ENVIRONMENTAL & ENERGY ECONOMICS AND POLICY

BEPP/OIDD 2630

Spring Semester 2023, Tu/Th 12:00-1:30 p.m., SHDH 211

Note: This syllabus will be continuously updated. Please check Canvas for the latest version. Readings will be added/updated throughout the semester and as policy developments occur.

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Course overview. Over the last several decades, energy markets have become some of the most dynamic markets of the world economy. Traditional fossil fuel and electricity markets have seen a partial shift from heavy regulation to market-driven incentives, while rising environmental concerns have led to a wide array of new regulations and “environmental markets”. The growth of renewable energy is another source of rapid change, but brings with it a whole new set of technological and policy challenges. This changing energy landscape requires quick adaptation from energy companies, but also offers opportunities to turn regulations into new business. The objective of this course is to provide the economist’s perspective on a broad range of topics that professionals in the energy industry will encounter. Topics include the effect of competition, market power and scarcity on energy prices, extraction and pricing of oil and gas, geopolitical uncertainty and risk in hydrocarbon investments, the environmental policies related to the energy sector and their effectiveness, cap-and-trade markets, and transportation policies. There is special emphasis on the economics and finance of renewable energy, including an introduction to energy storage.

Readings. A mix of newspaper articles, academic papers, reports, plus the following textbook:
Nathaniel Keohane and Sheila Olmstead (KO), Markets and the Environment, Washington, D.C.: Island Press, second edition, 2016. Starred (*) readings are required. Many starred readings are short. Non-starred readings are optional but I will discuss them in class, and you are highly encouraged to read them if you want further background on a specific topic. The best way to use the readings is as a supplement to the lectures, which overlap partially (but certainly not perfectly!) with the readings. You will be responsible for required readings not covered in class.

Prerequisites. An introductory microeconomics course (ECON1, or another course approved by the instructor) will be sufficient in most cases; BEPP 2500 or an equivalent intermediate microeconomics course is recommended.
**Attendance.** Attendance is mandatory. Please email me in advance if you have a good reason not to attend a particular session.

**Format.** For most lectures, I will post prep questions on Canvas. Some lectures have pre-recorded videos. I will build on the video content in the lecture, so it is really important that you watch the assigned video beforehand. Occasionally, when a video is on the longer side, I will start the class later, so you have the option to watch it within the allocated 90-minute lecture slot. Feel free to email me (cc: Prakash) any questions that arise as you watch the videos.

**Strategy games.** Students will participate in two strategy games. The OPEC game is a series of simulations of the world oil market. Student teams represent countries and try to maximize profits by making output decisions that determine the world oil price. The Electricity Strategy Game is a simulation of an electricity market. Student teams manage a portfolio of generation units (coal, natural gas, nuclear and renewables) and bid into an electricity market.

**Guest lectures.** The course has three guest lectures by various energy experts. This year’s emphasis will be on renewable energy finance, renewable energy policy, and energy storage. Guest lectures will be joint with the MBA course *Energy Markets and Policy* (BEPP/OIDD 7630) and will take place on Tu/Th from 3:30-5:00 p.m. These lectures will be recorded. Attendance is mandatory unless you have a conflict with another class and the content of the guest lectures is fair game for questions on assignments and exams.

**Assignments and grading.** Three equally weighted assignments (30%), an exam (35%), the OPEC Game (12.5%), the Electricity Strategy Game (12.5%) and class participation (10%). The assignments are take-home. You may discuss assignments with other students but you need to formulate and submit answers on your own or joint with at most two other classmates. You earn participation points for submitting brief answers to pre-lecture questions on Canvas; only timely submission with good-faith effort counts, not accuracy/score. The exam will be on April 20 (in class). You should plan to attend the exam. Contact Beth Moskat in BEPP (emoskat@wharton.upenn.edu) if you have a scheduling conflict with another class, a medical issue, or an emergency. No other exceptions. Please do not email me about alternative exam dates for other reasons as I have no flexibility to accommodate such requests in all fairness to other students.

**Practice questions.** An extensive set of practice questions and solutions will be posted early in the semester. You can discuss them with the TA or with me during office hours if needed.

**Cheating policy.** It should not be necessary to say this – but for completeness: all students are expected to comply with the University of Pennsylvania’s Code of Academic Integrity. It is the policy of the department, and this course, to immediately fail any student for the course who is in violation of the University’s Code of Academic Integrity. Additional sanctions may be imposed of the Office of Student Conduct. The Code of Academic Integrity can be reviewed here.

**Electronics.** Taking notes on tablets is permitted. Phones are permitted for responding to polls, but should otherwise not be a distraction to you or your classmates. **No laptops as the sound of typing has proven to bother other students.**
Other details. The course is included in Wharton undergraduate concentration in Business, Energy, Environment and Sustainability, the Environmental Studies majors from the Earth & Environmental Science department, and in the university-wide minors in Environmental Studies and Sustainability and Environmental Management. Non-Wharton students are welcome and encouraged to contact the professor in advance to discuss prerequisites.

ELECTRICITY MARKETS

Lecture 1 (Jan 21): Basic Economics Review (Video Only)

(*) Work through the first two problems in the Basic Economics Review Session – Problems document on Canvas (Files/Assignments/Practice questions)

Pre-recorded video: Basic Economics Review Session

Note: There will be no lecture during the regular hours from 12:00-1:30 p.m., but I will be in the lecture room from noon-1:00 p.m. to answer questions about the review questions and about the course in general.

Lecture 2 (Jan 17): Course Introduction & Energy Overview


Lecture 3 (Jan 19): Market Efficiency and Scarcity Pricing

Topics: market efficiency; scarcity pricing; electricity markets; refined products markets.

(*) Pre-recorded video: Market Efficiency

Pre-recorded video: Scarcity Pricing (I will cover this in class too.)

(*) KO Chapter 4: “The Efficiency of Markets”.


Lecture 4 (Jan 24): **Market Power in Electricity Markets (Start Lecture: 12:40 p.m.)**

*Topics:* market power; deregulation.

(*) **Pre-recorded video:** Market Power


Lecture 5 (Jan 26): **Electricity Market Design**

*Topics:* California electricity crisis; Texas electricity crisis; electricity retail pricing.

**Pre-recorded video:** Electricity Retail Pricing


OIL AND GAS MARKETS

Lecture 6 (Jan 31): Oil and Natural Gas Extraction and Pricing (1) & Introduction to the OPEC Game (End Lecture: 1:00 p.m.)

Topics: trends in oil and gas reserves; optimal extraction; Hotelling model.

(*) Pre-recorded video: Hotelling Model

(*) Pre-recorded video: Hotelling Model Extensions

(*) KO Chapter 6: “Managing Stocks: Natural Resources as Capital Assets”.

(*) Lecture notes on the Hotelling model for optimal resource extraction (on Canvas).


Lecture 7 (Feb 2): Oil and Natural Gas Extraction and Pricing (2)

Topics: oil and gas price volatility; forecasting; futures.

(*) Video: Khan Academy, Forward and Futures Contracts, Lessons 1-5 (link). Lessons 6-12 are optional, but please watch if you need further explanation after the lecture.


J. Hamilton, 2009. “Understanding Crude Oil Prices.” The Energy Journal 30(2): pp. 179-188 (see Readings folder on Canvas). (Note: this reading is old but still relevant!)
Lecture 8 (Feb 7): **Upstream Investment under Uncertainty**

Topics: NOCs vs. IOCs; upstream contracts; drilling investment under uncertainty; geopolitical risk; expropriations.


**ENERGY AND ENVIRONMENTAL POLICY**

Lecture 9 (Feb 9): **Global Climate Change**

Topics: climate change impacts; the climate change debate; discounting; risk and uncertainty; social cost of carbon.

(*) Pre-recorded video: Climate Change Discounting.

(*) Lecture notes on climate change mitigation and discount rates (on Canvas).


Lecture 10 (Feb 14): **Externalities and Policy Instruments & OPEC Group Meetings**

Topics: environmental externalities; tragedy of the commons; Coase Theorem; property rights; taxes vs. subsidies vs. standards; effect of regulations on business; double dividend.
(*) Pre-recorded video: Externalities and Policy Instruments.

(*) KO Chapter 5: “Market Failures in the Environmental Realm”.

(*) KO Chapter 8: “Principles of Market-Based Environmental Policy”, pp. 139-162.


Lecture 11 (Feb 16): **Cap-and-Trade (End Lecture: 1:00 p.m.)**  
*Topics*: basics of cap-and-trade; cost-effectiveness; introduction to market design issues.

(*) Pre-recorded video: Cap-and-Trade.

(*) Lecture notes on the economics of cap-and-trade (on Canvas).


Lecture 12 (Feb 21): **Designing Real-World Environmental Markets**  
*Topics*: market design issues in cap-and-trade markets; EU Emissions Trading Scheme; RECLAIM; acid rain trading program.


Lecture 13 (Feb 23): **OPEC Game Debriefing**

Lecture 14 (Feb 28): **Demand Response and Virtual Power Plants**  
*Guest speaker*: Elta Kolo, Vice President, Huck Capital

*Topics*: demand response; virtual power plants; home batteries; buildings as power plants.

(*) Rocky Mountain Institute, “Virtual Power Plants, Real Benefits”, January 2023 (link).


(*)& Climate Tech VC, “Buildings as Power Plants”, 12/2/22 (link).

Lecture 15 (Mar 2): **Fuel-Economy Policy**

*Topics:* policy developments in the car industry; fuel-economy standards; gasoline tax; unintended consequences from fuel-economy standards; cost-benefit analysis; electric vehicle policy.


--- SPRING BREAK ---

Lecture 16 (Mar 14): **U.S. and Global Policy Developments**

*Topics:* global carbon trading developments; U.S. climate change policy.


(*)& S. Twidal, K. Abnett and N. Chestney, “EU Carbon Hits 100 Euros Taking Cost of Polluting to Record High”, Reuters, 2/21/23 (link).


(*)& “Q&A: What is China's Carbon Trading Scheme?”, Phys.org, 2/7/21 (link).


**THE ECONOMICS AND FINANCE OF RENEWABLE ENERGY**

Lecture 17 (Mar 16): **The Economics of Renewable Energy & Introduction to the Electricity Strategy Game**

*Topics:* levelized cost of electricity; environmental benefits of renewables.
Lecture 18 (Mar 21): **Renewable Energy Finance (1)**

*Topics*: intermittency; the variable value of renewable energy; intro to renewable energy finance; tax credits; accelerated depreciation; solar leases and PPAs.

(*) Lecture notes on renewable energy finance and policy, pp. 4-7 (on Canvas).


Lecture 19 (Mar 23): **Renewable Energy Finance (2) & Electricity Strategy Game Auction**

*Topics*: energy storage basics; tax equity; securitization.

(*) Pre-recorded video: Energy Storage Basics.

(*) Lecture notes on renewable energy finance and policy, pp. 11-13 and 19 (on Canvas).


Lecture 20 (Mar 28): **Energy Storage**

*Guest speaker:* Marco Ferrara, Co-Founder and Senior Vice President, Form Energy

*Topics*: the economics of storage; the various technologies; the connection between storage and large-scale renewables deployment.

*Note: this lecture will be held outside the regular class time in a different location (3:30-5:00 p.m.; JMHH F85).*


Optional: Form Energy’s *Insights* page has several other interesting articles (link).

Lecture 21 (Mar 30): **Renewable Energy Finance (2) (Video Only)**

*Topics*: renewable portfolio standards; (S)RECs.

*Note*: There will be no lecture during the regular hours from 12:00-1:30 p.m., but I will hold extra virtual office hours about the content of this lecture on Monday April 3, 3:00-4:00 p.m. You can join on Canvas via the Zoom tab.

(*) Pre-recorded video: Renewable Energy Finance

(*) Lecture notes on renewable energy finance and policy, pp. 8-11, 13-18 (on Canvas).

Lecture 22 (Apr 4): **Renewable Energy Policy**

*Topics*: net metering; PACE; feed-in tariffs; tenders; import tariffs; green subsidy vs. carbon tax; waterbed effect.


Lecture 23 (Apr 6): **Renewable Energy Project Finance**

**Guest speaker**: Gianluca Signorelli, VP, Head of Project Finance and M&A Execution, U.S. SB Energy (SoftBank)

*Topics*: renewable energy project finance, tax equity, capital structure, PPAs, hedging.

*Note*: this lecture will be held outside the regular class time in a different location (3:30-5:00 p.m.; JMHH F85).

Lecture 24 (Apr 11): Financing Offshore Wind Investments

Guest speaker: Udit Goyal, Head of Project Finance, Offshore North America, Ørsted

Topics: investing in wind energy, wind energy finance, wind energy contracts.

Note: this lecture will be held outside the regular class time in a different location (3:30-5:00 p.m.; JMHH F85).

(*) Center for American Progress, “The Road to 30 Gigawatts: Key Actions to Scale an Offshore Wind Industry in the United States”, 3/14/22 (link).


Lecture 25 (Apr 13): Electricity Strategy Game Debriefing

Lecture 26 (Apr 18): Unintended Policy Consequences & Course Wrap Up

Topics: congestion policies; enforcement; cheating; emissions leakage; course summary.

Lecture 27 (Apr 20): Exam

Note: the exam will be held during the regular class time in two different rooms (see below).

Lecture 28 (Apr 25): Final Q&A (Optional)

Note: this session is fully optional; I will answer any remaining questions about the course materials, topics we did not touch on, or academic research in environmental and energy economics. If there is interest, we can do a mini case study about the possible transformation of oil and gas companies to green energy supergiants; materials below:


“Sustainable Business Transformation - The Ørsted Case”, The Conference Board, 6/17/20 (link). (This is a podcast.)
DUE DATES

Assignment dates

Assignment 1: posted on February 2, due by February 16
Assignment 2: posted on March 9, due by March 27
Assignment 3: posted on April 4, due by April 18

OPEC Game

January 31 Introduction to the OPEC game in class
February 3 Production quantities due by 10 p.m. for phase 1, period 1
February 6 Production quantities due by 10 p.m. for phase 1, period 2
February 8 Production quantities due by 10 p.m. for phase 2, period 1
February 9 Production quantities due by 10 p.m. for phase 2, period 2
February 10 Production quantities due by 10 p.m. for phase 2, period 3
February 13 Production quantities due by 10 p.m. for phase 2, period 4
February 14 OPEC group meetings in class
February 15 Production quantities due by 10 p.m. for phase 3, period 1
February 16 Production quantities due by 10 p.m. for phase 3, period 2
February 17 Production quantities due by 10 p.m. for phase 3, period 3
February 20 Production quantities due by 10 p.m. for phase 3, period 4
February 23 OPEC strategy memo due before class
February 23 OPEC game debriefing in class

Electricity Strategy Game

March 16 Introduction to the Electricity Strategy Game in class
March 20 Bids due for the ESG test run
March 23 First ESG divestiture auction, in class
March 27 ESG strategies due by 10 p.m. for year 1, day 1
March 29 ESG strategies due by 10 p.m. for year 1, day 2
March 30 ESG strategies due by 10 p.m. for year 1, day 3
April 3 Sealed portfolio bids for year 2 due by 10 p.m.
April 5 ESG strategies due by 10 p.m. for year 2, day 1
April 6 ESG strategies due by 10 p.m. for year 2, day 2
April 7 ESG strategies due by 10 p.m. for year 2, day 3
April 13 ESG strategy memo due before class
April 13 ESG debriefing in class

Exam

Date/time: Thursday April 20, 12:00-1:30 p.m.
Locations: last names A through L – SHDH 211; last names M through Z – SHD 1206