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

SUMA K5650 Solar Project Development
Scheduled Meeting Times and Location: Wednesdays 6:10pm – 8:00pm, Location TBA
Number of credits: 3

Instructor:	Dan Giuffrida djg2149@columbia.edu/daniel.giuffrida@gmail.com
Office Hours:	2 hours proceeding class time and by appointment
Response Policy:	Please come to office hours or send me an email with questions or to set up an appointment. I will respond within 12 hours with an answer and/or a doodle to set up a meeting time.

Course Overview

At the end of this course, students will be prepared to fully evaluate the technical and financial aspects of a solar project. They will be equipped with skills allowing them to either develop or rigorously vet solar project proposals.

The course introduces and provides students with a holistic understanding of the end-to-end solar development process. The course has two goals:

A) To provide students a deep understanding of the dozens of critical interrelated steps critical to developing a successful operating solar project.

B) To equip the students with the tools and understanding of the skills necessary to develop a solar project beginning with site selection encompassing the entire process to commissioning and operations.

We begin the course providing the students with an understanding of the different segments of the solar industry; covering the upstream business, the main players both upstream and downstream and then outlining the different downstream markets: utility, commercial, and residential. We will then hone in on the distributed generation segment of the market; commercial, and residential. To begin, we will cover the critical value drivers of solar: sunlight resource, grid energy cost, tax credits, state and utility incentives including renewable energy credit markets. Energy consumption and production, despite what critics will say about renewables, is the main value driver of the move to renewables. In that light, we will cover in detail, net metering, national and local electricity markets, and electric utility tariff structure to understand how value is generated and measured. We will conduct energy consumption analysis for different end-users to see how solar can and will be deployed and valued across different geographic and utility tariff classes.

We will focus on site selection, delving deep into how site characteristics affect system design and ultimately energy production; building azimuth, roof age, RTU locations and parapet walls, roof tilts and materials. We will utilize satellite imagery software to identify viable solar locations as well as utilizing automated solar design software (Helioscope) to design systems. We will cover how to use energy production modeling software, PV Watts and PV Syst, which accurately predicts energy production based on dozens of parameters.

In addition to energy, incentives still play a key role in driving value for solar projects. We will cover state incentive markets, focusing on their design, how they drive value and how and when they de-risk projects for investors and owners. We will also cover federal tax incentives.

We will cover interconnection requirements to be a grid-tied power facility. In addition, we will cover required authorities having jurisdiction and when and how a solar development project must meet their requirements.

Financial valuation and modeling will be a heavy part of this course. The course will cover how to build an income and cash flow statement for a solar project, concepts around valuing solar projects, as well as how investors structure and value solar projects. Students will build capabilities around solar project financial modeling. They will leave the course with the ability to build from scratch a viable solar financial model.

All course concepts will culminate with the creation of a term project in which students create a solar proposal. Students will select from a list of sites around the country. They will utilize resources learned in the course to conduct energy consumption and production analysis, design a system, create a proposed financial structure, outline the financial and environmental benefits for all stakeholders, and provide the financial model backing those benefits. The proposal will include any interconnection and incentive applications required to get their project "shovel ready."

This course satisfies the MS in Sustainability Management curriculum area requirements in Area 2 Economics/ and Area 5 General and Financial Management. This course is also approved for the Certification in Sustainable Finance.

Learning Objectives

It is imperative that sustainability managers can rigorously analyze solar and other distributed energy technology projects. A key aspect of careers in sustainability is energy procurement and management. To effectively do this, one must be able to vet and analyze how to procure green energy.

The course will provide skills to those who wish to pursue careers in corporate sustainability with the requisite understanding and toolset to evaluate solar opportunities and shape future green energy corporate strategy. Additionally, it will prepare students with ambitions of entering the solar industry in sales, origination, development, finance or project management. Students will learn and develop the following skills and objectives:

1) Demonstrate understanding of solar value drivers and how geographic, financial, regulatory and legislative changes will affect solar project valuations and more broadly accelerate or decelerate solar adoption.
2) Explain in clear and concise detail many foundational concepts in solar such as: net metering, variable and demand rates, insolation, power purchase agreement, partnership flip, ITC, kilowatt hour, internal rate of return, discount rate, net present value, solar renewable energy credit among others.
3) Explain in clear detail how geographic differences can explain varied financial return due to sunlight, seasonality, energy rates, electric rate structure, and incentive market design.
4) Explain why certain solar system financial ownership structures work better with different types of property ownership structures.
5) Explain how solar system value is split amongst stakeholders in different financial structures.
6) Develop skills to build a viable, bankable financial model after being give only a system's address.
7) Develop skills necessary to prepare a solar project for funding including: energy consumption analysis, system design, system energy production analysis, financial model creation, interconnection application preparation, and incentive capture.

Readings

There is no single textbook that covers this course. Readings will be selected from various textbooks, publications, journals, and other sources. All readings are listed below in the course schedule.

Resources

The readings will be provided via Canvas. Students will need to utilize the free PV Watts energy production tool. In addition, a free trial of the Helioscope software will be provided. Microsoft Excel will be required for all financial modeling exercises and for both exams and term project.

Course Requirements (Assignments)

Participation

Participation in all lectures and project activities is required. Contributions are expected to enhance the quality of the class experience for all students. All students will be asked to provide a short presentation on a current event in the Solar industry at the beginning of class once or twice throughout the semester. Students should be thorough in presenting key issues as well as providing insights and implications of the event at hand. Students are also expected to bring to class comments on and sources for current events that occurred during the prior week and are reasonably related to the course topic. Students should be prepared to discuss current events presented by other students. Additionally, students are expected to contribute to the Canvas discussion board.

Midterm exam

The Midterm exam in week 8 will consist of 15 short answer questions covering key terms and computational questions covering energy production utilizing the PV Watts tool. In addition, students will be asked to respond to 3 long form questions covering the calculations regarding the Investment tax credit, deprecation, energy consumption, and electric rate analysis.

Final Exam

Final exam will cover short answer questions on financial valuation topics. It will consist of 15 short answer questions covering financial valuation metrics, financial valuation calculations, and solar energy specific financial concepts. The majority of the exam will require students to construct a financial model from given parameters and answer questions about the model. The students will provided with the necessary solar energy and financial assumptions needed to construct a full financial cash flow model that allows students to conduct valuation on an example solar project.

Example midterm/final exam questions:

1) In New York City, which direction should solar panels be tilted? Why?

2) If a building in Los Angeles consumes 1,000,000 kWh of energy per year, what size solar system is appropriate to offset approximately 90% of this consumption? A) 6 MW B) 600 kW C) 60 kW
3) Why would a solar yieldco investment firm prefer to enter into a long-term contract to sell its SRECs?
4) What is a demand charge?
5) If a building is a night peaking facility with time-of-use pricing, can onsite solar work to reduce their energy usage? Please explain. If no, what technology could be deployed?
6) What are the benefits to a solar system owner of string inverters versus central inverters?

Term Project

Students will be put into groups of 2-3 and will create a solar proposal for a preselected location. The students will chose a location in the US and create a solar proposal. The proposal will require students to create a solar system design, justification for solar system sizing based on electric consumption and rate analysis. They will be required to create a solar system production projection model to approximate system energy production. They will be required to create a cash flow financial model. Based on their understanding of the occupant of the building and their financial position, they will propose a financial structure that best fits the building occupant and defend their approach. In their proposal, they will provide completed interconnection and incentive application specific to their solar system.

Evaluation/Grading

The final course grade will be computed using a weighted index of numeric grades that combine performance under attendance and participation, midterm exam, final exam, and term project. The weighted index will be scaled into a letter grade scale from F to A+ based on an expectation that a class representative of the population of Columbia masters students will receive a median grade of B+ or A-.

Class Participation: 5%

Participation will be evaluated based on the quality of the students' contributions in class discussions each week and/or posting relevant comments/questions to the Canvas discussion board regarding course readings and case studies. In addition, students will be required to present 1-2 times per semester a short presentation of current events and issues in the solar industry.

Midterm Exam: 25%

The midterm exam will be evaluated based on the correctness of several short answer questions covering key terminology and key concepts covered to this point. In addition, several long answer questions will require both computational and written a responses. The midterm will be graded on a scale of 0-100.

Final Exam: 30%

The final exam will be evaluated based on the correctness of several short answer questions covering key terminology and key concepts covered throughout the semester. Students will spend a majority of the exam period constructing a financial model to calculate income, cash flow, and investment returns of a solar project. To construct the model requires students to show aptitude and understanding of several concepts which must be thoroughly understood to translate into a correct and viable excel financial model.

Term Project: 40%

The project will be evaluated based on the accuracy of calculations and financial models. They will also be evaluated based on the reasoning and support they provide as justification for their approach to how they arrive at their proposed solar solution. In addition, the professionalism, clarity of information presentation, and clarity of the overall written proposal will be evaluated. Each member of the group will receive the same grade.

Course Policies

Attendance

Regular attendance in lectures is required. Students are expected to have done the readings for each session prior to the lecture.

Participation

Participation in all lectures and project activities is required. We expect your contributions to enhance the quality of the class experience for yourself and others. This involves making relevant, useful and non-obvious comments, or posing pertinent questions, in clear and succinct language. During the lectures, come prepared to answer impromptu questions about the readings and course assignments.

Late work
All assignments must be submitted on the published due dates. In the absence of well-documented extenuating circumstances, I will deduct 10 points from the assignment grade score for each day that you are late in submission.

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

Course Schedule/Course Calendar

Date	Topics and Activities	Readings (due on this day)	Assignments (due on this date)
Week 1:	Introduction to Solar: Understanding the industry Verticals	1) Historical Summary of Installed price of Photovoltaics[i] (*70 pages, from leading renewable energy research laboratory at University of California Berkeley*) 2) SEIA – 2015 Solar Market Insight report[ii] (*60 pages; report from US solar trade association*) Total Pages: **130 pages**	
Week 2:	Solar Project Value Drivers	1) National Renewable Energy Laboratory – Photovoltaic System Pricing Trends[iii] (*31 pages; author: U.S. Department of Energy renewable energy research arm)* 2) National Renewable Energy Laboratory – 2014 Renewable Energy Databook[iv] *(114 Pages; author: U.S. Department of Energy renewable energy research arm)* 3) Solar Energy Engineering, Chp. 2[v] (*Pg. 58-122; graduate level solar engineering text)* 4) Let it Shine, Chp. 24-29. Perlin & Lovins[vi] (*98 pages; authored by UCSB physics professor and co-founder of Rocky Mountain Institute)* Total Pages: **307 pages**	
Week 3:	Energy Consumption, Production & Rates	1) Electricity Markets and Power System Economics, Chp. 1 & 2 (*pp. 1-51; Graduate text by University of Hong Kong professor*)[vii] 2) Solar Energy Engineering, Chp. 9[viii] (*Pg. 481 – 538; graduate level engineering text*) 3) California ISO – Locational Marginal Pricing[ix] (*80 pages; California power market independent system operator*) 4) National Renewable Energy Laboratory – "Solar Power and the Electric Grid"[x] (*4 pages; U.S. Department of Energy renewable energy research arm*) Total Pages: **192 pages**	
Week 4:	Site Selection, System Design & Production Modeling	1) Photovoltaic Systems Engineering, Chp. 21-46 (*pp. 103-161; graduate text on PV system design by professor emeritus at Florida Atlantic University*)[xi] 2) Solar Energy Engineering, Chp 11[xii] (*Pg. 583 – 695; graduate level engineering text*) 3) Rocky Mountain Institute – "Simple BoS – Reducing Solar PV soft costs"[xiii] (*61 pages*	1) Familiarize self with PV Watts: http://pvwatts.nrel.gov/ 2) Familiarize self with Helioscope.

		from leading renewable energy research think-tank) Total Pages: **199 pages**	
Week 5:	Incentive Markets	1) National Renewable Energy Laboratory – "Solar Renewable Energy Certificate Markets: Status & Trends"[xiv] (*48 pages; author: U.S. Department of Energy renewable energy research arm*) 2) Rocky Mountain Institute - "Net Energy Metering, Zero Net Energy, and The Distributed Energy Resource Future"[xv] (*49 pages; author: leading renewable energy research think-tank*) 3) Chapter 7, pg. 85-95 Project Development in the Solar Industry[xvi] (*Director, Solar Frontier America, Inc.)* Total Pages: **107 pages**	
Week 6:	Tax! The ITC & MACRs	1) National Renewable Energy Laboratory – "Implications of the Scheduled Federal Investment Tax Credit Reversion for Renewable Portfolio Standard Solar Carve-Out Compliance"[xvii] (*47 pages; U.S. Department of Energy renewable energy research arm*) 2) Title 26 – Internal Revenue Code 48[xviii] (*16 pages; Internal Revenue Service*) 3) Corporate Finance, Ivo Welch, chapter 17 (pp 545-593)[xix] (*48 pages; MBA corporate Finance text by UCLA finance professor*) Total Pages: **111 pages**	1) Submit draft of Term Project. Must include site, energy consumption and production analysis, preliminary system sizing, and electric rate analysis.
Week 7:	Midterm Exam	STUDY for Exam	Midterm Exam
Week 8:	Interconnection, permitting and other AHJs	1) National Renewable Energy Laboratory – SAPC Best Practices in PV System Installation (*36 pages; U.S. Department of Energy Renewable Energy research arm*)[xx] 2) Photovoltaic Systems Engineering, Chp. 4 (*pp. 103-161; graduate text on PV system design by professor emeritus at Florida Atlantic University*)[xxi] 3) Chapter 3, pg. 23-36 Project Development in the Solar Industry (*Director, Solar Frontier America, Inc.)* Total Pages: **97 pages**	
Week 9:	Project Financial Modeling	1) Corporate Finance, Ivo Welch, chapters 1, 2 (pp 1-41), 13, 14 (pp. 387-481)[xxii] (*135 pages; MBA corporate Finance text by UCLA finance professor*) Total Pages: **135 pages**	
Week 10:	Project Valuation	1) Damodaran on Valuation, pages 1-66[xxiii] (*66 pages, MBA finance text by NYU business school distinguished professor*) 2) Corporate Finance, Ivo Welch, chapters 5 & 6	Complete 30 year revenue model projection

		(pp. 85-157)[xxiv] (*72 pages; MBA corporate Finance text by UCLA MBA finance professor*) Total pages: **138 pages**	
Week 11:	Financial Structures	1) Corporate Finance, Ivo Welch, chapter 16 & 18 (pp. 511-545, 593-639)[xxv] (*48 pages; MBA corporate Finance text by UCLA Business School finance professor*) 2) "Tax Equity 101"[xxvi] (*12 pages; Financial advisory firm Woodlawn Associates*) 3) "Taking Mystery out of Partnership Flip"[xxvii] (*2 pages; leading project finance law firm Akin Grump Strauss)* 4) "SEIA – Solar PPA Fact Sheet"[xxviii] (*5 pages; Solar Energy trade Association)* Total Pages: **99 pages**	Complete 30-year income statement and cash flow model
Week 12:	Investor Financial Modeling	1) National Renewable Energy Laboratory Solar Power Purchase Agreement (*33 pages; U.S. Department of Energy Renewable Energy research arm*) 2) National Renewable Energy Laboratory – 0% down Residential Lease Agreement (*21 pages; U.S. Department of Energy Renewable Energy research arm*) 3) Financial Modeling, Chp. 3 (*pp. 103 – 135; graduate finance text by MBA professor at Tel Aviv University*)[xxix] Total Pages: **86 pages**	Integrate Equity and tax equity sources & uses into financial model
Week 13:	Construction, Commissioning & O&M		1) Study for Exam 2) Prepare Term project
Week 14:	Final Exam	STUDY	Final Exam & Term Project

School Policies

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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.

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[i] Barbose, G.; Darghouth, N.; Weaver, S.; Wiser,R. (2014). *Tracking the Sun VII: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013*. Berkeley, CA: Lawrence Berkeley National Laboratory.
[ii] Solar Energy Industries Associate. *US Solar Market Insight Report – 2014 Year-in-Review*. 2014.
[iii] Feldman, David; Galen Barbose. (2014) *Photovoltaic System Pricing Trends.* Golden, CO. National Renewable Energy Laboratory.
[iv] Beiter, Philipp; Karin Haas, et al. *2014 Renewable energy Data Book*. U.S. Department of Energy.
[v] Kalogirou, Soteris A. Solar Energy Engineering, 2nd Edition. Academic Press, Waltham, MA. 2014.
[vi] Lovins, Amory, John Perlin. Let it Shine. Pg. 341-430. New World Library, California. 2013.
[vii] Gan, Deqiang, Donghan Feng, Jun Xie. Electricity Markets and Power System Economics. CRC Press, Boca Raton, FL; 2014.
[viii] Kalogirou, Soteris A. Solar Energy Engineering, 2nd Edition. Academic Press, Waltham, MA. 2014.
[ix] Treinen, R. *Locational Marginal Pricing (LMP): Basics of Nodal Price Calculation*. California ISO.
[x] Turchi, Craig. *Solar Power and the Electric Grid.* National Renewable Energy Laboratory.
[xi] Messenger, Roger A. Jerry Ventre. Photovoltaic Systems Engineering. 3rd edition. CRC Press. Boca Raton, FL 2010.
[xii] Kalogirou, Soteris A. Solar Energy Engineering, 2nd Edition. Academic Press, Waltham, MA. 2014.
[xiii] Morris, Jesse; Koben Calhoun; Joseph Goodman; Daniel Seif. *Reducing Solar PV Soft Costs – A Focus on Installation Labor*. December 2013. Boulder, CO. Rocky Mountain Institute.
[xiv] Bird, Lori; Jenny Heeter; Claire Kreycik. *Solar Renewable Energy Certificate (SREC) Markets: Status and Trends.* 2011. Golden, CO. National Renewable Energy Laboratory.
[xv] Rocky Mountain Institute. *Net Energy Metering, Zero Net Energy and the Distributed Energy Resource Future.* 2012. Snowmass, CO. Rocky Mountain Institute.
[xvi] Fong, Albert; Jesse Tippett. Project Development in the Solar Industry. December 2012. CRC Press.
[xvii] Heeter, Jenny; Travis Lowder; Eric O'Shaughnessy; John Miller. *Implications of the Scheduled Federal Investment Tax Credit Reversion for Renewable Portfolio Standard Solar Carve-out Compliance.* 2015. Golden, CO. National Renewable Energy Laboratory.
[xviii] Internal Revenue Service. Internal Revenue Code, Title 26, Code 48.
[xix] Welch, Ivo. Corporate Finance: 3rd Edition. 2014. Ivo Welch.
[xx] Doyle, C, A. Truitt, D. Inda, R. Lawrence, R. Lockhart, M. Golden. *SAPC Best Practices in PV System Installation, 2015*. Golden, CO. National Renewable Energy Laboratory.
[xxi] Messenger, Roger A. Jerry Ventre. Photovoltaic Systems Engineering. 3rd edition. CRC Press. Boca Raton, FL 2010.
[xxii] Welch, Ivo. Corporate Finance: 3rd Edition. 2014. Ivo Welch.
[xxiii] Damodaran, Aswath. Damodaran on Valuation. 2nd Edition. Pp 1-66. 2006. Wiley.
[xxiv] Welch, Ivo. Corporate Finance: 3rd Edition. 2014. Ivo Welch.
[xxv] Welch, Ivo. Corporate Finance: 3rd Edition. 2014. Ivo Welch.
[xxvi] Lutton, Josh. "Tax Equity Structures 101." Woodlawn Associates. 2013.
[xxvii] Burton, David, Joe Sebik. "Taking Some Mystery Out of the Alternative Energy Flip Partnership Structures." Equipment Leasing & Financing Magazine. May/June 2013.
[xxviii] "Solar Power Purchase Agreements." Solar Energy Industries Association." December 2012.
[xxix] Benninga, Simon. Financial Modeling, 3rd edition. MIT Press, Cambridge, MA 2008.