Columbia University School of Professional Studies
Master of Science in Sustainability Management

SUMA PS5197 Financing the Clean Energy Economy
Fall 2017, Mondays 6:10-8:00pm
3 Credits

Instructor: Curtis Probst, CFA; csp2138@columbia.edu (cell, if urgent: 646 645-6595)
Office Hours: By appointment (email to schedule), preferably afternoons before class; 2929 Broadway, 5th Floor
Response Policy: Email is my preferred mode of communication. Students should expect a response the same or next business day

Course Overview

We need to transition towards a more environmentally-sustainable society given both concerns around pollution and its health effects, and the impacts of extreme weather and climate change. The production and consumption of energy is the largest contributor to these concerns, and so the transition to a clean energy economy is essential. At the same time, given the energy needs of the world's growing population, energy security and affordability are also critical issues. New technologies and effective policies are needed to help drive increased deployment of renewable energy and energy efficiency.

At the same time, finance is increasingly being recognized as a key lever to drive the implementation of clean energy. Without the ability to attract the requisite capital, it is difficult to scale renewable energy and energy efficiency technologies. In order to meet the climate targets articulated in the 2015 Paris climate conference, clean energy investment would need to increase to over $1 trillion each year. Fortunately, public and private sector capital providers have begun to respond. For example, in 2016, over $80 billion of green bonds were issued in the global capital markets to fund clean energy investments. Furthermore, in several nations and in a few US states, green banks have been formed as public-private partnerships to fund clean energy initiatives. Even for governments and institutions that ascribe less value to the environmental benefits, many see significant investment opportunities in clean energy, and the ability to create new jobs and improve economic productivity. While the level of interest and creativity in financing the clean energy economy is high, there is a need for continued growth and innovation.

This course focuses on the finance and market aspects of the clean energy economy, and integrates technology, policy and finance to provide an understanding of both the opportunities and challenges. This course focuses on renewable energy generation, as mass electrification using clean generation sources is necessary to sustain our energy-dependent lives and economies. It also looks at energy efficiency, including two specific end-uses of energy that are responsible for the majority of emissions: personal vehicles and buildings. Throughout the course, finance will be analyzed as a barrier to, or enabler of, greater adoption of clean energy.

Interactive lectures, and guest speakers where appropriate, will cover these topics in eleven classes: The course begins with three classes providing a basic understanding of the U.S. electricity market: (1) historical context and the role of finance, (2) energy fundamentals and current state of energy markets, and (3) clean energy and grid integration. The next three classes describe financial aspects of clean energy and finance: (4) key finance concepts, (5) financial modeling of power projects, and (6) modeling other clean energy initiatives. Armed with an understanding of the electricity sector and financial modeling, students then integrate those two areas with five classes that discuss: (7) challenges of the clean energy economy, (8) electricity pricing and financing distributed energy resources, (9) clean energy financing mechanisms, (10) building energy efficiency and (11) electric vehicles. The final two classes will be reserved for group presentations.

Course assignments will include financial models, problem sets, case studies, and a final group presentation. The financial modeling will be designed to take into account the varying levels of student experience. An important aspect of the course is for students to learn some of the analytical tools used by industry practitioners to make investment decisions. While no specific financial modeling experience is required, students should have basic spreadsheet skills or be prepared to learn them.

As the course progresses, students will learn to appreciate the roles of technology, policy, and finance in the transition to a clean energy economy. Upon completion of this class, students should understand the fundamentals of the U.S. electricity sector, the role of clean energy, the opportunities and limitations of finance, and have an appreciation of different mechanisms to support clean energy finance.

The course is designed for both students with a limited background in finance but with an interest in building that skill set, and for students with prior backgrounds in finance that are seeking to apply those skills to the financing of the clean energy economy. This course is approved for the Certificate in Sustainable Finance requirement.

Learning Objectives

By the end of this course students will be able to:

- Describe how the existing electricity markets function in the U.S., and how clean energy technologies are developing within, and apart from, these markets
- Assess the implications of larger adoption of clean energy technologies to the broader electric grid
- Summarize some of the existing business models and financial techniques for bringing clean energy to markets
- Create basic financial models for evaluating clean energy opportunities and demonstrate good technique in the development of these models
- Discuss some of the key opportunities and challenges faced in transitioning to clean energy in general, and more specifically, to electric vehicles and energy-efficient buildings
- Identify mechanisms that can be used to support the development and deployment of clean energy

Considering the breadth of the energy and financial markets, and the rapidly evolving nature of each, the goal is not to learn about every means of financing clean energy. The course's objective is to provide students a new level of comfort in discussing the role of finance in the transition to a clean energy economy. Students will focus on several specific examples of that transition through the class materials, and may choose a specific area in which they have personal interest for the group presentation.

Readings

Required:

American Wind Energy Association. "Wind Energy Facts at a Glance". Web. 23 July 2017. http://www.awea.org/Resources/Content.aspx?ItemNumber=5059&navItemNumber=742 (1 page)

California ISO. "What the duck curve tells us about managing a green grid", 2016. Web. 4 August 2016. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf (4 pages)

Clean Energy States Alliance. *A Homeowner's Guide to Solar Finance: Leases, Loans, and PPAs,* May 2015, pp. 1-17. Web. 4 August 2016. http://www.cesa.org/assets/2015-Files/Homeowners-Guide-to-Solar-Financing.pdf (17 pages)

Federal Energy Regulatory Commission. *Energy Primer: a Handbook of Energy Market Basics* November 2015; pp. 1-4, 35-56. Web. 4 August 2016. http://www.ferc.gov/market-oversight/guide/energy-primer.pdf (26 pages)

Fitzgerald, Garrett, Chris Nelder and James Newcomb. *Electric Vehicles as Distributed Energy Resources*. Rocky Mountain Institute, June 2016, pp. 5-9. Web. 4 August 2016. http://www.rmi.org/pdf_evs_as_DERs (5 pages)

Fitzgerald, Garrett et al. *The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Executive Summary.* Rocky Mountain Institute, October 2015. Web. 23 July 2017. https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/05/TheEconomicsOfBatteryEnergyStorage-ExecutiveSummary.pdf (8 pages)

Hansen, Lena, Virginia Lacy and Devi Glick. *A Review of Solar PV Benefit & Cost Studies, 2nd Edition.* Rocky Mountain Institute, September 2013, pp. 1-19. Web. 4 August 2016. http://www.rmi.org/elab_empower (19 pages)

Jones Lang LaSalle et al. *Empire State Building Case Study*. 2009. Web. 4 August 2016. https://www.esbnyc.com/sites/default/files/ESBOverviewDeck.pdf (80 slides)

Lazar, Jim. "Teaching the 'Duck' to Fly, Second Edition." The Regulatory Assistance Project, February 2016, pp. 5-9. Web. 4 August 2016. http://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-teachingtheduck2-2016-feb-2.pdf (5 pages)

Lazard. *Lazard's Levelized Cost of Energy Analysis-Version 10.0.* December 2016. Web. 23 July 2017. https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf (22 pages)

NC Clean Energy Technology Center. "Commercial Guide to the Federal Investment Tax Credit for Solar PV", December 2015. Web. 4 August 2016. http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2015/12/CommercialITC_Factsheet_Final-dec2015update.pdf (6 pages)

Solar Energy Industries Association. "Solar Market Insight Report 2017 Q2". [summary]. 2017. Web. 23 July 2017. http://www.seia.org/research-resources/solar-market-insight-report-2017-q2 (21 pages) **no need to purchase report; review the summary only**

U.S. Energy Information Administration. "Basics"; *Electricity Explained: Electricity in the United States,* 10 May 2017. Web. 23 July 2017. http://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states#tab1 (1 page)

U.S. Energy Information Administration. "Generation, Sales & Capacity"; *Electricity Explained: Electricity in the United States,* 10 May 2017. Web. 23 July 2017. http://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states#tab2 (1 page)

U.S. Energy Information Administration. "Basics"; *Energy Use for Transportation,* 17 May 2017. Web. 23 July 2017. http://www.eia.gov/Energyexplained/?page=us_energy_transportation#tab1 (1 page)

U.S. Energy Information Administration. "In Depth"; *Energy Use for Transportation,* 28 June 2017. Web. 23 July 2017. http://www.eia.gov/Energyexplained/?page=us_energy_transportation#tab2 (1 page)

Wilson Sonsini Goodrich & Rosati. *Project Finance Primer for Renewable Energy and Clean Tech Projects,* August 2010. Web. 4 August 2016. https://www.wsgr.com/PDFSearch/ctp_guide.pdf (17 pages)

Optional:

Brighthub.com. "Time Value of Money: Explaining With Examples," 27 July 2011. Web. 4 August 2016. http://www.brighthub.com/office/finance/articles/122127.aspx (1 page)

Brighthub.com. "Understanding Net Present Value as a Measure of Future Cash Flows," 30 December 2011. Web. 4 August 2016. http://www.brighthub.com/office/finance/articles/17646.aspx (1 page)

Brighthub.com. "Explaining Hurdle Rates: Calculations, Considerations and Pitfalls," 2 June 2011. Web. 4 August 2016. http://www.brighthub.com/office/finance/articles/118918.aspx (1 page)

Brighthubpm.com. "Understanding the Internal Rate of Return (IRR) Formula," 23 November 2010. Web. 4 August 2016. http://www.brighthubpm.com/project-planning/96515-understanding-the-internal-rate-of-return-irr-formula/ (1 page)

Lazard. *Lazard's Levelized Cost of Storage-Version 2.0.* December 2016. Web. 23 July 2017. https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf (46 pages)

NARUC. *Distributed Energy Resources Rate Design and Compensation*. November 2016. Web. 26 May 2017. https://www.naruc.org/rate-design/ (181 pages)

O'Sullivan, Dr. Francis M. and Charles H. Warren. *Solar Securitization: An Innovation in Renewable Energy Finance*. MIT Energy Initiative, July 2016. Web. 4 August 2016. http://energy.mit.edu/publication/solar-securitization-innovation-renewable-energy-finance/ (38 pages)

Wilson Sonsini Goodrich & Rosati. *Innovations and Opportunities in Energy Efficiency Finance,* May 2014. Web. 4 August 2016. https://www.wsgr.com/publications/PDFSearch/WSGR-EE-Finance-White-Paper-14.pdf (32 pages)

Resources

The readings have been carefully chosen to provide up-to-date resources on the topics covered in this course. For additional materials, or for academic support more generally, students may wish to consider the resources listed below.

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: http://library.columbia.edu/.

SPS Academic Resources
The Office of Student Life and Alumni Relations (SLAR) provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

Course Requirements (Assignments)

I. Statement of purpose (5%)
Provide a one-page (double-spaced) statement of purpose on what you are looking to get out of the class. Please highlight any particular skills you can contribute to the class or to your group. Please also identify one or more clean energy technologies, currently being deployed, in which you have a particular interest (this may help you identify a topic for the group presentation and fellow group members). Please include your name and UNI on your submission.

II. Five problem sets/case studies assigned during the semester (65%)
Assignment 1 (10%): Will involve the creation of a basic financial model. **Please pay attention to the financial modeling "best practices" discussed at the end of the lecture on key financing concepts (Class 4)**. The model will focus on basic financial concepts, and good modeling techniques. Students will be required to provide a soft copy of the Excel spreadsheet and print out the model (two pages) in a manner that is legible, labeled appropriately and formatted neatly.

Assignment 2 (10%): Will involve the creation of another financial model, this time used to calculate the levelized cost of energy for a specific technology(ies). This model will take the basic financial concepts and good modeling techniques practiced in Assignment 1, and apply them to specific clean energy applications.

Assignment 3 (15%): Will involve the creation of a financial model for a clean energy project. This model will involve the application of more concepts based on the discussion of project finance. The model will focus on more complex model design, and will also build on the skills practiced in Assignments 1 and 2.

Assignment 4 (15%): Will be a set of quantitative and qualitative short answer questions. These questions will discuss the basic elements of: U.S. electricity markets, clean energy technologies, integration of clean energy into the grid and financial techniques for bringing clean energy to market.

Assignment 5 (15%): Will involve an analytical case study (which may include a financial model) of one aspect of the transition to clean energy. Students will be expected to identify both the opportunities and the challenges, and what if any financing mechanisms might accelerate deployment of the technology.

III. Group Presentation (25%)
Will be a group presentation summarizing the key aspects of a particular clean energy technology or project. The deliverable will be the in-class presentation, plus the associated PowerPoint slides. The targeted group size and length of presentation will depend, in part, upon final enrollment in the class, but would likely be groups of 4-5 students and presentations 15-20 minutes in length. The majority of the grade (20%) will be based upon professor/CGA evaluation of the assignment, and 5% based upon peer evaluations provided by fellow group members who will evaluate your relative contribution.

IV. Class Participation (5%)
Attendance alone does not count towards your participation grade. Contributing to class discussions means enhancing the quality of the class experience for yourself and others. It involves making relevant, useful and non-obvious comments, or posing pertinent questions, in clear and succinct language.

Evaluation/Grading

The final grade will be based on your performance on the statement of purpose (5%), 5 problem sets/case studies assigned during the semester (65%), final group presentation to the class (25%), and class participation (5%).

The final score will comprise the following:
Statement of Purpose = 5%
Assignment #1 = 10%
Assignment #2 = 10%
Assignment #3 = 15%
Assignment #4 = 15%
Assignment #5 = 15%
Group Presentation = 25%
Class Participation = 5%

The following clarifies how points awarded for course requirements will be translated into letter grades for the course:
A+ is for extraordinary work, above and beyond; A = 93-100; A- = 90-92; B+ = 87-89; B = 84-86; B- = 80-83; C+ = 77-79; C = 74-76; C- = 70-73; D = 65-69; F = below 65

Course Policies

Participation and Attendance

You are expected to do all assigned readings, attend all class sessions, participate in class, and engage actively and cooperatively with others in completing the final group presentation. In particular, please be especially attentive to guest speakers, and develop appropriate questions in advance. 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 the instructor in advance.

Late work
There will be no credit granted to any written assignment that is not submitted on the due date noted in the course syllabus without advance notice and permission from the instructor. Assignments submitted late with permission from the instructor will normally be marked down one letter grade absent extenuating circumstances.

Citation & Submission
Written assignments must cite sources (use any acceptable citation style e.g., APA, Chicago, MLA), and be submitted to the course website (not via email). For certain assignments (if so indicated), students may also be required to submit printed hard copy.

Course Schedule/Course Calendar

Session Date	Topics and Activities	Readings (due this day); required unless otherwise indicated	Assignments (due on this date)
One 9/11	**History of the Energy Industry and the Importance of Finance** Topics: *Introductions *Goals/ Context *Course Key Themes/ Goals *Class Deliverables *Brief History of Energy Industry *Importance of Finance Activities: *Introductions *Course Overview *Lecture *Discussion	n/a	--
Two 9/18	**Energy Fundamentals and Electricity Markets in 2017** Topics: *Forms of Electricity Production *Basic Terminology *Production Efficiency *LCOE *Variable Costs *Fixed Costs *Electricity Prices Activities: *Recap of Prior Lecture *Lecture *Discussion	Federal Energy Regulatory Commission. Energy Primer: a Handbook of Energy Market Basics November 2015; pp. 1-4, 35-56. (26 pages) U.S. Energy Information Administration. "Basics"; Electricity Explained: Electricity in the United States, 10 May 2017. (1 page) U.S. Energy Information Administration. "Generation, Sales & Capacity"; Electricity Explained: Electricity in the United States, 10 May 2017. (1 page)	--
Three 9/25	**Clean Energy and Grid Integration** Topics:	American Wind Energy Association. "Wind Energy Facts at a Glance", 23 July 2017. (1 page)	Statement of purpose due 9/25

	*Grid context of clean energy technologies *Major energy "products" *Role of renewable generation *Net metering and load-based resources *Role of storage and EVs in grid integration Activities: *Recap of Prior Lecture *Lecture *Discussion	California ISO. "What the duck curve tells us about managing a green grid", 2016. (4 pages) Fitzgerald, Garrett et al. The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Executive Summary. Rocky Mountain Institute, September 2015, pp. 1-8. (8 pages) Solar Energy Industries Association. "Solar Market Insight Report 2017 Q2". [summary]. 2017. (21 pages)	
Four 10/2	**Overview of Key Financing Concepts** Topics: *Basic financial concepts *Capital structure (debt vs. equity) *Importance of market conditions *Different types of financing *Tax aspects of financing *Project finance *Basics of financial modeling Activities: *Recap of Prior Lecture *Lecture *Discussion *Class Exercise	Lazard. Lazard's Levelized Cost of Energy Analysis-Version 10.0. December 2016. (22 pages) NC Clean Energy Technology Center. "Commercial Guide to the Federal Investment Tax Credit for Solar PV", December 2015. (6 pages) Optional: Lazard. Lazard's Levelized Cost of Storage-Version 2.0. December 2016. (46 pages) For those without previous finance knowledge, it may be useful to read about certain key concepts e.g., the time value of money, NPV, hurdle rates (cost of capital), and IRR. Brighthub.com has some good online articles including: Brighthub.com. "Time Value of Money: Explaining With Examples," 27 July 2011. (1 page) Brighthub.com. "Understanding Net Present Value as a Measure of Future Cash Flows," 30 December 2011. (1 page) Brighthub.com. "Explaining Hurdle Rates: Calculations, Considerations and Pitfalls," 2 June 2011. (1 page) Brighthubpm.com. "Understanding the Internal Rate of Return (IRR) Formula," 23 November 2010. (1 page)	

Five 10/9	**Financial Modeling for Energy Projects** Topics: *How to do a financial model of an energy project *How to determine a levelized cost of energy (LCOE) *The overall structure of project finance transactions Activities: *Recap of Prior Lecture *Lecture *Discussion *Group Formation	Wilson Sonsini Goodrich & Rosati. *Project Finance Primer for Renewable Energy and Clean Tech Projects,* August 2010. (17 pages)	Assignment #1: Basic financial model
Six 10/16	**Financial Modeling – Other Clean Energy Measures** Topics: *Other examples of how to model clean energy *How to model financial transactions *Four different examples of financing clean energy assets Activities: *Recap of Prior Lecture *Lecture *Discussion *Group Meeting Time	Clean Energy States Alliance. A Homeowner's Guide to Solar Finance: Leases, Loans, and PPAs, May 2015, pp. 1-17. (17 pages)	Assignment #2: Levelized cost of energy model
Seven 10/23	**Challenges of Green Energy** Topics: *Applicability of project finance in developing renewables *Ways in which early-stage companies/ technologies are financed *Financing of mature/ late-stage companies Activities: *Recap of Prior Lecture *Lecture *Discussion *Guest Speaker	n/a	
Eight 10/30	**Rate Design and the Financing of Distributed Energy Resources** Topics: *Basics of setting rates for electricity *Complexities of rate design *Distributed energy resources (DERs) *Rate design issues that are relevant to DER economics and possible future rate design approaches	Hansen, Lena, Virginia Lacy and Devi Glick. *A Review of Solar PV Benefit & Cost Studies, 2nd Edition.* Rocky Mountain Institute, September 2013, pp. 1-19. (19 pages) Lazar, Jim. "Teaching the "Duck" to Fly, Second Edition." The Regulatory Assistance Project, February 2016, pp. 5-9. (5 pages)	Assignment #3: Financial model for a clean energy project

	Activities: *Recap of Prior Lecture *Lecture *Discussion	Optional (as a reference guide): NARUC. *Distributed Energy Resources Rate Design and Compensation*. November 2016. Web. 26 May 2017.	
Nine 11/13	**Financing Mechanisms for Clean Energy** Topics: *Framework for financing *Mechanisms to remove barriers Activities: *Recap of Prior Lecture *Lecture *Discussion	Optional: O'Sullivan, Dr. Francis M. and Charles H. Warren. *Solar Securitization: An Innovation in Renewable Energy Finance*. MIT Energy Initiative, July 2016. (38 pages)	Assignment #4: Quantitative and qualitative short answer questions
Ten 11/20	**Building Energy Efficiency** Topics: *Importance of buildings in aggregate energy use and some of the various factors driving energy use *Differences between new buildings and existing buildings *Additional benefits of building energy efficiency and the general process *Case studies of building energy efficiency Activities: *Recap of Prior Lecture *Lecture *Discussion *Guest Speaker	Jones Lang LaSalle et al. *Empire State Building Case Study.* 2009. (80 slides) Optional: Wilson Sonsini Goodrich & Rosati. *Innovations and Opportunities in Energy Efficiency Finance,* May 2014. (32 pages)	Assignment #5: Analytical case study
Eleven 11/27	**Electric Vehicles and the Grid** Topics: * Importance of transportation in general, and automobiles in particular, as a source of emissions (and use of energy) *Different alternatives to traditional automobiles, using different fuel sources *EV opportunities and challenges Activities: *Recap of Prior Lecture *Lecture *Discussion *Guest Speaker	Fitzgerald, Garrett, Chris Nelder and James Newcomb. Electric Vehicles as Distributed Energy Resources. Rocky Mountain Institute, June 2016, pp. 5-9. (5 pages) U.S. Energy Information Administration. "Basics"; Energy Use for Transportation, 17 May 2017. (1 page) U.S. Energy Information Administration. "In Depth"; Energy Use for Transportation, 28 June 2017. (1 page)	
Twelve 12/4	**GROUP PRESENTATIONS DAY 1** Activities: *Group Presentations/Q&A	n/a	Group Presentation: first set of teams*

Thirteen 12/11	**GROUP PRESENTATIONS DAY 2** Activities: *Group Presentations/Q&A	n/a	Group Presentation: second set of teams*

* Group presentation order based first on team preferences, then random selection where necessary to finalize order.

School Policies

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 http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-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.

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: http://health.columbia.edu/services/ods/support.