Prospectus for

Comillas University
Massachusetts Institute of Technology
Electricity Systems (COMITES) Program

UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID

INSTITUTO DE INVESTIGACIÓN TECNOLÓGICA

Massachusetts Institute of Technology

Comillas University Massachusetts Institute of Technology Electricity Systems Program

Comillas University in Spain and the Massachusetts Institute of Technology Energy Initiative (MITEI) have launched COMITES, a major program focused on the electric power system of the future. This program is designed to:

- Identify a range of technology and policy options and solutions to meet future power system challenges
- Develop new operations and planning methods for 21st century electricity systems
- Create new models to help integrate electricity and gas supply, distribution, and generation infrastructures, operations, and regulatory frameworks

COMITES will apply the capabilities of these two world-class research institutions to educate and explore in depth the operation and capacity expansion of power systems under a range of new circumstances, with an eye toward reducing carbon and other harmful emissions, increasing energy security, integrating new technologies, lowering costs, informing investment options, ensuring reliability, and developing more consumer choices.

Enabling a clean, reliable, and affordable electricity supply

Electric power and gas systems have long been considered technologically mature, but we are now entering a period in which there will likely be significant changes in how these systems operate, as well as in the services they provide, the sources of energy supplies, and the infrastructures and regulatory structures that support them.

Driven in large part by the need to dramatically reduce greenhouse and other emissions from the power sector, policies requiring significant deployment of intermittent renewable energy in power generation have proliferated in states across the US and in countries around the world. This is already taxing existing system operations in a variety of circumstances and raising complex policy and regulatory issues of how to address the multiple impacts of intermittency.

World events and trends are also likely to have major impacts on supply and generation options. The accident at Fukushima has diminished public confidence in nuclear energy and could further increase the risk premium for investors and operators. At the same time, the availability of unconventional natural gas resources across the globe could greatly enhance opportunities for gas-fired power generation creating significant interdependencies between the gas and electricity infrastructures. This complex relationship will be further complicated by the addition of intermittent renewable resources into the generation mix.

Energy security and environmental concerns are creating demand for electrification of the transportation system, and climate change will drive major desalination needs in arid regions and concomitant needs for electricity. For these and other reasons, electricity demand growth is expected to outpace that of energy overall.

On the technology front, advanced metering, widespread introduction of communications and information technologies, distributed generation, new transmission technologies, and electric vehicles will facilitate the application of energy-efficiency measures and create new services and end use options for electricity consumers — provided that the transmission and distribution grid can enable such choices.

Changes in the power sector and the range of new opportunities pose a unique set of economic, operational, technical, and regulatory challenges that could affect the affordability, reliability, and security of the power system. Current analysis tools, developed for the existing power system, need to be upgraded or redesigned to guide decisions by stakeholders as the new system evolves.

Presently available models cannot adequately address the large dimensionality of vast interconnected power systems with distant renewable resources and growing policy and economic uncertainties. These systems issues are the interdependence of time-scales, where long-term planning decisions cannot ignore the short-term dynamics of intermittent renewables, electrified transportation, and demand-response technologies.

Addressing the challenges of future power systems and developing the next generation of analysis tools are the focus of an expanded partnership between Comillas University and MITEI. These two major research institutions have joined forces to establish COMITES, promote education, develop tools, and carry out analyses at the intersection of technology, policy, and regulation.

Collaborative research

COMITES envisions three areas of initial investigation that will build on the strengths and experience of the participants, subject to sponsor interest:

Impacts of large-scale penetration of intermittent renewable generation

As countries increasingly embrace intermittent renewable resources, they will need to confront the planning and operational challenges these resources pose for their power systems, eventually leading to a change in paradigm, However, significant research is needed in how future power systems are planned, operated, and controlled.

The mix of generation technologies, as well as the market rules, will have to adapt to accommodate the presence of intermittent generation. Regulatory adjustments might be needed to attract investment in "well-adapted" technologies. The operation and planning of distribution and transmission networks will also be profoundly influenced. To provide insights for these decisions by industrial and regulatory entities, improved models will be developed that enable long-term planning for generation and transmission expansion, integrating the shorter time-scale dynamics and explicit treatment of stochasticity. Using these tools, COMITES research teams will also identify open issues, analyze them from a technical, economic, and regulatory perspective, and make policy recommendations.

Some work in this area has already been carried out by Comillas and MIT researchers in the context of The Future of Natural Gas and The Future of the Grid multidisciplinary studies. The issues were also addressed in an April 2011 MITEI symposium on Managing Large-Scale Penetration of Intermittent Renewables. The challenges of intermittent sources at large scale are becoming evident in Europe, the US, and elsewhere. There has been work to systematically allocate costs — COMITES will develop the technical basis to inform regulatory approaches for doing so.

Interaction between gas and electricity networks

The global increase in the use of natural gas for electric power generation and the recent exploitation of significant new gas sources require a better understanding of the interdependencies between the electricity markets and the natural gas supply infrastructure. The existing operation and capacity expansion models for electricity markets and gas supply are largely stand-alone models, with extremely limited coupling, if any. Consequently, projections of natural gas demand for electric power generation do not account for any limitations in the natural gas supply infrastructure, projections of natural gas pipeline and storage capacity requirements do not reflect the detailed information on electric generation requirements or differences in market and contract structures, for example.

This area of research would develop additional modeling capabilities to provide greater analytical insight into the interdependencies between increased natural gas use for power generation and natural gas supply infrastructure requirements.

Electrification of the transportation system

Supported by public policies reflecting a range of concerns and goals, distributed generation and electric vehicles are expected to increase in penetration during the next few decades. The challenges and opportunities associated with these technologies may require systemic changes in the way the electric grid is planned and operated.

This line of research explores ways of accommodating these new technologies that maximize their net benefits. Topics include the changes in design of distribution networks and the corresponding adaptation of regulatory schemes; the new emerging activities and business models; and the promotion of innovation in power system operation, the provision of ancillary services, and the use of information technologies. This work will also develop and apply improved modeling capabilities to account for the coupled time-scales, coupled electricity-transportation systems, and uncertainty/variability in the behavior of individual agents.

As with the intermittency topic, MITEI held a symposium on Electrification of the Transportation System. Comillas researchers have participated in several European funded projects on these topics, contributing with sophisticated distribution models and regulatory assessments.

Other avenues of research

Other research topics under consideration include:

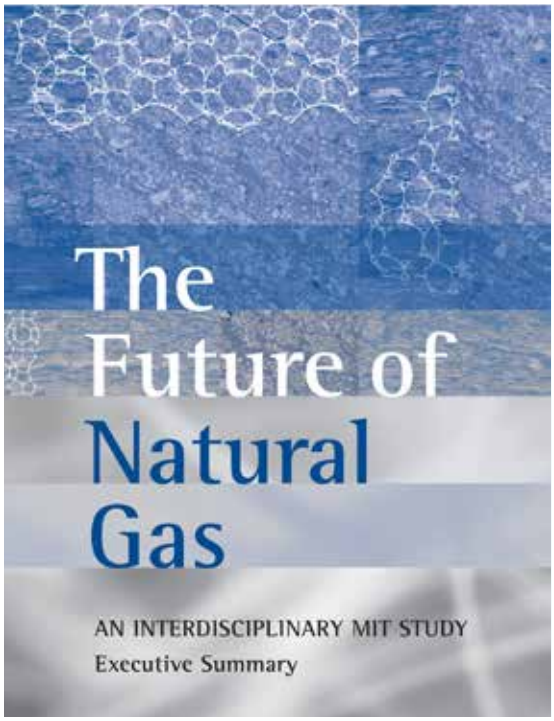
- provision of universal access to electricity
- integration of conventional and renewable sources of electricity generation in island systems
- understanding and promotion of electricity consumer responsiveness to power system conditions
- design of regulatory mechanisms to enhance adequacy and firmness in electricity supply
- security and control issues in power systems operation
- oligopolistic behavior in power systems
- formats of reconciliation of energy and climate objectives with competitive market goals
- network tariff design
- integration of enhanced power system models in general equilibrium economic and climate change models.

As already stated, we see the research agenda as one that will adapt to emerging challenges and sponsor interests.

Education

Faculty and researchers from both institutions cooperate in education activities within the scope of the areas covered by this agreement. Examples of this collaboration include the course "Engineering, Economics, and Regulation of the Electric Power Sector" offered by the Engineering Systems Division (ESD) as well as the Sloan School of Management and the Department of Electrical Engineering and Computer Science of MIT, the ESD graduate course "Modeling of Electric Power Systems," and the Independent Activities Period intensive course on "Power System Models for a Low Carbon Economy" also from ESD. Similarly, faculty from MIT have also been invited to participate in education activities that take place at the School of Engineering (ICAI) of Comillas in relation to the topics covered in this agreement, in particular the multi-university EU-sponsored Erasmus Mundus Ph.D. program in Sustainable Energy Technology Strategies.

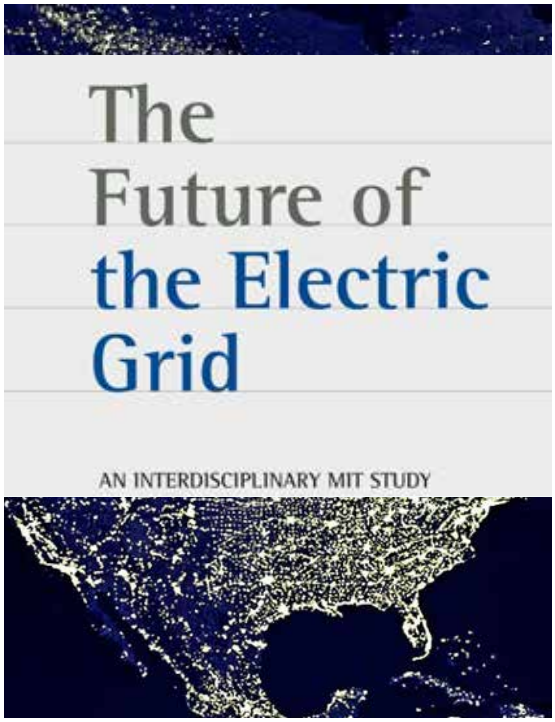
The Program includes visits of students between both universities for the purpose of research or education. The Steering Committee identifies topics of common interest and promotes the usefulness of these interactions. MIT-Spain, with ample experience in this kind of international exchange activity, collaborates in the organization of visits of MIT students to Comillas or to Spanish companies under the auspices of this agreement.

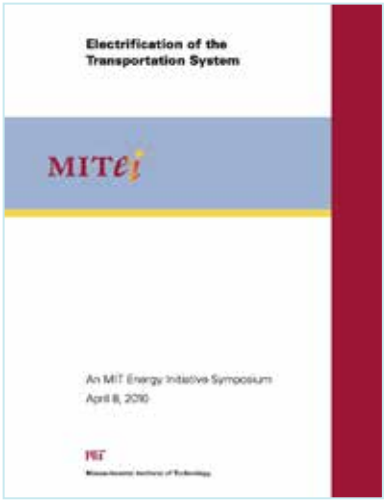


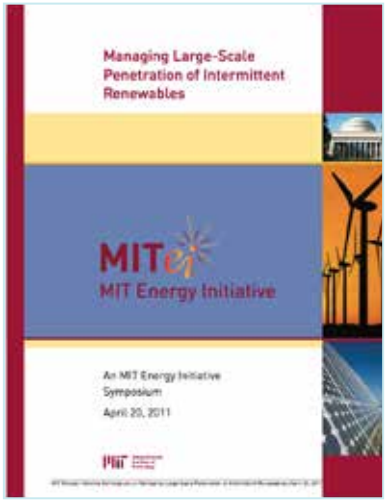
Domain expertise

The research teams at MIT and Comillas have:

- A long tradition of education and research in energy related topics;
- A record of playing key advisory roles to industry and government on issues requiring technology analysis and policy choices;
- A demonstrated ability to work collaboratively with industry partners and tackle major energy sector challenges;
- A track record of energy and power research and analysis, collaborating on the completed MIT Future of Natural Gas and Future of the Electric Grid studies, and on the current Future of Solar Energy study;
- A commitment to independence and the highest ethical standards; and
- A willingness to think creatively and outside conventional norms.







Program Steering Committee

The Program will primarily consist of collaboration in research and analysis activities. It will evolve over the years in response to resource availability, emerging challenges to electric power systems, and a continuing dialogue between researchers and sponsors. A steering committee drawn from the collaborating universities and the sponsors will meet semi-annually to review progress and to guide new research directions; MITEI Director Ernest Moniz will be the initial chair.

The researchers will be drawn from multiple disciplines in combinations that will be tailored to the research problems under consideration.

Massachusetts Institute of Technology

At MIT, researchers will be drawn principally from MITEI, ESD, the Sloan School of Management, the School of Engineering, the Economics department, the Center for Energy and Environmental Policy Research (CEEPR), and the Joint Program on the Science and Policy of Global Change. Many of the researchers hold appointments in more than one of these units. The initial Steering Committee members from MIT are:

Engineering Systems Division: **Mort Webster** (MIT Principal Investigator)
Sloan School of Management: **Dick Schmalensee, Chris Knittel**
School of Engineering: **Munther Dahleh, Konstantin Turitsyn**

Comillas University

At Comillas University, researchers will come from the several departments of the ICAI and the Institute for Research in Technology (IIT). The initial Steering Committee members from IIT are:

Institute for Research in Technology (IIT): **Carlos Batlle** (Principal Investigator), **Pedro Linares, Ignacio Pérez-Arriaga**
Electrical Engineering Department: **Michel Rivier, Luis Rouco**

Support the Program

COMITES will be established as a consortium to provide a platform for supporting the shared activities of its members. More specifically, annual membership dues of $35K for COMITES will support: two graduate students (one in each location) to help with research/education activities; one workshop and one short course each year (events will rotate between campuses); the development of sponsored research agendas and projects for interested members, including assistance with campus visits and faculty meetings; and the governance/administration of the consortium.

COMITES members who elect to sponsor additional research projects above a threshold of $100K will have a reduced consortium membership fee of $20K. Consortium member representatives, with MIT and Comillas leadership, will form an executive steering committee to provide strategic direction to COMITES.

For more information on COMITES, contact:
Prof. Mort Webster (mort@mit.edu) or Prof. Carlos Batlle (batlle@@iit.upcomillas.es).

Carlos Batlle
IIT Principal Investigator

Comillas Pontifical University

Comillas Pontifical University is directed by the Society of Jesus, which is the private institution with the highest number of universities in the world. For more than a century, the ICAI has provided top professional and leaders to Spanish industry, particularly in the power sector. Its IIT does research and postgraduate education in various technological fields and is funded through participation in projects of interest to industry and government that respond to a clear social demand. IIT is the leading Spanish academic research group in electricity markets and hosts the multi-university EU-sponsored Erasmus Mundus Ph.D. program in Sustainable Energy Technology Strategies.

Mort Webster
MIT Principal Investigator

Massachusetts Institute of Technology

MIT is a world-class research and educational institution, advancing knowledge in science, technology, and analysis to serve the nation and the world in the 21st century. MITEI is an Institute-wide initiative established to mobilize the capabilities of the Institute to help meet the world's pressing energy challenges and build on MIT's capabilities and lengthy history of providing real-world solutions to difficult societal problems. The Initiative is designed to accelerate innovation in energy science, technology and policy through the integrated application of the institute's cutting-edge capabilities in science, engineering, management, planning, and social science.

For more information on COMITES or to explore how you can help support it, please contact:

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