Evolution of the Global Energy System: From Earth's Deep Past to Civilization's Future
Fall 2012 – Rutgers SAS Honors Seminar (01:090:252:01)

Tue./Fri. 11:30am-12:50pm, Brett Hall Seminar Room, College Ave. Campus

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Course Description

The flow of energy drives natural and human systems. The balance between incoming solar energy and outgoing thermal energy is the fundamental driver of Earth's climate. The photosynthetic transformation of solar energy to chemical energy, and the respiratory transformation of chemical energy to other forms of chemical energy, to useful work, and to heat drive almost all of Earth's biosphere. The development of human civilization has been closely tied to the ability to capture an ever-increasing fraction of the Earth's energy budget, first primarily through agriculture and later primarily through combustion of fossil fuels. As a side effect, humanity is effecting major changes to both the climate and the biosphere in which it evolved. Concerns about these changes and about the security of energy supplies are major drivers of modern economic and policy decisions.

This seminar, intended for students from all academic majors, will examine the evolution of energy supply, energy demand and the global energy system as a whole, from the rise of photosynthesis to the development of agriculture, the Industrial revolution, and the modern, carbon-constrained world. It will investigate the historical relationship between energy use and economic welfare and possible scenarios for the coupled development of the global energy system and Earth's climate over the coming centuries. Familiarity with basic mathematical and scientific concepts (comparable to high school physics) will be assumed; moderately sophisticated mathematics (e.g., calculus) will be discussed but not required for homework.

Student goals

At the end of this course, you should be able to: (1) Qualitatively and quantitatively assess the flows of energy in natural and human energy systems, and (2) Evaluate the sustainability and feasibility of current and proposed human energy systems, in the context of natural energy flows and historical changes in natural and human energy systems.

The course is divided into five units, focused respectively on fundamental concepts of energetics, the current human energy system, the pre-human natural energy system, the development of the human energy system, and the future of the human energy system. The goals for each of these sections are:

1. To be able to articulate concepts of energy and entropy and gain comfort with different commonly encountered units of energy.

2a. To identify the major energy demands and major proximate sources of energy employed in the global, national, state and personal energy systems, and rank their relative importance;
2b. To quantitatively assess how changes in personal behavior impact personal energy demand;

3a. To explain the flow of physically primary energy sources (nuclear and gravitational) through to proximate sources;
3b. To construct a simple model of Earth's energy balance and employ it to assess the climatic response to changes in greenhouse gas concentrations;

4. To evaluate the relationship between human population, wealth, and energy consumption over the course of human history

5. To assess the implication of continuations of those trends into the future and evaluate the benefits and costs of different alternative scenarios.

In the course of achieving these goals, you should gain comfort with order-of-magnitude estimation, box modeling, collaborative presentations, and writing.

Texts

You'll need copies of the following texts for the entire course:

- *Energy: A Beginner's Guide*, by Vaclav Smil
- *Sustainable Energy Without the Hot Air*, by David MacKay (available online at withoutouthotair.com, though I personally recommend a paper copy)
- *Eating the Sun,* by Oliver Morton

In addition, we'll read a number of papers that will be uploaded to Sakai.

Assignments

"Minute" Papers will be occasionally assigned either pre-class or in the last few minutes of class. These are graded on completeness, and will generally involve writing a 1-paragraph reflection upon or question about material covered in class or in the readings, or responding to a short prompt. These will count toward the class participation portion of your grade.

Field Trips: There will be two field trips during the term, one during class to the campus co-generation plant and solar farm (Sept. 18), and one on Saturday, October 20, to the coal mining region of eastern Pennsylvania. In addition, there will be a third "field trip," also in class, to the Rutgers Climate Research Symposium on Nov. 9. These will count toward the class participation portion of your grade, and should also inform your written assignments. If you are truly unable to make the Saturday field trip, please let me know, and let me know why, within the first two weeks of class and I will provide a substitute assignment for you.

Quantitative Exercises are designed to help you get comfortable with the mechanics of the natural and human energy system. They will inform your writing exercise, group presentations, and final paper. Due dates will be revised as the course progresses to keep these in sync with the reading and the material.

The first set of exercises will focus on your personal energy audit; the second set will focus on the Earth's climate and carbon cycles.

Grading: They will be graded on a three point scale (√+,√, √-); some may not be collected, at my discretion. Please note, however, that it will be very challenging to do the written and group exercises without completing these.

Collaboration and citations: I encourage you to collaborate on the quantitative exercises, as this will likely help you learn much faster. You can also use any resources available to you. Scientists collaborate with each other all the time; they just cite each other to avoid "stealing" ideas. Therefore, I ask only that you explicitly cite any ideas or hints you get from other people, books, the Internet, or other resources, in your homework.

Guidelines: Please make sure submitted homework assignments adhere to the following guidelines to avoid plagiarism or losing credit unnecessarily:

- Cite any work you get from outside sources, and any classmates or others with whom you work. (If you do a problem completely in your own head, state so explicitly.)
- Show your work and explain your thinking (so that someone who didn't know how to solve the problem could follow your work). If you are doing a problem set in Excel, please make sure any parameters are explicit in their own cells, not hidden in formulas; and annotate your spreadsheet with textual statements of the relevant equations or algorithms.
- Box, circle, or highlight your final answer(s). Make your conclusions clear.

Written Assignments will provide you with the opportunity to reflect upon the exercises, readings, class discussion, and/or field trips. These must be completed individually.

Grading: They will be given letter grades; the lowest grade of the three will be dropped. Grades will be based on content and presentation. For every 24 hours past the deadline an assignment is turned in, half a letter grade will be deducted.

Citations: You *must* cite any sources you use in your essay; failure to do so is a form of plagiarism. Citations should be in (Author, Year) format.

Guidelines: Please turn your essays in electronically via the Sakai Dropbox, in .DOC, .RTF or .PDF format. These should be double-spaced in 12-point Times New Roman with 1" margins, and never more than 5 pages of text. (Some assignments may have tighter page limits; and, depending on the assignment, figures may not count toward the page limit.)

Group Presentations provide the opportunity to share, develop and implement ideas collaboratively. They will each culminate in an ~15-20 minute in-class oral presentation and a 1-page abstract.

The first two presentations will relate to your personal energy audits; the third will involve the assessment of policy proposals.

Grading: These will be given letter grades, based on your presentation and abstract. At the time you turn these into Sakai, you should also give me a paragraph statement, reflecting the consensus of your group, on the contribution of each group member to the activity. These contributions will be taken into account in assigning your grade. The abstract, final slide deck, and contribution statement are due midnight two days after the presentations are given in class. For every 24 hours past the deadline an assignment is turned in, half a letter grade will be deducted.

Citations: Any figures on your slides that you did not generate yourself must be cited in (Author, Year) format in the corner of a slide. You should have a "References" slide at the end of your slide deck, which need not be presented but should provide full citations for all of these.

Guidelines: Use PowerPoint, Keynote, or comparable software to prepare your presentation. In general, effective PowerPoint presentations use the slides to highlight key figures; if your slides are more

than 25% text on average, they are probably not designed as well as they could be. Please do not spend your presentation reading text off your slides.

Abstracts should be double-spaced, 1" margin, 12 pt Times New Roman font, and no more than 1 page. The bibliography does not count toward the page limit.

Presentations, in PPT or PDF format, should be uploaded to Sakai after your presentation and will be made available to the entire class. Your abstract, in DOC, RTF or PDF format, should also be uploaded to Sakai and will likewise be shared. Please include the name of all group members on both the title page of the slide deck and on the abstract.

Final Paper: Your final paper, due during exam period, will provide you an opportunity to synthesize everything you've learned in the course. It will ask you to place your personal energy consumption in the context of past, current and potential future energy systems. Except for the page length restrictions, guidelines are as for the written assignments.

Extra credit: You can get extra credit by participating in discussion on the class Sakai site of (1) energy- or climate- related talks happening on campus and (2) energy- or climate-related news articles that I post on the Sakai site. I will try to keep you informed of opportunities as I become aware of them, and please let me know of any interesting seminars or news articles you find. For talks, the Rutgers Energy Institute website, rei.rutgers.edu, is a good place to look. For news articles, good places to look include eenews.net (I encourage you to sign up for their daily newsletters), green.blogs.nytimes.com and climateprogress.org.

Attendance

The class exist to here you achieve the goals of the course, and it will be much harder for you to do so without them. I therefore expect you to attend and participate in class; this will constitute a significant fraction of your grade. If you have a legitimate reason for not attending (e.g., illness, family emergency, etc.), please let me know at least 24 hours in advance by email.

Likewise, both so that you get the fully learning experience and out of respect for your fellow students, I expect you to show up to class on time. Failure to arrive in a timely fashion on a regular basis will lower your course participation grade.

Electronic Devices (Phones, Computers, Tablets)

Humans are poor but self-deluding multitaskers. We can cycle attention between different tasks, but have great difficulty actually focusing on multiple activities at the same time. For example, it is extremely unlikely that you can give full attention to the class if you are on your phone or checking out Facebook at the same time.

Please be respectful of me and your fellow students – please do not use your phone in class. If phone use in class is a recurring problem, I will talk to you about it; and if it persists, I will regard a day in which you check your phone in class as an unexcused absence, and it will affect your class participation grade accordingly.

Likewise, laptop or tablet use in class is allowable only in support of class activities. Appropriate uses include making presentations, reading papers, taking notes, or looking up something class-related on the Internet in response to specific instructions from me. Examples of inappropriate uses include checking email, Facebook, Twitter, or GChat. Inappropriate laptop or tablet use will be treated the same way as phone use.

Academic Integrity

All students enrolled in the School of Arts and Sciences Honors Program are responsible for upholding the highest standards of student behavior, as specified under the University Code of Student Conduct, including but not limited to strict adherence to the terms of the University's Academic Integrity Policy.

Please make yourself familiar with the terms of the University Code of Student Conduct (http://studentconduct.rutgers.edu/), including the University's Academic Integrity Policy (http://academicintegrity.rutgers.edu/).

Grading

The grading metric will be subject to revision, but will be roughly:

20%: Course participation
20%: Quantitative exercises
20%: Written assignments
20%: Group presentations
20%: Final paper

Indicative Course Schedule (Subject to Revision)

	Unit	***Topics***	***Assignments***	***Readings***
9/4	1: FUNDAMENTAL CONCEPTS	Overview / Introductions/ What is energy and why should you care?		Smil, ch. 1; MacKay, ch. 1-2; Morton, Introduction
9/7		Laws of thermodynamics; units	BIO DUE	MacKay ch. I; Morton 2.1
9/11	2: ENERGY SUPPLY AND DEMAND	What do **we** use energy for?	QE 1 DUE	Smil, ch. 5; MacKay ch. 3, 5, 7, 9, 11, 13, 15, 17; NAS (2008); [Eshel and Martin (2006)]
9/14	*Field trip to campus co-gen and solar*	*Field trip to campus co-gen and solar*	QE 2 DUE	Morton 8.5; Campus Cogen paper; Rutgers Sustainability report
9/18		Where does our energy come from?	QE 3 DUE	
9/21				
9/25		Group presentation: PEA Reports	GROUP 1 DUE	
9/28			ESSAY 1 DUE -- 9/30 at midnight	
10/2	3: NATURAL ORIGINS	Earth's natural planetary energy balance		Smil, ch. 2; Morton 4.1; Glasfeld & Gesenbrecht
10/5				
10/9		Photosynthesis, metabolism,		Morton 2.2, 2.3; 4.2,

		and the global carbon cycle		4.3, 4.4, 5.2, 5.3, 5.6, 6.2, 7.2, 7.3
10/12				
10/16	*[NJ Voter Registration Deadline is 10/18]*	Pre-Field Trip Presentations		
10/19		Pre-Field Trip Presentations	HANDOUTS DUE	"Coal in Pennsylvania", [AGI, "Coal and the environment";EIA, "Coal Production in the United States"]
10/20	*Anthracite Region field trip*	-----		Krajick, "Fire in the Hole"; [GSA field guide]
10/23	4: FUTURES	The Kaya identity, energy use and economic welfare		read QE 4; Smil, ch. 6; World Bank on U.N. Millennium Goals, through page 23; BP Energy Outlook (2012), "Global Energy Trends" chapter
10/26		Climate Change		Morton, 8.6; Hansen et al. (2012); Myhrvold & Caldeira (2012)
10/30	CANCELLED DUE TO SUPERSTORM SANDY		QE 4 DUE	
11/2	CANCELLED DUE TO SUPERSTORM SANDY			
11/6	*(Election Day -- remember to vote)*	Climate Change and Resources	ESSAY 2 DUE	
11/9	*Rutgers Climate Research Symposium*	Rutgers Climate Research Symposium		
11/13		Group presentation: PEA followup; Resource distribution and limits	GROUP 2 DUE	Dukes (2003); Yergin (2011); Murray and King (2012)
11/16		Scenarios and opportunities		Morton, 9.1; Mackay ch. 27-29 and skim all preceeding chapters; Smil (2011), "The Latest Infatuations"; Schiermeier et al. (2008); [Pacala & Socolow (2004); [Chu & Majumdar

				(2012); Hoeffert et al. (2002)]
11/21		Policy dissection		(see policy analysis handout)
11/27		Policy dissection (continued)		
11/30		Group presentation: Policy scenarios	GROUP 3 DUE	
12/4	*(AGU – CLASS CANCELED)*			
12/7	*(PROF. Kopp OUT -- Prof. Clint Andrews, guest instructor)*	Andrews: Climate change adaptation		
12/11	*(PROF. KOPP OUT -- Prof. Frank Felder, guest instructor)*	Felder: Electric power system of the United States		
12/14	READING PERIOD -- Optional Review/Discussion Session			
12/20			FINAL PAPER DUE	

Readings in brackets are optional.

Assignment Previews

Assignments are subject to revision as the course goes on, but for your planning, the general theme of the different assignments are:

- Pre-Course Personal Background and Bio
- QE 1: Personal energy audit data collection
- QE 2: Unit calculations for personal energy audit
- QE 3: Personal energy usage
- Group presentation 1: Personal energy targets
- Writing assigment 1: Reflection upon personal energy audit
- Group presentation 2: Evaluation of personal energy targets
- QE 4: Kaya identity
- Writing assignment 2: Briefing memo for President Lincoln on benefits and costs of fossil fuels generally and coal in particular
- Group presentation 3: Scenario analysis of a political movement's energy policy
- Final paper: Briefing memo for Prime Minister Singh on fossil fuels, climate change and economic development goals