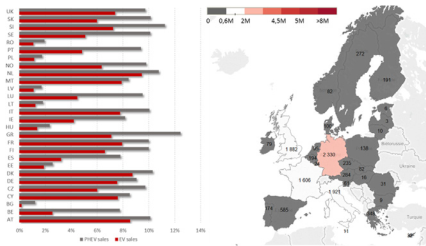
# SCelecTRA: prize for best 2030 scenario for electric mobility

Selected as part of the European ERANET-Electromobility+ program[a] and coordinated by IFPEN, the SCelecTRA[(1)] project was aimed at assessing the potential and conditions for the development of electric mobility in Europe up to 2030. What is particularly original about this project is its cross-disciplinary approach, *via* the development of a road transport demand simulation model (based on economic hypotheses), methodological developments in Life Cycle Assessment (LCA) and a TIMES model[b] for economic optimization, simulating all the European energy sectors and their interactions.

The project evaluated more than sixty different prospective scenarios, leading to electrified (electric and plug-in hybrid) vehicle market shares of between 15 and 30% by 2030. These vehicles represent the most favorable alternative to conventional vehicles in terms of the impact on the reduction of fossil fuel consumption and greenhouse gas emissions. However, the impact of this technological solution varies between European countries depending on the carbon intensity of their respective energy mixes. In addition, the LCA results highlight the importance of the battery production phase in their environmental performance.

In all cases, the emergence of an electrified vehicle market cannot be achieved without the large-scale development of a network of recharging terminals[c]. In addition, the project demonstrates that scrappage schemes and electric vehicle purchase incentive programs appear to be more effective than additional taxes on traditional fuels[(2)] to promote this technology.

Ongoing improvements on the TIMES model make it possible to determine whether the additional electricity demand could be covered by lower consumption in other sectors or will require new capacities.



*Market shares and vehicle stock in the EU in 2030.*

a - European research program (FP7); Grant N 12-MT-PREDITG01-2-CVS-2.
b - TIMES (The Integrated MARKAL-EFOM System) models are bottom-up models for dynamic optimization under the effect of constraints concerning the modeling of medium-term energy scenarios (2030-2050). For more information: https://iea-etsap.org/
c - Between 100 and 200 terminals per 1,000 vehicles in 2030.

(1) *Scenarios for the electrification of transports in Europe – SCelecTRA Final Report, Report, EU, SCelecTRA (FP7 ERA-NET project), June 2015.*

(2) *P. Gastineau,* ***B. Chèze,*** *Fuel price and income elasticities of the road transport demand in Europe: A dynamic panel data analysis, Transportation Research Part A: Policy and Practice,* in revision.

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# Biofuels: contagion factors between agricultural and oil markets?

In order to combat climate change, numerous countries introduced policies promoting the use of 1st-generation biofuels, generating a 7-fold increase in their production between 2000 and 2014. In parallel, rising agricultural commodity prices since 2005 have nourished the food versus fuel debate concerning the use of food resources to produce energy.

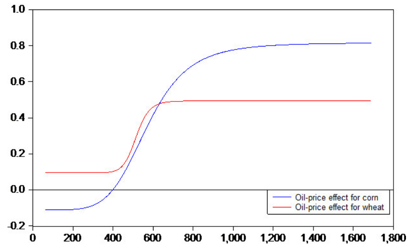
A number of factors have contributed to these price increases, including the strong economic growth of emerging countries, leading to a change in their eating habits, or unfavorable climate conditions in producing countries. However, rising oil product prices may also have played a role via an increase in agricultural production costs and an increased demand for biofuels due to their improved price ratio with respect to fossil fuels.

A study of the relationships between agricultural and oil markets reveals that their prices are even more closely correlated if the amount of biofuels produced is high. This correlation has been significantly reinforced in the case of American corn (daily biofuel production using this resource has oscillated between 1,400 and 1,800 thousand barrels since 2014) and this effect is not limited to agricultural products used in energy production but is also spreading to food substitutes, such as wheat[1].

These price increases do not always benefit agricultural raw material exporting countries due, for example, to the increased cost of their energy imports, following the rise in oil prices. In fact, their current account is not affected by agricultural commodity price variations when the oil price is more than $45 per barrel.

In addition, the main economies importing agricultural goods have been able to keep the value of their food imports constant by reducing import taxes on these goods. Agricultural commodity price increases have therefore not had any impact on the economic growth of these countries *via* their current account[2].

The price of oil has been a key factor in agricultural prices, following the development of 1st generation biofuels, but one of the ambitions of the 2nd generation, produced using agricultural and forest residues, will be to overcome this contagion effect.




*Correlation between US prices for agricultural commodities and oil as a function of daily biofuel production in the USA.*


(1) **A. Paris,** *On the link between oil and agricultural commodity prices: do biofuels matter?, submitted to Energy Studies Review, 2016.*

(2) *G. Gomes,* ***E. Hache,*** *V. Mignon,* ***A. Paris,*** *On the current account–biofuels link in emerging and developing countries: do oil price fluctuations matter?, submitted to Resource and Energy Economics, 2017.*



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# Biomethane production: a lever for the circular economy!

The development of methanisation sectors is part of a drive to create a circular economy that simultaneously serves three purposes: treat waste, supply energy (biogas[a]) and produce fertilizers (digestates). Biogas can then be purified to form biomethane, which is then injected into the mains gas network. As a supplement to natural gas imports, this regional production of biomethane is a potential lever for the energy transition.

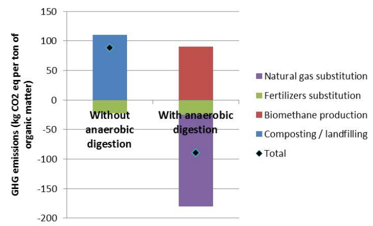
As part of a project aimed at recycling livestock farming waste and biowaste produced in the same area, IFPEN has carried out Life Cycle Assessments (LCA) to simultaneously compare the environmental impacts of "waste treatment" and "energy supply" services, in the presence or absence of a methanisation sector[1]:

- without the sector: storage and spreading of livestock manure, landfilling and/or composting of biowaste, energy supply by natural gas combustion;
- with the sector: anaerobic digestion of biowaste and livestock manure, combustion of the biomethane produced and recycling of digestates.

This study underlines the fact that methanisation enables – for the same amount of energy produced – a significant reduction in greenhouse gas (GHG) emissions, thanks to the combination of services provided: approximately 180 kg of $CO_2$ equivalent[b] less per ton of waste, half of which is due to their treatment and the other half to the energy supply.

Furthermore, the $CO_2$ produced by biogas purification can be recycled using a methanation process[c]. Analysis of coupling of the two processes highlights the impact on the overall performance of the electricity mix composition used to produce the hydrogen required, *via* water electrolysis[2].

This territorial methanisation approach could be compared with the anaerobic digestion of dedicated crops (like in Germany), with the latter not providing any "waste treatment" service.




*GHG emissions in "without" and "with" methanisation scenarios for the treatment of one ton of organic matter.*

a - Biogas is composed of methane ($CH_4$), $CO_2$ and impurities.
b - Since all GHG emissions share $CO_2$ as a common unit, the term $CO_2$ equivalent is used for all of them.
c - Power to Methane: industrial methane production process *via* catalytic conversion of dihydrogen ($H_2$) and carbon monoxide (CO) or carbon dioxide ($CO_2$).


(1) **A. Bouter,** *SETAC Europe 25th Annual Meeting 2015.*

(2) ***P. Collet,*** *E. Flottes,* ***A. Favre, L. Raynal,*** *H. Pierre, S. Capela, C. Peregrina. Applied Energy, 2016, 192, 282-295. DOI: 10.1016/j.apenergy.2016.08.181*



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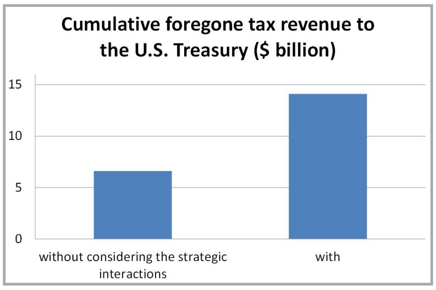
# Welcome to the club! Understanding and overcoming the obstacles to the adoption of CCS technologies

The widespread adoption of $CO_2$ capture and storage (CCS), a key factor in combating climate change, requires the joint adoption of these technologies by independent players: emitters, transporters, storers, policy-makers. In a liberalized economy, it is necessary to create the conditions for a coordinated approach between these individual decision-makers. Game theory, designed precisely to study these strategic interactions between independent players, has guided various studies conducted recently at IFP School.

The first of these studies demonstrated that coordinating the decisions of emitters and a $CO_2$ pipeline operator is similar to the creation of a club of emitters sharing a common infrastructure[(1)]. Due to the heterogeneity of players, the value of the tax on $CO_2$ emissions, required for the existence of the club, must be greater than the average cost of capture, transport and storage. In addition, obliging a transporter to use a non-discriminatory tariff structure can raise this minimum price or even jeopardize the feasibility of a CCS project. These results therefore call into question the tariff regulation applied to $CO_2$ pipelines.

The second of these studies focused on "carrot and stick"[a] type of incentive policies that could be proposed to encourage the adoption of this technology[(2)]. In this case, the "carrot" takes the form of fiscal incentives[b] to reward emitters installing CCS systems without waiting until the last moment; with their decision helping to bring down the cost of CCS *via* learning effects. In an American case it was demonstrated that it was essential to take into account the strategic interactions among the emitters because otherwise the cost of the fiscal incentives required is significantly under-estimated.

These innovative approaches help provide a clearer understanding of the CCS economy with a view to adapting the public policies that will accompany its development.




*Comparison of the cost of the fiscal incentives required for adoption of CCS in the USA.*

(1) ***O. Massol, S. Tchung-Ming,*** *A. Banal-Estañol, (2015), European Journal of Operational Research, 247(1), 259-275, ISSN 0377-2217.*

(2) *A. Banal-Estañol, J. Eckhause,* ***O. Massol,*** *(2016). Energy Policy, 90, 246-252, ISSN 0301-4215.*

a - For example: the requirement placed on thermal power stations to achieve, by an announced future point in time, a restrictive threshold of emissions per kWh, requiring the adoption of capture.
b - For example: investment and operational subsidies.

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# Consequential LCA and impacts assessment of legislation on the energy transition

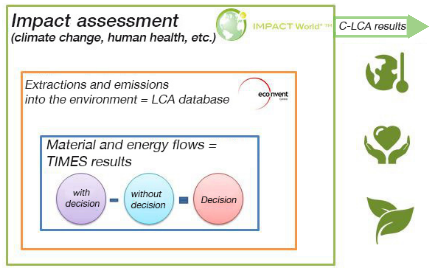
Life Cycle Assessment (LCA) is an environmental impact assessment tool that is generally static, linear and limited to the description of physical flows when the aim is to assess the impacts associated with a sector or a product. The question of the relevance of the method for quantifying the environmental consequences of public policies over a given time horizon was raised when the French law concerning the energy transition for green growth (the "LTECV" law), which is liable to modify the country's energy mix, was passed. A method was therefore developed to anticipate the potential impacts of one of the objectives set: the introduction of 15% renewable energies into the transport sector by 2030.

This approach, known as consequential LCA, uses the MIRET French energy sector prospective modeling tool (IFPEN's TIMES[a] model), coupled with an LCA approach[(1)].

The TIMES-MIRET economic optimization model reveals energy flow modifications resulting from exogenous mobility demand trajectories driven by objectives such as those of the LTECV.

The differential between material and energy flows with and without the LTECV objective is then translated, via the EcoInvent LCA database, into a differential between extractions and/or resource waste and/or pollutant emissions into the environment. The impacts associated with these extractions and emissions are then assessed using the Impact World + method in terms of consequences on human health, climate change or ecosystem quality.

A spatial approach is currently taken into consideration to more effectively model the environmental impacts on a local scale (e.g. impacts on water, soil, etc.). This issue is continuing *via* a PhD thesis jointly supervised with INRA and CIRAIG[(2)]. The research aims primarily to determine how the geographic variability of these impacts is influenced by that of data derived from TIMES-MIRET and LCA models. Geographic price disparities of biomass resources are particularly tested here.




*Incorporation of the TIMES model results into the LCA approach.*

a - See article on SCelecTRA project.
b - Examples: mobilization of resources, activities of refining and biofuels sectors, new electricity or gas requirements, along with the evolution in car stock and other means of transport.

(1) ***F. Menten, S. Tchung-Ming, D. Lorne , F. Bouvart.*** *Renewable and Sustainable Energy Reviews, 2015, 43, 942–960. DOI: 10.1016/j.rser.2014.11.072*

(2) ***L. Patouillard.*** *PhD thesis (2013-2017): Regionalization in consequential LCA: case of alternative sectors for transport in France in 2030.*

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# Renovation of housing: how to support the energy transition of French households?

The national energy transition will largely depend on changes in household energy consumption. In 2015, the residential sector alone was responsible for 30% of final energy consumption and 25% of $CO_2$ emissions in France[a]. However, the magnitude of the energy spending is closely correlated with the type of housing (individual or collective), its energy performance, its heating system and its geographic location, as well as the conditions for getting bank loans to carry out energy-related renovation projects.

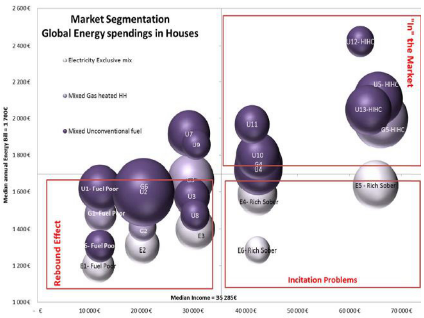
In this context, IFPEN looked at the energy consumption behavior of French households between 1999 and 2013, and studied the trade-off between the quality and cost of the energy services available in the residential sector and overall budget restrictions (share of the budget allocated to energy spending). Using a methodology borrowed from organizational sciences and strategic marketing[b], we built a typology of energy consuming households where targeted groups (fuel poor, high income and high consuming households) are clearly and separately identified through a simple and transparent set of characteristics[(1)].

According to this typology, energy poverty is a reflection of financial poverty, with the households concerned all belonging to the first two income deciles. Over and above this observation, the study also shows that households in apartments – frequently ignored in the energy efficiency market – are over-represented among energy-poor households, but also among high-income and high-energy-consuming households.

These results will make it possible to target policies to support energy renovation in the residential sector, either public (tax credits, eco-loan, etc.) or private (creation of financial tools) tailored to the different household groups identified[(2)].

a - Department of observation and statistics (SOeS), French Ministry for the Environment, Energy and the Sea, 2016.

b - G.V. Kass, 1980. Chi-Square Automatic Interaction Detection - CHAID. Journal of Applied Statistics.




*Breakdown of French households on the basis of income/energy bill.*


(1) ***E. Hache, D. Leboullenger,*** *V. Mignon, Energy Policy, 2017. DOI:10.1016/j.enpol.2017.04.038*

(2) ***E. Hache, D. Leboullenger,*** *La Revue de l'Énergie, 2016, 633, 391-398.*



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## News

- *On April 4th, IFPEN and the University of Lyon signed a collaboration agreement aimed at strengthening the links between higher education, research and industry.*

- *As part of the Higher Education and Research's "Instituts de Convergences" call for projects, launched by French Ministry for National Education, IFPEN has become one of the partners in the I2-DRIVE project concerning the creation of a cross-disciplinary Institute for data research.*

- *15 new IFPEN applications have been submitted in response to the Horizon 2020 European program's 2017 calls for proposals.*

- *With 184 patents filed, in 2016, IFPEN maintained its 13th place in the French National Industrial Property (INPI) rankings of patent filers in France.*

## Award

- ***Saifuddin Ahmed*** *was awarded the Helmut Knapp prize for his poster "On the condition of electroneutrality for multi-phase multi-component ionic systems using modified Albertsson model", at ESAT 2017 (European Symposium on Applied Thermodynamics), which was held in Bucharest in May. The Helmut Knapp prize rewards the best scientific poster presented by a PhD researcher.*

## Upcoming scientific event

- ***C2E-Colloids and Complex Fluids for Energies*** scientific conference, 4 to 6 December, Rueil-Malmaison – www.rs-colloids2017.com/

## Appointment

- *Le Groupe français des zéolithes (GFZ - French Zeolites Group) has reappointed* ***Nicolas Bats****, an IFPEN research engineer, as its Chairman.*

## Publications

- *OGST – IFP Energies nouvelles journal – Issue 1, volume 72-2017, dedicated to the DEFI scientific conference: Gathering Physico-Chemical and Flow Properties.*

*http://ogst.ifpenergiesnouvelles.fr*


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