Energy, Engines and the Environment

The subject of energy permeates every aspect of our lives. Environmental and sustainability issues have become more and more cogent, with global warming becoming a primary environmental concern about which most industrialized countries are more or less mobilizing. The energy "landscape" has been varying rapidly in some respects: for example, nuclear energy was thought to be making a comeback, until the environmental disaster of Fukushima reversed the trend. The source of fossil fuel has been shifting from coal to gas, with the developments of fracking technology and the availability of vast reserves of shale gas, with the US poised to become a net exporter of fossil fuels in the near future. But even in this area there is controversy on the environmental implications in a partially unregulated industry, with the potential of moratoria or outright ban of fracking on a state by state basis. Yet, some features of the energy make up remain unchanged: wind, solar and other renewable sources are playing an ever increasing role, but off a relatively small base. Therefore, despite intense research and development in carbon-free technologies, the majority of the energy supply through the middle of this century and beyond will stem *inevitably* from fossil fuels. As a result, combustion technologies, coupled with reactants/products treatment and, cost permitting, carbon capture and sequestration will remain central to energy consumption for several decades. A solution to the energy problem will involve a combination of conservation, increased efficiency and new technologies.

With these premises in mind, I developed a course aimed to cover the fundamentals of a field that is central to the future of the world and of which *all* students should be knowledgeable. The field is rapidly evolving and, although an effort will be made to keep abreast of the latest developments, the course emphasis will be on timeless fundamentals. We will begin by discussing key concepts of thermodynamics, including the definition of various forms of energy, work and heat as energy transfer, the principle of conservation of energy, first and second laws. It is impossible to understand energy on a rational and quantitative basis without an elementary understanding of thermodynamics. Subsequently, we will discuss the physics of global warming and climate change, which have resulted in the need to wean ourselves off fossil fuels. Next, the course will focus on carbon-free energy sources, including solar, wind, hydro and biomass, the sum of which is still an unfortunately modest fraction of the total energy supply in the world. As a result, we will have to visit also traditional fossil-fuel power plants and engines, that are currently involved in 85% of energy conversion worldwide. We will conclude with some considerations on energy policy and with the "big picture" on how to tackle future energy needs.

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Office Hours: flexible and arranged via e-mail

Intended audience: Freshmen and sophomores in science and engineering, non-science majors (all years)

Prerequisites: A score of 4 or 5 on an AP test in math and/or science.

Required Texts: 1) Wolfson, R., "Energy, Environment and Climate," Norton and Company, 2nd edition, 2011 ($93.00 new)- *Note*: the latest editions of refs. 4 and 5 (see below) are being evaluated in case they offer a better alternative.

2) J. B. Fenn, *Engines*, *Energy and Entropy* (Freeman, but unavailable), a witty textbook by ChemE Emeritus Professor, John B. Fenn, winner of the 2002 Chemistry Nobel Prize. Electronic copies will be made available.

Class Meetings: class will meet twice a week, Tu-Th 1:00-4:15, Room TBD.

Grade: Nearly weekly HWK sets (25%) and in-class quizzes (35%), final exam and/or project (40%).

Additional Resources

3. Archer, D., "Global Warming: Understanding the Forecast," 2nd edition, Wiley, 2012.
4. G. Boyle, "Renewable Energy," Oxford University Press, 3rd edition, 2012.

5. J.A. Fay and D.S. Golomb, "Energy and the Environment: Scientific and Technological Principles," 2nd edition, Oxford University Press, 2012
6. MacKay D. JC., "Sustainable Energy- Without the Hot Air," a highly readable monograph (free downloaded at www.withouthotair.com)

The following books make for an easy, nontechnical read:

7. M. Goldstein and I.F. Goldstein, *The refrigerator and the Universe*, Harvard U. Press- a delightful book in which the concepts of energy and entropy are described clearly. It has virtually no math.
8. H. Christian Von Baeyer, *Maxwell's Demon*, Random House, 1998- another very readable, non-technical book, with some interesting historical notes on some of the original players in the thermodynamics arena.
9. V. Smil, *Energies*, MIT Press, 1999- a generalist approach presenting an integrated survey of all kinds of energy and their impact on civilization.
10. D. Goodstein, *Out of Gas*, Norton, 2004- straddling both the energy component and the sustainability components of this course.
11. S. Weart, *The Discovery of Global Warming*, Harvard University Press, 2003

Links to articles and reports covering specific topics will be posted on Canvas, as we progress. Typical sources are Science, Nature, The Economist, the BBC website, US government and international agency sources. They will be listed in lecture compendia that will be posted periodically on Canvas usually in Power Point format.

Schedule

Week	
1	Introduction: the big picture-take 1. Definition of various forms of energy, work and heat as energy transfer. Equivalence of work and heat. First law of thermodynamics: conservation of energy. Carnot cycle. Entropy and the second law of thermodynamics.
2	Global warming and climate change. Solar energy,
3	Wind energy and hydroelectric energy; C-free left over (geothermal, ocean, nuclear); the grid; bioenergy
4	Fossil-fuel power plants and engines. Pollution from fossil fuels. Carbon capture and sequestration.
5	Hydrogen. Efficiency. Energy policy. The big picture-wrap up