Duke | NICHOLAS SCHOOL *of the* ENVIRONMENT

Energy Technology and its Impact on the Environment
ENVIRON/ENERGY 631—Spring 2021

Tuesday and Thursday, 10:15 to 11:30
Grainger Hall 1112 (Field Auditorium)

Instructor

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Teaching Assistants

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Course Description and Learning Objectives

After a century of incremental development, the global energy system is entering a period of unprecedented change. New technologies and resources, new markets and business models, and new policy drivers and regulatory challenges are emerging—with concern about climate and the need to make deep reductions in greenhouse gas emissions adding momentum to the transition. Understanding this transition and its ability to mitigate the negative environmental and social impacts that energy supply and use create requires an awareness of how the current energy system came to be, how it operates, and how it might evolve to continue providing the energy services on which our quality of life depends. Familiarity with energy technology and science is at the core of this understanding. Technology change alone will not solve our environmental problems, but knowledge of the factors that drive the design, performance, and costs of both current and emerging energy technologies is central to any assessment of what might be feasible going forward.

This course examines conventional and emerging energy technologies in this larger context, with a focus on electricity generation and transmission, power system planning, vehicle design, and low-energy building construction. While the material is grounded in the basics of energy science and uses this knowledge to explore the design and operation of technical systems, the course stresses how technology interacts with economics, policy, and other social factors to affect its use. By the end of the semester, you will be able to:

- Describe trends in the development of conventional and emerging energy technologies, as well as the social, regulatory, and economic factors that shape these dynamics
- Apply basic energy science principles (such as thermodynamics and electromagnetics) to describe the operation of and improvement potential for both conventional and emerging technologies
- Critically evaluate assumptions behind claims about the performance, economics, and environmental impacts of energy technologies, and appreciate tradeoffs among these factors
- Assess the extent to which improvements in conventional energy technologies, as well as the further development and deployment of renewable and other "green" technologies, may help achieve environmental goals across media (air, land, and water)
- Explain how designers and operators of energy systems approach their work

Course Format

This is a hybrid class. The entire class will meet both Tuesday and Thursday, with half of you in person and half online each day (trading places in between). For possible COVID tracking reasons, you may only attend the in-person session for which you registered, though you may attend both weekly sessions online if you do not feel comfortable in the classroom. Either way, you must attend all class sessions at the scheduled time.

Each week I will post a series of video recordings to Sakai that provide background content and supplement the assigned readings, and you must watch these recordings prior to our Tuesday session. We will use our scheduled class time for discussion of this material, additional lecture coverage, small group problem solving, and other participatory exercises. The course will wrap up with presentations of your project work.

Finally, **I ask that you remain flexible.** We need to be ready for anything this semester, including the possibility that the class will go entirely online at some point if regional and campus conditions warrant such a move. Let's hope that doesn't happen, but we will adapt if it does. I'm also excited to try this class format, but it is an experiment and we may decide to make changes along the way if other means of achieving the course goals and learning outcomes look like they will be more successful.

Respect for Diversity and Honest Analysis

Energy supply and use are inseparable from our daily lives and lifestyle choices. Hence, many of the topics we will cover have a political and even personal subtext, and some of you may arrive with strong opinions about the past, present, and future of energy and all that it affects. My goal is to help you reason through the complexities of how we might balance conflicting societal goals that require more than technical problem solving or idealistic visions of how cultural change occurs. I also understand the temptation to see the issues we will encounter this semester in either-or terms (e.g., "fossil fuels are always bad", "renewable energy is always better"). While I will respect the individual conclusions you reach, I ask that you *lead with evidence and analysis rather than opinion* and I will try to model this behavior in class. In short, let's strive to be honest brokers and respect differences in personal and cultural preferences. The fact that we come from many different places and backgrounds is an asset and I will draw on the diversity of your experiences as a valued resource.

Beyond that, I teach because I like spending time with students. If you all looked, felt, and thought like me it wouldn't be nearly as interesting and I wouldn't learn nearly as much as I continue to learn after many years in the classroom. I enjoy getting to know you as individuals and will do whatever I can to create a comfortable environment in which we can all be challenged and learn together.

Prerequisites

Lincoln Pratson's *Energy and the Environment* (either the undergraduate ENVIRON 231 or the grad-level ENVIRON 711) is a prerequisite, and we will pick up where the class left off at the end of Fall Semester 2020. While the sequence of topics is similar, I will assume that students have the broad energy system foundation ENVIRON 231/711 provides and will therefore not spend significant time on review. Note that I will also assume this level of background knowledge on assignments and exams.

Coursework and Grading (*graduate and undergraduate students*)

Your grade will be based on the following:

Assignments	25%
Group Project	20% (All group members receive the same grade)
Exam 1	25%
Exam 2	25%
Lecture Quizzes	5%

I will use the following rubric to translate your cumulative weighted score (percentage) into a final grade:

[99 to 100]	A+	[80 to 83)	B-
[93 to 99)	A	[77 to 80)	C+
[90 to 93)	A-	[73 to 77)	C
[87 to 90)	B+	[70 to 73)	C-
[83 to 87)	B	Below 70	F

Assignments: The assignments will consist of quantitative problem solving and short-answer reflective questions. Due dates follow, though note that these dates are subject to change. **You must complete each assignment individually; though you may discuss assignment questions with your colleagues, the work you submit must be your own (per the Duke Honor Code).**

ASSIGNMENT	DUE DATE	ASSIGNMENT	DUE DATE
1	04 Feb	**5**	25 Mar
2	18 Feb	**6**	08 Apr
3	25 Feb	**7**	20 Apr
4	16 Mar		

Group Project: The project will give you an opportunity to explore an emerging energy technology or system that we would not otherwise cover in class. Examples include, but are not limited to, tidal, ocean, and geothermal power; algal biofuels; advanced battery designs; and similar concepts. Working in groups, you will prepare and submit a short research brief and a class presentation. See the project overview on Sakai for details.

Exams: The two exams will take place on your own time outside of class per the schedule below. You will have two hours to complete each exam online through Sakai once you begin and you may not return to the exam at a later time. The exams will consist of a mix of quantitative problems and short-answer questions. While you may use your personal notes and all class materials available on Sakai, you may not collaborate with anyone else in or out of the class or use external resources. I will report all violations of this policy to the Nicholas School Dean's Office and you will automatically fail the class. We will not have a separate final exam after classes end.

EXAM	COVERAGE	AVAILABLE	DUE
1	Weeks 1 through 6 (generation through CCUS)	Monday, March 1 at 8:00 am	Thursday, March 4 by 5:00 pm
2	Weeks 7 through 13 (geothermal through buildings)	Monday, April 19 at 8:00 am	Thursday, April 22 by 5:00 pm

Lecture Quizzes: Each recorded lecture will contain one or more embedded PlayPosit questions. These lecture quizzes will be graded pass/fail and all must be completed by class on Tuesday each week for full credit. This portion of your grade will be scaled by the percentage of quizzes that you complete. For instance, if you submit 80% of the quizzes, they will contribute 0.80 * 100 points * 0.05 = 4 points to your final class score, rather than the 5 point maximum.

Policy on Late Assignments and Missed Exams and Illnesses

All assignments must be uploaded to Sakai by the posted due date. Assignments handed in after the posted deadline will incur a 25 point penalty for each 24 hour period they are late. **Assignments submitted more than 3 days (72 hours) after the posted due date and time will not receive credit**. Please do not ask for exceptions.

Exams cannot be made up and you will not receive credit for an exam if you fail to submit your work on time. I will make exceptions only for serious illnesses and personal emergencies.

Undergraduates: If you are sick and cannot complete assigned work, please contact me and also submit a Short-Term Illness Notification Form (STINF) at: https://trinity.duke.edu/undergraduate/academic-policies/illness. The website provides instructions, but note the following text: **"**Definition of Incapacitation: An incapacitating health issue is one in which you are hospitalized, under medical care for a short-term condition, or otherwise sufficiently debilitated as to be unable to perform basic academic tasks. Colds, headaches, or other such mild complaints that result in your feeling less than 100% are not considered incapacitating, and you should not use the Incapacitation Form in such instances." In the event of something even more serious, of course, I will make every effort to accommodate your situation.

Grad students: If you are sick and cannot complete assigned work, please contact me. If your illness will affect multiple classes and you are a Nicholas School MEM or MF, you should also notify Cynthia Peters, Nicholas School Assistant Dean Student Services, at petersca@duke.edu or 919-613-8071.

Readings

Readings are available on Sakai with each week's lesson and we will not use a separate textbook. The schedule below also lists reading assignments, which you must complete prior to each day's class. I may also assign additional readings based on your interest in related topics. Your job is to read critically and use the factual basis we develop in class to reach your own conclusions about the issues we discuss.

Sakai

If you are registered for the class, you will have complete access to our Sakai website. All course materials, including this syllabus, recorded lectures, readings, assignments, and exams, are available on Sakai.

Classroom Etiquette

Please arrive on time and refrain from checking email and social media, texting, and websurfing while we are together. These activities are more obvious that you might think, and I will not hesitate to cold call anyone who appears to be using their device for anything other than notetaking or researching the occasional discussion question. If I feel that electronic media are becoming too much of a distraction, I will ask everyone to turn off and store all phones, laptops, and other devices during class.

My Expectations of You

This is your course. At minimum, I expect you to attend class and be an active participant, which, in turn, requires that you prepare for each class in advance and arrive having completed the readings and other assignments. I also expect you to have an open mind, think critically, and use what we learn in making your own judgments.

In addition, if you have suggestions on how to improve the course, please let me know. Feedback received midstream can be more useful (to you and me) than end-of-term evaluations, and I am happy to make reasonable changes if a majority concurs.

What You Can Expect from Me

I'm here to help you learn. I will do my best to understand and appreciate the diversity in your backgrounds, interests, and analytical strengths, and I have tried to design the course to accommodate these differences while providing opportunities to help you develop in new areas. Again, I appreciate feedback. I'm available during my office hours if you have questions about the class (or life in general), and am happy to find mutually agreeable times outside of these windows to meet. Just let me know what works best for you.

Safety Measures

While I am excited to be in the classroom this spring, *all of us* (including me) will need to observe several rules to keep us safe:

- Each of us must be cleared to come to campus each day
- Each of us must wear a mask in the classroom at all times
- You must attend the in-person section for which you are registered and may not move between sessions, even for a single week in which you might have a conflict
- You may not eat or drink in the classroom
- You should clean your desk area before and after class with the disinfecting solution provided in the classroom
- You must sit in designated seats
- All of us must maintain social distance (i.e. a minimum 6 foot separation) from each other at all times
- We all must follow the other terms of the Duke Compact as they pertain to classroom activity
- We all should do our best to maintain a sense of humor about this situation ☺

Nicholas School Honor Code and the Duke Community Standard

All activities of Nicholas School students, including those of you in this course, are governed by the Duke Community Standard (https://integrity.duke.edu/new.html), which states:

"Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and nonacademic endeavors, and to protect and promote a culture of integrity.

To uphold the Duke Community Standard:

- I will not lie, cheat, or steal in my academic endeavors;
- I will conduct myself honorably in all my endeavors; and
- I will act if the Standard is compromised."

Please add the following affirmation to the end of all assignments and your project, and sign your name beside it: "I have adhered to the Duke Community Standard in completing this assignment."

Schedule

This schedule below is subject to change, and I may modify it as we go along if extra time is needed (or desired) for particular topics. I'll provide updates in class and via email. See above for assignment and project due dates. The bibliography below provides full reading citations.

WEEK	DATES	TOPIC	READING
1	Jan 20	Class Introduction; Electric Power Generation and Transmission	*See the Week 2 readings if you want to get an early start!*
2	Jan 26/28	Electric Power Generation and Transmission (continued)	The Future of the Electric Grid, Appendices A and B (pages 235 to 260) Reactive Power Primer
3	Feb 2/4	Electric Power Generation and Transmission (continued)	The Future of the Electric Grid, Chapter 2 ("Enhancing the Transmission Network and System Operations," pages 31 to 52) Electric Power Systems, Sections 4.1 to 4.3.1 (pages 85 to 101) Sources of Grid Reliability Services

WEEK	DATES	TOPIC	READING
4	Feb 9/11	Energy Technology Cost Estimation; Steam (Rankine) Cycles	Improving Cost Estimates for Advanced Low-Carbon Power Plants Introduction to Engineering and the Environment, Sections 5.1 to 5.5 (pages 162 to 210) Energy for Sustainability, Sections 4.5.4, 4.5.5, and 10.5 (pages 136 to 141 and 410 to 413)
5	Feb 16/18	Steam (Rankine) Cycles (continued)	Introduction to Engineering and the Environment, Sections 5.1 to 5.5 (pages 162 to 210)
6	Feb 23/25	Carbon Capture Use and Storage	The Outlook for Improved Carbon Capture Technology, Sections 1 and 2 (pages 630 to 638) Fossil Power, Guilt Free Turbines Can Use CO2 to Cut CO2 Putting CO2 to Use (pages 1 to 27)
7	Mar 2/4	Other Steam Cycles--Geothermal Energy and Nuclear Power **Exam 1**	GeoVision: Harnessing the Heat Beneath Our Feet, Chapter 2 ("What is Geothermal Energy?," pages 9 to 46) Energy Systems and Sustainability, Chapter 11 ("The Future of Nuclear Power," pages 427 to 464)
8	Mar 11	Other Steam Cycles—Wrap up *No class Tuesday, March 9*	*No readings*
9	Mar 16/18	Solar Energy	The Future of Solar Energy, Chapters 2 and 3 plus Appendices A and B (pages 19 to 73 and 253 to 283)
10	Mar 23/25	Wind Energy	Energy Systems Engineering, Chapter 13 ("Wind Energy Systems," pages 399 to 443)

WEEK	DATES	TOPIC	READING
11	Mar 30/Apr 1	Energy Storage; Hydrogen	DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA, Chapter 1 ("Electricity Storage Services and Benefits", pages 1 to 28) So, What Exactly Is Green Hydrogen? Mind the Storage Gap: How Much Flexibility Do We Need for a High-Renewables Grid?
12	Apr 6	Electric Vehicles *No class Thursday, April 8*	Emerging Technologies for Higher Fuel Economy Automobile Standards
13	Apr 13/15	Building Electrification and Reducing Building Energy Use	Building Electrification Passive House
14	Apr 20/22	Project Presentations **Exam 2**	*No readings*

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