Abbreviated Syllabus as of 2/12/2021. Please see Sakai for updates.

Electricity Markets | Spring 2021 | ENV 717

Nicholas School of the Environment | Duke University

Time
T-TH 8:30am – 9:45am

Instructor
Dalia Patino Echeverri
dalia.patino@duke.edu
Phone: 919-613-7461
Office hours: Tuesdays & Thursdays 9:45-10:00am
Fridays: 3:30- 4:30 PM

Teaching Assistants
Ruoshui Li (ruoshui.li@duke.edu) Office hours: TBA
Traian Nirca (tn110@duke.edu) Office hours: TBA

Course Description

This course examines basic concepts in economics and engineering necessary to understand the operation of the electric power system, with a focus on U.S. organized wholesale electricity markets.
It provides students with knowledge and quantitative tools for analyzing the performance of the electricity system, the effect of different policies and market designs, and the possible steps towards a resilient, reliable, economic, safe, and environmentally sustainable energy sector.

Prerequisites
Introductory microeconomics (ECON 51), Economic Principles, Resource and Environmental Economics (ENV270), applied regression analysis (ENV 210: Applied Data Analysis or equivalent), **Energy Systems Modeling (ENV716)**, Energy and the Environment (ENV211), C***o-requisite:*** **Energy Technologies and its Environmental Impacts (ENV 631)***
Admission by permission of instructor.

The class will build on a background of undergraduate economics, and computer based quantitative analysis (e.g. MS Excel, Pyhton, Pyomo, CPLEX). The material will also include basic concepts of physics, finance, electric power systems, optimization, probability, statistics and computer programming. Students without previous knowledge in at least three of these areas are likely to struggle and are discouraged from enrolling.

*All students must have taken ENV716 before enrolling in this class. Exceptions can be made for those who can demonstrate mastering the content of ENV716 in an oral exam in my office during the first week.

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*The content of ENV631 has been modified to cover Physics concepts that were previously covered in this course. For that reason I have removed most of the Physics material. Those who are not enrolled in this class need to make an effort to attend a few lectures in ENV631 (please get a syllabus of ENV631 and plan accordingly), to study the supplementary slides in Physics posted to Sakai, and will be required present additional course work (including a picture of their construction of a DC motor).

Students who should not enroll in this course:

Students who anticipate missing or arriving late to 3 or more lectures **should not take the course.** In my experience these students struggle catching up with the content covered in class, will slow the pace of the lectures, and will disrupt a productive learning environment.

Similarly, students who cannot refrain themselves from texting or browsing the web or working on other assignments during class time are strongly encouraged to not take the class. Past experience shows that the presence of these students in the classroom disrupts a productive learning environment. (Please see section on class etiquette).

If you are a Fuqua student, you are welcome to enroll but you should NEVER use the differences in schedule and school requirements (e.g. spring break, field trips, internship) as an excuse for being late with homework, for missing classes or for needing any schedule accommodations. **If you are a Fuqua student and anticipate conflicts with the schedule that will force you to miss 3 or more lectures, please do not take this course.**

Please do not ask me if you can audit this class. I do not allow auditors because in my experience auditing students do not read or do homework and therefore waste their time coming to class.

Students who do not enjoy "getting into the weeds" of the technical issues of power systems are also discouraged from enrolling.

Some of the concepts everyone should review before classes start:
-Electricity Industry Fundamentals: Fundamentals of electricity generation (coal, natural gas, wind, solar photovoltaic cell, solar thermal, nuclear, geothermal), different between energy and power, NamePlate Capacity, Heat rate (Gross and Net), Capacity Factor, air emissions, air emissions controls. Familiarity with EIA's AEO (http://www.eia.doe.gov/oiaf/aeo/), eGrid Database (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html), IECM software (http://www.cmu.edu/epp/iecm/) (an introduction to this material is provided in ENV716 and covered more in depth in Tim Johnson's Energy Technologies class during the month of January – audit those lessons). EPA's Acid Rain Program (http://www.epa.gov/airmarkets/progsregs/arp/index.html). Energy units and unit's conversion.
- Calculus: Derivatives and partial derivatives. Integrals. Maxima and minima of a function. Lagrange multipliers
-Finance: Net Present Value, Continuous compounding of interest. Financial Markets. Derivatives. Fixed Charge Factor. Levelized Cost.

-<u>Algebra</u>: Systems of linear equations. Matrix addition, subtraction, and multiplication. Inverse of a Matrix.
-<u>Probability</u>: Experiments, sample spaces, probability of events, discrete and continuous random variables, pdf, cdf, expected value, variance, probability distributions (normal, uniform, exponential, binomial, weibull), stochastic processes (Brownian motion, Geometric Brownian motion, Mean Reverting Processes) Montecarlo simulation.
-<u>Statistics</u>: Descriptive statistics, inferential statistics, linear regression (univariate and multivariate). Correlation and Autocorrelation.
-<u>Optimization</u>: Formulation of mathematical programming problems. Formulation in canonical form using sigma notation. Post optimality analysis. Linear and integer optimization. Optimization in excel. How to formulate a power capacity planning problem
-<u>Excel</u>: Functions, Array Functions, Tables and Pivot Tables, Active Controls, Macros (Procedures and functions), Solver, data Analysis.
-<u>Pyton</u>: basic data structures, implementation of linear programming models.

Textbooks and Readings

- Kirschen, Daniel S., and Goran Strbac. *Fundamentals of Power System Economics,* John Wiley and Sons Ltd, Chichester, England, 2004.
  FIRST CHAPTERS ARE POSTED ON SAKAI

Other recommended (optional) textbook

- Stoft, Steven., *Power System Economics: Designing Markets for Electricity,* IEEE Press and Wiley Interscience and John Wiley and Sons, Inc., Piscataway, NJ, 2002.
- Conejo, Antonio J., Baringo Luis., Power System Operations, Springer International Publishing AG 2018

Supplemental readings as indicated in class schedule below, many available on the internet, and others available via Sakai.

Sakai and PC compatibility

Readings, class announcements, schedule changes, grades, power point slides and working files (in excel, Jupyter, etc) will all be posted to the course Sakai site. Students are also encouraged to use Sakai's discussion boards to continue the discussion of course issues beyond the classroom. Anyone having trouble working with the Sakai site should seek help from their fellow students, or contact Information Technology.
Occasionally I will post excel files that illustrate some quantitative analysis. I use a windows PC with MS Office 2016 and it is your responsibility to solve all the compatibility issues to keep up with the materials posted.
