FiME

Dauphine Polytechnique CREST EDF
Research Initiative

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Finance for Energy Markets Research Initiative

INSTITUT EUROPLACE DE FINANCE
CHAIRE Finance & Développement Durable
DAUPHINE UNIVERSITÉ PARIS
ÉCOLE POLYTECHNIQUE
CREST Centre de recherche en économie et statistique
EDF

Editorial

Clémence Alasseur
Director of the Finance for Energy Markets Research Initiative

Nizar Touzi
Vice-chairman of the Chair "Finance and Sustainable Development"

The energy sector has been facing huge challenges and changes for the last ten years. In particular, the ongoing energy transition has led to the large-scale development of renewable energy and is fundamentally changing the traditional model. The electric power system is evolving from a purely centralized system to one with numerous local components. In particular, the role of consumers is changing from passive to active consumption, whereby they can control their consumption, produce energy by installing their own production capacity and choose their energy supplier. At the same time, competition is growing with the emergence of new providers and of aggregators of renewable production. Equally the economic model of the traditional actors in the gas and electricity markets is experiencing problems aggravated by substantial price declines in the energy markets. To facilitate these changes, public policy is seeking solutions by combining various tools: specific markets such as the emission allowances or capacities market, subsidies for carbon-free energy, and so on. Finally, the regulation needing to be introduced with the regard to the known or unknown impacts of financial actors in the energy market remains an open question.

Since its inception the Finance for Energy Markets Research Initiative (FiME) has oriented its work so as to provide quantitative methods and thinking useful to decision makers. One original feature of our research initiative is the variety of the team, consisting of academics and research engineers in applied mathematics and economics, which allows us to offer new approaches and viewpoints, as is illustrated by the work presented in the following pages. This mix also brings closer together the academic and the industrial worlds for a better dissemination of research. After several years of existence, FiME's dynamism continues unabated, as is evident from the diversity of its work: academic publications of course, whose quality is widely recognized, but also training and the organizing of conferences and major events (such as the thematic semester "Commodity Derivatives Markets: Industrial Organization, Regulation and Financialization"). The energy of the research center is also reflected in the adaptation of the research questions addressed, which are currently focused on interactions among actors. Though complex, these questions, which are essential for framing answers to issues in the energy sector such as public policy and pricing, can now be addressed thanks to the advances in modeling and numerical calculation made in recent years, particularly within FiME.

An overview of FiME

The FiME laboratory was created jointly by EDF, Paris-Dauphine University, the Ecole Polytechnique and CREST as a place to discuss and exchange views between academic researchers and research engineers in EDF R&D on the economics and finance of energy markets, in particular with regard to the development of new quantitative methods associated with this field (modeling, econometrics, calculation).

The FiME laboratory is now a Research Initiative of the Europlace Institute of Finance Foundation, working on a scientific sponsorship scheme. This status reflects the general interest dimension and the need to publicize the work. Scientific publications, training of young researchers and the dissemination of knowledge are an integral part of the laboratory's mission.

The support given to the Research Initiative by the Scientific Council of the "Finance and Sustainable Development" Chair, chaired by Pierre-Louis Lions, also reflects its high standards in terms of the scientific work carried out.

More than a single place of exchange, the FiME laboratory is effectively a series of places that since 2007 have been organized around the regular seminar at the Institut Henri Poincaré, through scientific collaborations, supervision of doctoral theses, and conferences, as well as training programs for EDF engineers.

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Partners

Alain Burtin

Program director, Energy Management, EDF R&D

" We have reached our initial goals "

The Energy Management lab was created ten years ago to focus on applying knowledge and methods from financial mathematics to the challenges of electrical systems. Similar issues come up in both of these fields, including the challenge of portfolio management, so we expected the association to be effective. Still, financial tools had to be adapted to our particular field of activity. Rather than commission studies from external experts, EDF decided to form academic partnerships that would enable us to develop in-house expertise and ensure optimal knowledge transfer to our operational needs. This type of initiative is often tough to get off the ground, because it can take quite some time for people to integrate a different, complex professional culture. But in this case, the academics and business people who came into the FiME were successful at forming an effective team. We have now reached all of the goals that we set a decade ago in terms of both collaborative research projects and published studies. Furthermore, not only are the challenges that led to the lab's creation still perfectly relevant, but we have discovered additional interests worth focusing on, especially as a result of the most recent United Nations Conference on Climate Change (COP 21).

Marc Ringeisen

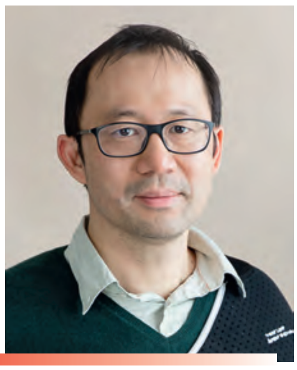
Head of the Osiris department at EDF R&D

" Gaining valuable time "

With 140 employees in seven different research groups, the Osiris department at EDF R&D (Optimization, SImulation, RIsk and Statistics) covers a vast area. Our work ranges from carrying out economic studies to devising asset portfolio management tools for power plants and commercial contracts. We also provide input on development and investment strategies for the EDF group. The scope is wide, and it is being redefined by the profound changes currently taking place in the electricity industry. We have recently been experiencing a difficult situation in our markets due to extremely low prices; this has highlighted the importance of improving our understanding of the effects of the changes so we can define potential adaptive measures effectively. Against this background, FiME helps us save valuable time. We benefit from the perspectives of highly specialized academics, who are also deeply informed and acquainted with our specific problems and issues.
What's more, contributions are not just theoretical. Some of the tools in use today that were developed by our department for EDF's operational divisions benefited from the laboratory's work. Similarly, FiME gives us access to techniques that are typically not employed at EDF, such as real options theory for investment, enabling us to form opinions quickly on their potential applications in the world of energy. Simply being in a position to test these new approaches is very rewarding."

Huyen Pham

Professor, University of Paris-Diderot, probability and random variables laboratory



" A stimulating framework "

I became officially affiliated with the FiME in 2014, after having worked with the lab for several years. This has involved supervising three PhD students and one post-doctoral student who is still working on models of investment and strategic interaction for electricity markets with a focus on sustainable development. I initially became interested in working with the FiME because it offered new sources of inspiration for my own work. My background is in financial mathematics, and the electricity field has led me to consider new types of challenges and constraints, such as problems linked to non-storage and the effects of the increasing impact of new technologies. This has given me the opportunity to test my modeling techniques, uncover their limitations, revise the models concerned, and try out others. This is all very stimulating! For academics like myself, working in a close partnership with a company directly concerned with the issues we study makes our research more real and directly relevant. In addition, the business people I work with in the lab have strong scientific backgrounds, so we are able to speak each other's language. It is easy to communicate and enriching for everyone.

Elyes Jouini

Vice-president of the University of Paris-Dauphine

“ Intense research activity ”

During its ten years of existence, the FiME has largely proven its value. The lab has fulfilled the role it was expected to, carrying out the projects it was created to do as well as intense research enriched by partnerships with the Ecole Polytechnique and, recently, with the Groupe des Écoles Nationales d'Économie et Statistique (GENES), which is attached to the French Ministry of Economics and Finance. At the University of Paris-Dauphine, we have developed a wide variety of synergies with EDF researchers. Over the years, the lab has attracted the interest and involvement of an increasingly broad range of people, so in addition to people from the university's math department, members of the departments of computer science, economics, management, and law have gradually gotten involved in lab projects. The subjects explored at FiME reflect this evolution. From an initial focus on primarily financial issues, it has come to address topics including big data, statistics, and intelligent networks. All FiME research combines theory and practice, and it relies on highly sophisticated research techniques. There is therefore plenty to ensure the ongoing interest of all those involved for many years to come!

Frank Pacard

Vice-president for academic affairs and research, Ecole Polytechnique

“ Enriching interactions between the academic and professional spheres ”

The energy field is experiencing an increasing need for mathematical modeling and optimization to deal with a variety of issues, including energy pricing, risk management, new regulations, production base management, and even new modes of electricity production. For the past ten years, the FiME laboratory has provided researchers from different institutions with a meeting place where they can share and compare different viewpoints, approaches, and methods for dealing with these challenges. It also provides them with a means to keep in direct touch with field professionals and practical applications. Interaction between academics and professionals is extremely enriching for both groups of people. EDF was a pioneer in this type of collaboration, and more and more people involved in the evolution of the energy sector are striving to take part in such dynamics. Indeed, we are increasingly receiving training requests from companies that would like to further build their skills and expertise. In late 2015, Ecole Polytechnique Executive Education (our professional learning unit) and FiME co-created a certification program called Finance and Management for Energy Markets. It covers a full range of factors involved in energy asset management: market and system operations, pricing models, asset valuation and optimization, geopolitics, and more. This collaborative initiative once again highlights the capacity of an organization like FiME to effectively contribute to real energy challenges.

Jean-Michel Lasry

Chairman of the steering committee of the Finance and Sustainable Development Chair, emeritus professor, University of Paris Dauphine

“ A multi-disciplinary international research network ”

Ten years is quite an accomplishment for a lab, and for a private chair! During the past decade, we have continuously strived to ensure the relevance of our research by relying heavily on our high quality, multi-disciplinary research network. The FiME has completed two five-year phases of activity, and we are very proud of what our teams have accomplished and of the satisfaction reported by our sponsors, particularly because people were initially quite surprised by the initiative. We have since demonstrated the value of using financial tools to deal with the financial and economic challenges of sustainable development. Similarly, we have pioneered the use of “Mean Field Games” modeling approach, an approach that is now used by dozens of teams worldwide, in particular for smart grid calculations. We in turn are benefiting from their findings. Indeed, one of the major strengths of the FiME is our connection to a vast international network, established with numerous academic institutions. In my opinion, this is a major advantage for EDF. The broader, more diverse, and more international the FiME research network, the greater its creative potential. Finally, the integration of the University of Paris Dauphine into Paris Sciences et Lettres (PSL*) has further opened the door to collaborative work that is bound to be significant in the short and medium term.

Researchers

Academia

Imen Ben Tahar

Imen Ben Tahar is associate professor of Applied Mathematics at Paris-Dauphine University. She has a PhD in Mathematics. Her work relates to stochastic control and mean field games with application in economics, energy markets.

Romuald Elie

Romuald Elie is professor of Applied Mathematics at Paris-Est Marne-la-Vallée University. He holds a PhD in Mathematics. His main research areas are concerned with financial mathematics, numerical probability, stochastic control, contract theory and mean field games.

Damien Fessler

Damien Fessler holds a doctorate in Economics, and carries out research in the history of economic ideas and economic epistemology. He is currently engaged in post-doctoral work within the "Finance and Sustainable Development" Chair and the "FiME Research Initiative", where he occupies the position of General Secretary.

Joseph-Frédéric Bonnans

A graduate of the École Centrale Paris and PhD in Engineering from the University of Technology of Compiègne, Joseph-Frédéric Bonnans is a senior researcher at the French National Institute for Research in Computer Science and Control (INRIA) and leader of the COMMANDS team, researching dynamic optimization, at the Centre for Applied Mathematics, École Polytechnique.

Ivar Ekeland

Ivar Ekeland has been a professor at (and president of) Paris-Dauphine University and at the University of British Columbia (Vancouver). His research focuses on mathematics, finance and economics. His latest book, *Le syndrome de la grenouille*, is concerned with climate change. He has received honorary doctorates from various universities and is a member of several academies.

Emmanuel Gobet

Emmanuel Gobet is a professor of Applied Mathematics at the École Polytechnique. He is an engineering graduate from the École Polytechnique and holds a PhD in Probability from Paris Diderot University. He joined FiME in 2011. His work relates to probabilistic algorithms, financial mathematics, stochastic control and backward stochastic differential equations, and supervised learning.

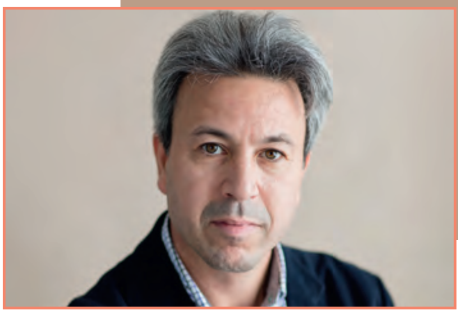
Marc Hoffmann

Marc Hoffmann received a PhD in Statistics from Paris-Diderot University in 1996 under the supervision of Dominique Picard. He is professor of Statistics at Paris-Dauphine University, and joined the FiME group in 2011. His research interests are statistical modeling of stochastic processes with a view towards nonparametric statistics, with applications in high-frequency finance and population modeling in biology. He is also coordinator of the Havas-Dauphine Chair “Economie et Gestion des Nouvelles Données”.

Jérôme Lelong

Jérôme Lelong is associate professor at ENSIMAG. He has an engineering degree from Ecole Nationale Supérieure de Techniques Avancées and holds a PhD in Applied Mathematics from Ecole des Ponts ParisTech. Aided by his expertise on stochastic optimization and high performance computing, his work focuses on numerical methods for financial mathematics.

Nizar Touzi



Nizar Touzi is professor of Applied Mathematics at the École Polytechnique and chairman of his department since 2014. He was invited to the International Congress of Mathematicians in 2010, awarded the Louis Bachelier prize of the Academy of Sciences in 2012, selected in the European Research Council European program in 2012 and obtained the Europlace award for best Young Researcher in Finance in 2007, the IEF best paper award in 2005 and the University of Toronto Dean's Distinguished Chair award in 2010.

Delphine Lautier

Delphine Lautier is a professor at Paris-Dauphine University, associate researcher at MINES ParisTech and a member of the Scientific Council of the Finance and Sustainable Development Chair. Her research focuses on the financialization of commodity markets. In the context of the Chair, Delphine Lautier has developed: i) equilibrium models on the relationship between physical and paper markets; and ii) a large-scale approach to systemic risk.

Huyên Pham

Huyên Pham is professor of Mathematics at Paris Diderot University. A graduate of the Ecole Normale Supérieure de Lyon, he holds a PhD in Applied Mathematics from Paris Dauphine University. He was laureate in 2007 for the Louis Bachelier prize awarded by the French Academy of Sciences, and is currently member of the scientific council of the Bachelier finance society. His research interests include stochastic control, numerical probabilities, and their applications to financial modeling and energy management.

Bertrand Villeneuve

Bertrand Villeneuve is a professor at Paris-Dauphine University. An engineer graduated from the École Centrale Paris, he also holds a PhD in Economics (EHESS, 1996). He is also scientific director of the “Fondation du Risque” and associate editor of the Journal of Risk and Insurance. His main interests include risk management, insurance and commodity markets.

Researchers

Engineers

The first duty of a research engineer is not to produce academic research, but operational solutions for industry. However, the FiME Research Centre offers research engineers a way to keep up with the state of the art in techniques for economic and numerical methods, while ensuring that academia are aware of the issues affecting the energy industry. In this way, they split their time between operational projects of the EDF group and research work assessed according to their publications and their relevance.

René Aïd

Holder of a PhD in Applied Mathematics and of an HdR in Economics, René Aïd is a research engineer, Deputy Head of OSIRIS (Optimization, SImulation, RIsk and Statistics for energy markets) at EDF R&D. After leading teams in economic calculation and risk management models at EDF R&D, he has specialized in price modeling and optimization of production. His research focuses on the analysis of long-term risk management, investment dynamics and the application of mathematics to corporate finance.

Corinne Chaton

Corinne Chaton holds a PhD in Economics from the University of Toulouse for her work on “Investment decisions in an uncertain environment with application to the electricity sector”. After working at the Research Department of Gaz de France, she joined the Economics Department of EDF R&D in November 2005, studying issues pertaining to electricity, gas and the environment. Since 2011, she has been an associate professor at François Rabelais University (Tours). She has also been an associate researcher at the CABREE (Centre for Applied Business Research in Energy and the Environment) at Alberta University.

Clémence Alasseur

Clémence Alasseur has been director of the Finance of Energy Markets laboratory since 2014. Previously, she directed R&D projects on energy market risk management for operational divisions. Her research interests include the modeling of prices and pricing for the electricity system. She holds a PhD in Physics from the University of Orsay (2005) and is a graduate of the Ecole SUPELEC.

Olivier Féron

Olivier Féron is an engineering graduate from the École Supérieure d’Électricité and holds a PhD in Physics from the University of Orsay (2006). He joined EDF as a research engineer in Statistics and Financial Mathematics applied to the energy market. He joined the FiME Research Centre in 2009. His interests include electricity price modeling and financial risk management.

Nadia Oudjane

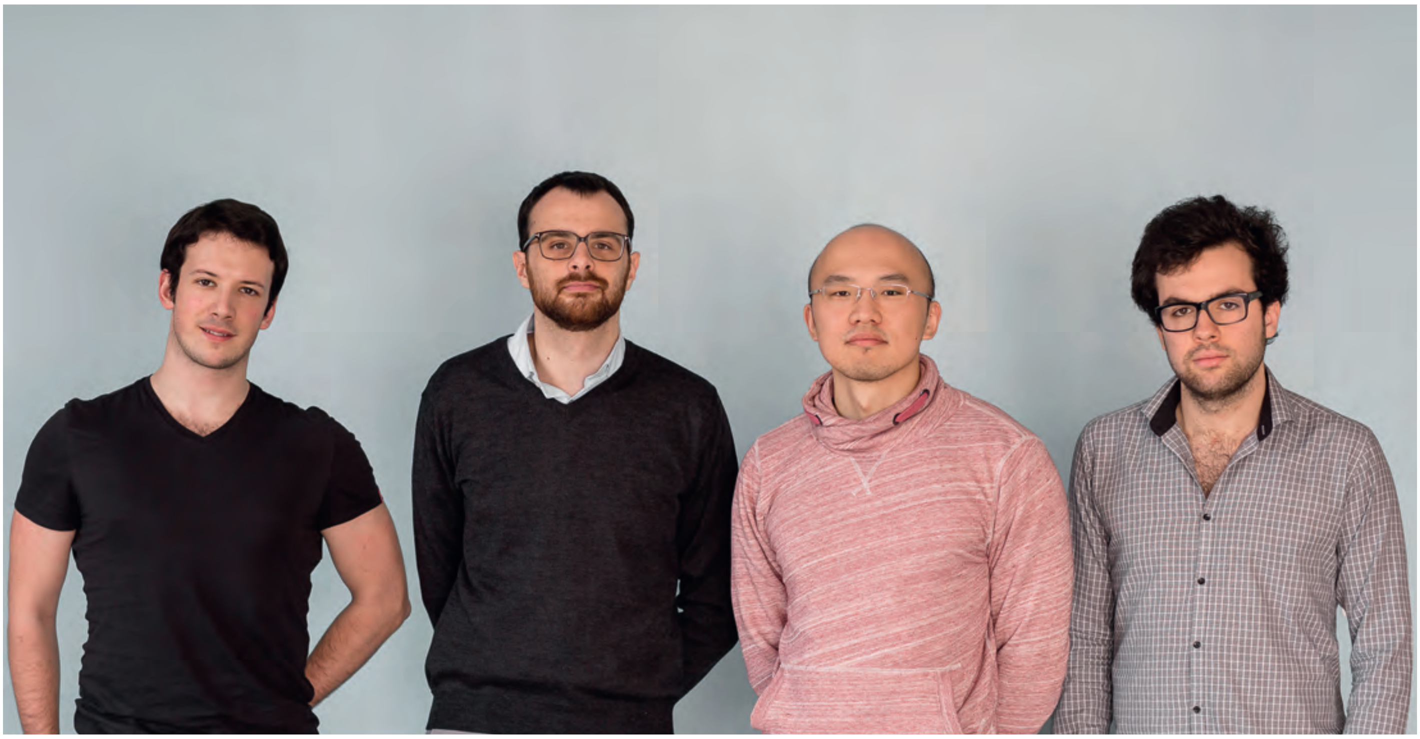
Nadia Oudjane is an engineering graduate from the École Nationale Supérieure d'Aéronautique et de l'Espace (ENSAE). She holds a PhD in Applied Mathematics and an HdR in Science. She is an expert research engineer at EDF R&D in Probability and Statistics and works on numerical methods for energy management in a stochastic environment.

Xavier Warin

An expert research engineer at EDF Lab and a graduate of the École Nationale Supérieure des Techniques Avancées, Xavier Warin has worked in the field of neutronics, and in particular on convection-diffusion equations. A specialist in numerical methods, he has also worked in the field of finance, the development of stochastic control tools and on decision-making tools for investment projects.

PhD students and post-doctoral researchers

The participants at the FiME Research Centre include PhD students and post-doctoral researchers from diverse institutions. The topics they study also benefit from multi-disciplinary research between economics and applied mathematics.



Hadrien De March   Matteo Basei   Gang Liu   Thomas Deschatre

DISMANTLING NUCLEAR PLANTS HOW TO OPTIMIZE EDF FUND MANAGEMENT

Based on an interview with Marie Bourrousse (EDF R&D) about the article, "Hedging under multiple risk constraints" by Ying Jiao, Olivier Klopfenstein and Peter Tankov, and on "Asset Liability management with capital injection and withdrawal" by Claudio Fontana, Peter Tankov and Xavier Warin.

EDF is under legal and regulatory obligation to maintain and manage a fund specifically dedicated to covering the costs of dismantling nuclear plants when they reach the end of their life cycles and to managing nuclear waste storage. Current uncertainty as to the evolution of financial markets has caused FiME researchers to study how this fund can be most effectively managed.

France has the most nuclear power plants of any member of the European Union, with 58 nuclear reactors operated by EDF. As stipulated by the French law of 28 June 2006 on the sustainable management of radioactive materials and waste, EDF maintains a specific fund reserved for the long-term costs of nuclear energy (power plant dismantling and waste disposal). The value of the fund (a portfolio of financial assets) must be equal to or more than the future liabilities (present value of long-term costs), which at the end of 2015 came to €23.6 billion. If ever there is a gap between asset and liability values, government authorities can intervene and dictate measures for reestablishing the required balance. It is therefore important to manage assets so as to minimize the risk of their value falling below that of liabilities. The goal is to avoid having external regulators force EDF to inject additional cash into the fund.

An intrinsically complex issue of asset-liability management

Reaching this goal implies overcoming several management hurdles. First of all, there is the fact that it is impossible to cover fully the financial risk of future liabilities. Technically, the matter is difficult to deal with because of the long-term nature of the costs associated with decommissioning a nuclear power plant; insurance that covers such a lengthy period does not exist.

In addition, as per a 2007 decree, the regulatory discount rate used to calculate liabilities may not exceed the expected return on assets. As a result, it is important to identify asset management strategies that take into account shortfall risk, or the risk of asset value depreciation to a level inferior to liabilities, while also ensuring minimal returns.

Finally, recent market conditions (low interest and inflation rates, repeated financial crises on stock

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and liability markets since 2008, and so on) have in recent years triggered the development of new asset management tools.

A new approach

Asset-Liability Management (ALM), a mixture of risk and portfolio management, is one such tool. “We are in critical need of a benchmark of optimal long-term management that we can use to craft and justify our management choices,” says Marie Bourrousse, who oversees ALM research projects carried out by EDF R&D for the finance department's ALM division, which is in charge of strategically placing the funds reserved for long-term nuclear costs. Due to legal constraints and market conditions, it seems necessary to reconsider and amend current fund management practices. Even if optimal management solutions are merely theoretical and exist only within a stylized framework, being able to explicitly describe them can provide insight into appropriate directions to take in real life. Indeed, decisions must be made as to what kinds of placements to make with which assets, taking into account current market conditions as well as fund value compared to liabilities.

Increasingly realistic research

The results of the first theoretical studies done with researchers from the University of Paris-Diderot Probabilities and Random Models Laboratory (LPMA) have produced interesting results that provide some insight into certain effects of the fund regulatory constraints. Further research is needed and is currently under way. While it is too soon to say precisely what the next step will be, the researchers involved seem likely to discover new insights that are likely to be both publishable and applicable for effective fund management.

APPLICATION

Current research projects should help EDF to optimize management of the fund reserved for the long-term costs of nuclear power plants. This theoretical study makes it possible to identify the critical factors to take into account when making both R&D and ALM decisions.

METHODOLOGY

The researchers looked at the management of the EDF fund reserved for long-term nuclear costs as a matter of asset-liability management, as the fund is composed of financial assets whose value at any given time must always be superior to liabilities. Stochastic optimization (in the random context of financial markets) was performed on financial asset placement strategy and on fund endowments and with drawals. According to Marie Bourrousse, the numerical simulations carried out by Xavier Warin are extremely valuable and effectively complement this work. They make it possible to produce numeric results in cases where theory alone cannot provide explicit solutions.


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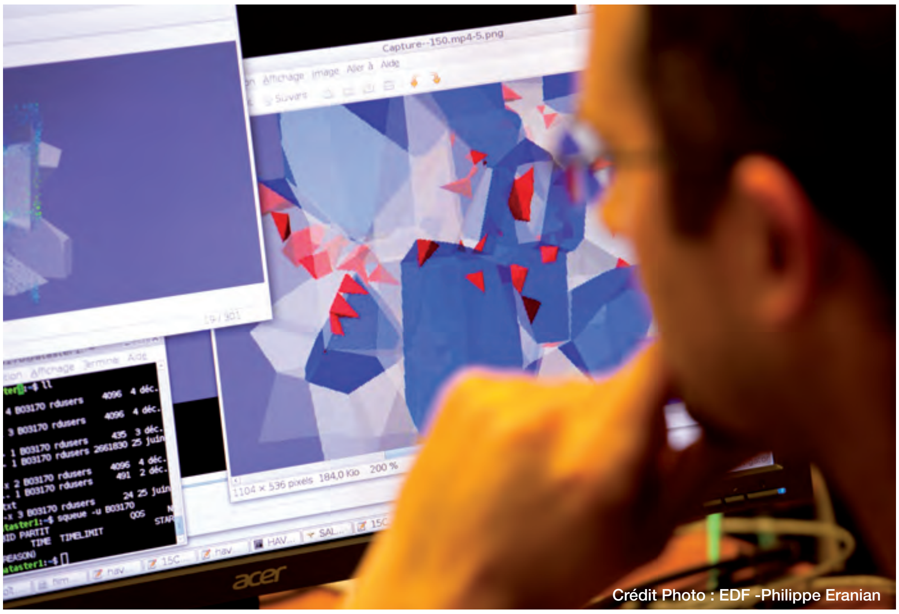
NUMERICAL METHODS FOR THE MODELING OF ENERGY MARKETS

Based on an interview with Emmanuel Gobet about the contribution made by FiME members to the literature on numerical methods for stochastic control.

Energy transition models aim to describe optimal solutions for decisions made in the face of an uncertain future. In order to do so, they rely on stochastic control equations whose solving is generally very complex and / or very costly in terms of calculation time. A handful of researchers at the FiME laboratory, headed by Emmanuel Gobet, are devising toolkits to enhance the numerical processing of these equations.

Formalizing economic problems with mathematical equations can provide insight into complex relationships or phenomena and help to quantify them. This formalization often leads to optimization problems that involve time dynamics, or, in other words, the random realization of different events over time (stochastic control equations). Since it is rare to have explicit analytical solutions available, numerical methods are often essential for analyzing these economic scenarios.

It is for this reason that researchers at FiME are helping to improve the methods for solving economic questions numerically. For a numerical solution to work, the methodology must be chosen carefully to suit the nature of the difficulty. It is critical, therefore, to have a toolbox that is large enough to be able to adapt the numerical methods to the economic formalization rather than vice-versa.



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Increasingly realistic and more complex economic models

Decision-support tools that can be used to inform private and public decision-makers are a major challenge. For these tools to be employed, the underlying models need to be realistic, which generally makes numerical solutions difficult. For the electricity market in particular, the models are often highly dimensional, meaning that the number of variables under consideration may be huge. The models typically include the prices of the different fuels for generating electricity - gas, coal and fuel oil - as well as thermal production outages, electricity demand, the production of renewable photovoltaic and wind energy, and so on. An increase in the scale of the problem usually results in a significant rise in computation time and substantial memory requirements (to store the numerical representations of the computed values). Sometimes it is not even possible to solve the problems on normal computers.

There is another source of complexity. With the major restructuring of the markets (including the opening up to new sources of competition, including consumer-produced energy), it would be ideal to represent as well the interactions between the different actors in the system, such as competition between producers or suppliers, or consumer reaction to a price signal. Finally, numerical methods should be capable of integrating another source of uncertainty related to the model itself: incorrect parameters that are difficult to estimate due to a lack of data, and uncertainty about the form of the model. This last aspect is crucial. If we are to have robust decision-support tools, they have to be capable of handling uncertainty.


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Developing new methods

The FiME researchers are working on upgrading existing numerical methods so they can be processed more accurately and quickly by computer. They are also designing new approaches for formulating additional - and sometimes radically different - dynamic optimization problems, which open up new possibilities for mathematical analysis and numerical solutions.

These new methods are paving the way for parallelization, enabling researchers to decompose a calculation into several sub-calculations performed simultaneously to accelerate the execution time while ensuring the convergence of the algorithm, i.e. the fact that the calculation generates the correct outcome. This research, in conjunction with work carried out elsewhere in the academic world, has made it possible to move from solving five-dimensional stochastic control problems to problems with 12 to 15 dimensions in the space of a decade.

In a further development, when the number of observations is low (which would normally seriously restrict the accuracy of the algorithms), Gobet and his co-authors have designed a machine learning technique, similar to techniques used in data science, that guarantees an accurate numerical solution.

METHODOLOGY

The FiME researchers are working on upgrading existing numerical methods so they can be processed more accurately and quickly by computer. They are also designing new approaches for formulating additional - and sometimes radically different - dynamic optimization problems, which open up new possibilities for mathematical analysis and numerical solutions.

APPLICATION

The above methods are employed in various types of research at FiME, as described in this brochure: mean-field game models (p.16-17); hedging strategies based on pricing models (p.18-19); and principal-agent models (p.24-25).

Note that these methods have been developed collaboratively and have been distributed in other forms (in addition to academic publications):

- Via a benchmark site for comparing numerical methods on test cases, intended to ensure better reproducibility of numerical experiments and a wider diffusion of knowledge. http://numerical-stochastic-control.com/
- By creating an open calculation library for stochastic control, developed in C ++ with a Python interface and led by Xavier Warin.

TECHNOLOGICAL TRANSITION MODELS: IMPROVING OUR UNDERSTANDING OF THE IMPACT OF GOVERNMENT INCENTIVES

Based on an interview with René Aïd and articles co-written with Imen Ben Tahar: “A mean field game approach for technology transition” (forthcoming) and “Transition to electric mobility: an optimal grant price rule,” published in 2015 in *Commodities, Energy and Environmental Finance*.

Which is the more effective: increasing the automatic grant for purchasing an electric vehicle or boosting the subsidies given to manufacturers? René Aïd and Imen Ben Tahar set out to identify the best ways to encourage technology transition, which is now a major environmental challenge.

It is generally agreed that energy transition requires the large-scale transformation of current technological systems. Transitioning from one technology to a more environmentally friendly - but not necessarily more mature - replacement technology raises complex problems. Above all, the transition calls for significant government intervention in the form of subsidies or special tax measures. These are needed to stimulate demand for the new technology and to elevate it to a critical level, thereby guaranteeing favorable conditions for its development and distribution. Designing a successful policy means trying to analyze the effects of initiatives aimed at both consumers *and* manufacturers.

Giving grants to consumers

Electric vehicles account for only 1% of the French market. The slow uptake in electric mobility is partially due to the erratic nature of the government’s stimulus packages, which rely mainly on grants and subsidies. At the same time, given that there are around 40 million vehicles on the road in France, it is easy to understand why the authorities are somewhat reluctant; based on the € 7,000 “environmental bonus” or rebate initially proposed in 2012, it would cost billions of euros a year to convert all the country’s motor vehicles. Ben Tahar and Aïd sought to analyze the impact of this type of initiative using an approach derived from mean field game theory. Their aim was to model the collective dynamics of converting the car population by examining how individual consumers are influenced by the volume of electric vehicles already on the market. The idea is that the cost of the transition to electric vehicles decreases as the number of cars grows. While the rebate-style subsidies in this model do indeed appear to be a way of making the switch from gas to

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electric transport, the size of the grant has to be high enough to establish a practical equivalence between gas and electric vehicles. According to the assumptions of the model, the benchmark level of the grant — €7000 — would not achieve equivalence.

Subsidizing producers

In the second part of their study, Ben Tahar and Aïd looked at another type of subsidy: the grants given to manufacturers for developing a new technology, in this instance to construct electric vehicles. Subsidies on the supply side have the advantage of promoting the expansion of local industry, while consumer grants may have the opposite effect, as we have seen with photovoltaic panels, where production can be relocated in its entirety. In theory, supply subsidies also help to generate positive "learning by doing" externalities within a firm, since companies become more productive as they gain experience and knowledge. A second type of externality, known as the "learning spillover effect" (which is not reflected in existing technological transition models) may occur when a company's experience and learning also benefit its rivals. As in the previous approach, these effects were analyzed using a mean field game system, in which individual firms are sensitive to the average level of technological knowledge in their environment. The indirect — and positive — effects of subsidies act as a catalyst for innovation and technology transition.


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METHODOLOGY

René Aïd and Imen Ben Tahar adopted a mean field game approach to model the technological transition, including the phenomena of externalities inherent in the collective dynamics (especially learning and spillover effects). This approach, which was introduced in 2006, has expanded rapidly in recent years since it greatly simplifies the complexity of the calculations relating to the interactions between different actors.

APPLICATION

The research by René Aïd and Imen Ben Tahar is likely to enhance our understanding of the impact of government incentive schemes designed to stimulate technology transition. The work prompts us to consider not only the immediate costs of such measures but also the costs and benefits associated with the collective dynamics they may trigger.


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ELECTRICITY MARKETS: INTEGRATING PRICE VARIABILITY

Based on an interview with Pierre Gruet (EDF R&D) and his article "Efficient estimation in a two-factor model from historical data," co-written with Marc Hoffmann and Olivier Féron, forthcoming in *Finance and Stochastics*.

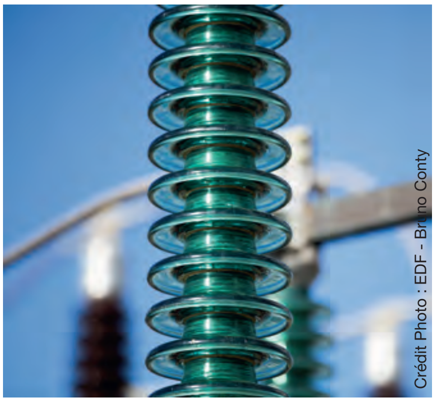
The price of electricity on a futures market varies considerably as the maturity date approaches. Researchers at FiME are trying to integrate variability into EDF's price modeling so that price movements can be estimated more accurately and associated risks reduced.

The specificities of the electricity market

Electricity is sold on wholesale (physical) and financial (futures) markets where the players include producers and suppliers as well as brokers and traders. The timeframes of the traded contracts, together with the fact that electricity cannot be stored, make these markets unique. Among other things, this means that agreements for supplying electricity always include precise details about the delivery period. FiME's statistical modeling group aims to investigate and develop decision-support models that take these peculiarities into account. Wherever possible, the models are bound to comply with two sometimes conflicting principles: they need to be simple enough to manage financial risk using financial instruments (option pricing and risk calculation); but they have to be sufficiently flexible and informative to incorporate as much statistical data as possible from historical situations and the market. The academic outcomes are systematically compared to real data.

Interacting with the futures market to manage risk

It may be to EDF's advantage to buy or sell futures contracts as a way of managing risk (linked to the large number of plants owned by the group and its dominant position as an electricity provider). In order to trade electricity on the market, EDF needs some idea of how prices are likely to evolve. More precisely, what is needed is a set of possible trajectories rather than an accurate prediction of the final prices. Three different entities within EDF - operational management, the upstream-



Crédit Photo : EDF - Bruno Conty

downstream optimization and trading division (responsible for production management) and the risk management division - all need increasingly efficient models to quantify market prices and guide their production or risk management decisions.

Crédit Photo : EDF - Jean-Louis Burnod

How can EDF factor in price volatility?

The goal of Gruet's research is to make the model currently used by EDF even more reliable. The data observed and collected on the markets indicates that prices become extremely volatile, and move more quickly and more drastically, as the end of trading and the time to supply electricity draw nearer. A better appreciation of the variations in this volatility in relation to delivery deadlines would lead to a more precise representation of the abundance of price changes in real terms. This is essential because mistakes in estimating fluctuations can prove very costly and have important consequences: EDF will not have taken the right positions, i.e., not bought or sold enough contracts in advance, if the changes in prices turn out to be far higher than anticipated.

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METHODOLOGY

Pierre Gruet and his co-authors analyzed a variant of a traditional model of electricity prices in the futures market with time-dependent volatility. This model includes two sources of uncertainty as a way of reflecting long and short-term volatility. The first takes into account phenomena such as changes in medium-term consumption trends or technological improvements to production processes. The second considers events that may occur shortly before the actual supply of electricity, such as snowstorms or power outages.

APPLICATION

The theoretical work undertaken by Pierre Gruet and his co-authors will help EDF enhance its own model for representing electricity prices on the futures markets. "The model won't be as technical or theoretical as the one that we used in our research," explains Gruet, "because that would just complicate the forecasts. But we're going to suggest small changes that are easy to implement from an operational perspective so that price volatility can be better represented throughout the year." This kind of adjustment can also be applied to other industries, such as insurance or finance, where the same type of model is commonly used.

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UNDERSTANDING THE LINK BETWEEN COMMODITY SPOT MARKETS AND FUTURES MARKETS

Based on an interview with Edouard Jaeck (Université Paris-Dauphine) and the papers “Speculation in commodity futures markets: A simple equilibrium model” by I. Ekeland, D. Lautier and B. Villeneuve and “Equilibrium relations between the spot and futures markets for commodities: an infinite horizon model”, by I. Ekeland, E. Jaeck, D. Lautier and B. Villeneuve.

Commodity markets have very varied characteristics, depending on the sectors (energy, metals, grain, etc.), but they also exhibit relatively regular features over time, if we confine ourselves to standard indicators such as the *basis* (the difference between futures prices and spot prices) and *hedging pressure* (which measures the hedging needs of a futures market). These properties can be explained at least partly by the relative distribution of the different actors present in these markets (industrial actors, “storers”, speculators). What influence do these various players have on the prices of commodities, when they are traded in both a spot market and a futures market? What will be the impact of an increase in the number of speculators in these markets? How do we account for the lasting price differences between different types of commodity – the fact that the futures price is in some cases consistently higher than the spot market price (contango) or vice versa (backwardation)? It is questions such as these that the model initiated by the work of Ivar Ekeland, Delphine Lautier and Bertrand Villeneuve seeks to illuminate.

The model

The simplest version of the model is concerned with the evolution of the price of a commodity over two periods, in a spot market and in a futures market where at t = 1 coupons are traded for physical delivery at t = 2.

The model involves three types of agent. The first are “storers”, who buy the goods in the first period and sell them in the second. They are obliged to sell their holdings in the second period, and hedge themselves in the futures market against a decline in commodity prices. The second type of agents are industrial actors, who use the commodity as an input in the production process. Because they have no storage capacity and are required to produce a certain amount of goods in the second period, they decide at t = 1 on the amount they will buy at t = 2 in the spot market. They also operate in the futures market to hedge against the risk of an increase in the spot price. The third group consists of pure speculators, who operate solely in the futures market.

Each agent carries out an optimization calculation: at t = 1 he decides on what positions to take in the two markets to maximize the returns for both periods. Accordingly, he makes predictions about the future state of the economy, taking into account all available information, including other agents’ choices (the so-called rational expectations hypothesis). Equilibrium occurs with the

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realization of this optimization calculation. It is then possible to examine how this equilibrium changes when the number of agents in each category is varied.

A typology of the different markets

By adopting this approach, it is possible to create a classification of markets, that is to say, to describe four typical configurations (corresponding to the relative distribution of the three groups of agents), to which specific properties pertaining to the relationship between the spot and futures markets can be linked. The model can be used to study the impact of the "financialization" of a market in each of these cases. Depending on the configuration of the market considered, an increase in the number of speculators will have a different (positive or negative) impact on the other agents.

Similarly it is also possible to study the impact of supply shocks in the different configurations. Ultimately, this model is expected to suggest hypotheses about the functioning of real markets, according to whether they exhibit the characteristics of one or other of these market categories modeled.

Extensions

Starting from the basic model, different variants may be envisaged (and have been in the context of FiME). So instead of being restricted to two periods, the dynamic case can be considered, enabling, for example, differences in the various actors' trading speeds to be introduced (as in Edouard Jaeck's doctoral thesis). It is also possible to add markets, such as that of another commodity, assuming that these two markets are linked. Or a stock market can be added, in which agents can hedge (as well as in the futures market). Finally, the effect of inserting information asymmetries into the model can be investigated.

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METHODOLOGY

The model considers three types of agents – "industrial actors", "storers" and "speculators" – active in two different markets, namely spot markets and futures markets.

The model is a partial equilibrium model (addressing a commodity market, all other things being equal) involving rational expectations (equilibrium is reached with the realization of the predictions made by the agents in the first period).

APPLICATION

- From the variety of configurations that can be generated from a small number of assumptions, the model can explain the properties observed in real markets.
- The model is able to consider the impact (differentiated according to different types of agent) of financialization (an increase in the number of speculators) and of supply shocks.

FUEL POVERTY: UNDERSTANDING BEHAVIORS TO PROVIDE BETTER SUPPORT

Based on an interview with Bertrand Villeneuve and his forthcoming paper, "Payment method and self-control", co-written with Corinne Chaton and Elie Lacroix.

How is it that some people put money aside for winter heating, only to discover late in the day that they do not have enough to cover their needs? Bertrand Villeneuve and his co-authors draw on behavioral economics to help understand this area of major concern – fuel poverty - and thereby design better assistance packages.

Key figures released by the *Observatoire National de la Précarité Energétique* (French Fuel Poverty Monitoring Center) in April 2015 show that fuel poverty (FP) affects about 5.1 million households (11.5 million people) in France, or about 20% of the total population. What exactly is FP? The condition is difficult to quantify because it involves so many different, interrelated factors: the economic vulnerability of households; poor thermal performance; and high energy prices. "One of the aims of our work is to provide a better understanding of what is meant by FP, since the term is used a great deal by the media, politicians and industry," explains Villeneuve. "A raft of social measures have been implemented and announced regarding FP, including energy vouchers. But we still face an important, definitive question: who is living in fuel poverty? We need to know so that we can come up with the best ways to support them."

Counter-productive behaviors

Villeneuve first began to take an interest in FP when supervising a student's CIFRE thesis with EDF R&D and Université Paris Dauphine. The program of this thesis has been launched by Chaton. "Elie Lacroix is doing his thesis on FP, and has looked at the relationship between FP and health from an econometric point of view." Villeneuve, Chaton and Lacroix decided to try to interpret individual behavior from a more theoretical perspective: why do some people "choose" not to spend enough on heating, lighting and cooking? What causes an individual to sacrifice his or her own best interests and health by choosing to live wrapped in blankets and so on?

Energy: a case apart

"We realized that if aid measures were designed using poor behavioral assumptions, they would

Crédit Photo : EDF - Christophe Beauregard be erroneous: they would completely fail to solve the problems they were supposed to address. It's important to recognize the obstacles facing people in their day-to-day decisions so they can be given effective assistance." Villeneuve and his colleagues drew on a field known as behavioral economics, where there is no a priori assumption that people are perfectly lucid, rational and consistent. "If FP was simply about poverty," continues Villeneuve, "all we would have to do is give people additional resources so they could earmark a greater share to their energy needs. But we now appreciate that there are specific problems when it comes to energy. It is a consumable that has particular idiosyncrasies, which probably means we need to offer special kinds of assistance - such as social tariffs and energy vouchers - to help households with their energy consumption."

The role of time inconsistency

Villeneuve and his research team took the unusual step of incorporating time inconsistency into their modeling, which in this case is the fact that consumers know that they should foresee the need to heat their homes properly by filling up their storage tanks, insulating their accommodations, or buying new boilers, so they can live in comfort, but ultimately they fail to take decisions that are in accordance with this awareness. "Winter comes and brings with it other needs. People are more likely to buy clothes or food or pay for life's ups and downs. They end up using less energy than they'd anticipated to the detriment of their comfort and, consequently, their health."

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METHODOLOGY

Bertrand Villeneuve and his co-authors incorporated ideas from a literature review of behavioral economics into their model, including time inconsistency (i.e., when consumers know they should heat their homes more but spend their money on other things instead). These concepts were used to mathematically represent energy consumption behaviors in a more accurate manner.

APPLICATION

Bertrand Villeneuve's research provides a way of thinking about the assistance that could be given to people living in fuel poverty. The results should enable governments to refine their social policies based on a clear understanding of the behavioral problems and the various tools available. The research is also of interest to EDF since the company has to estimate the (changing) numbers of people living in FP, if only for cash flow purposes and to calculate the level of compensation owed by the state for social tariffs. In addition, EDF needs to control outstanding payments, disconnections, and resulting drops in profits. Apart from the financial impacts, EDF has a preventive and support role to play. It still has to be able to manage, process and record new assistance schemes, such as the aforementioned energy vouchers.

ENERGY TRANSITION: NEW MODELS FOR UNDERSTANDING INCENTIVE MECHANISMS

Based on an interview with Nizar Touzi and his article "Moral hazard models for energy transition", co-written with René Aïd, Dylan Possamaï and Zhenjie Ren.

How can economic stakeholders be persuaded to install wind turbines or private customers to use off-peak energy? Researchers at the FiME laboratory aim to design new incentive systems for encouraging industrials and consumers to work towards energy transition.

Energy transition requires economic incentives. Such incentives are needed to steer manufacturers towards less carbon-intensive technologies and to incentivize individuals to adapt their behaviors to production constraints (such as fluctuating levels of renewable energy). This is actually what governments are doing by subsidizing renewable energies, and electricity suppliers by charging higher rates during peak hours. It is worth asking, however, whether these are the most effective methods, given the stated objectives. Renewable energy subsidies are granted to manufacturers on the basis of installed production capacity rather than on their efforts to cut down on production costs. Likewise, private customers could be encouraged to postpone consumption until after the peak period and to adapt their usage throughout the day in response to real-time signals.

Optimal continuous-time subsidies and tariffs

These issues are familiar to insurance companies, which identify policies to persuade insured parties to behave responsibly. The originality of FiME's work lies in the fact that it is not restricted to looking at tariffs or subsidies that are fixed for a given period. On the contrary, the researchers are considering scenarios where tariffs and subsidies could be modified at any time, in accordance with changes in demand and production or unexpected events. Their model depicts what could be an ideal incentive trajectory if it were possible to adjust the terms of the contractual relationship on an ongoing basis. It is, therefore, a type of benchmark for improving the design and functioning of existing incentive schemes.

Electricity consumption and smart meters

The first model proposed by Touzi and his fellow authors centers on electricity suppliers and consumers. On the one hand, consumers decide to switch on their appliances as and when they

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like, and it is considered inconvenient to have to modify or postpone usage to fit in with the constraints of production flexibility and availability. On the other hand, production capacity, especially for intermittent energy, cannot necessarily follow consumption patterns that are too erratic. By sending a price signal, this model can describe an optimal consumption trajectory, which reaches an ideal compromise between the collective good and individual consumer effort. Regulating consumption through pricing appears to be an effective way of reducing consumption variability. The study is of particular interest given the deployment in France (and Europe more widely) of intelligent and smart meters that can measure real-time customer usage and send suitable signals for altering behavior.

Matching subsidies to the investment costs of renewable energy

The second problem addressed by the researchers was to identify the least expensive way of promoting the development of renewable energy. While governments can observe the new capacities for generating renewables, they are not able to monitor the efforts made by industry to reduce production costs. It follows that subsidies based solely on production capacity do not stimulate the R&D that would lead to lower costs and scale down the need for future funding. The goal, therefore, is to offer the lowest subsidies that will nevertheless guarantee a pre-determined level of renewable energy in the system at a future date.

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APPLICATION

The two scenarios analyzed by Nizar Touzi and his co-authors demonstrate that their tool can be used to help devise constructive incentives for energy transition by:

- Designing new tariff agreements that incentivize consumption reduction, especially as smart meters continue to roll out
- Identifying more efficient subsidies for technological transitions

METHODOLOGY

The principal-agent approach was used to address the two issues, in which the principal (the electricity supplier or government) is not able to observe the efforts of the agent (consumers or wind turbine manufacturers). The main difficulty in both instances is finding the optimal contract (the subsidy or tariff) that will automatically prompt the agent to adopt good energy-saving behavior.

From a technical perspective, the solution draws on the latest research, partly developed by FiME, on the stochastic control theory of non-Markovian dynamics, i.e., optimizing decisions based on a complete history of the problem and not just its current state. In contrast to what has previously been possible on a technical level, problem resolution now includes explicit - and therefore exploitable - types of supply agreements or subsidies.

ADAPTING ELECTRICITY PRICING TO NEW CHALLENGES

Based on an interview with Ivar Ekeland and his forthcoming article “Second-best tarification for a producer-provider of electricity,” co-written with Dylan Possamaï, Romuald Elie, Nicolas Hernández Santibáñez and Clémence Alasseur.

The electricity market is being transformed - and not just by liberalization and the scrapping of regulated prices but also by the boom in renewable energies. Ivar Ekeland and his fellow authors investigated how suppliers can create new pricing packages that reflect these changes.

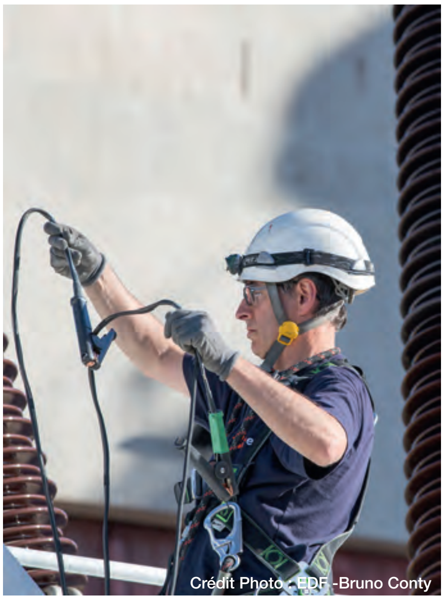
Pricing is a major concern for electricity suppliers. Market liberalization and deregulated tariffs, together with alterations to the electricity generation mix (especially the rapid growth in renewable energies), are forcing companies to rethink the packages offered to customers. Smart meters, which are currently being rolled out in Europe, are one of the tools that will help suppliers introduce innovative pricing schemes. But how can firms adapt their rates to changes in the energy mix, i.e. in the distribution of different methods of generating electricity? And how can they deal with the presence of other suppliers on the market?

Integrating competition and customer reaction

Similar problems arose under the old monopoly system, albeit in less acute form, but the captive customer is no more: consumers today only sign the contracts that suit their needs and are the most competitive on offer. Suppliers have to factor in customer reactions when setting their tariffs - not just whether customers sign a contract or not but also how they choose their levels of consumption. Companies must ensure that their rates do not seem arbitrary: rates should be easy to understand, transparent and explained in detail on the bills sent to customers.

Standard pricing problems

Electricity tariffs raise conventional optimization problems, with customers having a diverse range of requirements that need to be addressed with different rates. Private customers do not have the same consumption patterns as large manufacturers. For example, private customers tend to put on the heating and use the oven around the same hours of the day (at the end of the working day), whereas it is easier for manufacturers to take advantage of lower rates by moving some of their production to non-peak hours. Electricity suppliers are like auto insurers who do not know whether a potential customer is a careful driver or not: they have to set tariffs that will help them distinguish (or differentiate) between customers based on their preferences. Whereas auto insurers offer prices with a high deductible and low premium to attract safe drivers (and the opposite for less careful drivers), electricity suppliers play on the maximum usable power and cost per MWh.



Problems specific to electricity

Pricing, which is typically a very complex issue in competitive environments, is even more complicated in the electricity sector. In particular, suppliers have to take into account the fact that the production costs incurred by the producer at any given moment depend on overall customer consumption. Unlike other commodities such as wheat or oil, it is nigh on impossible to store electricity: production must be almost identical to consumption at all times. At peak hours, coal or gas-fired power plants may be called on to supplement nuclear and renewable plants. The cost of instantaneous production is much higher, and pushes up overall production costs. In addition, renewable energy (wind and photovoltaic) operates intermittently depending on weather conditions. And, finally, suppliers have to integrate public service obligations.

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METHODOLOGY

Ivar Ekeland and his co-authors designed a model based on the economic theory of information asymmetry, notably the principal-agent approach in adverse selection. The principal - the electricity supplier - offers a set of rates that varies according to the type of contract, the maximum power and the kilowatt-hour cost. The agents (the electricity consumers) fall into different categories depending on their tendency to use electricity at a given price. The principal does not know what category applies to a particular agent: he only knows the distribution of types in the population (through surveys, for example). Agents will, of course, only select tariffs that are more advantageous than the alternatives (with a different provider, for example). When optimizing its tariffs, the principal needs to take into account the fact that only a certain proportion of consumers will choose to sign up. The problem of the principal is to devise a price list that will maximize its profit.

APPLICATION

The research is valuable for electricity suppliers as it will help them to set tariff structures that are better suited to the needs of their potential customers and their own production mixes. The work also helps to better understand and measure the impact of competing suppliers entering the market. Thanks to this research, it should be possible to assess the cost of certain public service obligations, such as ensuring a minimum service across the country or offering special rates for people who are in precarious situations.

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FiME
Facts and figures

12 Academic researchers,
6 EDF R&D research engineers

15 PhD students and postdocs in 2016,
9 PhD thesis defended since 2011

20 Every year, around 20 papers published,
20 submitted to refereed journals or as contributions to collective works

6 Since 2009, six books produced by or with the support of FiME

13 More than 13 seminars organized every year

50 Over 50 presentations a year at conferences and seminars

2 On average two conferences organized or supported by FiME annually

FiME is also a partner in various subsidized projects that have been accepted or submitted, including:

- 2 ANR projects, one funded in 2015, the other submitted in 2016
- 1 COST project, submitted in 2015
- 1 European Knowledge Alliance project, submitted early 2016

FiME is certified by the “Finance and Sustainable Growth” Labex of the Institut Louis Bachelier
FiME was awarded the 2014 AEF prize for the best joint academic-corporate initiative.

FiME has organized jointly with the Finance and Sustainable Development Chair a thematic semester on the topic “Commodity derivatives Markets: Industrial Organization, Regulation and Financialization”. Funded by the “Finance and Sustainable Growth” Labex, the Global Risk Institute and the French Energy Council, the semester includes three conferences (two in Paris in 2015, one in Princeton in 2016), dedicated seminars and a summer school.

Training Programs

FiME

Research-based training: deprogram, formalize... and accelerate

Every year since the laboratory was founded, FiME has organized three or four made-to-measure training programs for EDF's R&D division. The courses, which are delivered by lab members or representatives from partner organizations, look at the nuts and bolts of a particular topic - such as stochastic calculus, Monte Carlo methods or micro-economics - and include a range of practical exercises and experiments. In addition to these traditional modules, since later 2014, FiME has been running a research-based training scheme. These programs are designed to enable research engineers to step back from problems and advance in their thinking. They are supported by a university researcher who advances his or her own interpretation and provides advice on the methodology in an approach derived from the PhD supervisor-student relationship. The training is available for small groups of two-to-six people, and takes the form of four or five half-day sessions interspersed with time for reflection and guided work. Thus far, five of these training programs have been set up, covering investment issues, global and local interactions for an electrical system, incomplete market valuation, simulation for the electricity transmission network, and medium-term decisions. A total of 21 individuals have benefited from the sessions, with overall positive feedback.

Marc Le Du
Project manager, local and global optimization, OSIRIS (Optimization, SImulation, RIsks, and Statistics for Energy Markets), EDF R&D

Within the OSIRIS department, I focus on connections between local and global issues, and, more specifically, on understanding the operating and financing challenges that a highly centralized electricity system must deal with as more and more local energy systems emerge. In early 2015, another engineer and I did research-based training in view of creating a case study that would illustrate these interactions in a simplified manner. We worked with Imen Ben Tahar, who teaches financial mathematics at the University of Paris-Dauphine. She was unfamiliar with our specific set of challenges and used mathematical tools with which we were similarly unfamiliar. This distance between her perspective and practices and ours made our exchanges highly worthwhile. As training sessions progressed, Imen gave us feedback on things that she found surprising or perplexing in the work we presented to her, and this pushed us to move beyond our habitual ways of thinking to uncover the truly relevant questions, especially with regard to the balance between the various aspects of the problem we wanted to describe. I am convinced that this training enabled us to subsequently carry out our work faster and more effectively. We are in the process of finalizing our case study and are hoping to take advantage of further academic partnerships to present it to others.

Joseph Mikael
Research engineer, OSIRIS (Optimization, SImulation, RIsks, and Statistics for Energy Markets), EDF R&D

In our department of research engineers, we are generally familiar with traditional forms of training courses, but research-based training was a first for me. Five other OSIRIS engineers and I worked with Nizar Touzi, a professor of applied mathematics at the Ecole Polytechnique, to explore optimization in incomplete markets. Our training consisted of five training sessions spread over as many months, starting last September and finishing in January 2016. During the first three sessions, Professor Touzi responded to our questions, and during the last two, we worked on two specific problems as a group: gas customer pricing, and market risk management for a supplier. The second issue is related to other projects that we are currently working on in OSIRIS, such as adapting our pricing model to take new variables into account, including price competitiveness. Professor Touzi suggested a model to use when we were working together, and it is now up to us to carry out our specific calculations and conduct simulations. This is the first learning experience of this kind, and I am now convinced that it is highly worthwhile for academics and field professionals to work together. I believe that working in this way has given me a boost and helped me progress in my work much faster than I otherwise would have.

FiME
Dauphine Polytechnique CREST EDF
Research Initiative

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