Syllabus: Social Systems, Energy, and Public Policy
Public Policy/Complex Systems/Environment 250
Fall 2017, Room 1230 Weill Hall

Aug 28, 2017

Instructor:
Irv Salmeen, Ph.D. Lecturer
Formerly: Associate Director Science and Technology Policy Program, Gerald R. Ford School of Public Policy; Research Scientist, LS&A Center for the Study of Complex Systems
e-mail: salmeeni@umich.edu
Office: 3236 Weill Hall
Office Hours: 11:30-1:00 Tuesdays and Thursdays or by appointment

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Course synopsis:

The course examines the question: if not fossil-fuels (coal, oil, natural gas), then what? Topics covered: technical and social origins of climate-change problem; the social and technical meaning of "energy"; why we depend on fire; how heat-engines harness fire; how energy is measured; the good and bad about fossil fuels; fuel economy of cars; urban transportation and traffic congestion; electrical grid; solar and wind energies; biofuels; electricity, electric cars; water-energy nexus; lighting; energy infrastructure in cities; space heating and cooling; air pollution; energy consumption of modern computing and internet; energy economics; energy policy writ large. The goal is to introduce students to quantitative and qualitative analytical tools that will help prepare them for subsequent in-depth analysis of energy systems problems at scales from individuals to governments.

The course qualifies for LS&A quantitative reasoning credit. It draws on publically available data posted on government websites, and it uses college-prep level high-school mathematics and physical science to explain quantitative relationships underlying the social, technical, and cultural elements of energy systems and policies. Homework is based on calculations, interpretive reasoning, or short paragraph responses to questions arising from in-class materials and from reading assignments.

Prerequisite: No formal prerequisite. High school physics, chemistry, calculus, and economics are helpful.

Resources: Course does not use a textbook. Course format is lectures with PowerPoint slides, outside reading assignments, and in-class individual or small group tasks. PowerPoint lecture slides, supporting materials, and reading assignments will be posted on the course *Canvas* site.

Grading: 70% on 10-12 homework assignments; 25% on one mid-term exam, 5% on in-class task participation. Grades: 88-100% is A- to A+; 79-87 is B- to B+; 70-78 is C-to C+. There is no "curve" or letter grade quota distribution.

Fall 2017 Public Policy /Complex Systems/Environment 250 ***Social Systems, Energy and Policy*** **Lecture Tuesday and Thursday 10-11:30 1230 Weill Hall** 27 Classes. 10 homework assignments. One exam.	
1. Sept 5 **Framing "The Energy" problem, Part 1.** Free list/pile sort exercise; evaluating prior attitudes and knowledge. Harnessing fire and the 19th Century Industrial Revolution leading into today's: energy problems. Technologies from steam engines to cars; electricity. Social changes. Wicked problems. What we do with "energy:" move stuff and heat stuff.	**2. Sept. 7** **Framing Part 2.** Discuss free-list data from Class 1. Defining the Energy Problems from DOE data. Fuels are burned to generate heat; heat engines convert heat into mechanical work: cars, trucks, planes, trains, electricity generation. Heat-engine unavoidably generate CO_2 and reject >60% as unusable. Policy implications.
3. Sept 12 **Moving stuff**. If we don't use heat engines, what else is there? All of energy policy and intertwined social-systems problems rest on quantifying "energy". Energy is "used" to move stuff or heat stuff: how hot, how much, how fast, how far? Understanding the meaning of the numbers: work, kinetic energy; gravity; the "energy content" of fuels.	**4. Sept 14** **Measuring "energy"** Moving stuff, work, and mechanics of motion. Examples: bicycle speed going downhill; why you go head-over heels when your bicycle hits a pothole; why traffic circles save fuel; why timed traffic lights save fuel; saving calories on your bicycle commute; work done lifting stuff. How the "heat content" of fuels is defined as mechanical work. Energy cost of a hot shower. Definitions of units: joule, watt; watt-hour, BTU, Quads, Calories.
5. Sept 19 **Energy yield of fuels.** Why we depend on fossil fuels: little bit makes a big fire; stable, easy to extract, cheap, chemical reaction with oxygen. Example: the heat of combustion for gasoline and other fuels. Carbon footprint: why natural gas yields half the carbon dioxide per unit energy than that gasoline; why natural gas is hard to use in cars. Meaning of "food calories."	**6. Sept. 21** **Power: the rate of doing work.**. How fast we burn the coal pile is power; the size of the coal pile is energy. Watts and horsepower. Examples: snow-blowing your driveway. Power in today's automobiles and why it conflicts with fuel economy. Muscle power. Estimating the capacity of humans to do work. Limits to human performance.
7. Sept 26. **Fuel-economy of cars**: meaning of corporate average fuel-economy. Treadmills for cars and trucks: EPA standardized test cycles. How much of the heat energy yielded by fuel consumption ends up turning the wheels? Depends on driving cycle, but in urban driving it is less than 15% for today's cars. How car mass determines car fuel economy. Intertwining of energy policy, car markets, consumer demand, and the realities of how car engines function.	**8. Sept 28** **Biofuels**. Are fuels, such as ethanol, derived from plants carbon-neutral? The systems chain of producing transportation ethanol from fermentation of cornstarch. Comparisons with sugar cane and cellulosic ethanol. Overall energy costs as corn in the field goes to fuel in the tank. Money costs, government subsidies, other policies. Biological production of methane.
9. Oct 3. **Urban transportation**. Urban traffic congestion Economist Thomas Schelling problem: no one wants to go there any more, it's too crowded. Commuting by car or bicycle? Human travel time budgets. Does public transit reduce CO_2? Does	**10. Oct 5** **Electricity Part 1** Recap EIA data on fuels used for electrical energy generation. CO_2 emissions from electricity sector. Data on end uses of electricity. How to generate electricity: batteries (electrochemistry); electromagnetic induction

public transit reduce congestion? Dilemmas of highway planning: Braess paradox—more highways may make congestion worse. Congestion is a Goldilocks problem. Will self-driving cars provide congestion relief?	(relative motion of a loop of wire and a magnet); photovoltaic effect (converting sunlight to electrical current.). Measuring electricity: volts, amps, ohms, power.
11. Oct 10 **Electricity Part 2.** Examples: overloading home circuit and why houses have safety circuit breakers. Cost of using electricity: what we pay the utilities. How long does it take to charge our cell phone? Survey of the origins of modern electrical grid and the concept of "central power" and its dependence on heat-engines to generate electricity. Edison's light bulb and the first central power. Tesla, AC/DC, transformers. Conceptualization of electrical grid origins of idea of public utility and natural monopoly. Electrical systems and the origins of government regulated utilities.	**12. Oct. 12** **Electricity Part 3**. Why modern grid is A/C Structure of modern grid: investor owned; municipal systems; cooperatives. Quantitative view of individual and local electrical energy consumption. Utilities' problems of load-factor and load-balancing. The Modern National Grid: North American Electric Reliability Corporation and grid security. Is access to electricity a right? Business of electricity and why governance matters.
Oct 17 **No class. FALL STUDY BREAK**	**13. Oct 19** **Electricity Part 4. Solar electricity**. Photovoltaic effect. Solar spectrum. Total energy of sunlight reaching Earth's surface; fraction of that energy that can be converted to electrical energy via photovoltaic effect. ASTM standard spectrum. Solar energy as a function of time of day, latitude, season. Estimation of electrical energy that can be practically exploited. Solar water heating. Roof top and central-power solar electricity. Coupling solar electricity to grid versus off-grid. Land-use constraints.
14. Oct 24. **In Class Exam**	**15. Oct 26** **Electricity Part 5. Wind generated electricity**. Properties of wind; velocity distribution, altitude dependence, geographical distribution of "wind resources." How much wind kinetic energy can be converted into electricity? Betz's law. Load factor. Intermittency problem and electrical energy storage. Coupling wind and solar generated electricity to the grid. Not in my backyard! Wind turbines and land use constraints.
16. Oct. 31 **Electric cars.** How they work? Motors, & batteries: primary energy source? Range anxiety and recharging. Measuring energy efficiency of electric cars. Social and economic impacts of electric cars. Policy: how to pay for roads, if there is no gas-tax revenue? Durability under recharging. Why a 200-mile range battery needs an 800 pound battery": it's a matter of electrochemistry.	**17. Nov 2** **Water and energy nexus.** Electrical energy demand of urban potable and waste water systems. Water demand for cooling: industrial, electric utilities. Estimated water demand for cooling of urban electric vehicle recharging stations. Water demand for fracking. Agricultural water demand. Drawing from deep aquifers.
18. Nov 7 **Lighting**. Black-body radiation. Cultural impact of electric lights post 1910 or so. Lighting energy consumption. Black body spectrum and why incandescent light bulbs are a <2% "efficient". Human eye response to solar spectrum. Light emitting diodes; compact fluorescent bulbs. Candle	**19. Nov 9** **Cities and energy infrastructure** Highways, streets, and getting about. High-rise living and vertical commuting; elevators. Where people live: suburban sprawl. Energy efficiency in dense cities: (co-generation of electrical energy and heating/cooling-- UM central campus power plant

light. Psychophysics of color temperature. Black-body radiation and Steffan-Boltzman law.	does that.) Getting electrical energy, water, and natural gas into cities.
20. Nov 14 **Space heating and cooling** HVAC. Interior comfort: human body heat balance, Steffan-Boltzman law. Heating and Air conditioning, building ventilation, insulation etc. Electrical energy demand and livability of deep south (Texas, Florida, etc) and southwest deserts (Arizona)	**21. Nov 16** **Air pollution Part 1.** Coal burning: a killer for centuries, proved guilty in the 1950s after the Great London Fog. How we know—epidemiology. Los Angles photochemical smog: what causes it and why it is hard to avoid.
22. Nov 21 **Air pollution Part 2.** Fine-particle air pollution and impact on urban health. Air pollution epidemiology in 2016. The story of leaded gasoline and the health effects of lead poisoning	**Nov 23** **Thanksgiving break**
23. Nov 28 **Electricity: the internet, communications, Big Data.** Cyber security and the Grid and natural-gas distribution systems. Energy requirements for cell-phone networks.	**24. Nov 30** **Economics and energy businesses** Central power. A natural monopoly? Is access to electricity a constitutional right? How much should we pay? Regulation or deregulation. Natural gas versus coal. Nuclear power. Is central power "inevitable?" Distributed power; micropower.
25. Dec 5 **Energy policy part 1**. History of energy. Crisis response. OPEC. Emergence of natural monopoly concepts. Regulated utilities. Contrast between U.S. and Europe. Market driven "emergent policies"	**26. Dec 7** **Energy policy part 2**. How much will we need and what will we need it for? EIA energy demand forecast models. Meaning of estimates. Modeling growth: exponential growth; limits to growth (logistic function.) Energy futures forecasting EIA projections. **Renewable Energy Portfolio Standards (RPS**). **Municipal independence. E**conometric studies of RPS success (or not.) Estimating renewable electrical energy production potential for states. Land requirements
27. Dec **Global energy challenges.** US policy challenges. Central authority and governance of public commons. Infrastructure security, replacement, upgrades, etc.	

Reading assignments (partial list as of Aug 28))

Improving Public Engagement With Climate Change: Five "Best Practice" Insights From Psychological Science by Sander van der Linden, Edward Maibach, and Anthony Leiserowitz in Perspectives on Psychological Science 2015, Vol. 10(6) 758–763.

Biofuel's carbon balance: doubts, certainties, and implications by John Dicco in Climatic Change (2013) 121:801–814

Dilemmas in a General Theory of Planning: Wicked Problems by H. W. J. Rittel and M.M. Webber in

Policy Sciences (1973) vol 4 pp 155-169.

Electrification of America: The Systems Builders by Thomas Hughes in Technology and Culture (1979) Vol 20, pp 124-161

Thomas Edison and the Social Construction of the Early Electricity Industry in America by P. McGuire, M Granovetter, M. Schwartz in *Explorations in Economic Sociology*, Ed.- Richard Swedberg, New York: Russell Sage Foundation (1993)

U.S. Electricity Industry after 20 years of Restructuring by Severin Borenstein and James Bushnell (2014) in Annual Reviews of Economics vol 7

U.S. Energy Transitions 1780-2010 by P. A. O'Connor and C. J. Cleveland in Energies Vol 7 pp 7955-7993 (2014)

The Challenges Of Congestion In Regional Transportation by Anthony Downs (2004) Text of his talk in 2004 to City of New York Transportation Board. Extracted from his book "*Still Stuck in Traffic*" 2004. Brookings Institution Press