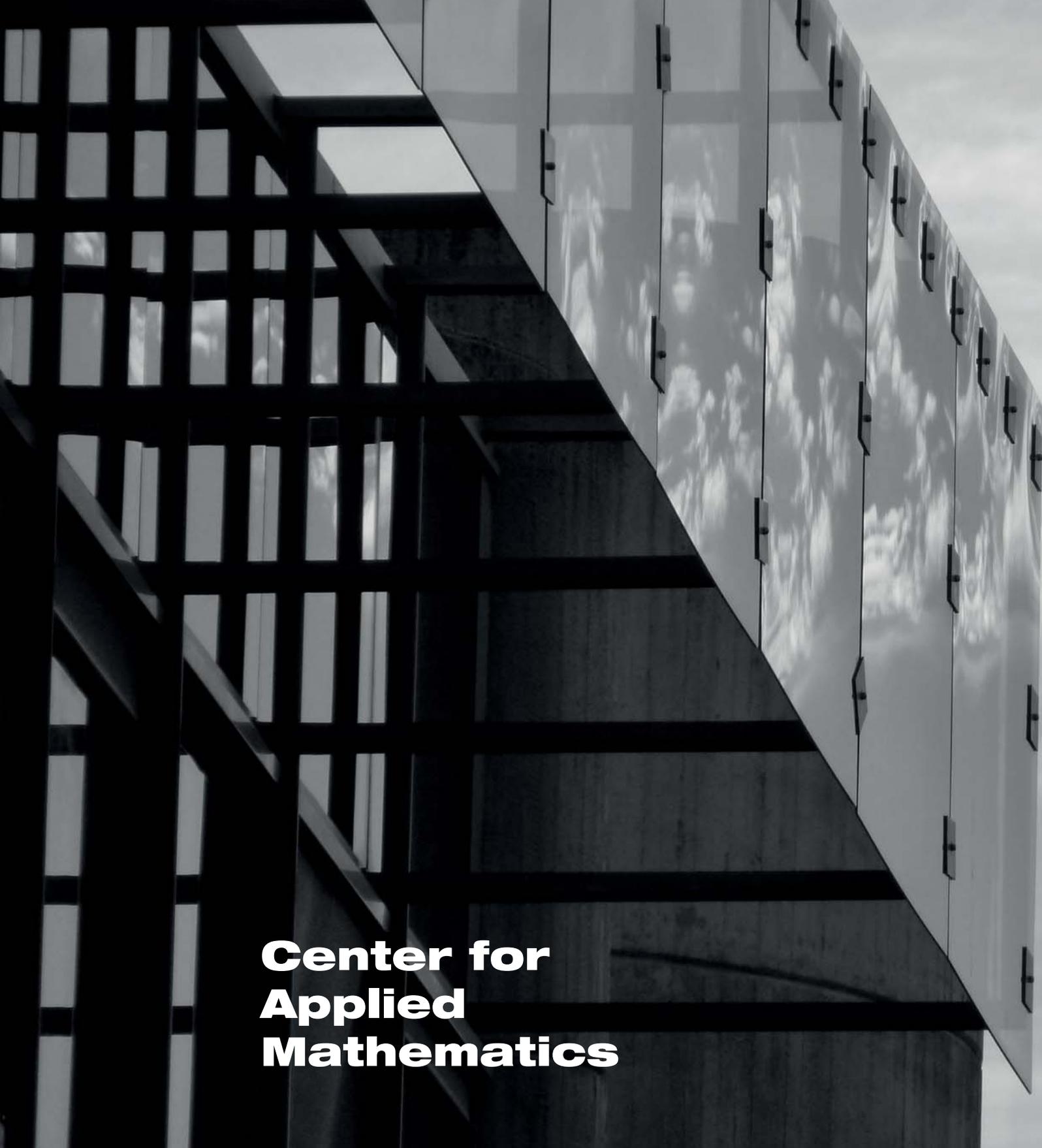


# CMA

## Center for Applied Mathematics



# ACTIVITY REPORT 2016



# **Center for Applied Mathematics**

**Advanced Master's OSE  
MIG Systèmes Embarqués  
Doctoral Studies  
Prospective and climate change  
MPDD Chair**



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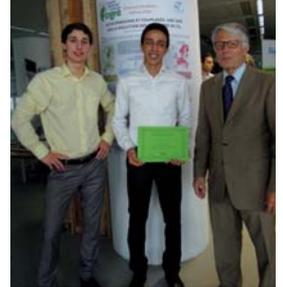
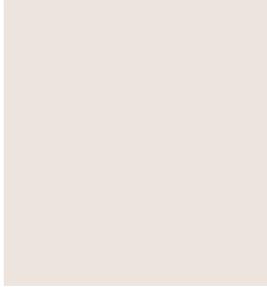
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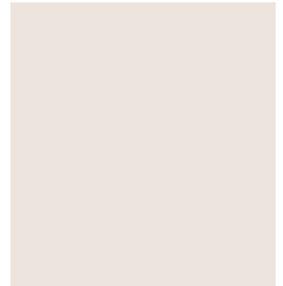
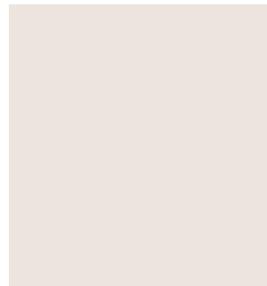
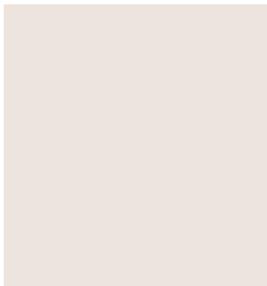
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# teaching



The CMA participates in the civil engineering syllabus with a course on “Prospective Modeling: principles and uses of mathematical models for evaluating policies on climate change”; organizes the “Embedded Systems” general engineer module; and participates in the Athens Program with courses on “C++ programming language”. It helps integrate the School into the local academic network by running the ParisTech doctoral program, “Control, Optimization and Prospective”, which is jointly accredited with the STIC Doctoral School at UNS. The Center teaches parts of the EEET and UNS Master’s degrees and is jointly responsible for a third-year module of the civil engineering program at Mines de Nancy. It runs the Advanced Master’s program on “Energy Systems Optimization” (OSE) [[mastere-ose.fr](http://mastere-ose.fr)] and teaches the entire module on optimization and prospective.



## DOCTORAL

## STUDIES

The CMA is responsible for the doctoral course, “*Control, Optimization and Prospective*” created in 2004 to support laboratory research topics.

### Course Director

**Valérie ROY**

This course is one of the four specialties of the STIC Doctoral School, for which PSL/MINES ParisTech and Nice-Sophia-Antipolis University (UNS) are jointly accredited.

The CMA enrolls its own doctoral students for this specialty, along with some INRIA doctoral students.

At the end of 2016, the doctoral department comprised 10 students.





## ADVANCED MASTER'S IN

The MINES ParisTech advanced Master's on "Energy Systems Optimization" is a 12-month course open to engineers and scientists who already hold a Master's degree and are keen to specialize in energy with an original, optimization-based approach.

**ENERGY  
SYSTEMS  
OPTIMIZA-  
TION**

**OSE**

### Course Director

**Gilles GUERASSIMOFF**

The course opens up a range of career prospects, such as study engineer, research engineer, project manager, energy purchaser, market analyst, and market risk analyst.

Teaching takes place in Sophia Antipolis and Nice and runs from 1 October to 31 March of the next year, in the form of lectures, conferences and projects on optimization and decision-making methods. Students are given an overview of energy systems that provides them with the keys to find long-term solutions to today's challenging constraints, such as climate change, dwindling resources, political and financial constraints, etc. At the end of the teaching program, the students undertake a 6-month internship from 1 April to 30 September with an industrial partner.

### Academic partners

The CMA, which organizes the advanced Master's, has partnered with CREDEN (Centre de Recherche en Economie et Droit de l'Énergie) at the economic science faculty of Montpellier I University for the economic side of the course, and EDHEC business school for the management side. The combination of these three complementary domains ensures a comprehensive understanding of the different paradigms of the energy domain.

### Focus on project-based teaching

The course, which involves multiple disciplines and combines technical, economic, legal, environmental and management aspects, is based on numerous projects on an overall theme.

Students must write a summary paper on the theme, which may be published by the Mines press.

They present their work to an audience of academics or institutional members during a study trip. The trip is a chance to apprehend the energy issue in an international context.

In addition, at the end of the course, students create an "event" in the form of a symposium, workshop or exhibition. This event must gather reference personalities working on the overall theme for a day of scientific debate.

Each month, the students produce a press review, Inf'OSE, on the energy field, which can be accessed at: <http://eleves-ose.cma.mines-paristech.fr/category/infose/>.

## Key events of the OSE Advanced Master's in 2016

### Class 2015/2016, on a study trip to the USA

After studying for six months at the CMA, OSE specialized Master's groups go on a study trip. The experience gives students an opportunity to consider different energy systems. This year, like last year, the class set off to California.

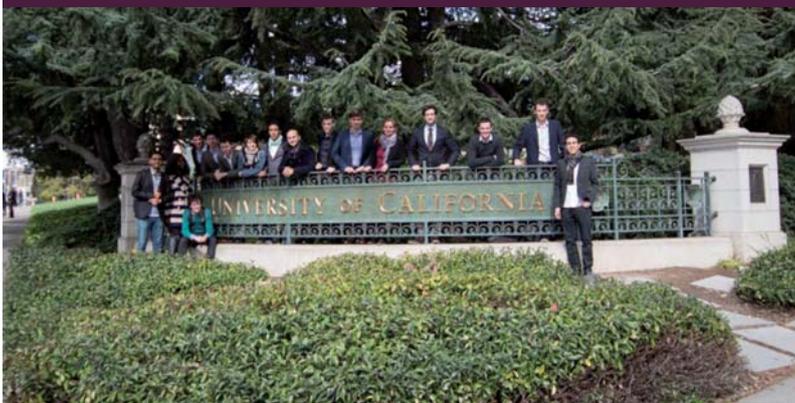
The ten-day trip was an occasion for students to test their knowledge of the energy field, in particular Microgrid technology, and to exchange with Californian industrials and academics on the latest progress and challenges in the global energy transition. They had the opportunity to participate in the PHILOMATHIA forum organized by BECI (Berkeley Energy and Climate Institute) and UC Berkeley on the topic, "Cities and People – Responding to Global Warming".

The students also held conferences on the subject of Microgrids, which was the focal topic for students at the CMA, UC Berkeley and the University of California at San Diego. They had a chance to visit renewable energy power facilities, a concentrated solar power plant, a wind farm and a photovoltaic installation.

In addition, they were able to discuss with their initiators the results of several Microgrid projects in California, at Naval Base San Diego, the University of San Diego and Santa Rita Jail.

The class of 2015/16 enjoyed a study trip full of discoveries.

*OSE Master's students in front of Berkeley University before the PHILOMATHIA forum*



*OSE Master's students in front of Santa Rita Jail*



*Students on the bus in front of IVANPAH*



*OSE Master's students in front of the Navy's premises*



*OSE Master's students in front of a turbine at PACIFIC WIND farm*





**JUNE 2016, honors for OSE Master's 2015 students**

Mohamed AMHAL and Cédric ANGLADE, two students of the MINES ParisTech (CMA) Advanced Master's on Energy Systems Optimization, won the second smartgrids competition for students organized by the Comité National Français du Conseil international des grands réseaux électriques (CNF CIGRE).

Participants had to write a 15,000-character article on the theme, "How can smartgrids help reduce greenhouse gas emissions?" The final round of the competition took place on 23 June at the RTE headquarters in Paris in the presence of numerous industrial partners of the event: RTE, EDF, General Electrics, Gimélec, Siemens and Supergrid Institute.

Mohamed AMHAL and Cédric ANGLADE won the first prize worth 2,000 euro for their article on electricity market coupling and interconnection development. They identified that developing interconnections leads to better integration of renewable energy, thus reducing the CO<sub>2</sub> content of electricity kWh. Taking Germany as an example, the pair analyzed the correlation between renewable production and interconnections.



**SEPTEMBER 2016: OSE Advanced Master's students and the MPDD Chair organized an event on Wednesday 28 September in Sophia Antipolis**





ACTIVITY REPORT  
2016

## OSE EVENT 28 September 2016

Students of the Advanced Master's class of 2015-2016 rounded off the academic year with a conference entitled, "Microgrids: Why, For Whom?" jointly organized with the Modeling for Sustainable Development Chair. Nadia MAÏZI, director of the Center of Applied Mathematics, and Gilles GUERASSIMOFF, head of the Master's, opened the event, which dates from 2008 and is supported by industrial partners with the aim of finding energy solutions for sustainable development. One of these is microgrids, which employ hybrid systems originally developed to respond to electricity shortages in remote areas.

The OSE Master's students then presented the studies they had carried out during the year, which were the subject of a book published by the Presses des Mines in July 2017 and entitled: Microgrid: Pourquoi, Pour Qui? (Microgrids: Why, For Whom), cf. at right.

A number of subjects were covered at the event, such as, What is a microgrid? Who are microgrids for? How can they be made secure and reliable? Control and optimization; Keys to success; Adapting economic models; Convergence of multi-energy networks; and Microgrids through examples. The presentations were followed by a round table involving Chair partners on the subject, and presentations of existing projects in the presence of representatives from EDF, EN-EDIS, SCHNEIDER ELECTRIC and ADEME.

SEPT  
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SEPT  
30

## End September 2016, departure of the class of 2015/2016, arrival of the class of 2016/2017

The 16 students of the class of 2015/2016 handed over their places to the 16 students of 2016/2017



DEC  
15

December 2016, students from the Ecole des Mines de Nancy spent three days working on a common module on, "Comparative analysis of energy sectors" and tutorial classes on modeling run by Sandrine SELOSSE and Edi ASSOUMOU, as part of the OSE Advanced Master's course. The agenda included long-term prospective optimization.



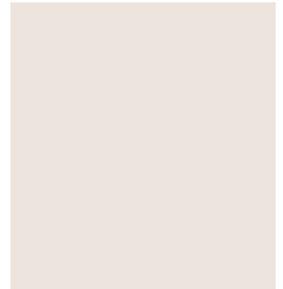
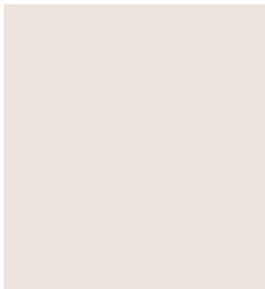
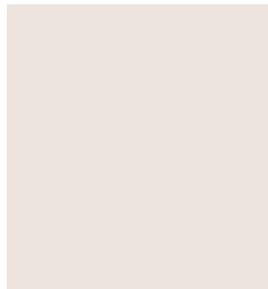
Nancy Mines students work on prospective studies together with OSE Master's students.



# research



The CMA develops an original scientific approach through its fundamental competencies in modeling, mathematics of control and decision-making, and real-time computing, in order to tackle increasingly complex systems. This combination of fundamental disciplines means that systems can be approached via a range of themes reflecting major industrial challenges and societal issues. Our research projects thus include: climate issues (technologies, carbon, energy, water, depletion of materials), security of sensitive industrial sites, control systems for space, the connection between electricity and carbon markets, and electrical systems integrating technologies related to renewable energy and smart grids.



## PROSPECTIVE

Thanks to its capabilities in modeling, optimization, mathematics of control and decision-making and real-time computing, the CMA has developed expertise to aid decision-making in the energy field. Its prospective approach is based on optimization models in the MARKAL/TIMES family developed as part of the IEA (International Energy Agency) program on which the CMA represents France.

AND  
CLIMATE  
CHANGE

### Informing public policies

#### Decision aid aimed at ministries

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#### Directors

**Nadia MAÏZI**  
**Edi ASSOUMOU**

Initiated by the Strategic Analysis Center's Energy Commission to evaluate low-carbon scenarios for 2050, our approach was also used for the work of the 2050 Energy Commission, ordered by the Energy Ministry with the aim of establishing French energy strategy for 2050. This was made public in early 2012. The CMA, through its MPDD Chair (cf. infra), has worked with the Treasury Office to model scenarios using its TIMES-France model. These scenarios translate hypotheses of deploying or withdrawing nuclear power, as enacted by Minister Besson. The object of this academic exercise was to aid the Commission in its thinking process. The analyses and conclusions were published in a specific annex of the final report and were the object of several CMA presentations centered on the energy transition debate and a publication in the journal Applied Energy, "Future prospects for nuclear power in France", Vol. 136, 31 December 2014, pages 849 to 859. In 2015, the Ministry for the Environment, Energy and the Sea appointed Nadia Maïzi as a member of the expert committee on the energy transition. This committee was formed to advise on carbon budget and low-carbon strategy projects, respect for established carbon budgets, projects involving multi-annual programming of energy in mainland France and non-interconnected zones, and on implementing this programming before the first period of the current programming comes to an end.

To accompany this expert mission, a new thesis was initiated in early 2016 at the CMA with Ariane Millot to explore decarbonation levers at national level and evaluate the energy transition question. This thesis explores the conditions for stemming the rising trend of greenhouse gas emissions at national level. These questions are being tackled from different perspectives, both in terms of state policy, and also by considering the impact of solutions initiated at other levels by civil society (e.g. companies, associations, citizens). In parallel, the research work should evaluate the objective conditions for transition, employing analogies derived from other contexts (physical and social sciences), looking at lessons learned in other European countries, and taking a retro-prospective approach (from 1970 to the present) on the scale of France.



## Decision aid for the tertiary sector

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### SmartEnCo project

#### Project managers

**Valérie ROY**  
**Gilles GUERASSIMOFF**

The SmartEnCo project involves devising a decision-making tool for reducing energy and water consumption and CO<sub>2</sub> emissions in tertiary buildings and small-scale industries. The project is piloted by IZYPEO in Sophia Antipolis, a start-up launched in 2010 that produces WEB solutions for environmental performance. The project partners are WIT, located in Saint-Laurent du Var, which devises Building Energy Management Systems, and ActaConsult, a Nice-based engineering firm specializing in sustainable development. The CMA's role is to develop innovative algorithms to improve control/command management of this type of building, and to give personalized advice on how to continue improving buildings' environmental performance. Two experimental sites have been set up, one at the technical department of the town of Antibes, and the other at Marineland aquatic park on its Kid's Island site.

A doctoral thesis began at end 2015/early 2016 with the start-up Homepulse (formerly WattGo), which specializes in energy services using data flows and works in particular on disaggregating residential sector load curves. Elise PUIPIER is responsible for modeling the dynamics of household electricity consumption in relation to exogenous variables collected from a very detailed questionnaire sent to a representative panel of the French population coupled with a highly sampled measurement of global consumption. The aim of this modeling is to appraise sources of energy saving in households.

## International issues

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### Bioenergy sectors and water conflict

#### Project managers

**Nadia MAÏZI**  
**Sandrine SELOSSE**

A doctoral thesis entitled, "The bioenergy market and water conflicts: implementation in the integrated model TIAM-FR" was initiated in 2014 under the direction of Sandrine SELOSSE as part of the CMA's prospective modeling research program. Seungwoo KANG's research concerns the increasing development of bioenergies to combat climate change and the depletion of fossil resources. This calls for a tool capable of reliably and pertinently evaluating the role of these resources and the associated technologies. TIAM-FR (TIMES Integrated Assessment Model) is such a tool, and its first task was to evaluate as accurately as possible the potential for deploying bioenergy globally, as well as regionally, while considering the geopolitical and commercial challenges of international trade. Mr. Kang worked on adapting the model to give a more detailed representation of biomass resources, including a disaggregation of the biomass industry and a new estimation of the potential taking into account agricultural land areas and production levels. In terms of crops, this detailed breakdown made it possible to apply specific biofuel policies while limiting, for example, the use of food resources to energy purposes and thus avoiding any conflict with food security issues. The initial focus was the Asian zone constituted by

China, India, Japan and South Korea, and this was the subject of a publication in the journal Energy Strategy Reviews (<https://hal-mines-paristech.archives-ouvertes.fr/hal-01234013>). The thesis then continued with an analysis of bioenergy exchanges, which were implemented in the TIAM-FR model. This study was presented at the 24th European Biomass Conference & Exhibition in Amsterdam and at the 70th Semi-annual ETSAP Workshop in Madrid. In addition, the partnership with the World Energy Outlook (WEO) team of the International Energy Agency (IEA) was renewed in 2016, consisting in a methodological study of calculating forest potentials. The collaboration also led to an analysis of the evolution of biomass in developed countries, and Europe in particular. This involved studying final domestic equipment that consumes bioenergy broken down into type of household, along with types of domestic biomass and their evolution in terms of consumption broken down into type of household. In a second stage, using data supplied by IEA, a study was initiated to determine the variables that explain changes in energy choices in developing countries, with the aim of discussing the regional tensions that can arise as a result of limited biomass in the long term.

## International issues

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### Conflicts over materials

### Project managers

**Nadia MAÏZI**

**Antoine BOUBAULT**

Research was carried out in 2016 and early 2017 by Antoine BOUBAULT to quantify material resources for low-carbon electric production in 2100.

In response to climate change, decarbonating the means of production is viewed as an opportunity to combine a lower environmental impact with economic growth. However, building a zero-carbon world by 2100 will require huge quantities of energy and materials. The TIAM (TIMES Integrated Assessment Model) model is used in this project to generate materials consumption scenarios, employing either a business-as-usual (BAU) scenario or a Paris Agreement scenario using a database for Life Cycle Assessment. This original approach makes it possible to combine information on requirements for raw materials, and shows that the energy system needs much higher quantities of resources in the Paris Agreement scenario, and in particular when numerous raw materials become potentially critical for the electricity sector, and when photovoltaic solar, wind, hydraulic, geothermal and nuclear are associated with technologies that require huge quantities of materials, especially for their infrastructures. While most energy prospective models ignore the influence of raw materials, this analysis shows that the resulting energy systems can lead to unrealistic energy system scenarios. A prospective modeling that takes up the principles of industrial ecology could however result in a more reliable analysis of policies aimed at curbing the consumption of raw materials. Some difficulties persist, such as the scant availability of data on flows and stocks of materials, and the absence of a strict framework to compare life cycle inventories of technologies. This research will be presented at the conference, “Mineral Prospectivity – current approaches and future innovations” organized by BRGM.





## Informing technologic choices

### Smart grids and renewable energy

#### Project manager

#### Nadia MAÏZI

In partnership with SCHNEIDER ELECTRIC, these studies continue the work done on integrating spatiality to evaluate issues regarding the use of the electricity grid in a long-term prospective based on models from the TIMES family. The first studies of this grid integration involved making electricity system reliability evaluations compatible with the time dynamic associated with long-term prospective exercises. Supply reliability evaluates an electricity system's capacity to guard against operating incidents, and is characterized by the voltage plan and the frequency, whose characteristic times range from a few milliseconds to a few hours. In contrast, long-term prospective exercises focus on how energy systems evolve over several decades, and do not deal with reliability. Electricity systems proposed on the prospective horizon may therefore no longer guarantee reliability, which is all the more crucial since the massive integration of renewable energy could work to the detriment of reliability, because of the complexity of managing intermittence. We developed two reliability indicators to quantify in an original way electricity systems' reliability according to the associated production mix. The interest of these indicators was illustrated for Reunion Island, which has set a target of producing its electricity from 100% renewable energy by 2030, then for France by 2050. To fully tackle the question of wide-scale integration of intermittent renewable sources, we also need to know the type of deployment adopted for net-

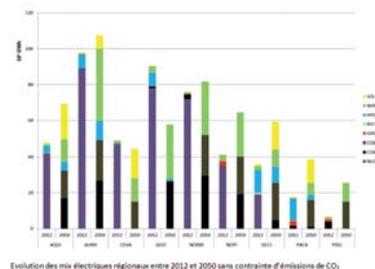
work infrastructures: this choice involves differentiating a standard meshed vision of the centralized electricity system from a decentralized vision. Vincent KRAKOWSKI's thesis, started in late 2012 and defended on 6 December 2016, aimed to integrate items linked to spatiality into TIMES models in order to add to and extend previous approaches.

These studies were presented at around fifteen international conferences and were filed for patent at the end of 2011, extended in late 2012.

They were also the object of a reliability analysis extended to cover the French system for the annual United Nations conference on climate change in Durban, and for the Energy 2050 Commission, mentioned above.

A thesis was initiated in October 2014, supervised by Edi ASSOUMOU, on "transitions and interactions of energy systems in multi-scale models".

Multi-scale models are manipulated to understand the issues and constraints created by the transition of local energy systems and for sensitive zones in the grid. Both spatially and temporally, system behavior, problems and challenges are different depending on the scale. The aim of the doctoral research carried out by Jérôme GUTIERREZ is to identify these divergences in order to characterize transitions and interactions in energy systems at different scales.





### Vincent KRAKOWSKI's thesis, defended on 06/12/2016

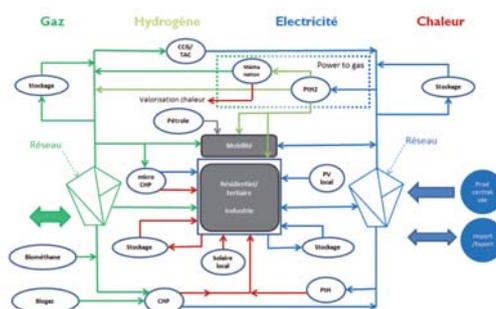
Power systems are currently facing several issues in order to evolve and integrate less carbon-heavy, and potentially more local, production. Prospective model-based analysis is a precious tool for exploring the possible long-term developments of these systems and comparing their advantages and disadvantages. However, to ensure relevance, it is important to reconcile the spatial and temporal phenomena that occur at various scales. Power system management depends on constantly maintaining a complex supply-demand balance. Meeting this challenge requires anticipating demand variations and power plant availability, combined with regulation systems to resolve remaining discrepancies. These regulations are activated in from a few seconds up to several hours. On shorter timescales, power systems show inherent robustness: the power grid creates an electromagnetic coupling between synchronous machines allowing them to share their inertia. This inertia, which takes the form of kinetic energy, is instantaneously available to face natural demand or supply fluctuations. To ensure that proposed long-term scenarios are consistent with the robustness requirements of power systems, which enable their management, this robustness must be assessed using prospective modeling. In this work, we propose an indicator, calculable within prospective studies, which assesses power system stability, namely its ability to return to synchronism after a perturbation. This indicator is based on an aggregated description of the transportation power grid and describes the electromagnetic coupling brought by the power grid. When combined with a bottom-up model from the MARKAL/TIMES family describing the French power system, this synchronism indicator, along with another indicator quantifying the available kinetic reserve, enables us to assess the consequences of renewable penetration, especially in terms of power system robustness.

## Prospective analysis of multi-energy flexibility solutions

### Project managers

**Nadia MAÏZI**  
**Edi ASSOUMOU**  
**Sophie DEMASSEY**

Rémy DOUDARD began a doctoral thesis in October 2015, in partnership with GRTgaz and directed by Nadia MAÏZI, Edi ASSOUMOU and Sophie DEMASSEY. The aim of this research is to evaluate the impact of flexibility solutions (power-to-gas, power-to-heat, demand response, storage) over the long term, taking a prospective approach combined with its optimal paradigm, in order to make appraisals and choices regarding the efficiency of the proposed solutions. The focus will be on the role that natural gas plays in the flexibility of the energy system. GRTgaz is currently involved in several pilot projects involving natural gas and hydrogen.





## Extending knowledge of systems

### Behaviorial paradigms

### Project managers

**Nadia MAÏZI**  
**Edi ASSOUMOU**

### Research on “Degrowth”

In late 2015, François BRIENS defended at thesis directed by Nadia MAÏZI on a prospective modeling and macroeconomic study of Degrowth societies. The notion that dominant economic growth is an end in itself or a necessary condition for “development” has been increasingly put into question by socio-economic, democratic and environmental challenges. Since the early 2000s, the ideas behind “Degrowth” have been the subject of increasing attention and lively debate. Supporters of the concept suggest ways of moving towards “frugal abundance” societies. Using a prospective exercise combining participative scenarios and numerical modeling, this research sheds light on the debate.

After reproducing Degrowth in a historical context and detailing the underlying concepts, BRIENS worked with a series of interviews to establish Degrowth scenarios for France. His innovative and original approach was to develop a specific input-output model for the long-term exploration of potential implications in terms of jobs, public finance, energy consumption, atmospheric pollution and waste production for each scenario.

### Lifestyle exploration

Thomas LE GALLIC started his research in December 2013, to explore how lifestyles develop in energy-climate prospective exercises, supervised by Nadia MAÏZI and Edi ASSOUMOU. The aim is to propose a methodological development with a view to understanding the socio-economic reality of breakdown hypotheses associated with lifestyle. This will enrich representations of socio-economic mutations, which are often inadequate in standard prospective exercises, and will allow us to employ transition hypotheses that are rarely explored for want of tools or suitable methods. This is because lifestyles describe behavior patterns that are essential determinants of energy consumption and greenhouse gas emissions (relating to e.g. consumption patterns, time and space relationships, types of leisure, mobility habits and types of cohabitation). This thesis, which is due to be defended in 2017, is partnered by ACTeon, a consultancy and research firm specializing in environmental policy. The research has been presented at a number of symposia, including in July 2016 at the ISDRS Conference in Lisbon, where Thomas LE GALLIC won first prize for the best paper.



After brilliantly representing PSL/MINES ParisTech at the competition “My thesis in 180 seconds”, organized by the CNRS and the CPU in April 2016, CMA doctoral student Thomas LE GALLIC attended the ISDRS (International Sustainable Development Research Society Conference) in Lisbon in July, where he won the prize for best paper. The winning article was co-written with Edi ASSOUMOU and Nadia MAÏZI, and entitled “Investigating long-term lifestyles changes in France: a statistical and modeling approach.” The text is available on the HAL website at: <https://hal-mines-paristech.archives-ouvertes.fr/hal-01355927>

## Modeling energy consumption

The CMA is continuing its work on the issues of household precariousness in the face of options to reduce CO<sub>2</sub> emissions in the coming decades. These studies were initiated by Jean Michel CAYLA's research, which integrated household behavior into a long-term approach, as part of his thesis defended on 3 March 2011, entitled "Households under carbon constraint. Prospective modeling of the residential and transport sectors using TIMES". Supervised by Nadia MAÏZI, J-M. CAYLA developed a TIMES-type bottom-up optimization model centered on the residential and transport sectors: TIMES-households, integrating a highly disaggregated representation of households that produced much more robust results than the standard approach based on average households. This achievement made use of an original questionnaire devised by J-M CAYLA and sent to 2,000 households, which for the first time crossed energy consumption behavior in residential and transport usage. These studies highlighted the constraints facing households and their energy choices, in terms of cost and comfort. The creation of a carbon tax to reduce greenhouse gas emissions, and its combination with targeted subsidies, have the effect of limiting the distorting impact on household budgets. This research was the subject of several publications. Continuing with this work, Elena STOLYAROVA worked on a thesis entitled "Modeling household energy consumption and investment strategies", supervised by Nadia MAÏZI and H  l  ne LE CADRE, in partnership with EDF R&D. The aim of this research was to understand how households behave in terms of managing energy, and in particular their investment strategies for heating systems (electricity, wood, gas, etc.). The thesis was defended on 7 April 2016 at MINES ParisTech, 60 Boulevard Saint Michel, Paris.



Few studies to date have centered on French households' energy preferences in terms of energy renovations in the home. Yet, these are crucial to establish an efficient, realistic energy policy for the residential sector, both in terms of potential aid and targets. Are households interested in renovation work with high energy-saving potential? How much are they ready to pay and is it enough to cover the actual costs? How many households have no choice of heating system and what is their profile? The thesis attempted to answer these questions in an empirical way using discrete choice models. The first step was to analyze the technical, socio-demographic and spatial constraints that households face and that can potentially interfere with energy choices in the home. A method for detecting constrained households was developed and then applied to heating choices in 2006 and 2013. It shows that the number of potentially constrained households went from 49% in 2006 to 17% in 2013 and that access to the gas mains is the greatest constraint. In addition, constrained households find themselves equipped with standard heating systems (boilers or direct electric heating), whereas non-constrained households are almost equally likely to adopt the different types of heating available, including wood stoves and heat pumps. The second phase involved studying household preferences for heating equipment and renovation work. This second part used an unprecedented experimental survey specially devised for the research and sent to 2,000 households. The aim of the survey was to reproduce the choice situation to ascertain comprehensive information that is not available from standard surveys. The work shed light on household preferences in the absence of constraints and their heterogeneity. Several economic indicators were deduced from the functional form of the model, i.e. implicit upgrading rates, consent to pay, and reservation prices. The study thus showed that French households are ready to invest twice as much in insulation as they are in heating improvement works. This preference is all the greater when the households concerned experience thermal discomfort. We also observed that households are interested in new energy-efficient technologies, such as renewable energy, heating pumps and smart heating management. Lastly, the preference study reveals two obstacles to developing new technologies: the first is that the preference inertia increases with the age of the respondent; the other is that on average the sums that households are prepared to invest do not always cover the actual market prices. For example, an average household is ready to invest a maximum of around €5,500 on improving their heating system, while the cost of fitting a highly efficient heat pump is €13,500.



# SMART CITY

The CMA's expertise in real-time computing, energy system optimization and long-term prospective make it well placed to understand the challenges raised by intelligent networks. The Center is active in several major programs on this theme. The CMA is involved in a number of projects relating to sustainable towns and transport, optimization of the demand response in water supply networks and data centers, and the optimal sizing of a micro-grid that takes uncertainties into account.

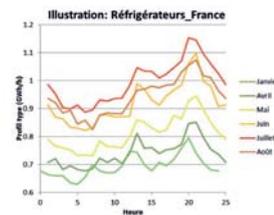


## ANR SUD project

### Project managers

**Nadia MAÏZI**  
**Edi ASSOUMOU**

Since late 2013, the CMA has been participating in a new ANR project called "Dynamic Urban Systems" as part of the Sustainable Cities and Buildings program. Urban energy consumption depends partly on the numerical growth of inhabitants, and partly on the proliferation of urban requirements (in particular those connected to mobility and habitat). The objective of the SUD project is to evaluate their long-term structural dynamics over a multi-annual horizon while maintaining a detailed approach to the character of hourly-seasonal requirements and its impact on the operational constraints of urban systems. To do so, three main urban energy flows are considered: thermal energy flows, electric energy flows, and passenger flows in private cars for everyday journeys. The SUD platform being developed will make it possible to simulate the different technical measures (PV, electric vehicle, storage) or price-based ones on an urban scale. The 48-month project is led by CITERES, which is the coordinator, LET, IFSTTAR, ENERGIES DEMAIN, ARMINES, INNHOTEP, ENIA and LEMA. The role of the CMA is to propose a method to evaluate seasonal time-of-day electric load curves at an hourly rate per usage.



## Water / energy issues

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### Optimizing water supply systems

#### Project manager

**Sophie DEMASSEY**

The optimization of water supply networks is a flourishing research domain that goes hand in hand with several concomitant factors, such as increased water consumption, which entails creating new networks; gradual deterioration of installations, which require renewal; rationalization of installation costs and energy consumption, which involves detecting leaks, automation and more efficient use of pumps; and changes in the electricity supply, with the integration of intermittent energy sources and fluctuating prices, which calls for careful management of pumping.

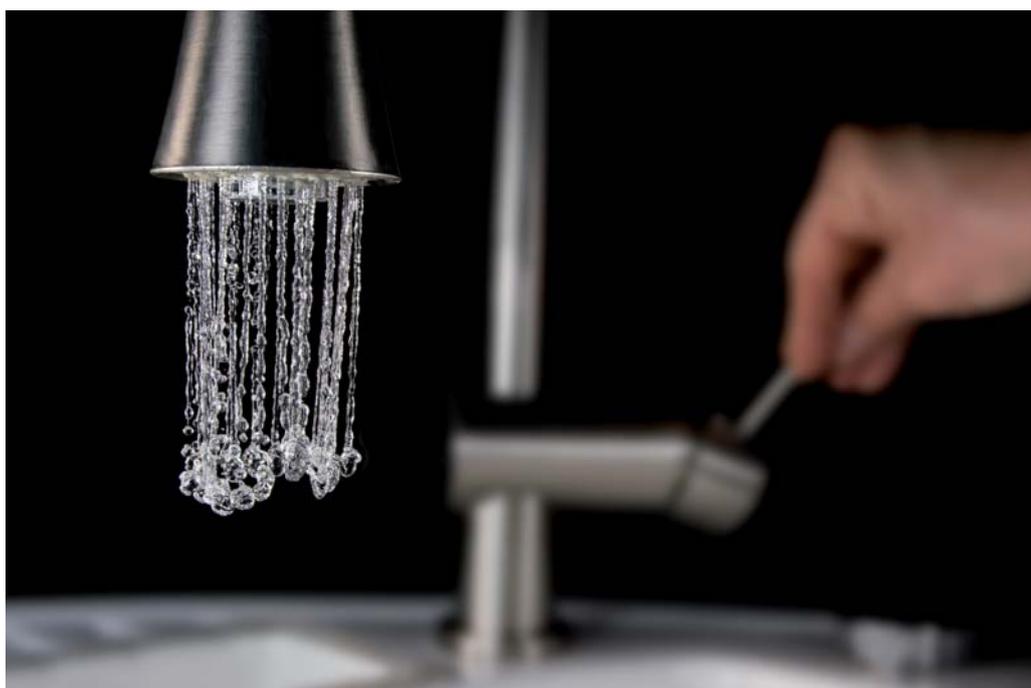
Mathematical programming is the preferred approach and applies to all time scales. However, two problems stand out in published studies: at a strategic level, the sizing of gravity-fed networks and, at operational level, the planning of pumping station operations. Due to their algorithmic complexity, the two problems are studied separately. They are however intrinsically linked in practice: the conveyance of drinking water is more likely to be backstreamed than gravity-fed, and the daily programming of a pumping station depends on its size.

The thesis that Gratién BONVIN commenced in December 2014 aims to develop an integrated, optimization approach to water supply systems from short to long term, going from the real-time management of a network up to its design.

The result is a new, quadratically constrained convex programming model for “day-ahead” planning. Testing at a major rural pumping station in France has demonstrated clear benefits in comparison with the current manual operation, i.e. operational, automated pumping plans; substantial energy and financial savings (on average 15% of the electricity bill); a pressure drop in the network and thus fewer leaks in the pipeline. The work has been the subject of a first publication [Bonvin et al., A convex mathematical program for pump scheduling in a class of branched drinking water networks, Applied Energy (2017)].

Following its success, we have worked on a new, even more efficient, purely linear model based on pre-calculating flow dynamics in the network for all possible pump configurations.

Given the effectiveness of these optimal control solutions, we are working on an innovative way of integrating them into mid-range optimization solutions (e.g. choice of electricity supply contract) and long-term solutions (resizing the network), taking into account the operating costs of active elements in the network.





**Water / energy issues**

**ETSAP project (ECN-CENSE)**

**Project manager**

**Sandrine SELOSSE**

In 2016, CMA took part in the project, “Enhancement of ETSAP E-TechDS database with cooling technology parameters for power plants” financed by ETSAP (IEA) and led by ECN (Energy research Centre of the Netherlands) with the participation of CENSE (Center for environmental and sustainability research, Portugal). The background to this project stems from the fact that energy systems and water resources are fundamentally connected: we cannot manage either separately because the availability of one affects the availability of the other. Thus, the decreasing availability of water will inevitably have an impact on the energy sector, which is growing. According to the OECD, the energy sector was responsible for 15% of freshwater withdrawals worldwide in 2010. In 2030, global demand for water, including energy, is likely to exceed supply by around 40%. At least one third of this demand will be connected to bioenergies. The water footprint generated by different energy sector technologies

could therefore become a competition issue. The energy sector names water as one of the six key themes that will define its future, and it is increasingly important to evaluate the physical, economic and environmental feasibility of energy projects. To analyze the future deployment of technologies and policies in the energy sector, the water-energy nexus needs to be tackled, and modeling tools will need to be developed to do so. The ETSAP Energy Technology Data Source (E-TechDS / <http://iea-etsap.org/index.php/energy-technology-data>) is a series of technical data sheets that provide information on a full range of energy technologies involving a number of technico-economic parameters. However, information is still lacking on the technologies’ water consumption. This project aimed to fill this gap, enriching the E-TechDSs with different technologies for cooling electricity plants and their principal characteristics in the context of electricity production.

**M.U.F.F.I.N.S project**

**“Mesuring nUDges’ eFFicacy in reduclng eNErgy conSUmption”**

**Project managers**

**Ankinée KIRAKOZIAN**  
**Sandrine SELOSSE**  
**Gilles GUERASSIMOFF**



As part of the MUFFINS project, led by GREDEG (University of Nice Sophia Antipolis / CNRS) and financed by Academy 5 of IDEX Côte d’Azur University, CMA carried out an experiment to test and compare the effectiveness of different types of nudge policies to reduce company employees’ energy consumption. This energy-saving project is financially and environmentally crucial given the current context of increasingly scarce resources, climate change and pollution. Public policies have been developed in this area (taxes, energy consumption standards, subsidies, green certificate markets, etc.), but in the field of behavioral economics, the main focus has been on the often-complementary use of “nudge” policies. A nudge is a form of public policy that aims to change individuals’ behavior without employing financial incentives (taxes) or obligations (standards), but rather by informing people to encourage them

to comply with the chosen behavior. The objective of the MUFFINS research project takes up this behavioral economics perspective, employing a field experiment to analyze the impact of nudges relating to employees’ energy consumption. This work is original in two ways. First, the targeted public is unusual insofar as existing studies are aimed only at households. This experiment looks at employees in their place of work, i.e. a situation in which they are not responsible for the energy bill. Secondly, while most studies focus on one type of nudge per experiment, this experiment tested three. The investigation involved French companies and the data collected was then subject to statistical and econometrical processing to determine the effectiveness of different nudges on saving energy.

## **Robust optimization of a micro-grid**

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### **Project manager**

**Sophie DEMASSEY**

How can we determine the size of electricity facilities, including different sources and energy storage components, so as to keep investment and operation costs to a minimum over a 20-year lifespan, and given the uncertainties of how demand and the production of intermittent sources will evolve over that period? To answer this complex problem, Aurélien HAVEL, a graduate of the OSE 2015 program, set up a generic solution of robust optimization, based on the Lagrangian relaxation of a linear program into whole numbers, integrated into a comprehensive web service including the specification of upstream instances and the visualization of solutions calculated downstream. Dimitra IGNATIADIS then improved both the calculation complexity and the modeling detail by implementing a multi-period investment-planning model instead of an annualized sizing model.

## **Optimized management of data centers**

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### **CMA project manager**

**Sophie DEMASSEY**

The high energy consumption of data centers is increasing in line with their expansion. Although technological progress has made it easier to master this consumption, astute operational management solutions are also required to bring down the energy bill while maintaining a high level of service for users.

The CMA is working on devising this kind of solution in partnership with the SCALE team at Nice Sophia Antipolis University as part of the EU project DC4Cities ([www.dc4cities.eu](http://www.dc4cities.eu)).

The constraint programming model developed adapts the functioning of tasks over a one-day time horizon depending on both the variable production forecast of renewable energy sources and the level of service contractually required by customers. These conflicting criteria are brought together in the single target of minimizing energy costs and financial penalties connected to the service. The prototype is available on the DC4Cities download platform. The work has been the subject of a publication: [Hermenier et al. Scaling Energy Adaptive Applications for Sustainable Profitability, in Proceedings of Euro-Par'17, LNCS (due for publication)].



## SYSTEM



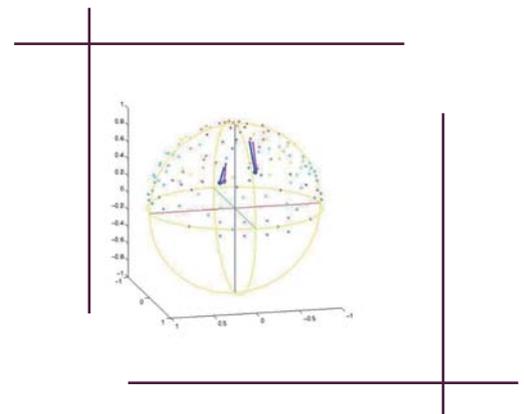
### Inverse problems, applications in medicine and geophysics

#### Project manager

**Jean-Paul MARMORAT**

In collaboration with INRIA's APICS and ATHENA projects, the CMA is tackling a class of inverse problems concerning the detection of mono- and dipolar sources. Data are constituted through isolated measurements of a potential, carried out at the frontier of a particular 3D domain. The unknown factors are the positions and moments of sources inside the domain that generate this potential. Outside these sources and inside the domain, the potential verifies a Laplace equation. In biomedical applications, the domain is the cranium, the potential is electric or magnetic, the sources are epileptic focuses, and the measurements are thus electro- or magnetencephalograms. In geophysical applications, the domain is the Earth, the potential is gravitational, and the sources are inhomogeneities of matter, and so we measure fluctuations in potential in comparison with the reference potential. This ill-defined problem is tackled using 2D rational approximation methods in different cut planes. The singular lines of the approximants can be used to go back to the original positions. These methods are being tested on simulated and real data. An APP software program has been filed for patent: FindSources3D <http://www-sop.inria.fr/apics/FindSources3D/fr/index.html>

A partnership was initiated in 2013 with the German company BESA (Brain Electrical Source Analysis) to undertake joint research on the subject and use the source location software. The project continued in 2014 and the software is currently in a phase of consolidation and transcription into C++. An article on this research was submitted in 2016 to Rendiconti dell'Istituto di Matematica dell'Università di Trieste: "Uniqueness result for an inverse conductivity recovery problem with application to EEG", Maureen Clerc, Juliette Leblond, Jean-Paul Marmorat and Christos Papageorgakis. [https://www.openstarts.units.it/dspace/bitstream/10077/13164/1/17\\_RIMUT48.pdf](https://www.openstarts.units.it/dspace/bitstream/10077/13164/1/17_RIMUT48.pdf)



## SMART

## GRIDS

Given the significant changes in electricity production and consumption patterns, France needs to build intelligent electricity networks, or smart grids. Integrating new information and communication technologies into the electricity grid should make it easier to manage electricity consumption and production in the country.

In 2013, the government therefore initiated a study entitled Réseaux Electriques Intelligents de la Nouvelle France Industrielle (REI), coordinated by RTE's chairman, Dominique Maillard. Nadia MAÏZI, Professor at Ecole des Mines de Paris, represents the Institut Carnot on the project and ensures MESR correspondence. The research done on this project led to a 10-point road map designed to consolidate the French electricity and computing industries on new high-growth markets that create jobs.

Two of the ten action points set out in the plan are led by Nadia MAÏZI:

- The first of these is Action 3, which is to create an intelligent electricity network academy offering courses on smart grids to develop the industry in France and abroad. Work carried out on this project has resulted in an initial mapping of smart grid courses listed on the internet, and discussions and research on establishing a classification of courses under the REI label, including the production of a form.

- Action 9 involves defining the research and development strategy for deploying the French smart grid industry. The research carried out in this area has led to a number of R&D recommendations.

In April 2015, the plan was renamed the Think Smartgrids Association, presided by M. MONLOUBOU, Director of ENEDIS of which MINES ParisTech is a member. (For more information, see the association's website [www.thinksmartgrids.fr](http://www.thinksmartgrids.fr)).

Nadia MAÏZI has been appointed to the board and named Chairwoman of the training commission. The training commission, with active input from the CMA, has created a web application that lists and maps training courses featuring smart grids at companies and institutes in France. The aim of this list is to identify any training gaps in terms of smart grids, with a parallel evaluation of industrial requirements, and to inform students and companies who want to learn about smart grids.

In 2016, in pursuit of the same objective, the commission worked with industrial partners to list companies' requirements in terms of skills. In 2017, an accreditation scheme was set up for courses that fulfill the training and skills criteria established by the commission. In addition, a one-day event is planned for the end of 2017, devised to bring together industrials and academics and encourage synergies and partnerships. A call for smart grid proposals has been made to research laboratories and R&D teams at association member institutions and companies.

For more information go to: [www.thinksmartgrids.fr/formations](http://www.thinksmartgrids.fr/formations)





## MODELING



## DEVELOPMENT CHAIR

The Chair is co-directed by Nadia MAÏZI, Director of the MINES ParisTech Center for Applied Mathematics, and Jean-Charles HOURCADE, Director of CIRED (International Environment and Development Research Centre). For the period covering 2008-2013, it was granted a budget of 2.5 million euro. The Chair was extended in 2014 for another four years, still jointly directed by Nadia MAÏZI and Jean-Charles HOURCADE, with the following partners: ADEME, EDF, GRTgaz, SCHNEIDER ELECTRIC, and the French Ministry for Ecological and Inclusive Transition as associated partner.

### The Chair's objectives

The objective of the MPDD Chair is to create a driving force to facilitate decision-making in debates on scientific and technological issues related to energy-climate constraints. Responding to the energy, environmental and economic constraints that face industrials and state leaders making strategic choices, the MPDD's project centers on the following challenges:

- Ensure stronger presence from founding laboratories and their partners in important places of national and international expertise on sustainable development to work on the energy-climate issue, extending their current involvement at the Strategic Analysis Center (for France – thanks to initial support from the French Energy Council), the IEA (World Energy Outlook, Energy Technology System Analysis Program), OECD, the World Bank and the Intergovernmental Panel on Climate Change.
- Foster a prospective platform for aiding decisions involving economics-resources-climate on issues relating to energy and climate policies, industrial development and technological choices in a context of changing competition rules. This platform will gradually integrate connections between energy/climate and other key areas of the sustainable development challenge.
- Ensure international academic reach by running international symposia, publishing in expert journals (economics, management and applied mathematics), and organizing special editions of specialist journals (energy, environment, transport, water) on sustainable development themes.
- Set up funding programs for doctoral studies and training seminars that respond to the requirements of partner companies in the prospective field (raising awareness of the benefits of a prospective approach in carrying out their activities, extending and transferring competencies in the domain).
- Make up for the national shortage of a syllabus “on and through” a prospective approach.



## Development of TIMES prospective modeling tools

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### TIMES

#### Project manager

**Edi ASSOUMOU**

The long-term planning models resulting from the model family MARKAL/TIMES (MARKet ALlocation/The Integrated Markal Eform System) are at the heart of the chair's modeling activities. This approach is based on optimization of a technico-economic representation of the energy system. It is based on a methodological corpus being developed by the ETSAP (Energy Technology Systems Analysis Program), which is an international co-operation program run by the International Energy Agency, IEA. The CMA's geographical perimeters for this approach are France, Europe and the World. The CMA has invested in particular in developing the France model, which is unique, with constant developments and improvements since 2003. At the outset, the model was focused on the electricity question, but it has successively evolved to give an overall representation of the energy system, and then a refinement of certain sub-sectors and modules. These constant developments concern in particular biomass, the electricity sector, residential and transport sectors, and the revision of technological databases. The TIMES-France model can be used to evaluate for France the implications of different energy scenarios, such as factor 4, carbon value, and withdrawal from nuclear energy. Current investigations are centered on flexibility in multi-energy systems and the impacts of transforming the production system and life styles.

### TIAM-FR

#### Project manager

**Sandrine SELOSSE**

The CMA is also developing the model TIAM-FR (Times Integrated Assessment Model), which is the French version of the TIAM model from the ETSAP-TIMES family. TIAM-FR is used to develop carbon-constraint scenarios in order to identify the regional impacts of global commitments to reducing CO<sub>2</sub> emissions in different regions in the world (Paris agreement), including the weight of these carbon constraints depending on a region's level of development. More precisely, the aim was to determine how ambitious climate commitments are in terms of the target to limit the global temperature rise to 2°C and to establish the weight of this constraint at regional level, particularly between industrial, fast-emerging and developing countries. In parallel with these scenarios, technology deployment scenarios are being developed, such as carbon capture and storage, with the aim of debating the technico-economic plausibility of climate policies. This work has been the object of presentations at international conferences (IEW, EURO and ETSAP) and was the subject of a publication in the Cahiers de la Chaire Modélisation prospective (Working paper No. 2016-01-18) with a particular focus on how the development of these decarbonization solutions impacts water.

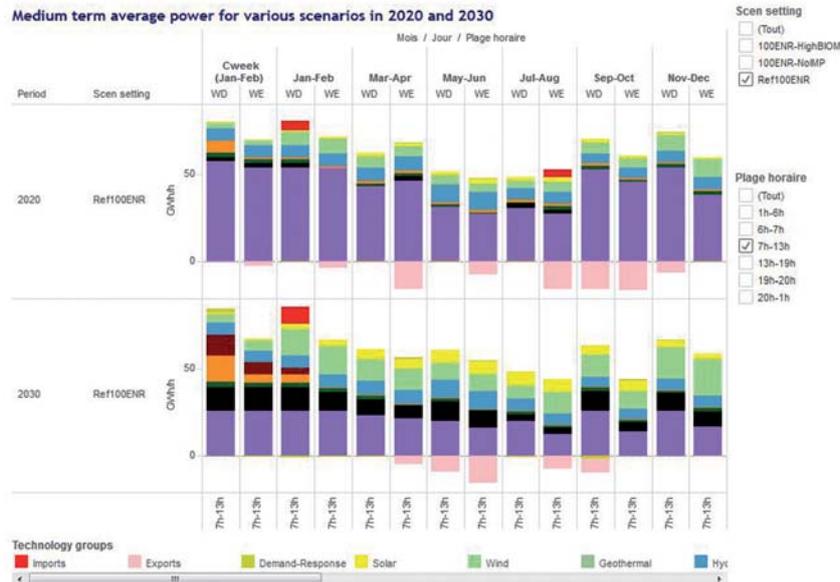


## Development of a centralized archiving tool for Markal/TIMES models: MCOPM platform

### Project manager

**Sébastien FOLIO**

The computer engineer Sébastien FOLIO is continuing the work he started in 2013 with Evariste CHAINTREAU on the MCOPM platform. This archiving tool stores the CMA's mathematical study models in a centralized database so that they can be preserved and used again. In addition to safeguarding data, the platform certifies the reuse and further exploitation of data, whatever system was used to generate them. One of the developments is a new data analysis tool for the center's models called "sensitivity study", which directly fits into the MCOPM platform. This tool automatically generates a considerable number of results by causing a variation in one of the model's parameters. The effects of this variation on the entire model can then be studied to understand its reactivity and limitations. In 2015, new results-processing tools were developed to resolve the issue of the considerable quantity of data generated. These tools can be used to automate studies and by researchers to create dynamic presentations of their results, which were published on the Chair's website in 2016.



## Prospective Modeling Platform

The objective of the Modeling Platform project is to enable modeling teams, administrative bodies and Chair partners to exchange and compare information gleaned from prospective modeling to facilitate public policies relating to the energy transition in France. Several seminars and workshops are organized each year: MPDD Chair seminars on the key challenges of modeling the low-carbon transition include working seminars and methodological workshops. Data, results and methodological choices are made accessible to illustrate the conditions for using models in their current stage of development and feed into discussions between modelers and users on the methodological obstacles to improve the tools.

Two seminars were organized in 2016:

### Seminar 1:

The technico-economic dimensions of transition, Scenarios for integrating renewable energy sources, Friday 13 May 2016, MINES ParisTech, Paris

On the agenda of this seminar chaired by Nadia MAÏZI (CMA, MINES ParisTech) (presentations in French):

- Anne-Laure DUBILLY, ADEME: Study of 100% RE Electricity by 2050
- Vera SILVA, EDF: Technical and economic analysis of a European electricity system using 60% RE
- Vincent KRAKOWSKI, CMA, MINES ParisTech: Scenario of 40% to 100% renewable: reliability and spatiality
- Counterpoints by Dominique FINON (CIRED): Questions on the economic and institutional conditions of extra-market development of RE with variable inputs

More information on this seminar can be found on the Chair's website:

<http://www.modelisation-prospective.org/fr/s%C3%A9minaire-1-dimensions-technico-%C3%A9conomiques-de-la-transition>

### Seminar 2 :

Macroeconomic and financial dimension of the transition, Modeling macroeconomic impacts (growth, employment) of the energy transition in a context of long-term stagnation, Tuesday 13 September 2016, France Stratégie, Paris

On the agenda of this seminar chaired by Nadia MAÏZI & Xavier TIMBAUD (OFCE):

- Terms of the debate on "long-term stagnation": Michel AGLIETTA (CEPII)
- Options chosen and potential developments in:
  - Three-ME (Frédéric REYNES, ADEME)
  - IMACLIM (Ruben BIBAS & Jean Charles HOURCADE, CIRED)
  - OECD-IAE/WEM (Jean CHATEAU, OECD)
- Counterpoints: potential links with technological dynamics: Nadia MAÏZI (MINES Paristech, CMA)

More information on this seminar can be found on the Chair's website:

<http://www.modelisation-prospective.org/fr/s%C3%A9minaire-2-dimension-macro-%C3%A9conomique-et-financi%C3%A8re-de-la-transition>



## The Chair's key conferences in 2016

DIDELOT Alice, MAÏZI Nadia, MAZAUURIC Vincent, ASSOUMOU Edi, SELOSSE Sandrine (2016), Balancing Energy Efficiency And Fossil Fuel : The Role Of Carbon Pricing, The 8th International Conference on Applied Energy, ICAE2016, 2016, Beijing, China. <hal-01439647>

KANG Seungwoo, SELOSSE Sandrine, MAÏZI Nadia (2016), Contribution of global CO2 emissions pledges to bioenergy market expansion: A long term analysis of bioenergy trade using TIAM-FR model, 24th EUBCE – European Biomass Conference and Exhibition, Amsterdam, The Netherlands, 6-9 June (poster et actes)

SELOSSE Sandrine and MAÏZI Nadia (2016), The place of Bio-energy with carbon capture and storage in the future Energy-Climate regime: a long-term analysis with TIAM-FR, 24th EUBCE – European Biomass Conference and Exhibition, Amsterdam, The Netherlands, 6-9 June (Actes indexés dans SCOPUS)

SELOSSE Sandrine, KANG Seungwoo, MAÏZI Nadia (2016), On the way to a decarbonized world: an analysis of the Paris Climate Agreement with TIAM-FR, The 35th Edition of the International Energy Workshop (IEW), June 1-3, University College of Cork, Cork, Ireland

ASSOUMOU Edi and SELOSSE Sandrine (2016), Technology transfer challenges, UN Climate Change Conference 2016, COP22/CMP12/CMA1, 7-18 November, Marrakech, Morocco; UNFCCC pavilion, November 7<sup>th</sup>.

MAÏZI Nadia, DIDELOT Alice, MAZAUURIC Vincent, ASSOUMOU Edi, SELOSSE Sandrine (2016), Impacts of fossil fuel extraction costs and carbon pricing on energy efficiency policies, International Energy Workshop, Jun 2016, Cork Ireland. <hal-01439703>

SELOSSE Sandrine and MAÏZI Nadia (2016), What energy system after the Paris Climate Agreement, EURO XXVIII, European Conference on Operational Research, Poznan, Poland, July 3-6

KANG Seungwoo, SELOSSE Sandrine and MAÏZI Nadia (2016), Methodological long-term analysis of global bioenergy potential, Working Paper, Les Cahiers de la Chaire, N°2016-03-21

POSTIC Sébastien, SELOSSE Sandrine, MAÏZI Nadia (2016), \*Energy sector contribution to regional climate action: The case of Latin America\*\*, \*Working Paper, Les Cahiers de la Chaire, N°2016-02-20

SELOSSE Sandrine and MAÏZI Nadia (2016), \*Exploring the biomass carbon capture solution to climate policy: A water impact analysis with TIAM-FR\*, Working Paper, Les Cahiers de la Chaire, N°2016-01-19

## Events organized by the Chair in 2016

### GRTgaz Chair MPDD Day 2016

Energy and our changing lifestyles.

Contributions of a prospective approach

Wednesday 14 December 2016 - MINES ParisTech, 60 boulevard Saint Michel, Paris

Energy-related questions are crucial to sustainable development issues, from energy security to climate change, including adapting to our constantly changing lifestyles, producing in a way that encourages local initiatives, and achieving more balanced land planning. In public debates, these issues sometimes take the form of contradictory messages and give energy sector stakeholders the challenge of making long-term decisions amidst a sea of uncertainties.

This one-day event attempted to show that it is possible, using prospective tools, to understand the mechanisms at work at the origins of possible futures rather than leaving them in the hands of rhetorical games. The work undertaken through this Chair shows how prospective models offer a safeguard against “visions of the future” deployed with no concern for internal consistency, along with a guide for public deliberation and business decisions. It looks at the connection between energy and lifestyles and the specific role of different energy sources, especially gas given its development and the economic and political determinants of the industry's future.

Find all the details on this event on the Chair's website:

<http://www.modelisation-prospective.org/fr/journ%C3%A9e-grtgaz-chaire-mpdd-2016>



## EDF-MPDD Chair Day 2016

Putting models and energy scenarios to good use

Thursday 28 January 2016, Salons Etoile Wagram, 6 Avenue de Wagram, 75008 Paris

With the participation of ADEME,

GRTgaz,

SCHNEIDER Electric

Ministry of Ecology, Sustainable Development and Energy

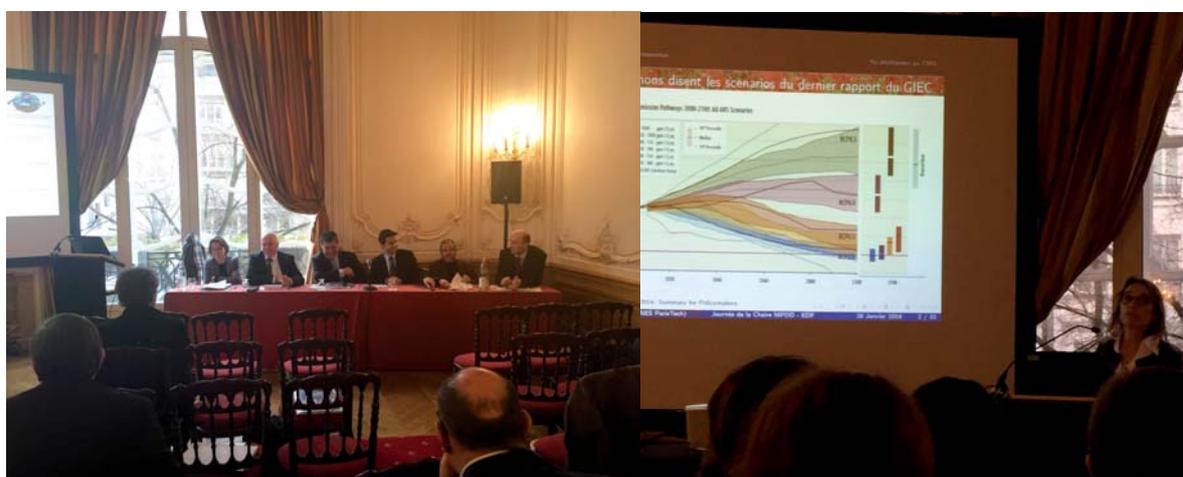
Find all the details on this event on the chair's website:  
<http://www.modelisation-prospective.org/fr/journ%C3%A9e-edf-chaire-mpdd-2016>

Increased calculation capacities have resulted in much more complex long-term models and an exponential growth in the number of available scenarios produced by academic networks for national and international institutions. But this proliferation, far from feeding into public debate or supporting the business world, is increasingly met with indifference, if not defiance. We consider, however, that associating numerical modeling with a prospective approach is crucial to inform decisions with long-term scenarios.

The objective of this one-day event is to organize a discussion between scientific communities and companies by looking at the fundamentals of a prospective approach, the development of modeling methods, and ways of using scenarios. One goal is to encourage a debate on the conditions for use of prospective tools by companies, either directly for internal requirements, or indirectly so that they can situate themselves in public debates. An important point is to clarify the connections between models, scenarios and prospective exercises.

We illustrate the use of prospective modeling by looking at diverse issues, such as:

- The technological possibilities for a “low-carbon” energy transition in the electricity sector in Europe ;
- The long-term determinants of energy demand: role of infrastructures, spatial dynamics and lifestyles ;
- Short-term/long-term links in the transformation dynamics of energy systems ;
- Breakdown of NDCs and emissions pledges in the different regions of the world (Europe, USA, emerging countries) ;
- The impact of gas and non-conventional oil on global energy equilibriums and the price of hydrocarbons ;
- Incentive effectiveness and economic and social impacts (competitiveness, employment) of different public regulation measures: carbon tax, EU-ETS ;
- The role of financial tools in triggering energy investments in an uncertain context.





**COP 22**

Marrakech, Morocco, November 2016

The Chair participated in COP22, which took place in Marrakech, Morocco, from 7 to 18 November 2016. A side event was organized entitled, “Combating climate change in the Mediterranean, Africa and the Middle East”, devised to highlight and analyze the challenges and complexity of planning low-carbon electricity systems in countries in the Mediterranean, Africa and the Middle East.

As a reminder, ParisTech participates as a RINGO (UN-observer Research and Independent Non-governmental Organization) at the United Nations Conference on Climate Change through its MPDD Chair and the Association of Sustainable Ecological Engineering Development (ASEED).

During this side event, the expert panel discussed how the region sees the future of its energy system in the context of the Paris Agreement. The lessons learned from modeling exercises and technological innovations illustrated the debate, which covered climate policies, regional integration, energy resources and the evaluation of ecosystem services.

Contributions were made by:

- Nadia MAÏZI, MINES ParisTech, France: Introduction
- El Hadi BENYOUSSEF, Ecole Polytechnique, Algeria: climate change and consequences in Algeria
- Edi ASSOUMOU, MINES ParisTech, France: Technological transfer issues
- Youba SOKONA, AREI (Africa Renewable Energy Initiative): Access to low-carbon energy in Africa – challenges and initiatives in the electricity sector post-COP21
- Samir AMOUS, APEX Conseil, Tunisia: An analysis of African INDCs: main characteristics and how to finance them
- Jui Wen CHEN, ASEED: JW Eco-Technologie – Carbon capture, anti-climate change, a new revolutionary type of green economy. A profitable solution to generate water in the desert.
- Jean Charles HOURCADE, CIRED, France: Conclusion

The side event was devised to offer a forum for quality discussions on the plausibility of future energy systems and the challenges of deploying them. It provided an opportunity to show how prospective modeling can effectively contribute to establish dialogue between decision-makers, experts and scientists. Beyond that, the event contributed to reflections on orienting public and private strategies in a process of supporting negotiations on climate.





**COP23 | FIJI**

**UN CLIMATE CHANGE CONFERENCE**

**BONN 2017**



6-17 novembre 2017

# CMA

## Center for Applied Mathematics



# ACTIVITY REPORT

# 2016

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