MINES ParisTech | PSL

ACTIVITY 2017

report

Centre for Applied Mathematics

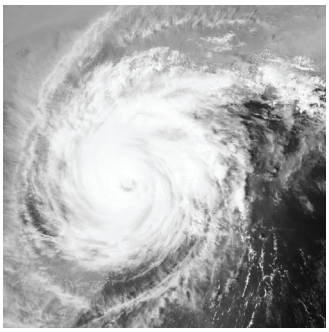
Sophia Antipolis

10 Chaire MPDD

dixième anniversaire

CHAIRE MODÉLISATION PROSPECTIVE au service du DÉVELOPPEMENT DURABLE





2008 - 2018



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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] and teaches the entire module on optimization and prospective.

I / Doctoral studies

II / Advanced Master's in Energy Systems Optimization, OSE

III / Key events of the OSE Advanced Master's in 2017

I / Doctoral studies

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

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 2017, the doctoral department comprised 10 students.

Derniers arrivants :
Mathieu Denoux, Carlos Andrade, Gildas Siggini, Paul Javal

Course director : Valérie ROY

II / Advanced Master's in Energy Systems Optimization, OSE

Course director: Gilles GUERASSIMOF

Academic partners

The CMA, which organizes the advanced Master's, has partnered with CREDEN (Centre de Recherche en Economie et Droit de l'Energie) 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/. The numerous and varied professional opportunities after the course include research engineer, project manager, energy purchaser, market analyst and risk analyst.

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.

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.

III/ Key events of the OSE Advanced Master's in 2017

16 February 2017
Two OSE Advanced Master's students winners of the CNF CIGRE smart grid contest

Two of our Master's students, Geoffrey Orlando and Quentin Souvestre, won the third student smart grid contest organized by the French National Committee of the International Council on Large Electric Systems (CNF CIGRE). Participants had to write an article of 15,000 characters on the theme, "How new technologies are likely to impact smart grid design and management". The final round of the competition took place on 16 February 2017 in Paris at the premises of RTE at La Défense. It was attended by several industrial companies that partnered the event: RTE, EDF, General Electrics, Gimélec, Siemens and Supergrid Institute. Geoffrey and Quentin received the first prize of €2,000 for their article entitled (in French), "Vehicle-to-Grid, a solution to reduce the impact of decarbonized mobility on the electrical system". They succeeded Mohamed Amhal and Cédric Anglade, also OSE Master's students, who won the contest in 2016.

March 2017, the class of 2016/2017 on a study trip to the USA

Following six months of training at the Center for Applied Mathematics, OSE Advanced Master's students go on a study trip. The experience gives the students an opportunity to discover a different view of energy systems. The class of 2016/2017 went to California from 4 to 13 March 2017 on a trip based on the theme of energy recovery from waste. The trip kicked off with a day at the Berkeley campus. The students were welcomed at the Berkeley Energy and Climate Institute where they made two presentations, one on optimal usage of a park of batteries, a subject proposed by the start-up Elum, and the other on the theme of recovering energy from waste. They went on to visit several sites during their stay, at the University of Stanford, All Power Labs, Altamont Landfill & Resource Recovery Facility, EDF Inc., EDF Renewable Energy, Puente Hills Landfill Gas-to-Energy Facility, Primus Power, San Francisco Public Utilities Commission, Scavenger Company, SMUD, and Total. The trip was jointly organized by Ankinée Kirakozian and Gilles Guerassimoff and proved highly instructive for students graduating in 2016/2017.

http://ose.cma.mines-paristech.fr/sites/ose.cma.mines-paristech.fr/files/files/p2016_Voyage_OSE_Californie.pdf

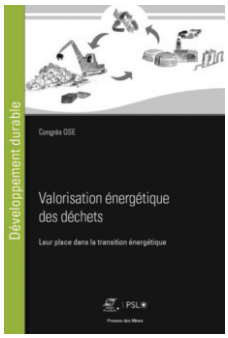
Late September 2017, New academic year for OSE students

On 25 September, the 18 new OSE students (class of 2017) started their course, while on Tuesday 26 and Wednesday 27 September, the graduating students defended their work.

Academic promotions 2016 and 2017

28 September 2017, organization of the OSE congress

On Thursday 28 September 2017, the 17th OSE event took place, jointly organized by OSE Master's students from the class of 2016 and the MPDD Chair. The congress, which took place at MINES ParisTech in Sophia, was on the theme of the energy transition through recovering energy from waste. Following an introduction by Marc Daunis, vice-president of CASA, the students presented their work on waste, policies adopted, recovery methods, and the future and challenges facing the sector. Two round tables were organized in the afternoon. The first was entitled, "Waste and territories – how can we reach targets for energy recovery from waste: what are the resources, recovery methods, and integration problems?" It was chaired by representatives from Véolia, Air Liquide, Pizzorno Environnement, Akajoule and GERES. The second round table, on "How networks can contribute to energy recovery from waste", was led by representatives from GRDF, GRTgaz and MiniGreenPower The full discussions feature in the conference proceedings published by Presses des Mines.



Find the whole discussions in the conference proceedings published by Presses des Mines

December 2017

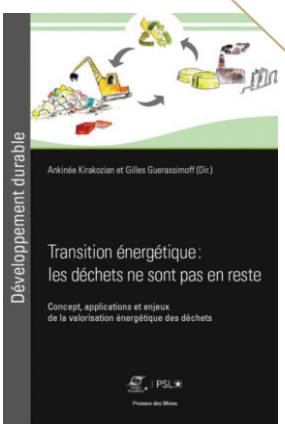
December 2017, students from the Ecole des Mines de Nancy spent three days working on a common module on, " Comparative analysis of energy sectors" and tutorial classes on modeling run by Sandrine SELOSSE and Edi ASSOUMOU, as part of the OSE Advanced Master's course. The agenda included long-term prospective optimization.

MINESnancy
ARTEM

Early 2018, publication of a book by the class of 2016/2017

This book presents the different methods for transforming waste into energy and looks at how these procedures are used around the world with a list of production volumes and types of waste elimination. The accent is on the environmental and economic impacts of the different electricity production methods known as direct methods. These include traditional direct methods (incineration, methanation), and more recent, experimental approaches (pyrogasification, energy recovery of CO_2 from micro-algae). In addition, the publication includes a description of indirect methods for recovering energy from waste (development of insulators, recycling of nuclear fuel, etc.).

The book makes an analysis of consumers' individual efforts to recover energy, and the principles and practices of industrial ecology for energy recovery in industry. It concludes with a critical assessment of energy recovery from waste (such as incineration and methanation), opening up new areas for reflection.



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), optimal management of complex systems (micro-grids, water supply systems, gas and electricity grids), electricity and carbon markets, and electrical systems integrating technologies related to renewable energy and smart grids.

I / Prospective et changement climatique

II / Smart city issues

III / System parameterization Inverse problems, applications in medicine and geophysics

IV / New research lecturer

V / Official accreditation to direct research

VI / Smart Grids

I/ Prospective and climate change

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.

Informing public policies

Decision aid aimed at ministries

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. 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 in 2011. The object of this academic exercise was to aid the Commission in its thinking process. The analyses and conclusions were published in 2012 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.

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.

This France model version led to a contribution to the work of the Quinet Commission launched in September 2017 whose object is to reevaluate a carbon value for France.

Decision aid for the tertiary sector

Axe DataScience (from short to long term)

Project managers: Valérie ROY
Gilles GUERASSIMOFF
Sandrine SELOSSE



In the same vein as the GridTeams, SmartEnCo and E3D-Environnent projects, and the work carried out with the company HomePulse (Ex WattGo), we are developing algorithms to improve energy management, in particular in buildings in both the residential and tertiary sectors.

Our approach is based on two major complementary lines. The first involves crossing the study of load curves and exploiting questionnaires allowing us to gather pertinent data on the state and rate of equipment of the buildings concerned. The other involves exploring incentive techniques (nudges) designed to integrate behavioral aspects into new predictive methods.

These two lines are based on the implementation of datamining techniques applied to big data. The temporal series and questionnaires include varied aggregated information that can be exploited by machine learning. In addition, the large-scale arrival of the Internet of Things (IoT) is opening up a field of complementary data that we aim to integrate into our approach.

Initial results in the residential sector based on data from the Powermetrix panel demonstrate the huge potential of data sciences. The integration of nudges, which we were able to test in an experiment carried out in the PACA region with the MUFFINS project (cf. infra) organized with Nice Côte d'Azur University (UCA) in the tertiary sector, confirms the interest of pursuing these activities. MUFFINS in fact demonstrated that some nudges offered to employees had a significant influence on their behavior regarding their energy consumption in the workplace.

Another objective of studying data from sensors is to come up with more pertinent scenarios in long-term prospective models. Integrating behavior into building management choices or into the influence of climate variations on the load curves of buildings (Projet Clim2power, cf. infra) are improvements that will boost the pertinence of our models devised to aid decision-making.

Live Cycle Assessment of the Energy System

ACVs energies

Project manager: Edi ASSOUMOU

The building sector alone represents almost half of the total energy consumption in France, and two-thirds of electricity consumption. All energy transition scenarios make the renovation of building stock a priority. Yet in "classic" life cycle assessments, fixed coefficients are used to evaluate the impact of electricity consumption over the duration of the project, despite the fact that the electricity system will evolve. To overcome this problem, different LCA methods will be proposed by this project. The options, which are applicable to electricity production or district heating, include attributional or consequential LCAs, static or dynamic LCAs, global or differentiated impacts per usage, impacts based on historical data, models or prospective scenarios, and the consideration of local production exported into the grid. With this in mind, the project aims to establish a methodology to integrate these developments into tools used in practice by building developers.

More specifically, the CMA will need to make a prospective evaluation of the LCA of electricity and gas grids subject to future thermal regulations affecting building developers.

The project, which is financed by ADEME, started in December 2017 and is due to end in late 2020.

The project partners are: Armines/MPT Centre Efficacité énergétique des Systèmes; École des ingénieurs de la ville de Paris; Armines/MPT Center for Applied Mathematics; IZUBA Energies..

International issues

Bioenergy sectors

Project managers: Nadia MAÏZI
Sandrine SELOSSE

Initiated in 2014, Seungwoo KANG's thesis entitled "The place of bioenergy in a low-carbon world: Prospective analysis and development of the biomass industry in the TIAM-FR model" fits into the CMA's prospective modeling research program. Directed by Sandrine SELOSSE, this PhD looked at the growing development of bioenergies to tackle climate change and the associated issues of energy system decarbonization. The main objective was to produce a tool capable of reliably and pertinently assessing the role of these resources at the different stages of the biomass process. TIAM-FR (TIMES Integrated Assessment Model) proved appropriate to assess the potential of deploying bioenergies at both global and regional level considering agricultural areas, productivity levels and conflicting land uses. The integration of international biomass trading and pre-treatment technologies into the model were key areas of this thesis, which in 2017 was the object of a third publication in a peer-review journal, International Journal of Oil, Gas and Coal Technology. The partnership formed in 2015 with the World Energy Outlook (WEO) at the International Energy Agency (IEA) continued in 2017 with an analysis of the evolution of biomass in developed countries through the study of final equipment of households that consume bioenergy by type of residence. The results of Seungwoo KANG's analysis were published in a WEO article in 2017.

SEUGWOOD KANG DEFENDED HIS THESIS ON 22 DECEMBER 2017

With growing concerns about the environment, countries are increasing efforts to reduce their fossil fuel dependency, the major source of greenhouse gas emissions, by replacing them with clean energy sources including bioenergy. Spurred by the Paris Agreement and climate change mitigation targets, bioenergy is being highlighted as a pathway to decarbonize society. This thesis concentrates on the perspectives of bioenergy development and aims to analyze the evolution of bioenergy production in view of policies, global exchange of biomass resources, and the sustainable use of bioenergy in the long term in a context of decarbonization of societies. In terms of analysis, the thesis focuses on improving the implementation of the bioenergy chain in CMA's global energy system optimization model, TIAM-FR. The manuscript is structured in four chapters. The first chapter presents the current position of bioenergy, bioenergy development strategy, and how these are integrated into our modeling approach. The second chapter presents the developments implemented on the bioenergy chain in TIAM-FR. The third chapter demonstrates our work on evaluating the potential of biomass resources. Lastly, the role of bioenergy in the climate change mitigation context is discussed on a global scale with a focus on four Asian countries, China, India, Japan and South Korea.

Conflicts over materials

Project managers: Nadia MAÏZI
Antoine BOUBAULT

Research was carried out in 2016 and 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 was presented at the conference, "Mineral Prospectivity – current approaches and future innovations" organized by BRGM and is the subject of a forthcoming article, «Closing the TIMES integrated assessment model (TIAM-FR) raw materials gap with life-cycle inventories» in the Journal of Industrial Ecology.

Climate change and electricity systems

Projet Clim2power

Poject manager: Edi ASSOUMOU

Clim2Power is a research project that aims to develop an online climate service capable of integrating seasonal meteorological forecasts into decisions made in the European Union electricity sector. In particular, the project seeks to make better use of seasonal weather forecasts to improve the management of electricity production. Electricity producers and commercial companies, electric system operators and regulators, energy consumers and water managers could all benefit from the results of this research project.

This European project, which comes under the European research area for climate services known as ERA4CS, started in 2017 and is set to last three years. The CMA's role is in particular to coordinate the development of a European electricity system model.

The project's partners are the University of Lisbon, Portugal; EDP-Electricity, Portugal; meteorological service, Germany; University of Natural Resources and Life Sciences, Austria; Vienna Energy, Austria; ARMINES/Mines ParisTech Center for Applied Mathematics, France; ACTeon, France; MINES ParisTech Observation, Impacts, Energy Center, France; University of Cork, Ireland; and Luleå University of Technology, Sweden.

A thesis was also initiated on this subject in late 2017. With research by Gildas SIGGINI under the supervision of Edi ASSOUMOU, its objective is to use a prospective optimization approach with a high temporal resolution to investigate potential evolutions of the European mix under a constraint of climate variability in different scenarios. The results will provide elements for reflecting on the pertinence of energy transition choices.

Informing technological choices

Smart grids and renewable energy

Project manager: Nadia MAÏZI
in collaboration
with Vincent MAZAURIC

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. Their development was initiated as part of the thesis written by Mathilde DROUINEAU on "Prospective modeling and spatio-temporal analysis: integrating electricity grid dynamics", which she defended in December 2011. The interest of these indicators was illustrated for Reunion Island, with Stéphanie BOUCKAERT's thesis: «Contribution of Smart Grids to the energy transition: evaluation in long-term scenarios» defended in December 2013. Its objective was a mix of electricity production employing 100% renewable energy sources by 2030, and by 2050 in France. To fully tackle the question of wide-scale integration of intermittent renewable sources, we also need to know the type of deployment adopted for network 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. Gondia SECK terminated this work as part of her post-doctoral research.

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.

Prospective analysis of multi-energy flexibility solutions

Project manager: Edi ASSOUMOU

To reach energy system decarbonization targets, a number of technological options exist, such as biomethane, syngas produced by power-to-gas, hydrogen, and CCS. In what situations could these sectors be developed to reach the targets? What are the competition/cooperation perspectives for these technologies?

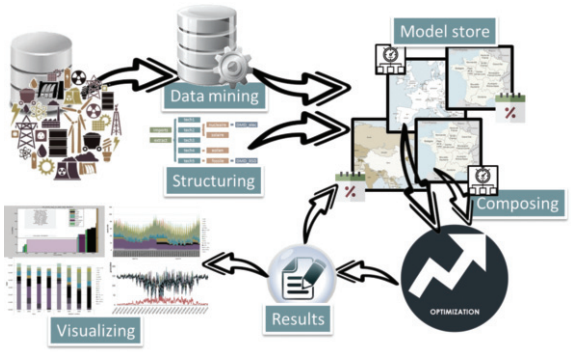
The objective of the thesis pursued by Rémy DOUDARD under the supervision of Edi ASSOUMOU is to make a prospective assessment of the positioning of these options up to 2050 in France, taking into account the resulting pathways and considering constraints of seasonal/intraday flexibility. The research began with the production of final demand scenarios in gas/electricity systems. The integration of possible vector substitutions (electricity, gas, hydrogen) for energy uses then provided the first elements for reflection.

The thesis, which was initiated in October 2015, is being carried out in partnership with GRTgaz, which has partnered the MPDD Chair since 2014. It is due for defense at the end of 2018.

Interactions of energy systems in multi-scale models

Project manager: Edi ASSOUMOU

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. This thesis will be defended in 2018.



Extending knowledge of systems

Behavioral paradigms

Project managers: Nadia MAÏZI and 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.

Exploring lifestyles

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 research was the object of a publication in 2017: Thomas Le Gallic, Edi Assoumou, Nadia Maïzi, "Future demand for energy services through a quantitative approach of lifestyles", Energy, Elsevier, 2017.

The thesis, which was carried out in partnership with ACTeon, a consultancy and research firm working on environmental policy, was defended on 21 December 2017.

THOMAS LE GALLIC DEFENDED HIS THESIS ON 21 DECEMBER 2017

Consumerist lifestyles in industrialized countries are considered to be one of the main reasons for the depletion of global resources and degradation of the environment. One of the keys to achieving a sustainable future is to bring about changes to these lifestyles, which are often pursued by particular economic classes in developing countries. However, until now, the lifestyles issue has been only marginally considered in public policies, including those aimed at addressing the challenges of energy transition and climate change mitigation. Our research was initiated to encourage all parties engaging with these issues to take future lifestyles into account. To this end, we focused on a prospective approach, which is one of the tools and processes most commonly used to support decision-makers in tackling long-term challenges raised by energy transition and climate change. We identified a lack of depth in foresight studies that address lifestyles, especially model-based studies. The models generally used in these studies do not allow for proper consideration of this multidimensional issue. In response, we propose a conceptual framework to develop our understanding of the lifestyle concept and clarify its role in the energy system. As a core contribution, we developed a modeling approach to simulate lifestyle-change scenarios for France. This formal approach allowed us to quantify the demands for housing, mobility, goods and services that arise in these scenarios, and define the structure of energy uses. Three scenarios for lifestyle changes are considered in the thesis to demonstrate the implementations of the proposed approach.

Modeling energy consumption

The CMA is continuing its work on the issues of household precariousness in the face of options to reduce CO_2 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 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.

II/ Smart city issues

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

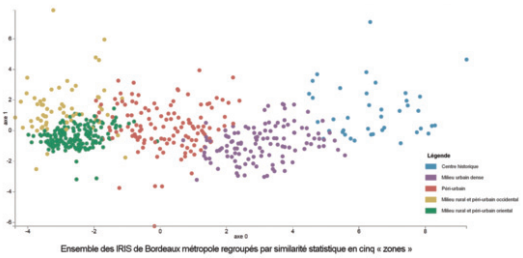
Project managers:
Nadia MAÏZI
Edi ASSOUMOU

Since late 2013, the CMA has been participating in an 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 (PVs, electric vehicles, 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. The project will be completed in mid-2018.

Contribution of prospective modeling to issues associating urban planning and energy

Project manager: Nadia MAÏZI

Urban planners in France make little use of available data in their approach to territory due to lack of time and skills in the domain and at planning agencies. To fill this gap, in October 2017 the CMA initiated a study in partnership with the urban planning agency Nicolas Michelin & partners. The thesis, entitled "The challenges of evaluating urban transformation scenarios that respond to energy/climate, social and cultural issues", is the work of Matthieu DENOUX under the supervision of Nadia MAÏZI. The research aims to develop the means to evaluate the impact of the different ways of transforming cities by studying quantitative and qualitative scenarios. Using prospective modeling techniques, the project works on constructing an optimization model to compare several approaches proposed by urban planners on a territory, from an energy and environmental, and especially social and economic, point of view. The work started by drawing conclusions from the abundant scientific literature on urban modeling and determining the themes and questions that interest urban planners and modelers, before building a prospective model on the chosen territory.



Water /Energy issues

Optimizing water supply systems

Project manager:
Sophie DEMASSEY

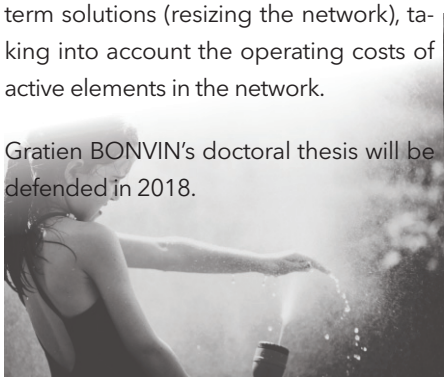
LThe optimization of water supply networks is a flourishing research domain that goes hand in hand with several concomitant factors, such as increased water consumption, which entails creating new networks; gradual deterioration of installations, which require renewal; rationalization of installation 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 Gratien 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. To deal with the complex dynamic optimization of management, original non-linear programming models and associated resolution methods were proposed. A first approach to convex programming with quadratic constrains applied to connected networks was tested at a large rural pumping station in France. Unlike the manual operation currently in practice, this alternative considers demand forecasts for the day ahead, resulting in substantial energy and financial savings (on average 15% of the electricity bill). It also reduces pressure in the network and therefore reduces leaks in the pipelines. The approach was then extended to regular distribution networks: the loss of non-convexity was compensated by a stronger relaxation and a generic approach of mixed resolution in the liner and non-linear programming, which when subject to an extensive empirical analysis, appeared to be more efficient than specific methods. Lastly, we designed a resolution heuristic that was considerably faster, based on a new linear formulation in continuous variables, resulting from 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.

Gratien BONVIN's doctoral thesis will be defended in 2018.



Water /Energy issues

ETSAP project (ECN-CENSE)

Project manager: Sandrine SELOSSE

2017 saw the end of the project, «Enhancement of ETSAP E-TechDS database with cooling technology parameters for power plants», which kicked off in 2015 and was financed by ETSAP (IEA). Led by ECN (Energy research Centre of the Netherlands), the CMA participated in the project 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.

The results of this project were also presented at an ETSAP workshop on modeling the water energy nexus in Zurich on 14 December 2017.

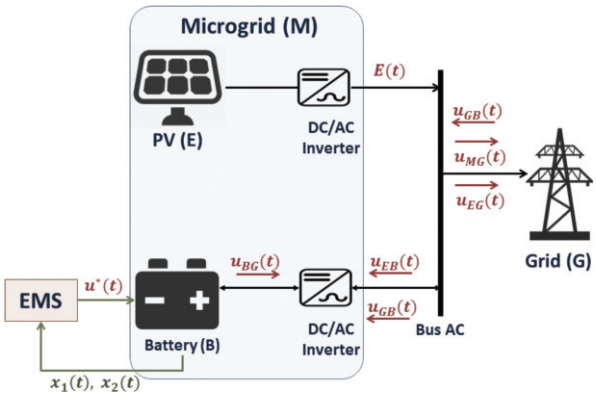
M.U.F.F.I.N.S «Mesuring nUdges' eFFicacy in reducIng eNergy conSumption» Project

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 the "Hommes, Idées et Milieux" academy of excellence at 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.

Piloting of a hybrid electricity production system

Project manager for the CMA: Sophie DEMASSEY



Hybrid systems associate various renewable resources (sun, wind); they deal with intermittence issues by employing storage technologies and purchasing electricity generated from non-renewable sources (electric networks or diesel generators). These systems therefore aim to supply the electricity grid or a local micro network with a daily profile of electricity production that takes into account weather forecasts. The strong development of hybrid systems has been accompanied by diverse software solutions, often developed on a case-by-case basis, devised to manage purchasing and storage operations in real time to bring down their costs while following the engagement profile as closely as possible. The ambition of the doctoral thesis by Arnold N'Goran, which began in February 2017 in partnership with Bertin Technologies, is to design and implement a solution that is efficient (in terms of optimal solutions and reduced response time), generic (or at least flexible and upgradable) and that integrates uncertainties on forecast data in a robust optimization approach.

Optimal and robust sizing of a micro-grid

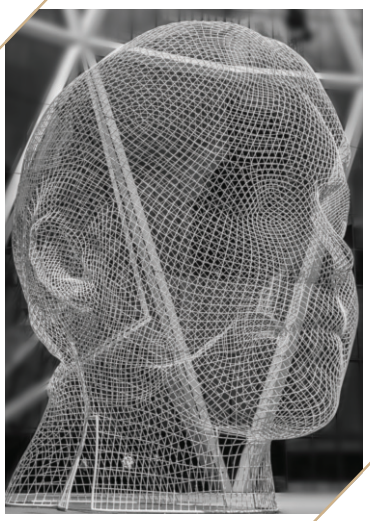
Project manager: Sophie DEMASSEY

The challenge here was to determine the size of electrical facilities, including different sources and energy storage components, so as to incur minimal investment and operation costs over its lifespan, and taking into account uncertainties regarding the evolution of demand and the production of intermittent sources over the same horizon. Two OSE Master's students were invited to tackle this complex problem. Aurélien HAVEL developed a generic robust optimization solution based on the Lagrangian relaxation of a linear program in whole numbers, and integrated into a complete web service including the specification of upstream instances and the visualization of solutions calculated downstream. Dimitra IGNATIADIS made improvements both to the calculation complexity and to the detail of the modeling, involving implementing a multi-period, investment-planning model to replace the annualized version of the sizing model.

III/ System parameterization Inverse problems, applications in medicine and geophysics

Project manager: Jean-Paul MARMORAT

In collaboration with INRIA's FACTAS 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 is currently underway with Aix-Marseille University and LA TIMONE Hospital in Marseille. The project was the subject of presentation at a conference in 2017: "Maureen Clerc, Juliette Leblond, Jean-Paul Marmorat, Christos Papageorgakis. Inverse conductivity recovery problem in a spherical geometry from EEG data: uniqueness, reconstruction and stability results. TAMTAM 2017 – 8th Conference on Trends in Applied Mathematics in Tunisia, Algeria & Morocco, May 2017, Hammamet, Tunisia. pp.1, http://tamtam2017.enit-lr.tn/registration.html."



IV/ In 2017, the CMA took on a new Research Lecturer: Welington de Oliveira

Welington De Oliveira is a Brazilian mathematician specializing in the areas of stochastic optimization, non-differentiable optimization, and its applications to energy system planning problems. He joined the CMA on 1 August 2017.

Prior to the CMA, he was a research lecturer at the mathematics department of Rio de Janeiro State University (UERJ). He also held a post-doctoral scholarship position at the Institute for Pure and Applied Mathematics (IPAM), and was a researcher at the Center for Research into Electric Energy (CEPEL-ELETROBRAS) in Rio de Janeiro

At the CMA, he works on research into stochastic and non-differentiable optimization. Welington also participates in teaching the OSE Advanced Master's and in the CMA's partner research projects. With the research lecturer Sophie DEMASSEY, at the end of 2017 he secured a CIFRE partnership research contract with EDF with the objective of integrating uncertainties into tools and functions of short-term anticipatory management of the electricity grid. Mastering uncertainty is indispensible to guarantee the optimization of the electricity network in anticipatory management. By efficiently taking uncertainties into account, it should be possible to anticipate the presence of constraints, optimize decision-making to remove them, and master the costs of employing leverage.

In terms of dissemination of his research, in December 2017 Welington published a scientific article in a specialized operational research journal, «Target radius methods for nonsmooth convex optimization», Operations Research Letters, Elsevier, 2017. In October 2017, he was a member of the scientific committee at the 13th International Seminar on Optimization and Related Areas, in Peru (http://isora2017.imca.edu.pe). In November, as part of the Gaspard-Monge program for optimization and operational research, Welington presented his work on variational analysis applied to economic problems of electricity distribution during the PGMO event in Paris.

With the support of the CMA, Welington will continue his research and lecturing activities in 2018 and set the wheels in motion for obtaining official accreditation to direct research (HDR)

V/ Four CMA researchers granted official accreditation to direct research (HDR) from 29 May to 30 June 2017

Gilles GUERASSIMOFF defended his application on Monday 29 May 2017 at the STIC (information and communication sciences and technologies) doctoral school at the University of Nice Sophia Antipolis. His HDR was entitled "Energy systems: control, modeling and prospective".

His HDR dissertation relates to energy systems and almost 20 years of research working on how to better represent, improve and optimize them. The dissertation begins with a presentation of the author's background, followed by a first part on energy system prospection. Through two domains of application, i.e. renewable energy sources and industry, the paper shows how to model then optimize a sector to respond to the evolution of energy demand while minimizing the total actualized cost of the considered system. The second part is devoted to the development of modeling and control techniques for energy systems following the emergence of numerous means of measurement. The application to residential and tertiary buildings illustrates the implementation of data science methods now applicable to the sector thanks to the mass availability of data on the evolution of pertinent variables acting on the energy behavior of the systems under consideration.

Edi ASSOUMOU defended his HDR entitled «Modeling as an approach to the long-term investigation of energy systems" on 22 June 2017, also at the STIC.

The research described in this dissertation considers numerical modeling as the component of an exploration of complex systems on long-term horizons for which direct experiments are not possible. For energy systems, these are indispensible support material to fathom the transition conditions anticipated by different energy policy targets. Faced with the complex questions and the evolution of knowledge generated by different disciplines, an open-minded, constantly investigative attitude to models is inevitable. Ultimately, models are conceptual objects devised to serve inter-disciplinarity.

This dissertation looks more specifically at the author's research activities and is divided into two parts. The first part describes Edi ASSOUMOU's academic career to date, while the second gives an overview of his research work and several perspectives.

Sandrine SELOSSE presented her HDR at the Doctoral School of Economics and Management at the University of Montpellier on 2 June 2017, entitled "Prospective analysis of international climate policies: how negative emissions and developing countries could save our climate".

The manuscript centers on the research activities undertaken by the author since 2008 on prospective modeling of energy systems and analysis of long-term scenarios. She participates in prospective modeling projects at the CMA and more precisely works on deploying long-term prospective models as part of ETSAP (Energy Technology System Analysis Program), which is run by the International Energy Agency (IEA), and the Sustainable Development Modeling Chair (MPDD). Sandrine SELOSSE is developing the technico-economic optimization model TIAM-FR (French version of the TIAM/TIMES Integrated Assessment Model) and contributes to the development of ETSAP-TIAM (official ETSAP version). Her research deals with prospective analysis of global energy-climate challenges and more specifically the global and regional impact on energy systems of climate policies taken as part of the United Nations Framework Convention on Climate Change (UNFCCC) and the Conference of the Parties. To this end, she implements different scenarios expressing international climate commitments and looks at, on the one hand, the challenges, considering developing countries' contributions to reducing their greenhouse gas emissions, and on the other hand, the technological challenges involved in the low-carbon transition, such as carbon capture and sequestration.

Sophie DEMASSEY defended her HDR, "Compositions and hybridizations for applied combinatory optimization" at the STIC, UNSA on 30 June 2017.

The growing complexity of combinatory optimization problems confronting decision-makers in all domains, ranging from logistics to energy and the environment and including health and the building sector, has led to the development of increasingly sophisticated solutions. However, these solutions often put performance ahead of flexibility, genericity and easy adaptation to a modification in the problem. This dissertation looks at the benefits of declarative approaches, based on an abstract modeling of problems and resolutions that use generic modular algorithms in the flexible and effective processing of difficult composite optimization problems. The study centers on the hybridization of complementary programming techniques through constraints (global constraints), mathematical programming (relaxations and decompositions), graphs or automats, within tools employed to aid modeling, automatic composition of models, and optimal resolution. The study is illustrated by contributions made to resolve industrial problems like managing resources in data centers and personnel planning.

VI/ Smart grids

In 2013, the government therefore initiated a study entitled Réseaux Electriques Intelligents de la Nouvelle France Industrielle (REI), coordinated by the chairman of the RTI board, Dominique Maillard. Nadia MAÏZI, Professor at Ecole des Mines de Paris, represented the Institut Carnot on the project and ensured 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.

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.

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

- The first of these is Action 3, which involved creating 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 involved 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 Mr. MONLOUBOU, Chairman of the Board at ENEDIS, replaced in April 2018 by Olivier GRABETTE member of the RTE board – Deputy Director General in charge of the Prospective department.

For more information, see the association's website, 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.

The commission has 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.

Several courses have been included in the register of training courses accredited by the association:

5 July 2017: Master's in Energy Transition and Territories (energy major), École Nationale des Ponts et Chaussées (in partnership with IFP-School), M2.

10 May 2017: Advanced Master's in Energy Systems Optimization, MINES ParisTech (post-Master's).

10 May 2017: Master's in Electrical Engineering for Smart Grids and Smart Buildings, Grenoble INP, M2.

In addition, the Think Smartgrids Association launched a call for proposals on smart grids with the aim of creating an exchange area on the theme at the Association and setting up a community involving industrials, SMEs, start-ups and academics.

To initiate this process, an afternoon of meetings was organized on 7 December 2017. The aim was to highlight selected research submissions to benefit from a seed fund.

Over 110 people attended the event, which took place on the premises of MINES ParisTech, 60 Boulevard Saint Michel, Paris.

Philippe Monloubou, Chairman of Think Smartgrids, opened the event. He declared in his introductory speech that: "The aim of the Association's first Academic/Industrial Innovation Day is to develop dynamic connections between academic and industrial spheres on the theme of smart grids." He also pointed out that: "This event continues follows on from the SME/Major Groups gatherings organized last November by Think Smartgrids, and the Invest in Smart Grids day, which aims to bring together investment funds and SMEs/startups."

Nadia Maïzi, chairwoman of the training commission, went on to explain the selection process for the nine proposals submitted.

Mr. JODET from the CGI then talked about the future investment program, followed by Mr. ABECASSIS from Ademe, who spoke of the forthcoming calls for the PIA's Smart Grids project operated by Ademe. Pierre MALLET of ENEDIS also presented the association's roadmap.

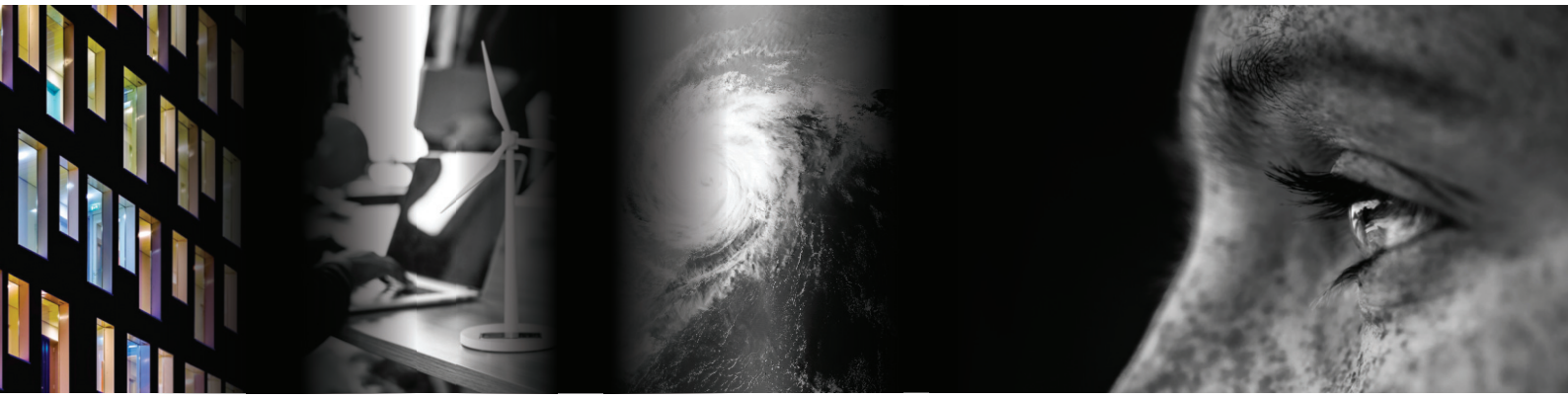
To conclude the day, a Posters session was organized, which provided an opportunity for researchers and industrials to ask any questions and choose the project that they wanted to join.

Photos MINES ParisTech, T. Vaerman

MODELING

For Sustainable 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 research at the 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.

I/ Development of prospective modeling tools

TIMES

Project manager: Edi ASSOUMOU

The long-term planning models resulting from the model family MARKAL/TIMES (MARKet ALlocation/The Integrated Markal Efom 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 cooperation 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.

The doctoral research carried out by Remy DOUDARD and Ariane MILLOT will serve to update and recalibrate the model, and extend research on alternative gas options.

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_2 emissions in different regions in the world (post-COP15 and in particular COP21 commitments), 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).

II/ 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 are published on the Chair's website.

III/ 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.

Deux séminaires ont été organisés en 2017 :

Seminar 1

Chaired by Nadia MAÏZI, this seminar took place on Wednesday 10 May 2017 at MINES ParisTech and centered on the theme of, **«Climate commitments: how do models deal with decarbonization?»**

The agenda featured (in French):

- Céline GUIVARCH, CIRED, Determinants of growth-emissions links and the cost of climate policies: an analysis of prospective scenarios sets

- Charlotte VAILLES, I4CE, Elaboration of EU energy-climate policies: review of the 2020 package and perspectives for 2030

- Sandrine SELOSSE, CMA MINES ParisTech, Energy systems in the post-Paris Agreement era: Analysis of decarbonization challenges using the TIAM-FR bottom-up optimization model

- Nadia MAÏZI, CMA MINES ParisTech, Counterpoints

Seminar 2

Chaired by Nadia MAÏZI, this seminar took place on Thursday 5 October 2017 at MINES ParisTech on the theme of, **«Challenges related to hybridation in technico-economic models» ParisTech, Paris**

The agenda featured (in French):

Introduction - Jean Charles HOURCADE (CIRED)

Hybridization in the Three-Me model and coupling with the MENFIS model: Issues related to hybridization in technico-economic models

Frédéric REYNES (OFCE)

Aurélien SAUSSAY (OFCE)

Discussion of coupling experiences involving IMACLIM-TIAM-KLEM:

Sandrine SELOSSE (MINES ParisTech, CMA): Reconciliation of top-down/bottom-up models. Experience of an approach combining TIAM-FR/IMACLIM-R

Julien LEFEVRE (CIRED): POLES-KLEM coupling

Foundations and contributions of hybridization in the IMACLIM model:

Julien LEFEVRE (CIRED)

Jean Charles HOURCADE (CIRED)

Counterpoints - Sylvain CAIL (ENERDATA): Experience of coupling the POLES model

IV/ The Chair's key conferences in 2017

Scientific publications

Publications (A.C.L Revue, Books and Chapters of books, Working Papers)

Bonvin Gratien, Demassey Sophie, Le Pape Claude, Maïzi Nadia, Mazauric Vincent. 2017. A convex mathematical program for pump scheduling in a class of branched water networks. Applied Energy, Elsevier, Clean, Efficient and Affordable Energy for a Sustainable Future, 185 (2), pp.1702-1711

Coatalem Martin, Mazauric Vincent, Le Pape-Gardeux Claude, Maïzi Nadia. Optimizing industries' power generation assets on the electricity markets. Applied Energy, Elsevier, 2017, Clean, Efficient and Affordable Energy for a Sustainable Future, 185 (2), pp.1744-1756.

De Oliveira Welington, Target radius methods for nonsmooth convex optimization, Operations Research Letters, Elsevier, 2017

Didelot Alice, Maïzi Nadia, Mazauric Vincent, Assoumou Edi, Selosse Sandrine. Balancing Energy Efficiency and Fossil Fuel: The Role of Carbon Pricing. Energy Procedia, Elsevier, 2017, 105, pp.3545 - 3550.

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V/ Events organized by the Chair in 2017

Modeling for Sustainable Development Chair Day - Prospective for Energy-Climate Issues

This one-day event took place on Wednesday 22 November 2017 at MINES ParisTech, Paris The agenda featured:

Opening of the Modeling for Sustainable Development Chair Day by Nadia MAÏZI (director of CMA) and Jean-Charles HOURCADE (director of research at CIRED).

Demand – Resources – Transition – International: six contributions resulting from prospective modeling

- Jules SCHERS (CIRED): The economic impacts of carbon tax revenue recycling in South Africa in a world with labor-saving technological change
- Seungwoo KANG (CMA-MINES ParisTech): Response from Asian countries to the 2-degree target (in French)
- Salahedinne SOUMMANE (CIRED): Managing oil rent and diversification in the face of climate change – focus on Saudi Arabia (in French)
- Antoine BOUBAULT (CMA-MINES ParisTech): Critical raw materials in the TIAM-FR model (in French)
- Simona de LAURETIS (CIRED): Lifestyles, energy and schedules: a macro-micro prospective analysis (in French)
- Ariane MILLOT (CMA-MINES ParisTech): Impacts of the LTECV objectives on the French energy system: analysis using the TIMES-FR model (in French)

Modeling for Sustainable Development Chair Day - Prospective for Energy-Climate Issues

following

Perspective in terms of the situation in France: presentation by Ophélie RISLER of the Energy and Climate Department at the French Ministry for Ecological and Inclusive Transition

International energy transition: what are the dynamics for change?

- The German model: Markus BLESL (IER, University of Stuttgart, Germany)
- The Indian model: Subash DHAR (DTU, Danemark)
- The Norwegian model: Kari ESPEGREN (IFE, Norway)
- The Mexican model: Séverine CARREZ (Chercheure associée à ASES-SC, France)

What vision of the energy transition do the Chair's partners have?

Presentations by partners of the MPDD Chair: ADEME - EDF - GRTgaz - SCHNEIDER ELECTRIC - DGEC

Modeling for Sustainable Development Chair Day - SCHNEIDER ELECTRIC

Smart energy in all its forms (in French)

This took place on Friday 9 June 2017 at HIVE, the headquarters of Schneider Electric in Rueil Malmaison, France "Smart" is a concept that associates all energy vectors, not just electricity, and involves a set of so-called flexible solutions. Smart energy, destined to be an innovative business, is employed in all types of commodity. The aim is to use it to achieve an energy transition compatible with the societal issues of decarbonization. This one-day event was organized by Schneider Electric to take a close look at the impact of solutions associated with smart energy – both in terms of technologies and short- and long-term objectives. It included an illustration of how the tools developed by Schneider Electric and the Modeling for Sustainable Development Chair contribute to responding to major strategic concerns.

Nadia Maïzi et Vincent Mazauric

The agenda featured:

Welcome and visit around Schneider Electric's Show Room, known as the "Innovation Hub".

- Opening by Christel Heydeman, Schneider Electric, Chairwoman France.
- Session (in French) "From the smart energy perimeter" chaired by Nadia Maïzi with:

  Christel Heydeman, Schneider Electric, Chairwoman France

  Thierry Sudret, ENEDIS, Smart Grids Director

  Thierry Leboucher, EDF R&D, Director Delegate

  Sébastien Henry, RTE, Director of Information Systems & Telecommunications

  Stéphanie Schneider, GRTgaz, Deputy Director, Strategy and Regulations

  Antoine de Fleurieu, GIMELEC, General Delegate
- Session (in French) "Synthesis and connection between smart energy issues" chaired by Vincent Mazauric, Schneider Electric

  Presentations by Jean Charles Hourcade of CIRED and Nadia Maïzi

  Variations of smart energy:

Session (in French) on "Local issues in long-term perspective" chaired by Alfredo Samperio and Gilles Vermot-Desroches, Schneider Electric

- Energy efficiency for smart grids through optimization and prediction (in French), Peter Pflaum, Schneider Electric
- Modeling the long-term complementarity of gas and electricity systems (in French), Remy Doudard, GRTgaz/CMA/MINES ParisTech
- Taxation and limitation of urban sprawl: a modeled approach (in French), Vincent Viguié, CIRED
- Flexibility: Holy Grail of the future energy system? (in French), Alain Malot, Schneider Electric
- Can "Pay As You Go" really give the poorest people access to energy? (in French) , Christophe Poline, Schneider Electric
- Conditions for a renewable France (in French), Gondia Seck, CMA/MINES ParisTech

Discussion and summing-up: Claude Le Pape

Conclusion: The meeting point between corporate smart energy issues and the Chair's research .

COP 23, Bonn 2017

The 23rd international climate conference took place from 6 to 17 November 2017 in Bonn, chaired by the Fiji Islands. COP23 marked the start of a process to translate the political ambitions of the Paris Agreement (COP21) into a detailed technical application manual

During COP23, the CMA organized a side event called "Islands and low carbon pathways" on 16 November in the Cities and Regions pavilion.

In most developing island states, energy requirements still depend on fossil fuel imports, despite the fact that local renewable energy sources could satisfy their needs.

Several experts discussed potential solutions that could enable islands to plan a new future for their energy system. The conference looked at technical constraints connected to energy production that could limit the decarbonization of the electricity network, and the massive introduction of intermittent energy.

Lessons learned from modeling exercises illustrated the debate in terms of specific requirements connected to issues of integrating renewable energy sources, accessing energy, and procuring secure electricity.

The side event featured high-quality exchanges on the plausibility of future energy systems and the issues involved in deploying them. In addition, it provided an occasion to demonstrate the benefits of prospective modeling, and to establish a dialogue between political leaders, experts and scientists.

Speakers:

- Nadia MAÏZI (CMA, MINES ParisTech, PSL Research University)
- Edi ASOUMOU (CMA, MINES ParisTech, PSL Research University),
- Sandrine SELOSSE (CMA, MINES ParisTech, PSL Research University)
- Vincent MAZAURIC (Schneider Electric)
- Emanuele TAIBI (IRENA)

COP23 | FIJI
UN CLIMATE CHANGE CONFERENCE
BONN 2017

VI/ Another key event

CMA researchers participated in the IFORS conference in July 2017

From 17 to 21 July 2017, the Center for Applied Mathematics attended the 21st Conference of the International Federation of Operational Research Societies – IFORS, in Quebec Canada.

The stream organized by Nadia Maïzi in the field of «Energy, Environment, Climate», entitled, "Long-term Planning in Energy, Environment and Climate", featured six sessions, five of which were led by research lecturers and doctoral students from the Center: Nadia Maïzi, Edi Assoumou, Sandrine Selosse et Ankinée Kirakozian, Sophie Demassey Gratien Bonvin, and Gilles Guerassimoff.

Excerpt from the program

SESSION Power Systems Planning and Uses - Edi ASSOUMOU

The long term potential for electricity and gas grids integration in France

Edi Assoumou, CMA Mines ParisTech ; Rémy Doudard, CMA MINES ParisTech ; Jerôme Gutierrez, CMA Mines ParisTech-ARMINES

SESSION Short- and Long-Term Optimization in Water Networks - Sophie DEMASSEY and Gratien BONVIN

Pump scheduling in drinking water distribution systems through convex relaxation and time step duration adjustment

Gratien Bonvin, CMA MINES ParisTech ; Sophie Demassey, CMA MINES ParisTech

SESSION Models for energy and environmental issues - Olivier BAHN

Long-term energy modeling for a decarbonized world: an assessment of the Paris Agreement with an optimization bottom-up model

Sandrine Selosse, CMA MINES ParisTech ; Seungwoo Kang, CMA MINES ParisTech Nadia Maïzi, CMA, MINES ParisTech

SESSION Behavioural Economics for Energy and Environmental Challenges - Sandrine SELOSSE and Ankinée KIRAKOZIAN

Bad, for the greater (public) good: Third-party monitoring and sanction on pro-environmental behavior. Ankinée KIRAKOZIAN, CMA MINES ParisTech ; Agrès FESTRE, GREDEG, University of Nice Sophia Antipolis ; Pierre Garrouste, GREDEG, University of Nice Sophia Antipolis ; Mira Toumi, GREDEG, University of Nice Sophia Antipolis

Nudging electricity consumption within firms. Feedbacks from a field experiment

Christophe Charlier, Economic, Université Côte d'Azur, CNRS, GREDEG ; Ankinée KIRAKOZIAN, CMA MINES ParisTech ;Gilles Guerassimoff, CMA MINES ParisTech ; Sandrine Selosse, CMA MINES ParisTech

Tools for the improvement of households energy management

Gilles Guerassimoff, CMA MINES ParisTech

SESSION Machine learning for applications - Gilles GUERASSIMOFF

SESSION Integration of intermittent and renewable energy sources – Nadia MAÏZI

Maximizing intermittency in 100% renewable and reliable power systems: A holistic approach applied to Reunion Island in 2030

Nadia Maïzi, CMA MINES ParisTech ; Vincent Mazauric, Strategy & Technology, Schneider Electric ; Edi Assoumou, CMA MINES ParisTech ; Vincent Krakowski, CMA MINES ParisTech ; Stephanie Bouckaert, CMA MINES ParisTech.

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