**15.S08** Energy Systems Optimization

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**Lecture Time and Classroom:** MW 2:30 – 4 PM, E62-233

**Office hours:** TBA

**Outline**:

Global warming is the most pressing challenge facing humanity today. According to the recent IPCC report, it is unequivocal that human activity, especially CO2 emission to the atmosphere, has been the key driving force behind global warming. To mitigate the crisis, a fundamental transformation of the global energy system must occur. This transformation needs to quickly bring down the rapid increase of global CO2 emissions and usher in a net-zero emissions system by mid-century. Decarbonization of the electric power system is at the heart of the transformation. Other infrastructure systems, such as natural gas, transportation, heat, and some industrial processes, also must decarbonize.

The course will first introduce the big picture of energy system transition, then go into details of the key decision-making problems in electric power systems, and study the couplings between power and other infrastructure systems, and finally assess energy system transition in an integrated fashion. This course aims to lead PhD or advanced master students to the forefront of energy system research.

**Topics:**

Lecture topics include (in the order of presentation):

1. Basics of climate change and the impacts on human society
2. Transition to net-zero emissions energy systems
3. Electric power systems: physics, engineering, and decision-making problems
4. Optimization models and algorithms for operating large-scale power systems
5. Stochastic and robust optimization for integration of renewable generation
6. Data-driven monitoring and maintenance of grid assets
7. Multistage optimization for long-term planning of clean power systems
8. Electricity market design: pricing and strategic behavior
9. Distribution grid operations and resiliency
10. Stability and control of future power grids
11. Electrification of transportation
12. Electrification of heating and smart buildings
13. Electrification of industrial processes and hydrogen
14. Multi-energy system modeling and optimization
15. Integrated system assessment

**Lecture schedule:**

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|---|---|---|
| 31-Jan | M | Overview, Global warming and climate model |
| 2-Feb | W | Global Warming history and present |
| 7-Feb | M | Net-zero emissions systems and pathways |
| 9-Feb | W | Overview of electric power systems |
| 14-Feb | M | Power engineering basics |
| 16-Feb | W | Power flows: solution methods |
| 21-Feb | M | Presidents' Day holiday |
| 22-Feb | T | ACOPF: modern optimization methods |
| 23-Feb | W | Daily unit commitment (UC): deterministic models |
| 28-Feb | M | Stochastic optimization for daily operation |
| 2-Mar | W | Robust optimization for daily operation |
| 7-Mar | M | Data-driven adaptive optimization for daily operation |
| 9-Mar | W | Grid topology control through transmission switching |
| 14-Mar | M | ARPA-E Grid Optimization Competition |
| 16-Mar | W | Electricity markets: Pricing and design |
| 21-Mar | M | Spring Break |
| 23-Mar | W | Spring Break |
| 28-Mar | M | Distribution grid: distributed coordination |
| 30-Mar | W | Demand response management |
| 4-Apr | M | Microgrid and maintenaining system stability |
| 6-Apr | W | Power system resiliency and optimal recovery from natural disasters |
| 11-Apr | M | Cyberphysical systems |
| 13-Apr | W | Multi-energy systems |
| 18-Apr | M | Patriot's Day holiday |
| 19-Apr | T | Drop Date |
| 20-Apr | W | Electrify transportation: EV charging and infrastructure planning |
| 25-Apr | M | Electrify buildings: smart buildings |
| 27-Apr | W | Electrify industrial processes |
| 2-May | M | Integrated energy system modeling |
| 4-May | W | Projects presentation |
| 9-May | M | Projects presentation |

**Grading:**

The course will have homework roughly every other week, a midterm, and a student project. Students, preferably from different disciplines, will team up to identify and work on a topic related to energy system optimization. Interaction with the MIT Energy Initiative will also be encouraged.

Homework: 20%
Midterm: 30%
Project: 50%

The course is 12 units.

**Prerequisite**:

The course is suitable for PhD students and master students with a strong analytical background, who are passionate about contributing to resolving the greatest challenges facing energy systems today. A good understanding of basic optimization at the level of 6.251J/15.081J or 15.093 will be needed. A course in analytics such as 15.072 will also be useful.