15.017/6.934J

Engineering, economics and regulation for energy access in developing countries

SYLLABUS

Ignacio J. Pérez-Arriaga, Robert Stoner and James Kirtley

Fall 2018

Instructors:

Prof. Ignacio J. Pérez-Arriaga, (Room E19-370h, ipa@mit.edu, 617-738 3302)

Dr. Robert Stoner, Deputy Director MIT Energy Initiative (Room E19-307, Stoner@mit.edu) and Director Tata Center for Technology and Design.

Prof. James Kirtley, Research Laboratory for Electronics, Room 10-098.

TA:

Stephen Lee, leesj@mit.edu

(Stephen’s office hours are after class or by appointment. Please feel free to reach out by email at any time)

Guest Lecturer(s):

Dr. Pablo Duenas Martinez, pduenas@mit.edu

Level: H-Level Graduate/Undergraduate. No prerequisites. Preferably (not mandatory) with background in policy analysis, microeconomics and/or engineering/science. Open to advanced undergraduates. No admissions cap.

Units: (3-0-9)

Meetings: M-W: 13:00–14:30 (E51.057), F(recitation):10:30-12:00 (E51.372)

Contact information: ipa@mit.edu

Stellar site: https://stellar.mit.edu/S/course/15/fa18/15.017/

Description:

This course presents the complex technical, financial, regulatory, and social challenges of providing universal energy access in developing countries, focusing on electricity supply, but also covering cooking and heating. Students will learn the adequate supply and demand technologies to meet the energy needs, the specific features of the power sector in developing countries, the role of large infrastructures of generation and transmission of electricity, the estimation of the energy demand, on-grid and off-grid modes of electrification, existing and innovative business models and regulatory instruments, tariff design, consumer preferences and willingness to pay, and electrification planning techniques. Students will make use of optimization models to plan on-grid and microgrid electricity supply. The course will prepare students to contribute to research, technology deployment, and policymaking for energy access worldwide as well as for future careers in industry, government, consulting, or multilateral development organizations.
This course twins with IDS.505, 6.695J, 15.032J “Engineering, economics and regulation of the electric power sector”, which has been taught in the Spring term for the last 10 years, but now focusing on electrification in the developing world, which is a completely different story. Both courses can be taken independently.

Program:


Module A: Introduction, course logistics, and understanding the context of poverty, development, and adequate technologies.

- **Session 1 (Wed-Sept-5-IPA):** Why worry about energy access in developing countries?
  What is the role of energy in economic and human development? How big is the energy access gap worldwide and why is it a concern? What can be done about it? What we know, and what we do not know and what are open issues for research? Why are we teaching this course and what can you expect to learn this semester? Logistics of the course.

  **Homework 1:** Each student has to choose a country where to apply what is learned throughout the course and start gathering information about it. Get familiar with the “resources” for the course.

  **Recitation 1** (Fri-Sept-7-IPA): Who is who in the class. Begin with Power Systems Primer. Physical aspects of electricity supply and demand.

- **Session 2 (Mon-Sept-10-IPA):** Poverty and development.
  Trying to understand the complexities of poor people’s lives. Why is poverty so persistent in some parts of the world? How does poverty affect the accessibility of energy services and vice versa?

- **Session 3 (Wed-Sept-12-IPA):** Relevant technologies for low-income communities.
  What makes a technology “relevant” (or not) for a low-income community? What are examples of relevant technologies for these communities and have they been useful? What is difficult or different about designing technologies for low-income rural communities?

  **Homework 2:** General overview of poverty and development in the selected country. Try to cover all sectors relevant to development, but pay special attention to energy-related issues,

  **Recitation 2** (Fri-Sept-14-IPA): Power systems primer.

Module B: Technologies for electricity supply and consumption.

- **Session 4 (Mon-Sept-17-IPA):** Power systems in developing countries.
  What is a power system? What are the components? How do they interact to provide people with electricity for an enormous range of uses? How are they operated and monitored? What are characteristic features of power systems in developing countries: technical, financing, ownership, regulation? Perhaps two sessions: one for the infrastructure and operation, other for economics and regulation; both focused as much as possible on developing countries.

- **Session 5 (Wed-Sept-19-IPA):** Challenges and pathways to achieve universal electricity access: A case example.
  A country with a deficit of electricity access will be chosen as a case example to show how and why such a deficit exists and persists, the paths to achieve complete electrification, and the challenges to be met in accomplishing this objective.
- **Session 6** (Mon-Sept-24-JK): Energy efficient appliances. Recent and expected advances in electricity consumption technologies. Lighting, fans, radios and TV sets, fridges, washing machines, batteries and electric motors.

- **Session 7** (Wed-Sept-26-IPA): Electricity demand and the definition of access. What do people use electricity for? How do we predict how much people will need and how do we measure what people actually use? How can “electricity access” be defined? Is there a basic right to electricity access? What is the “cost of non-served energy” and how can be quantified?

  Homework 3: Evaluation of the electricity services that can be achieved with different types of electricity supply: volume and quality of services, and supply cost.

  Recitation 3 (Fri-Sept-28): Invited guest. Experiences in the use of technology in enhancing development.

- **Session 8** (Mon-Oct-1-JK): Electricity generation technologies: on- and off-grid options. What energy sources can be converted into electricity? Which generation technologies are typically used for grid-based electricity and which are typically used in off-grid systems? Trade-offs between the main electrification modes: grid extension, non-connected mini-grids, and solar home systems. The utilization of information and communication technologies (ICT).


  Homework 4: Design of a feeder to meet some prescribed demands, supplied with on- and off-grid generation. Cost reduction in distribution network design. Topics in distribution regulation.


  Module C: Planning strategies and tools.

  - **Session 12** (Wed-Oct-17-IPA): Mini-grid Design.

Recitation 6 (Fri-Oct-19-MB or PB): Tutorial on the use of a computer model to support mini-grid design.

Homework 5: Analysis of cases of electrification planning using the REM model. Design of a mini-grid. Electrification planning of a region. Data collection. This homework (and only this homework) will be prepared by small teams of students.


- **Session 14** (Wed-Oct-24-IPA): The Reference Electrification Model (REM) Description of the REM model. The overall logic behind clustering of buildings, the design of microgrids and grid extension and the choice of electrification mode. Application of REM to a diversity of electrification cases.

Recitation 7 (Fri-Oct-26-PD): Tutorial on the use of the computer model REM to support regional electrification planning.

- **Session 15** (Mon-Oct-29-SL): Data collection methods, building identification and estimation of electrification status. Sources of the data needed to run electrification models: Technical equipment and consumption appliance characteristics, location of buildings and their nature from an electricity consumption perspective, demand for the different consumer types, existing network characteristics and layout, topography, economic parameters, willingness to pay, etc.

Recitation 8 (Fri-Nov-2): Showing of the movie, “Katiyabaaz”.

**Module D: Regulation, socio-economic and political factors, and business models.**

- **Session 16** (Wed-Oct-31-RS): Key actors in the universal energy access space. Relevant institutions and firms: local, national and regional (multinational); public and private supply providers and utilities; manufacturing companies; regulatory agencies and governments; rural electrification agencies; cooperatives and NGOs. Their present and potential respective roles in the electrification process.

- **Session 17** (Mon-Nov-5-IPA): Regulatory approaches to promote electricity access. Review of classic regulatory approaches for the different activities that are needed in electricity supply. Characteristics in developing countries with a deficit in electricity access that require a departure from the classic regulatory approach. Focus on the regulation on- and off-grid electricity supply at distribution level.

- **Session 18** (Wed-Nov-7-IPA): Tariffs, quality of service, and consumer preferences. The orthodox procedure for cost-reflective tariff design. The relationship between supply costs and expected quality of service. A review and critical appraisal of the existing tariffs and the procedures to determine them in developing countries with a deficit of electricity access. Affordability and the need for subsidies to fill any existing viability gap.
Homework 6: Description and analysis of the power sector regulation that relates to electricity access in the selected country.


- **Session 19** (Wed-Nov-14-MB/IPA): Tariff design for financial sustainability of microgrid supply.
  Cost analysis of mini-grids of different sizes with diverse mixes of consumer types, demand levels and affordability. Design of tariffs with varied levels of cross-subsidization to eliminate or reduce the viability gap between the total supply costs and the revenues from the tariffs.


- **Session 20** (Mon-Nov-19-IPA): The electrification landscape: countries and business models.
  A review of existing and proposed business models to achieve electrification: Independent large generation and transmission projects, distribution privatization and franchises, off-grid microgrids, stand-alone systems, and solar lanterns. Review of the potential of these business models in countries with a significant electricity access deficit. Discussion of case examples.

Term paper is issued: The term paper will consist of identifying regulatory mechanisms – either new or improvements of existing regulations – as well as other technical, political or social measures that can accelerate the electrification process in the country that each student has selected. The statement of the term paper will specify some concrete areas of activity that will have to be covered in the paper. The first part of the paper will provide the necessary background and the text will include any pertinent material from Homeworks 2 and 6.

- **Session 21** (Wed-Nov-21-RS/IPA): Social, political, economic, and other factors that influence electrification decisions.
  Review of the non-technical factors that influence electrification planning decisions and should be integrated in the electrification planning process. Design of the interaction between the optimization-based techno-economic approach and the “human factors” to be accounted for.

- **Session 22** (Mon-Nov-26-RS): Financing electrification.
  What financing mechanisms exist for both large- and small-scale energy infrastructure projects? What are the benefits and disadvantages of private finance, project finance, public finance, and public-private partnerships?


**Module E: Heating, cooling, and cooking**

- **Session 23** (Wed-Nov-28-JL): Heating, cooling, and cooking technologies
  What are the heating, cooling, and cooking challenges in developing countries? What sorts of technologies are used and what is the problem with these technologies? What business models exist to expand the use of cleaner, more efficient technologies?

- **Session 24** (Mon-Dec-03-JL): Non-technological factors related to improved cookstoves
  Challenges in the successful deployment and sustainable utilization of modern cooking technologies and review of useful experiences.
Module F: Governance, institutions and broader implications of electrification

- **Session 25** (Wed-Dec-5-RS): The role of government in electrification
  What has been the historical role of government in electrification in countries that have universal access? What can be learned from middle-income countries that have made major gains in electrification (e.g., China, Brazil, etc.)? How is the role of government comparable and how is it markedly different in these situations, and how does the state of economic development shape the role of government? What should government in the least electrified countries do differently to electrify more quickly?

- **Recitation 12** (Fri-Dec-7-IPA/RS): Experiences with financing and business models. Open for support in the preparation of the term paper.

- **Session 26** (Mon-Dec-10-IPA): Broader global implications of universal energy access
  Potential implications of diverse implementation paths of universal energy access on climate change. Energy transition and the utility company of the future in developing countries with a deficit in electricity access.

Presentation of the term papers.

- **Session 27** (Wed-Dec-12-IPA/RS/JK/SL): First day of term paper group discussions.
  An extended schedule will be used on that day and probably also the following ones (depending on the number of students), so that all papers will have sufficient time for discussion in small groups of about 5 students.

  During the discussion of the term papers, questions may be asked on the material presented in the compilation document. The course schedule specifies the dates when the homework compilation documents and the term papers are due.

Calculating final grades

Recitations are not mandatory, but they are strongly recommended, and some may even be essential to complete the homework effectively, as we will be presenting tutorials on how to use the computer models that will be used in homework. Most of the recitations will be taught by one of the instructors and will cover relevant topics that will complement the core content of the course. Some of them will be partly devoted to discussing past and future homework assignments.

The final grade for the course will be computed based on the take-home assignments (50%) and a final term paper (50%), including discussion. Participation in class (lectures and recitations) will be taken into account when determining the final grade.

Attendance to lectures is mandatory and will be considered for the final grade. No more than two unjustified absences will be accepted from students intending to obtain a passing grade.

Student Support Services

If you are dealing with a personal or medical issue that is impacting your ability to attend class, complete work, or take an exam, please discuss this with Student Support Services (S3). The deans in S3 will verify your situation and then discuss with you how to address the missed work. Students will not be excused from coursework without verification from Student Support Services. You may consult with Student Support Services in 5-104 or at 617-253-4861. Also, S3 has walk-in hours Monday-Friday 9:00-10:00am.

Student Disability Services
MIT is committed to the principle of equal access. Students who need disability accommodations are encouraged to speak with Kathleen Monagle, Associate Dean, prior to or early in the semester so that accommodation requests can be evaluated and addressed in a timely fashion. Even if you are not planning to use accommodations, it is recommended that you meet with SDS staff to familiarize yourself with the services and resources of the office. You may also consult with Student Disability Services in 5-104 or at 617-253-1674. If you have already been approved for accommodations, please contact us early in the semester so that we can work together to get your accommodation logistics in place.

**Policy on classroom behavior**
(Recommended by the Sloan Student Senate)
(Laptops and e-readers are permitted in this course)

- **Students are expected to arrive promptly on time and to stay for the entire class.** Faculty are expected to begin and end class on time.
- **Laptops and e-readers are not be open in the classroom except with explicit permission of the faculty** (e.g., when used as part of the instructional program or when required by students because of physical or other challenges)
- **Cell phones and PDAs are not be used or permitted to ring in the classroom.**
- **Students are expected to attend all classes.**

▷ **Please note that in accordance with this policy, MIT Sloan requires that students schedule campus interviews outside of scheduled class times and to make every attempt to schedule second round interviews and site visits outside of class times. Classes missed for such activities are not excused absences and may count against your participation grade.**