Energy and Resources Group (ERG) & Goldman School of Public Policy (GSPP)

Energy and Society (#28602)
ER 100 / 200 and Pub Pol C184 / C284

Tuesday & Thursday, 2:00 – 3:30 PM – Haas Faculty Wing F295

Professor Daniel M Kammen
Email: kammen@berkeley.edu | Twitter: @dan_kammen
Office Hours: Wednesdays mornings in 326 Barrows Hall – Signup at https://www.wejoinin.com/sheets/hoxnz

Note: <u>sections begin the second week of the semester, on August 27</u>

Among the questions we will address in this course are:

- ***In what ways has fossil-fuel use defined the 20th Century? What about the 21st?***
- ***What role is there for renewable energy and energy efficiency today and in the future?***
- ***What is the role of nuclear power in our present and future energy mix?***
- ***Could fuel cells or the hydrogen economy cause a revolution in the automotive industry?***
- ***How is climate change impacting energy systems?***
- ***How are energy issues different in developing nations from those in the 'North'?***
- ***What tools do you need to address these questions from an interdisciplinary perspective?***

Interested in these questions? Then Energy and Society is for you.

Each of these questions about the use and impacts of energy systems requires an interdisciplinary understanding that explores the scientific, technical, economic, social, political, and environmental opportunities and impacts of our energy system.

In this course, you will develop an understanding—and a technically and socially deep working knowledge—of our energy technologies, policies, and options. This will include analysis of the different opportunities and impacts of energy systems that exist within and between groups defined by national, regional, household, ethnic, and gender distinctions. Analysis of the range of current and future energy choices will be stressed, as well as the role of energy in determining local environmental conditions and the global climate.

ER200/PP284 are graduate versions of ER100/PP184, and their lectures and sections are held in common. ER200/PP284 includes additional material, with added analytic tools and problems on both the problem sets and the examinations.

Assignments and grading for the undergraduate and graduate courses are separate.

Course Goals

This course is designed to provide you with the methods, tools, and perspectives to understand, critique, and ultimately influence the management of technical, economic, and policy choices regarding the options for energy generation and use. We will focus equally on the technical, socioeconomic, political, and environmental impacts of energy.

We will examine the full 'life cycle', or 'cradle to grave to cradle again' of energy, from the stage of raw materials, or inputs, to generation, conversion, distribution, consumption, recycling, waste, impacts, and the ethnic, racial, gender, and economic inequities found in those stages. This work is inherently interdisciplinary, and will involve a fascinating but extensive effort to understand, critique, and integrate tools and perspectives from anthropology, cultural and ethnic studies, economics, engineering, physics, politics, sociology, and who knows what else.

The challenge of this integration is not simply one of learning and applying methods from very diverse disciplines, but more importantly is one of understanding how and when different types of analysis, disciplinary and political perspectives, and "voices" are heard, unheard, ignored, or discredited. Energy is a fundamental societal resource, the control of which reflects and shapes interactions both within society and between humans and the natural environment.

Coverage
Over the semester we will take a roughly chronological tour of the major fuel types used in human civilization. From there we will begin a broad-ranging analysis of the energy resource, combustion or conversion processes, application, waste, economic, social, political, cultural, and environmental impacts and options associated with these fuels and with the changing mix of fuels used within and across societies around the globe.

Assignments
There will be seven problem sets (35% of grade) and a policy memo (10%), a mid-term examination (20%), and a final exam (35%). The undergraduate policy memo is a 4-page product; 8 pages for graduate students. *The first two problem sets are only graded PASS/FAIL.*

Problem sets are posted online after class every other Tuesday, are due *online only* via bCourses.
Late assignments (30% penalty) will be accepted up to 6pm Pacific Time on the Monday following the posted deadline (when the solution set will be posted). Assignments turned in after this will receive no credit.

You will get the most out of the problem sets if you make an initial effort to work through all of the problems on your own. After attempting to solve the problems on your own, you may then work with other students to discuss different approaches. It is vital that you do your own work. It is a violation of the Code of Student Conduct to copy answers from anyone.

As part of your participation in the course, you are encouraged to use the bCourses discussion board to make comments and/or ask questions related to the readings or lectures. We will also post the answers to questions about the problem sets on bCourses, so be sure to check bCourses regularly.

Web-based readings: A number of readings, both *required and supplemental*, are available on-line. In order to download some of these, you will need to use an on-campus computer or set up your home computer or laptop with the campus proxy service. For instructions, see:
http://www.lib.berkeley.edu/using-the-libraries/connect-off-campus

All readings are also available on the course bCourses.
Required Reading* assignments should be completed before the lecture for which they are assigned. While I recognize that this is not always possible, you need to try; the material in lecture *does not simply review the readings*; *we use it as a basis for exploration of the course material and ideas.

Optional Field Trips

There will be several field trips during the semester. Each will be 3 - 6 hours (including travel time), and all will be Friday mornings. **Dates can change**

- **Field Trip #1**: Campus Combined Heat and Power Plant; 9 am September 15
- **Field Trip #2:** Windfarm, 9 am October 5
- **Field Trip #3:** Micro-hydropower, 9 am November 9

Graduate Student Instructors

GSI	Sections	Office Hours	Email
Nick Depsky	M 3-4pm, Wheeler 20 Th, 12-1pm Cory 289	M 11-12pm, Barrows 399 Tu 10-11am, Barrows 321	njdepsky@berkeley.edu
Salma Elmallah	W 1-2pm, Etcheverry 3113 F 12-1pm, Etcheverry 3109	W 2:30-3:30pm, Barrows 399 Th 9-10am, Barrows 399	salmae@berkeley.edu
Isa Ferrall	M 12-1pm, Wheeler 20 Tu 12-1pm, Moffitt 103	M 1-2pm, Barrows 399 Tu 4-5pm, Barrows 399	isa.ferrall@berkeley.edu
Christian Miller (lead GSI)	W 11-12pm, Dwinelle 182 Th 1-2pm, Haviland 12	M 11-12pm, Barrows 321 Tu 11-12pm, Barrows 321	cgmiller@berkeley.edu

Section meetings begin in Week 2 (i.e. starting 8/27).

Lecture Slides

Lecture slides (.pdf files) will be available for each lecture, and will be posted on the course website before the lecture. You should download the files and bring them to lecture so that you have all of the graphs and diagrams right in front of you. [We suggest using electronic copies when available to reduce paper waste.]

Wk	Date	Lecturer	Lecture #/Topic
1	8-23	Kammen	1. How Energy Use Shapes Society & the Environment
2	8-28	Kammen	2. Energy Toolkit I: Units, Forecasts, and the Back-of-the-Envelope
	8-30	Kammen	3. Energy Toolkit II: Fuels, Energy Content & Combustion
3	9-4	Kammen	4. Energy for 'the South' - Energy Transitions and Development
	9-6	Kammen	5. Energy for 'the South' - Biomass, Households, and Gender
4	9-11	Kammen	6. Energy Toolkit III: Energy Thermodynamics
	9-13	Kammen	7. Energy Toolkit IV: Thermodynamics of Modern Power Plants
5	9-18	Kammen	8. 'Hydrocarbon Man'
	9-20	Kammen	9. Evolution of the Modern Energy Economy
6	9-25	Kammen	10. Energy Toolkit V: Energy Economics
	9-27	Kammen	11. Energy Toolkit V: Environmental Economics
7	10-2	Horvath	12. Energy Toolkit VI: Life-Cycle and Cost-Benefit Analysis
	10-4	Kammen	13. Energy Efficiency 1: Devices
8	10-9	Callaway	14. Energy Efficiency 2: Buildings and Larger Energy Systems
	10-11	Kammen	15. Electricity Grids: Managing the Network
9	10-16	Friedman	16. Natural Gas, Fracking, and Carbon Capture and Storage
	10-18	**You!**	**Midterm Exam, In class**
10	10-23	Guest	17. Nuclear Energy: Physics and Engineering – Fission & Fusion
	10-25	Kammen	18. Nuclear Energy: Waste, Risk & Economics
11	10-30	Kammen	19. Energy Toolkit VII - Energy and Environmental Justice I (theory)
	11-1	Guest	20. Energy Toolkit VII - Energy and Environmental Justice II (practice)
12	11-6	Kammen	21. Renewable Energy 1: Solar Energy
	11-8	Kammen	22. Renewable Energy 2: Wind, Geothermal & Hydropower
13	11-13	Kammen	23. Renewable Energy 3: Electrochemistry - H_2, Fuel Cells & storage
	11-15	Guest	24. Renewable Energy 4: Industrial Bioenergy & Land Use
14	11-20	Kammen	25. Transportation systems and policies
	11-22		**HOLIDAY THANKSGIVING**
15	11-27	Kammen	26. Climate Change - Energy and Climate Science
	11-29	Kammen	27. Climate Change - Energy Policy

Final Exam: Group 5: Tuesday, December 11, 8 – 11 am

Problem Set #	Assigned	Due	Coverage
1	**8/28**	**9/6**	Short warm-up problems; analysis of utility bills; unit analysis; getting comfortable with the myriad of energy units. These problems may be unfamiliar in style for many of you; if necessary use the GSI's and study groups to 'get into the swing' of these calculations/estimates. You must, however, do your own work. P/F GRADING
2	**9/11**	**9/20**	Energy use at household and national scales; basic thermodynamics; combustion. P/F GRADING
3	**9/25**	**10/4**	Thermodynamics of energy systems, combustion of various fuels; comparisons of energy conversion efficiencies, emissions, financial analysis of power plants. Energy economics.
4	**10/4***	**10/11**	Life-cycle analysis; learning curves; energy efficiency, evolution of the modern energy system. [Shorter problem set]
5	**10/23**	**11/1**	Environmental justice; energy efficiency and conservation; the grid; nuclear energy.
6	**11/6**	**11/15**	Nuclear energy and waste, renewable energy systems, fuel cells and hydrogen.
7	**11/20**	**11/29**	Biomass energy, transportation, energy and climate, and climate policy.
Policy Memo	**12/4**		**11:59 PM -** due via bCourses assignment upload

*** Note: non-standard assignment dates (mid-term & thanksgiving). No late assignments accepted for PS #4 so that we can return to you graded problem sets prior to the mid-term exam.**

Problem sets are posted online (not physically distributed in class) & returned via bCourses only.

Do not leave problem sets for the final few days. They are not hard if started early; but they can be an unpleasant experience if left for the night before they are due.

There are two texts for the course:

Hirsh, Richard (1999) *Power Loss* (MIT University Press: Cambridge, MA).

Rubin, Edward S. (2001) *Introduction to Engineering & the Environment* (McGraw Hill: New York, NY).

We will use these two books extensively. While all required sections of these two books are available on bCourses, we also recommend you order them to have a permanent copy, because, you know, *books* are *cool.*

You should be familiar with the readings listed for each lecture date when the lecture occurs—they will be referenced under the assumption that you have read them already. Readings listed for **ER200/PP284** *are required for graduate students only. Readings listed as* **Supplemental** *will (perhaps obviously) supplement your understanding of the course material, but are not required to successfully complete the course.*

Week 1 – Introduction to Energy Systems and Society

Lecture 1 (8/23) – Energy and Society: How Energy Use Shapes Society & the Environment:

Recommendation: Get in the habit of looking for energy articles in newspapers and begin to get a feel for how ubiquitous and far-reaching energy issues are in society. In addition, check the opinion ("OpEd") and editorial pages of your favorite newspapers. As your last assignment of the course, you will be writing a 'policy memo' that in most cases can and should be submitted as an Op Ed yourself

Yergin, D. (1991) The Prize: The Epic Quest for Oil, Money, and Power (Simon & Schuster: New York).

Pages 11 – 16.[Yergin_1991.pdf]

Plus, read a selection – you decide how many -- of these energy-related op-eds or others you look up (a good habit). Op Ed pieces are the best guide available to the policy memo you will be writing.

Read these 'classic' energy OpEds:

Jeffrey Ball and Dan Reicher (2017) "Making solar big enough to matter" (3/21/2017)
https://www.nytimes.com/2017/03/21/opinion/making-solar-big-enough-to-matter.html?mcubz=1

Ralph Cavanagh (2013) "How we learned not to guzzle" (9/12/13)
http://www.nytimes.com/2013/09/13/opinion/how-we-learned-not-to-guzzle.html?_r=0

Kendyl Crawford (2016) "Addressing Environmental Justice in the Commonwealth"(3/23/2016)
http://altdaily.com/op-ed-addressing-environmental-justice-in-the-commonwealth/

Ban Ki-Moon (2012) "Powering sustainable energy for all" (1/11/12)
http://www.nytimes.com/2012/01/12/opinion/powering-sustainable-energy-for-all.html

Paul Krugman (2017) "Trump's energy, low and dirty" (5/29/2017)
https://www.nytimes.com/2017/05/29/opinion/trump-g-7-summit-energy.html?mcubz=1

There are many outlets to follow. For some local ones, see : @dan_kammen which is from the Renewable and Appropriate Energy Laboratory, rael.berkeley.edu, and "Energy @ Haas"

Week 2 – Methods in Energy Analysis

Lecture 2 (8/28) – Energy Toolkit I: Units, Forecasts, and the Back-of-the-Envelope:

Lovins, Amory (1976) "Energy Strategy: The Road Not Taken", *Foreign Affairs*, **55(1):** 65–96. [Lovins_1976.pdf]

Commentary on the Lovins paper from *The New York Times:*
John Tierney (2008) "A gift from the '70s: Energy lessons" (10/6/2008)
http://www.nytimes.com/2008/10/07/science/07tier.html?_r=1&8dpc&oref=slogin

ER200 & PP284:
Rubin, Edward S. (2001) *Introduction to Engineering & the Environment* (McGraw Hill: New York, NY) [Rubin, *EE*], *Rates of Technology Adoption*, Pages 669 – 677.

Supplemental:
Toolkit 1 (a review and refresher) – optional/reference for those who have not done these sorts of problems before.

Lecture 3 (8/30) – Energy Toolkit II: Fuels, Energy Content, and Basics of Combustion:

Masters, G. (1991) *Introduction to Environmental Engineering and Science* (Prentice Hall: NJ), pages 39–47. [Masters_1991_Enviro_Chemistry.pdf]

Supplemental:
Toolkit 2 (resource material)

Week 3 – Energy and Development

[9/3 is an Academic and Administrative Holiday - Sections on Monday will be canceled; attend a different section this week.]

Lecture 4 (9/4) – Energy for 'the South' I: Energy Transitions and Development:

Goldemberg, J. (1996) *Energy, Environment, and Development* (Earthscan: London, UK), 11 – 37. [Goldemberg_1996.pdf]

Alstone, P., Gershenson, D. and Kammen, D. M. (2015) "Decentralized energy systems for clean electricity access," *Nature Climate Change*, **5**, 305 – 314.

Lecture 5 (9/6) – Energy for 'the South' II: Biomass, Households, and Gender:

Kammen, D. M. and Dove, M. R. (1997) "The virtues of mundane science", *Environment*, **39**(6): 10–15, 38–41. [Kammen_1997.pdf]

Sovacool, B (2014) "Energy studies need social science," *Nature*, **511**, 529 – 530.

Kammen, D. M. (1995) "Cookstoves for the developing world," *Scientific American*, **273**, 72 - 75. [Kammen_1995.pdf]

Morrison, Sarah (2018) "Undercooked: An Expensive Push to Save Lives and Protect the Planet Falls Short". *ProPublica* https://www.propublica.org/article/cookstoves-push-to-protect-the-planet-falls-short

ER200 & PP284:

Crewe, E. (1997) "The silent traditions of developing cooks", *Discourses of Development*, R. D. Grillo and R. L. Stirrat, eds. (Berg: Oxford, UK), 59–81. [Crewe_1997.pdf]

Bose, S. (1993) "Women, Work, and Household Electrification in Rural India," *Money, Energy and Welfare* (Oxford University Press: Bombay, India), Chapter V, pages 143 – 181. [Bose_1993.pdf]. Note: this is a challenging reading.

Global Alliance for Clean Cookstoves (2016) "Gender-Based Violence in Humanitarian Settings: Cookstoves and Fuels." http://cleancookstoves.org/resources/478.html

Supplemental:

Bailis, Ezzati, Kammen, (2005) "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa," *Science*, 308 (5718): p. 98-103. [Bailis_2005.pdf]

Week 4 – Thermodynamics of Energy

Lecture 6 (9/11) – Energy Toolkit III: Energy Thermodynamics:

Masters, G. (1991) *Introduction to Environmental Engineering and Science* (Prentice Hall: NJ), pages 15 – 29. [Masters_1991_Energy.pdf]

Lecture 7 (9/13) – Energy Toolkit IV: Thermodynamics of Modern Power Plants:

Rubin, Edward S. (2001) *Introduction to Engineering & the Environment* (McGraw Hill: New York, NY) [**Rubin**, *EE*], Sections 5.1 - 5.6.3 (except 5.2.2 & 5.2.3); Pages 162 – 175, 179 – 215

Masters, G. (1991) *Introduction to Environmental Engineering and Science* (Prentice Hall: NJ), pages 327–339. [Masters_1991_Air_Pollution.pdf]

ER200 & PP284:
David Roberts (2017) "By 2020, every Chinese coal plant will be more efficient than every US coal plant" (5/16/2017) https://www.vox.com/energy-and-environment/2017/5/15/15634538/china-coal-cleaner

Supplemental:
Beér, J. M. (2000) "Combustion technology developments in power generation in response to environmental challenges," *Progress in Energy and Combustion Science*, **26**, 301 – 327. [Beer_2000.pdf]

[This is an advanced treatment of state-of-the-art fossil-fuel power plant design issues and opportunities].

Week 5 – 'Hydrocarbon man'

Lecture 8 (9/18) – Hydrocarbon Man:

Friedman, Thomas L. (2006) "The First Law of Petropolitics," *Foreign Policy*, **154:** (28 – 36). [Friedman_2006.pdf]

Farrell, Alex E., and Brandt, Adam R. (2006) "Risks of the oil transition," *Environmental Research Letters,* **1**, October 30. [Farrell_2006_Risks.pdf]

Hirsh, Richard (1999) *Power Loss* (MIT University Press: Cambridge, MA) Section I, Pages 1 - 54.

Lecture 9 (9/20) – Evolution of the Modern Energy Economy:

Hirsh, Richard (1999) *Power Loss* (MIT University Press: Cambridge, MA) Section I, Pages 55 - 88.

Week 6 – Energy Economics

Lecture 10 (9/25) – Energy Toolkit V: Economic Analysis of Energy Systems:

Rubin, *EE*, Chapter 13, Pages 545 – 577

Edenhofer, O. (2015) "King coal and the queen of subsidies," *Science*, 1286 – 1287. http://science.sciencemag.org/content/sci/349/6254/1286.full.pdf

Lecture 11 (9/27) – Environmental Economics:

Arrow, K. *et al.*, (2013) "Determining the benefits and costs for future generations," *Science*, **341**, 349 – 350.[Arrow_2013.pdf]

W. Pizer, M. Adler, Anthoff, D.J. Aldy, M. Cropper, K. Gillingham, M. Greenstone, B. Murray, R. Newell, R. Richels, A. Rowell, S. Waldhoff and J. Wiener, "Using and improving the social cost of carbon," *Science*, 2014, 346(6214): 1189-1190.

ER200 & PP284 [Supplemental for ER100/PP184]:

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., … & Larsen, K. (2017). Estimating economic damage from climate change in the United States. Science, 356(6345), 1362-1369.

Regulation Assistance Project (2016) *Revenue Regulation and Decoupling: A Guide to Theory and Application*
http://www.ourenergypolicy.org/wp-content/uploads/2017/02/rap-revenue-regulation-decoupling-guide-second-printing-2016-november.pdf

Week 7 – Life-Cycle Analysis and Efficiency

Lecture 12 (10/2) – Energy Toolkit VI: Life-cycle and Cost-Benefit Analysis:

Rubin, *EE*, Section 13.4, Life-cycle cost, 556 – 562.

ER200 & PP284 [Supplemental for ER100/PP184]:

Wynes, S. and Nicholas, KA (2017) "The climate mitigation gap: education and government recommendations miss the most effective individual actions" *Environmental Research Letters,* **12**, 074024. http://iopscience.iop.org/article/10.1088/1748-9326/aa7541/pdf

Hertwich, E. and Peters, G. (2009) "The carbon footprint of nations, a global, trade linked analysis", ES&T, *b,* 6414–6420. http://pubs.acs.org/doi/pdfplus/10.1021/es803496a

Jones, C. M. and Kammen, D. M. (2014) "Spatial distribution of U.S. carbon footprints reveals suburbanization offsets benefits of population density", *Environmental Science and Technology*, ***48*** **(2)**, 895 – 902. https://nature.berkeley.edu/er100/readings/Jones-Kammen-2014.pdf

Lecture 13 (10/4) – Energy Efficiency 1: Devices:

Rubin, *EE*, Chapter 7, and Section 13.8 of Chapter 13, Pages 281 – 314, 577 – 583.

Hirsh, Richard (1999) *Power Loss* (MIT University Press: Cambridge, MA), pages 90 – 117.

ER200 & PP284:

Attari, S. Z. DeKay, M. L. Davidson, C. I. and Bruine de Bruin, W. (2010) "Public perceptions of energy consumption and savings", *PNAS*, 2010. [Attari_2010.pdf]

Week 8 – Energy Efficiency (2) & the Grid

Lecture 14 (10/9) – Energy Efficiency 2: Buildings as Energy Systems

David B. Goldstein (2008) Extreme Efficiency: How Far Can We Go If We Really Need To? ACEEE Summer Study Paper.[Goldstein_2008.pdf]

ER200 & PP284:
Gillingham, K, *et al.,* (2013) "The rebound effect is overplayed", *Nature,* **493**, 475–476
http://www.nature.com/nature/journal/v493/n7433/full/493475a.html?foxtrotcallback=true

Supplemental:
Nagourney, A., *et al. (2015)* "California drought tests history of endless growth," *The New York Times*
http://www.nytimes.com/2015/04/05/us/california-drought-tests-history-of-endless-growth.html?smid=tw-share&_r=0

Lecture 15 (10/11) – Electricity Grids: Managing the Network:

Masters, G. (2004) "Transmission and Distribution," in *Renewable and Efficient Power Systems* (Wiley InterScience: New York), pages 145 – 151. [Masters_2004_TD.pdf]

von Meier, Alexandra (2006), "Reliability" and "Security," in *Electric Power Systems: a conceptual introduction* (John Wiley & Sons: New Jersey), pp. 229–234.[von_Meier_2006.pdf]

ER200 & PP284:

Fairley, P. (2004) "The unruly power grid", *IEEE Spectrum*, 13 August, 5 pages. [Fairley_2004.pdf]

Yang Yang, Takashi Nishikawa, Adilson E. Motter (2017) "Small vulnerable sets determine large network cascades in power grids," *Science* 17 Nov 2017, 358, Issue 6365, 886.DOI: 10.1126/science.aan3184

Reference:

Glossary of electricity terms. [Electricity_Glossary.pdf]

MATERIAL FOR THE MID-TERM ENDS HERE

Week 9 – Natural Gas, Fracking and CCS … and The Mid-Term Examination

Lecture 16 (10/16) – Natural Gas, Fracking, and Carbon Capture and Storage

Brandt, A. *et.al.*, (2014) "Methane Leaks from North American Natural Gas Systems," *Science,* **343** (6172), 733-735.

Deborah Sontag And Robert Gebeloff (2014) "The downside of the boom," *The New York Times*, 22 November, http://www.nytimes.com/interactive/2014/11/23/us/north-dakota-oil-boom-downside.html

ER200 & PP284:
MIT CCS roadmap - http://web.mit.edu/coal/
Chapters 2 and 3 (pages 5 – 42)

Supplemental:
Aisch, Gregor (2014) "What North Dakota Would Look Like if Its Oil Drilling Lines Were Above ground," *The New York Times*, November 25 https://www.nytimes.com/interactive/2014/11/24/upshot/nd-oil-well-illustration.html

Class (10/18) – Midterm examination

Week 10 – Nuclear Power

Lecture 17 (10/23) – Nuclear Energy I: Physics and Engineering – Fission/Fusion:

Deutch and Lester, (2004) Making Technology Work, Ch. 7: Nuclear Power and Its Fuel Cycle, Cambridge Univ. Press, Cambridge, UK, p. 109-133. [Deutch_2004.pdf]

Nain, V. (2017) "Progress in nuclear power technology", *Encyclopedia of Sustainable Technologies*, Elsevier, **3.** http://dx.doi.org/10.1016/B978-0-12-409548-9.10103-4

Supplemental:
Excellent online material on reactor types and performance is available at
http://www.nrc.gov/reactors/power.html
In particular, review 'About the NRC', 'Nuclear security', and read about the events (power production and management) at one of the featured reactors, such as Diablo Canyon (under nuclear reactors) that provides power to northern California)

Lecture 18 (10/25) – Nuclear Energy II: Waste, Risk & Economics:

Rubin, *EE*, pages 63-68, 175-178.

Lester, Richard K. "A Roadmap for U.S. Nuclear Energy Innovation," *Issues in Science and Technology* 32, no. 2 (Winter 2016). http://issues.org/32-2/a-roadmap-for-u-s-nuclear-energy-innovation/

The Nuclear Fuel Cycle Cost Calculator: http://thebulletin.org/nuclear-fuel-cycle-cost-calculator

ER200 & PP284:
Martin, R. (2016) "Fail-safe nuclear power," *MIT Technology Review*
https://www.technologyreview.com/s/602051/fail-safe-nuclear-power/

Supplemental:
Hultman, N., Koomey, J. G, and Kammen, D. M. (2007) "What history can tell us about the costs of future nuclear power", *Environmental Science & Technology,* **41(7):** 2088 - 2093. [Hultman_2007.pdf]

Week 11 – Energy and Environmental Justice: Theory and Practice

Lecture 19 (10/30) – Energy and Environmental Justice 1 (theory):

Pastor, Manuel, (2007) "Environmental Justice: Reflections from the United States", Ch. 14 in *Reclaiming Nature,* pp. 351–376.[Pastor_2007.pdf]

"Climate Change, Consumerism and the Pope with Prof. Daniel Kammen and Governor Jennifer Granholm -- In the Living Room with Henry E. Brady -- UC Public Policy Channel" http://www.uctv.tv/shows/29853

Islamic Call on Climate Change

Wilson Dizard (2015) "Islamic scholars call on faithful to help fight climate change," *Al Jazeera America* (8/18/2015) http://america.aljazeera.com/articles/2015/8/18/islamic-scholars-issue-climate-change-declaration.html

ER200 & PP284:

Stephen J. Flusberg, Teenie Matlock & Paul H. Thibodeau (2017), "Metaphors for the War (or Race) against Climate Change", *Environmental Communication* http://dx.doi.org/10.1080/17524032.2017.1289111

Supplemental:

Encyclical Letter Laudato Si': On Care for our Common Home (2015) Pope Francis http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

Lecture 20 (11/1) – Energy and Environmental Justice 2 (practice)

Sunter, D., Castellanso, S., and Kammen, DM (2017) "The environmental injustice of solar energy strategies".

John Bongaarts and Brian C. O'Neill (2018) "Global warming policy: Is population left out in the cold? ", *Science* **361** (6403), 650-652. DOI: 10.1126/science.aat8680

Supran, G. and Oreskes, N. (2017) "Assessing ExxonMobil's climate change communications (1977–2014)", *Environ. Res. Lett.* **12** (2017) 084019

Week 12 – Renewable Energy I & II: Solar, Wind and Water Power, Geothermal

Lecture 21 (11/6): Solar Energy

Haegel, N, *et al.* (2017) "Terawatt-scale photovoltaics: Trajectories and challenges", *Science*, **356**, Issue 6334, pp. 141-143. DOI: 10.1126/science.aal1288

Masters, G. (2004) "Photovoltaic Materials and Electrical Characteristics." *Renewable and Efficient Power Systems* (Wiley InterScience: New York), pages 445 – 463.[Masters_2004_PV.pdf]

ER200 & PP284:

SunShot Vision Study: Read the Executive Summary; Chapter 4, Photovoltaics: Technology, Cost, and Performance; and ; chapter[Solar_Vision_Study_2012.pdf]
Online Version: http://energy.gov/eere/sunshot/sunshot-vision-study

Supplemental:

Zheng, Cheng and Kammen, Daniel (2014) "An Innovation-Focused Roadmap for a Sustainable Global Photovoltaic Industry," *Energy Policy,* **67**, 159–169.
http://www.sciencedirect.com/science/article/pii/S0301421513012500

Lecture 22 (11/8) – Renewable Energy II: Wind, Hydropower and Geothermal Energy

Masters, G. (2004) "Wind Power Systems." *Renewable and Efficient Power Systems* (Wiley InterScience: New York), pages 307 – 354 (pages 335-347 are supplemental), 371 – 378. [Masters_2004_Wind.pdf]

"The Chinese are obsessed with building large dams" (2015) *The British Broadcasting Corporation*
http://www.bbc.com/future/story/20151014-the-chinese-are-obsessed-with-building-giant-dams

Latrubesse, *et al.* (2017) "Damming the rivers of the Amazon basin", *Nature*, **546**, 363 – 369. doi:10.1038/nature22333

ER200 & PubPol 284

Rebekah Shirley and Daniel M Kammen (2018) "Mundane is the New Radical: The Resurgence of Energy Megaprojects and Implications for Emerging Economies" *IEEE Technology and Society Magazine*, June, 18 – 26. DOI: 10.1109/MTS.2018.2826076

Week 13 – Renewable Energy III & IV: Electrochemistry, Fuel Cells & Storage, Bioenergy

[11/12 is an Academic and Administrative Holiday - Sections on Monday will be canceled; make an attempt to attend a different section this week.]

Lecture 23 (11/13) – Renewable Energy III: Electrochemistry - H_2, Fuel Cells & storage

Masters, G. (2004) "Fuel Cells," in *Renewable and Efficient Power Systems* (Wiley InterScience: New York), pages 206-228. [Masters_2004_Fuel_Cells.pdf]

Kittner, N., Lill, F. and Kammen, D. M. (2017) "Energy storage deployment and innovation: a multi-technology model for the clean energy transition" *Nature Energy*, **2**, DOI: 10.1038/nenergy.2017.125. https://rael.berkeley.edu/wp-content/uploads/2017/07/Kittner-Lill-Kammen-NatureEnergy-Storage-Innovation-2017.pdf

Lecture 24 (11/15) – Renewable Energy IV: Industrial Bioenergy and Land Use

Rubin, *EE*, Chapter 3, Pages 83-123.

Cornwall, Warren (2017) "Is wood a green source of energy? Scientists are divided", *Science*, http://www.sciencemag.org/news/2017/01/wood-green-source-energy-scientists-are-divided

ER200 & PP284:

Walsh, B, et al., (2017) "Pathways for balancing CO_2 emissions and sinks", *Nature Communications*, DOI: 10.1038/ncomms14856, PDF: https://www.nature.com/articles/ncomms14856.pdf

Supplemental:

Sanchez, Daniel L., Nelson, James H., Johnston, J., Mileva, A., and Daniel M. Kammen (2015) "Biomass Enables the Transition to a Carbon-negative Power System Across Western North America", *Nature Climate Change*, **5,** 230–234. doi:10.1038/nclimate2488. https://rael.berkeley.edu/wp-content/uploads/2015/03/Sanchez-Kammen-etal-BiomassEnablesCarbonNegativePowerSystems-NatureClimateChange-2015.pdf

Week 14 – Transportation Systems

[11/21-11/23 is an Academic and Administrative Holiday - No sections this week – please use office hours.]

Lecture 25 (11/20) – Transportation systems and policy:

International Energy Agency (2016) *Global EV Outlook*
https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

Sager, J., Lemoine, D, Apte, J. and Kammen, D. M. (2011) "Reduce growth rate of light duty vehicle travel to meet 2050 global climate goals." *Environmental Research Letters*, **6**(2), 024018.[Sager_etal_2011.pdf]

ER200 & Pub Pol 284:

Jones, C. M. and Kammen, D. M. (2014) "Spatial distribution of U.S. carbon footprints reveals suburbanization offsets benefits of population density," *Environmental Science and Technology*, ***48*** **(2**), 895 – 902. https://nature.berkeley.edu/er100/readings/Jones-Kammen-2014.pdf

Supplemental:

Kammen, Daniel M., and Sunter, Deborah A. (2016) "City-integrated renewable energy for urban sustainability," *Science*, **352**, 922 – 928. DOI 10.1126/science.aad9302. https://rael.berkeley.edu/wp-content/uploads/2016/05/Kammen-Sunter-CleanEnergyUrbanSustainability-Science-20May-2016.pdf

(11/22) – No Lecture – Thanksgiving Break

Week 15 – Energy and the Global Environment

Lecture 26 (11/27) – Climate Change I: Energy and Climate:

Rubin, *EE*, Chapter 12, Pages 470 – 537.

Intergovernmental Panel on Climate Change, Fifth Assessment Report
Working Group I (The Science of Climate Change), Summary for Policymakers
https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf

Supplemental:
Emanuel, Kerry (2005), "Increasing destructiveness of tropical cyclones over the past 30 years." *Nature*, **436**: 686–688, August 4. [Emanuel_2005.pdf]

Lecture 27 (11/29) – Climate Change II: Energy Policy:

Figueres, C., *et al.* (2017) "Three years to safeguard our climate," *Nature*, **546**, 593 – 595. doi:10.1038/546593a. https://rael.berkeley.edu/wp-content/uploads/2017/06/Figueres-ThreeYearstoSafeguardOurPlanet-Nature-2017_full.pdf

Hansen, J., Sato, M. and Ruedy, R. (2012) "Perception of climate change", *PNAS*, [Hansen_etal_2012.pdf]

Steffen, W. *et al. (2015) "*Planetary boundaries: Guiding human development on a changing planet" *S*cience, **347**, DOI: 10.1126/science.1259855. http://www-ramanathan.ucsd.edu/files/pr210.pdf

Supplemental:
Steven J. Davis et al (2018) "Net-zero emissions energy systems", *Science* **360** (6396) DOI: 10.1126/science.aas9793

Online resource: C-ROAD
http://climateinteractive.wordpress.com/2008/09/19/pangaea-our-decision-maker-oriented-uclimate-simulator/

Baer, P., et al. (2000). "Equity and Greenhouse Gas Responsibility." *Science* **289** (5488): 2287. [Baer_2000.pdf]

Final Exam (12/11) - Group 5: Tuesday, December 11, 8 – 11 am

Syllabus version date: August 30, 2018