Engineering Sciences 137. Energy within Environmental Constraints

Term: Fall 2014
Class hours: Tuesday and Thursday 1:00-2:30 PM
Room: MD-119

Instructor: David Keith
Office: My primary office is on the 4th floor of 1 Brattle Square, I have a SEAS office at Pierce Hall 125 at 29 Oxford St.
Telephone: 857-294-2050 Note: this is my cell number. I don’t use an office number. I prefer that you contact me by email, but if you do need to call please use my cell only between 7 AM and 7 PM.
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Office hours: TBD

Faculty assistant: Melissa Kappotis

Preceptor: Carolann Koleci
Office: Pierce 290 (on the bridge)
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Email: ckoleci@seas.harvard.edu
Office Hours: Monday, Wednesday: 1 PM – 4 PM; Tuesday, Thursday: 2:30–4:30 PM

1. Short course description (course calendar listing)

This course provides a systematic introduction to the energy system for students in engineering and applied sciences. Students should gain a working understanding of some of the most important energy technologies, from prime movers--gas turbines, steam cycles, and reciprocating engines--to secondary energies including fuel production and refining technologies and the electricity transmission and distribution system. The course aims at a systematic understanding of the energy system’s environmental footprint as a tool to help students who will work to reduce it. Energy is a commodity. One cannot hope to re-shape the energy system to meet environmental constraints without a rough working understanding of energy markets--costs, prices and elasticities of supply and demand. So the course will integrate engineering economics and other applied social sciences into the treatment of energy technologies to enable a system’s view of energy.

Prerequisite: Advanced high school mathematics, chemistry, and physics.
2. Extended description

**Environmental constraints.** Environmental constraints are the motivation that drives the entire course. I will provide a framework for understanding and evaluating the environmental consequences of energy use, but I will not attempt to teach the core science required to understand the energy systems impact. That framework organizes environmental impacts into three categories: climate, air pollution and land use. I will defend the choice of categories, explaining why other topics like water are not included, and for each category I will introduce a few of the most important concepts necessary for a quantitative understanding of the energy system’s environmental impact.

Environmental constraints are the focus of this course, but environment is but one of three grand energy challenges: energy poverty, energy security and environment. I will provide a brief overview—using simple quantitative comparisons where appropriate—that puts environment in the context of other energy challenges and puts energy in context of other environmental challenges.

**Energy technologies.** Engineering students can graduate with a strong theoretical understanding of mechanics and thermodynamics yet have no idea why diesel engines are efficient and how this is tied to generation of fine particles that are a major contributor to air-pollution mortality or of how these facts are related to the spread of direct-injection gasoline engines. A central goal of this course is simply to explain how some of the most important energy technologies work. I will alternate between deep dives into particular technologies and a system’s view that places each within an energy system that converts primary energy into energy carriers to finally produce energy services. I will focus on electricity and transportation the two sectors where a systems view is most relevant and largely ignore the buildings sector.

**History.** Our energy system did not arise as an optimal configuration that meets demand within scientific constraints. The development of the energy system is highly nonlinear in that early choices—Edison vs Westinghouse—shape the systems evolution on century-long timescales. Where appropriate the course will provide an introduction to the energy systems history that aims to inform students understanding of energy system transformations.

**Markets.** Understanding the science that underpins a few isolated energy technologies provides little insight into the energy system’s dynamics without some understanding of markets. My goal is an engineered understanding: not the details of energy futures trading one might learn in business school but rather the cascade of prices from primary energy to end use and the capital and operating costs of the major transformations from primary energy through delivery of useful energy.

The central goal is to encourage students to learn some of the most important cost and price structures across the energy system in standardized units. For example the fixed operation and maintenance (FOM) cost of power plant is denominated in $/kW-year, but one can just as easily think about FOM costs for transportation infrastructure in $/seat-year.

This is not an economics course which will focus on theory, instead the goal is to provide a rough-and-ready engineers understanding of discounting along with basic knowledge of supply and demand elasticities.
Distribution by topic and discipline.

- Distribution of content by discipline
  - 80% energy technology and systems and 20% environmental constraints.
  - 10% science, 60% engineering at the "how things work" level, and 30% social context primarily engineering economics and history.

- Topics
  - Three environmental impacts: CO₂ emissions, air pollutants (NOₓ, PM, SOₓ), and land footprint (land appropriation per unit of primary power).
  - Two energy sectors: electricity and transportation.
  - Primary energy sources including: fossil fuels, biomass, nuclear, solar and wind.

3. Expectations

Students are expected to
- attend all classes;
- be on time;
- submit assignments on time;
- be respectful of each other and of the instructor;
- be prepared to be cold-called; and
- do their best to prepare professional products for their assignments.

Students are expected to have read the required readings before class – many of the classes will be discussions of issues raised in the readings. Recommended readings represent additional resources that may be useful for students especially interested in a particular topic, but reading them is not required for class.

Collaboration. Any collaboration on quizzes is prohibited. The research paper is intended to be a new work by a single individual. Unless indicated otherwise I will assume that the research paper represents original work by the student who submits it. You may—and indeed are encouraged too—seek help from any source as you write the research paper but you must unambiguously distinguish your original work from that incorporated from others.

This means, for example, that students must observe SEAS and Harvard University rules regarding the citation of sources. Any sentences, paragraphs or calculations taken verbatim from the writing of (or interviews with) any other person or persons, or from your own writing that has been published elsewhere, must be placed in quotation marks and their source must be clearly identified. Slightly changing the wording of a sentence or the formatting of a calculation does not evade the requirement for citation. Indeed, whenever you are drawing an important argument or insight from someone else, even if you reword it into your own words, a reference to the source is required.

Including material from others in the assignments without appropriate quotation marks and citations is regarded, as a matter of School and University policy, as a serious violation of academic and professional standards and can lead to a failing grade in the course, failure to graduate, and even expulsion from the University.
4. Assignments & Grading

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<thead>
<tr>
<th>Activity/Assignment</th>
<th>Fraction of Grade</th>
<th>Date</th>
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<tbody>
<tr>
<td>Class participation</td>
<td>10%</td>
<td>NA</td>
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<tr>
<td>Quizzes</td>
<td>30%</td>
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<td>• There will be six 30 minute quizzes administered in class that test knowledge of assigned reading and lectures.</td>
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<td>16-Sept 9-Oct 21-Oct 4-Nov 18-Nov 2-Dec</td>
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<tr>
<td>• The best 4 of 6 quizzes will count toward the final grade.</td>
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<tr>
<td>Research brief</td>
<td>15%</td>
<td>14-Oct</td>
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<tr>
<td>• A short technical research analysis on an applied energy topic.</td>
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<td>• Topic must be agreed in writing with instructors by 2nd October.</td>
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<td>• Word length is limited to 2000 words.</td>
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<td>Group research project</td>
<td>15%</td>
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<td>• Group size: 3-5, with 4 recommended.</td>
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<tr>
<td>• A technical research analysis on an applied energy topic.</td>
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<td>• Presentation of work to class and expert guests.</td>
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<td>• Topic must be agreed in writing with instructors in advance.</td>
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<td>Final Exam</td>
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<td>• Content is cumulative and structure will be similar to the quizzes.</td>
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Assignments must be posted to the class page by midnight (11:59 PM Eastern time) on the day they are due. Late assignments will be marked down one grade for each day they are late, unless an exception is requested and granted in advance.

The class participation grade is evaluated on each student’s engagement with the class as a whole. Effective class participation requires that students read and review the assigned readings before coming to class. The class participation grade is not a measure of the quantity of a student’s interventions, but rather on the quality of verbal participation in class discussions. I am looking for interventions that (a) bring in evidence/ideas from the readings, (b) build on comments from others, and (c) link practical experience to the material being discussed.

The participation grade will also take account of student’s level of non-verbal attention and engagement. Although the use of laptops and table PCs is permitted for referring to the readings and lecture outlines and for taking notes, use of these devices for non-class purposes (work for other classes, and all internet related activities) has negative impacts on the overall class environment and is strongly discouraged. Even permitted use of laptops and tablets can have the negative effect of reducing the level of attention devoted to the class. As a result, failure to be engaged in the class, due to excessive focus on laptop or table can result in a lower participation grade.

5. Special Accommodations

If you have a documented disability (physical or cognitive) that may impair your ability to complete assignments or otherwise participate in the course and satisfy course criteria, please inform us at your earliest convenience so that instructional modifications or accommodations can be identified, discussed, and documented. Please contact the Accessible Education Office to request an official letter stating authorized accommodations.