COLUMBIA UNIVERSITY
School of Professional Studies

Master of Science in Sustainability Management

SUMA 5155 – Energy Markets & Innovation

[T TH 4:10-6pm – Online only] – 3 Credits

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Office Hours: By Appointment

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Course Overview

Existing energy sources and the infrastructures that deliver them to users around the world are undergoing a period of rapid change. Limits to growth, rapidly fluctuating raw material prices, and the emergence of new technology options all contribute to heightened risk and opportunity in the energy sector. The purpose of this course is to establish a core energy skill set for energy students and prepare them for more advanced energy courses by providing a basic language and toolset for understanding energy issues.

Using theoretical and practical understanding of the process by which energy technologies are developed, financed, and deployed, this course seeks to highlight the root drivers for change in the energy industry, the technologies that are emerging, and the factors that will determine success in their commercialization. Understanding these market dynamics also informs good policy design and implementation to meet a broad range of social welfare goals.

Upon completing the course, students should not only understand the nature of conventional and emerging energy generation and delivery, but also the tools for determining potential winners and losers and the innovative pathways to drive their further deployment.

General Learning Objectives

This course is designed to be inter-disciplinary, integrating skills from finance, marketing, technology, regulation and policy, and entrepreneurship. However, no prior knowledge is required to excel in this course. It is intended to establish a foundation of knowledge and framework for further study.

Methodologically, there are some basic skills for measuring, costing, and valuing energy and electricity that must be understood, which are particular to the energy industry. Therefore, non-trivial mathematical and spreadsheet work will be required to show the necessary competence in these skills. Students should be reasonably comfortable with spreadsheet modeling for computation and financial projection before beginning the course, or choose a good partner for completing problem sets.

The hardest part of any work in emerging technologies (particularly in the fast-changing energy sector) is to integrate vast amounts of information into useful and actionable information. It is vital to cut through the haze of data and uncertainty to identify key drivers for success and then present the qualitative and quantitative information necessary to determine the likelihood of and best pathway to success for a given solution. Such analysis will be messy and complex and will likely necessitate substantial supplemental research, but in the end will derive great practical benefit in the skills of analysis and presentation that will be useful in nearly every future career.

Readings

REQUIRED

1) ***The Energy System***, Travis Bradford, MIT Press, 2018
   (order online soon from Amazon, hardcopy or Kindle version, I recommend Kindle)
2) ***Thinking in Systems***, Donella Meadows, Chelsea Green, 2008
   (order online, fastest may be Amazon Kindle, or PC e-book app.)
3) Supplemental readings and videos from the syllabus below and articles posted for students

RECOMMENDED

1) ***Solar Revolution: The Transformation of the Global Energy Industry***, Travis Bradford, MIT Press, 2006

Assignments and Assessments

Grading will be based on class participation, problem sets, and a final exam. Students cannot take this course pass/fail.

1. Class participation (30%)

Class participation will count for **30% of the final grade**. A number of factors will contribute to your class participation grade:

a. Contributions in class and recitation: Thoughtful comments and focused questions that contribute to the learning environment are encouraged (quality, and connection to the course concepts and conversations, is the key factor here).
b. Attendance: students are expected to attend all classes and recitations
c. Contributions outside class: Providing links to articles, publications, videos, and data that support the classroom discussion or course concepts (these can either be used by me this semester or may be used to support future classes), actively creating a collaborative and collegial work environment inside and outside the class, suggesting edits or additional articles and papers to support the continued development for the class.

2. Five (5) Problem Sets (35%)

a. Five problem sets will be done in groups of up to 3-4 people and will account for **35% of the final grade**. These problem sets will reinforce concepts of measurement and metrics of energy, including generation and capacities, energy conversions, and calculation methodologies of cost and value of energy, electricity, and carbon. The calculations will be supplemented with qualitative assessments of the results.
b. Problem sets will be submitted online via CourseWorks. The deadline for each problem set is at 4:00 PM on the day they are due. Late problem sets will have grades deducted.

3. Final Exam (35%)

The final will count for **35% of the final grade**. It will both qualitatively and quantitatively test the fundamental concepts of class, the readings, lectures, and learnings from the problem sets. A list of the learning objectives is provided below, but should not be considered exhaustive for the purposes of the exam. Final Exams will only be given during the normal exam period.

The 10 Learning Objectives

10 things you should learn from this course (and will be tested on):

The list below sets out the objectives for the course and provides the basis for questions for the final exam. You should note, however, that I will not treat these topics in the sequence and structure in which they are presented here. Rather, I expect you to use this list as a roadmap to navigate the class. It is your own responsibility to map the contents of the class to these ten objectives and ensure that, by the end of the class, you are capable of answering questions related to these objectives using tools acquired in the course. In the end, meeting these objectives is also the list I hope you will use to evaluate the course.

1. Become fluent in Energy System concepts and terminology – technologies; current and emerging sources of energy; four dimensions of energy transformation; final energy services, and industry terminology and definitions
2. Understand the energy as a system – stocks, flows, and feedback; sustaining vs. reinforcing loops; supply chains; five forms of capital; system dynamics; system resilience and buffers; sustainable development
3. Describe the physical conversion of energy through the system – laws of thermodynamics; power to energy conversion; losses; heat rates; temporal shifting; transmission and transportation; efficiency; storage; and emission calculations
4. Link the energy system to micro-economic principles – Supply and Demand; supply curve construction; market and market function; price formation; producer and consumer surplus; profit (rent) maximization; average vs. marginal costs; short-term vs. long-term
5. Develop a complete framework of costing methods for both Energy and Power – Levelized Cost of Electricity; fungible LCOE comparisons; capital costs; Total Cost of Ownership (TCO); production cost; when costs are not independent; cycle cost; Cost per mile (CPM); Break-even Price (BEP); abatement cost
6. Determine sources of value in energy systems – energy services; load; revenue; behavioral limitations; total addressable market; integrated streams of values for power and energy; fractured petroleum economics; indexing; energy/ GDP linkages; energy poverty
7. Develop and intelligently use scenarios and forecasts of the future energy system – bottom up vs. top down methods; system peaks; margins and buffers; experience curves and learning; feedstock linkages; constraints, limits, and bottlenecks; asset lock-in; co-dependence; the tension between innovation versus depletion
8. Recognize and describe the role of competition in energy markets – sustaining versus disruptive loops; evolutionary changes vs. disruptive changes; market design; fungible comparisons; parity and disruption; product differentiation; switching
9. Understand the role and methods of investment in the energy system – compounding, financial analysis; project finance; project risk categories; debt vs. equity; venture capital; R&D; futures trading and speculation; retrofit and repowering; micro-finance
10. Know and apply tools used for analyzing energy market failures and solutions – myopia; externalities; informational asymmetries; natural monopolies; cartels; collective security; system collapse; policy interventions; market interventions

Course Readings and Assignments

- Topic 1-2 (General Principles) has a fairly large amount of industry and background reading – the course texts, "The Energy System" and "Thinking in Systems", are introduced along with some more academic papers about obstacles to change, policy design and impacts, tragedy of the commons, externalities, etc. You should flip through and understand the data sources within the World Energy Assessment, BP Energy Assessment, IEO, IPCC Reports, etc.

- Topic 3-7 (Electricity Systems) begins as an understanding of the existing electricity market and uses that market to demonstrate how physical transformations are made and then valued in one of the largest formal markets in the world. Understanding the pre ssures facing this market allow for examination of various solutions including efficiency and demand response. It also assesses all of the utility- and distributed-scale generation options available today using a framework for determining competitiveness, including fungibility and values. A number of practical, economic, and forecasting competences will be developed throughout this section, including LCOE methodology, price determination, disruption, and the role of storage.

- Topic 8-10 (Transportation Systems) begins by looking at the use of transportation services and constraints imposed by access to petroleum resources. It then looks at where and how capital can be deployed profitably to change this infrastructure, supplement fuels, or switch to other combustion options, and the limiting forces to those innovations. Finally, examining how transportation re-integrates with electricity architecture gives us an opportunity to examine the nature of paired technologies.

- Topic 11-13 (Other Energy Systems) will integrate a wide range of situations and technology options into an examination of comprehensive systems. The role of natural gas in the thermal system, energy impacts on the economic system, carbon pricing, and new methods of delivering vital energy to the world's poorest combine to help us spot emerging business opportunities now and in the future.

- *Links are Hot – You should be able to click through.*

Course Outline (Topic, Title, Assignments, Topics and Recitations)

		Title	Due	Topics Covered
General Principles (2 weeks)				
May 21	1	**Introduction to Energy Terms and Conversions**		Laws of Thermodynamics, Energy vs. Power, Conversions, Stocks and Flows, Cost vs. Value vs. Price, Fungibility, Constraints, Normative vs. Positive
May 23	2	**Energy as an Economic System and Dealing with Market Failures**	Bio Sheet	Energy Systems Dynamics, Supply Chains, Five Forms of Capital, Scenarios, Market Failures, Behavioral Economics, Interventions
Electricity Systems (4 weeks)				
May 28	3	**Understanding Organized Electricity Markets** *- The Grid*	PS #1 –	Generation, Transmission, Distribution, Cost of Service Recovery, Deregulation, Load types, Dispatchability, Interconnection
	4	**Generation Supply, Demand, and Price Determination** *- Fossil Fuel Generation*		Bus Bar Costs, LCOE, Price of Electricity, Multiple Value Streams of Electricity
May 30	5	**Project Finance and Development** *- Renewable Generation*		Project Finance, Cost of Capital (WACC), IRR, Risk, Fungibility of Generation Alternatives
June 4	6	**Demand Side Solutions** *- Energy Efficiency, Demand Response, and Storage*	PS #2 –	Devices, Load, Energy Efficiency, Economic Demand Response Measures, Ancillary Services, Storage Alternatives, Smart Grid
June 6	7	**Experience Curves, Disruptions, and Solar Energy** *- Distributed Generation*		Experience Curves, Learning, Technology, Disruptive Technologies, Net Metering, Distributed Generation, Utility Transformation
Transportation Systems (3 weeks)				
June 11	8 9	**Oil and Transportation Markets** *- Transportation Systems* *- Petroleum*	PS #3 –	Transportation Services, Passenger vs. Cargo, CAFE Standards, Unintended Consequences, Resource and Reserves, Quality, Peak Oil, Fracking, Delivery Systems, Energy Security
June 13	10	**Alternate Fuel Sources** *- Biofuels* *- Natural Gas Vehicles*		Feedstocks, Food vs. Fuel, Biofuels, RFS, Flex-Fuel Vehicles, Asset Lock-in and Co-Dependence, Cellulosic, Algae, Drop-in Fuels
June 18	11	**Electricity in Transportation** *- Electric Vehicles*	PS #4 –	EV, PHEV, FCE, Charging Networks, Grid Reliability, Stand-by Power, V2G, Spinning Reserves, Total vs. Addressable Market
Other Energy Systems (2 weeks)				
June 20	12	**Thermal Systems and Natural Gas** *- Natural Gas*		Thermal Energy, Natural Gas, Pipelines, Fracking & Shale Gas, Liquefaction
June 25	13	**Energy and the Global Economy** **Energy and the Environment**	PS #5 –	Energy and Macroeconomics, Energy Security, Energy and Development, Energy Access Climate Change, UNFCCC, ETS Trading System, Carbon Accounting, Sustainable Development
Final Exam				
June 27	**FINAL EXAM (in class)**			

Course Policies

Participation and Attendance
You are expected to complete all assigned readings, attend all class sessions, and engage with others in online discussions. Your participation will require that you answer questions, defend your point of view, and challenge the point of view of others. If you need to miss a class for any reason, please discuss the absence with me in advance.

Late work
Work that is not submitted on the due date noted in the course syllabus without advance notice and permission from the instructor will be graded down 1/3 of a grade for every day it is late (e.g., from a B+ to a B).]

Citation & Submission
All written assignments must use standard citation format (e.g., MLA, APA, Chicago), cite sources, and be submitted to the course website (not via email).

School and University Policies and Resources

Grading
The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

Copyright Policy
Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

> The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity
Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at https://sps.columbia.edu/students/student-support/academic-integrity-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Diversity Statement
It is our intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength and benefit. It is our intent to present materials and activities that are respectful of diversity: gender identity, sexuality, disability, age, socioeconomic status, ethnicity, race, nationality, religion, and culture.

Accessibility
Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: https://health.columbia.edu/content/disability-services.

Class Recordings
All or portions of the class may be recorded at the discretion of the Instructor to support your learning. At any point, the Instructor has the right to discontinue the recording if it is deemed to be obstructive to the learning process. If the recording is posted, it is confidential and it is prohibited to share the recording outside of the class.

SPS Academic Resources
The Division of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: https://sps.columbia.edu/students/student-support/student-support-resources.

Columbia University Information Technology
Columbia University Information Technology (CUIT) provides Columbia University students, faculty and staff with central computing and communications services. Students, faculty and staff may access University-provided and discounted software downloads.

Columbia University Library
Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online.

The Writing Center
The Writing Center provides writing support to undergraduate and graduate students through one-on-one consultations and workshops. They provide support at every stage of your writing, from brainstorming to final drafts. If you would like writing support, please visit the following site to learn about services offered and steps for scheduling an appointment. This resource is open to Columbia graduate students at no additional charge. Visit http://www.college.columbia.edu/core/uwp/writing-center.

Career Design Lab
The Career Design Lab supports current students and alumni with individualized career coaching including career assessment, resume & cover letter writing, agile internship job search strategy, personal branding, interview skills, career transitions, salary negotiations, and much more. Wherever you are in your career journey, the Career Design Lab team is here to support you. Link to https://careerdesignlab.sps.columbia.edu/

Netiquette
Online sessions in this course will be offered through Zoom, accessible through Canvas. A reliable Internet connection and functioning webcam and microphone are required. It is your responsibility to resolve any known technical issues prior to class. Your webcam should remain turned on for the duration of each class, and you should expect to be present the entire time. Avoid distractions and maintain professional etiquette.

Netiquette is a way of defining professionalism for collaborations and communication that take place in online environments. Here are some Student Guidelines for this class:

- Avoid using offensive language or language that is not appropriate for a professional setting.
- Do not criticize or mock someone's abilities or skills.
- Communicate in a way that is clear, accurate and easy for others to understand.
- Balance collegiality with academic honesty.
- Keep an open-mind and be willing to express your opinion.
- Reflect on your statements and how they might impact others.
- Do not hesitate to ask for feedback.
- When in doubt, always check with your instructor for clarification.

Lecture Readings, Assignments, and Questions

GENERAL PRINCIPLES (2 WEEKS)

1. Introduction to Energy Terms and Conversions

Topics Covered:

Why Energy Matters, Energy vs. Power, Stocks and Flows, Laws of Thermodynamics, Scenarios, Conversions, Constraints, Normative vs. Positive

Readings:

- **The Energy System [Preface & Chapter 1]**
- Holdren, J., "The Energy Innovation Imperative," Spring 2006.
- OPTIONAL - The McGraw Center, Princeton. "Active Reading Strategies," 2016.

2. Energy as an Economic System and Dealing with Market Failures

Topics Covered:

Energy Systems Dynamics, Six Forms of Capital, Cost vs. Value vs. Price, Fungibility, Market Failures, Behavioral Economics, Interventions

Reading:

- ***Thinking in Systems*** **[Through the end of Section 1]**
- **The Energy System [Chapter 2 & 3]**
- "BP Energy Outlook," BP, 2023 Edition
- REN21, "Renewables 2023 Global Status Report" **[Pages 11-22]**
- "energy [r]evolution: A Sustainable Global Energy Outlook " Greenpeace International and EREC, 2015 **[Read Introduction, Executive Summary, Chapters 3 and 4, and SKIM Pages 58-92]**

[Scan] Data Sources:

- "BP Statistical Review of World Energy" BP and Energy Institute, 2023
- "IEA Key World Energy Statistics 2021", International Energy Agency, 2021
- "Monthly Energy Review" DOE Energy Information Agency (EIA), August 2023

[Optional] Reference:

- "Deploying Renewables: Best and Future Policy Practice", IEA, 2011.
- "A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies", Short et. al., NREL, March 1995

ELECTRICITY SYSTEMS (5 WEEKS)

3. Understanding Organized Electricity Markets

Topics Covered:

Generation, Transmission, Distribution, Cost of Service Recovery, Deregulation, Load types, Dispatchability, Interconnection

Readings:

- **The Energy System [Chapter 4]**
- Binz, R. "Practicing Risk-Aware Electricity Regulation: 2014 Update," CERES 2012

4. Generation Supply, Demand, and Price

Topics Covered:

Bus Bar Costs, LCOE, Price of Electricity, Multiple Value Streams of Electricity, Risk

Readings:

- ***Thinking in Systems*** **[Section 2]**
- **The Energy System Chapter 5 & 6, (Particular focus on Appendix 5)**

5. Project Finance and Development

Topics Covered:

Project Finance, Cost of Capital (WACC), IRR, Fungibility of Generation Alternatives

Readings:

- **The Energy System [Chapters 7 & 8]**
- Lazard LCOE – Version 16

6. Demand Side Solutions

Topics Covered:

Devices, Load, Energy Efficiency, Economic Demand Response Measures, Ancillary Services, storage alternatives, Smart Grid

Readings:

- **The Energy System [Chapters 9 & 10]**

7. Experience Curves, Disruptions, and Solar Energy

Topics Covered:

Experience Curves, Learning, Technology, Disruptive Technologies, Net metering, Distributed Generation, Utility Transformation

Readings:

- **The Energy System Chapters [11 & 12]**
- [OPTIONAL] - Solar Revolution, Chapters 1, 6, 7, and 10

TRANSPORTATION SYSTEMS (4 WEEKS)

8. Oil and Transportation Markets

9. Oil and Transportation Markets (continued)

Topics Covered:

Transportation Services, Passenger vs. Cargo, CAFE Standards, Unintended consequences, Resource and Reserves, Quality, Peak Oil, Fracking, Delivery Systems, Energy Security

Readings:

- **The Energy System [Chapters 13 & 14]**

10. Alternate Fuel Sources

Topics Covered:

Feedstocks, Food vs. Fuel, Biofuels, RFS, Flex-Fuel Vehicles, Asset Lock-in and Co-Dependence, Cellulosic, Algae, Drop-in Fuels

Readings:

- **The Energy System [Chapter 15]**

11. Electricity in Transportation

Topics Covered:

EV, PHEV, FCE, Charging Networks, Grid Reliability, Stand-by Power, V2G, Spinning Reserves, Total vs. Addressable Market

Readings:

- **The Energy System [Chapter 16, Review Chapter 10 (Storage)]**

OTHER ENERGY SYSTEMS (2 WEEKS)

12. Thermal Systems and Natural Gas

Topics Covered:

Thermal Energy, Natural Gas, Pipelines, Fracking & Shale Gas, Liquefaction

Readings:

- **The Energy System [Chapters 17 & 18]**

13. Energy And the Global Economy

Topics Covered:

Energy and Macroeconomics, Energy Security, Energy and Development, Energy Access

Readings:

- **The Energy System [Chapter 19]**

Energy and the Environment

Topics Covered:

Climate Change, UNFCCC, ETS Trading System, Carbon Accounting, Sustainable Development

Readings:

- **The Energy System [Chapters 20 and postscript]**
- ***Thinking in Systems* [Section 3]**
- ***IPCC 6th Assessment Synthesis Report for Policy Makers***

Appendix: Energy System – Technical Video Links

Title	Video Link
The Future of Energy	**The Future of Energy?** https://youtu.be/Gz_L6KuqvFI
Understanding Organized Electricity Markets and Efficiency - *The Grid* - *Energy Efficiency*	**Electricity Generation 101 (5 min.)** http://www.youtube.com/watch?v=20Vb6hlLQSg&feature=related **Overview of the Electricity Grid (4 min.)** http://www.youtube.com/watch?v=38EEmWHI0C8 **Smart Grid (Institute of Electrical and Electronics Engineers, 9 min.)** http://www.youtube.com/watch?v=YrcqA_cqRD8&feature=related **A day in the life of the grid, July 21, 2011 (MISO, 33 min.) –** *Well worth the investment* https://www.youtube.com/watch?v=RdrMpElZWSM **[Optional] - Anatomy of a Transmission System (AEP, 4 min.)** http://www.youtube.com/watch?v=WTIQ_xcp0sU&feature=related **[Optional] - Anatomy of a Distribution System (AEP, 10 min.)** http://www.youtube.com/watch?v=YcBgxVfD70Q&feature=relmfu
Utility-Scale Generation Options - *Coal Thermal Power Plant* - *Gas Fired Combined Cycle* - *Co-Gen Plant* - *Utility-scale Renewables*	**Coal Power Plant (MidAmerican Energy, 6 min.)** http://www.youtube.com/watch?v=j0e772Vo73k **Combined Cycle Natural Gas (Duke Energy, 7 min.)** http://www.youtube.com/watch?v=iNspo_s-1jY **Co-generation Plant at NYU (3 min.)** http://www.youtube.com/watch?v=9m9SgsTTgiA&feature=related **Biomass Co-Generation Plant at Nagda site (4 min.)** http://www.youtube.com/watch?v=tARuhig03To **Hydro Power (2 min.)** http://www.youtube.com/watch?v=Pj4dZM4SIls **Nuclear Power – How it works (5 min.)** http://www.youtube.com/watch?v=_UwexvaCMWA **Wind Turbines (UVSAR, 10 min.)** http://www.youtube.com/watch?v=LNXTm7aHvWc&feature=related **Offshore Wind Construction (Belwind, 14 min.)** http://www.youtube.com/watch?v=x9IntSh2K7c **Utility Scale Solar PV (ABB, 2 min.)** http://www.youtube.com/watch?v=edYNj_TrTXY&hd=1 **Concentrating Solar Thermal (2 min.)** https://www.youtube.com/watch?v=tdivW7inP0k **Geothermal (3 min.)** https://www.youtube.com/watch?v=kjpp2MQffnw **Tidal and Wave Power (5 min.)** http://www.youtube.com/watch?v=tSBACzRE3Gw&feature=related
Energy Storage Options - *Electricity Storage*	**Columbia Social Enterprise Forum – Energy Storage and Battery Technology (56 min.)** http://www.youtube.com/watch?v=661-GIswZco&hd=1 **Pumped Hydro Storage – in German with translation (2 min.)** http://www.youtube.com/watch?v=GJ7ltJlMY9E **Grid Storage – A123 Batteries (DoE, 9 min.)** http://www.youtube.com/watch?v=6C8Ji05UJaw
Oil and Transportation Markets - *Petroleum* - *Supply Chain Analysis*	**Oil and Gas Drilling (4 min.)** https://www.youtube.com/watch?v=qhZ50NCbVKo **Refinery (14 min.)** http://www.youtube.com/watch?v=9Py8-Xy9MKo **Transportation Fuels – GHG implications (5 min.)** http://www.youtube.com/watch?v=hq2uWWBqe4M

	Megastructures - Oil Sands (40 min.) https://www.youtube.com/watch?v=5F17MXBZzc0 **Shale Oil (Energy Now, 28 min.)** http://www.youtube.com/watch?v=U_T-AwYOhp4&feature=related
Biofuels - *Biofuels*	**Ethanol from Sugar Cane- Production Process (15 min.)** http://www.youtube.com/watch?v=kP1S2HGf5-E **Ethanol from Corn – Production Process (5 min.)** https://www.youtube.com/watch?v=uE7DJVCa5h0 **How it is made – Biodiesel (4 min.)** http://www.youtube.com/watch?v=xLa83KIaEyw **Biofuels, Beyond Ethanol (10 min.)** http://www.youtube.com/watch?v=CkJJ-x7U5NI
Electricity in Transportation Markets - *Electric Vehicles* - *Fuel Cell Vehicles*	**The State of Electric Vehicles in America (29 min.)** http://www.youtube.com/watch?v=1ZGQgZPaQ6o&feature=relmfu **Energy 101 Fuel Cells (43 min.)** https://www.youtube.com/watch?v=41Nb6juV6MI
Natural Gas Markets	**Natural Gas Production and Marketing (Chesapeake Energy, 10 min.)** http://www.youtube.com/watch?v=2Gw_Bn-JqDg **Natural Gas Pipelines Operation (9 min.)** http://www.youtube.com/watch?v=aTTJeTaYDyc **Hydraulic Fracturing (Marathon Oil, 3 min.)** https://www.youtube.com/watch?v=VY34PQUiwOQ **Natural Gas: The Energy to move Forward (Conoco Philips, 5 min.)** http://www.youtube.com/watch?v=BzLZnidztpI **History – I am Natural Gas – 1959 (3 min.)** http://www.youtube.com/watch?v=PKX0GeF9w-k **History – Natural Gas Pipeline Development – 1959 (1 min.)** http://www.youtube.com/watch?v=Wodvxh6WEs4