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San José State University, Department of Environmental Studies

Solar Energy Analysis—ENVS 116—Fall 2015

Instructor: Dustin Mulvaney, Ph.D., Environmental Studies Department, San José State University

Office hours/location: Thursday 2:30–4:15 PM or by appointment, 111C Washington Hall

Office hours sign-up: http://www.sjsu.edu/envs/advising/ or **email:** dustin.mulvaney@sjsu.edu

Class meeting days / time / room: Tues-Thurs / 9:00–10:15 AM, Incubator Classroom, Clark 111

Prerequisites: ENVS 119, CHEM 001A, PHYS 002A (or equivalent)

Faculty Web Page and MYSJSU Messaging

You are responsible for regularly checking with the messaging system through MySJSU. Course materials such as the syllabus, assignments, readings, and handouts will be found on canvas: https://sjsu.instructure.com

Course Description

This course will provide students with a comprehensive overview of **sustainable solar energy resources, economics, and policy**. Part one of the course will review the basic knowledge about solar energy physics needed to understand how solar energy technologies work, the biophysical and resource limitations, and sustainable deployment strategies for a solar powered civilization. Part two focuses on the key economic and policy concepts for solar deployment. Part three looks at ecological and environmental justice considerations for sustainable solar energy deployment, while part 4 looks at the potential opportunities and challenges for distributed solar power generation.

Course Goals and Student Learning Objectives

At the end of this course, students should be able to:

- Understand the opportunities and challenges for sustainable solar energy development.
- Understand the principles and fundamentals of solar energy physics.
- Understand and assess the natural resource limitations of solar energy including land and raw materials.
- Describe basic economic and policy principles to solar energy deployment strategies.
- Assess current sustainability trends in the solar energy industry.

Required Readings are reports, research articles, manuscripts, and book chapters in pdf and are found on the canvas site: https://sjsu.instructure.com Readings are to be done before the class meeting time where they listed in the green sheet.

Library Liaison: Peggy Cabrera, peggy.cabrera@sjsu.edu

Classroom Protocol

You are expected to come to every class on time as class will begin promptly. Classroom participation will be reflected in your final grade. No cell phone, emailing, or text messaging during class, and please silence—*or better yet*—turn off your cell phones. If you need to make a phone call or send an email, please excuse yourself from class.

Dropping and Adding

Students are responsible for understanding the policies and procedures about add/drop, grade forgiveness, etc. Refer to the current semester's Catalog Policies section. Add/drop deadlines can be found on the current academic calendar and you should refer to the Late Drop Policy**.** Students should be aware of the current deadlines and penalties for dropping classes. Information about the latest changes and news is available at the Advising Hub.

Course Requirements & Assignments:

SJSU classes are designed such that in order to be successful, it is expected that students will spend a minimum of forty-five hours for each unit of credit (normally three hours per unit per week), including preparing for class, participating in course activities, completing assignments, and so on. More details about student workload can be found in University Policy S12-3 at http://www.sjsu.edu/senate/docs/S12-3.pdf

10% **Participation**. Share your thoughts about the readings, ask thoughtful questions, answer discussion prompts. Keeping good notes about the main points or views taken by authors is a good means a facilitating a sustained discussion. You will also be asked to work in small groups now and then in class, and you will be expected to be a contributing member to your group. Prepare for class and keep a **notebook**. You can use the one you may have started in ENVS 119. Come to class having completed the readings and note something important in your notebooks. Students will be called upon in class, and marked for preparations. Keep an organized notebook and maintain short annotations on the readings. You should have this in all of your information in one place when you come to class. Make sure to bring the assigned readings each class. You will you write a short summary of every article and keep notes on conversions, statistics, and other information on energy. If you take notes in the margins of your readings make sure to transfer important ones to your notebook. These notebooks may be evaluated to gauge your engagement with the readings and lectures.

30% **Assignments**: There will be five assignments that must be completed.

20% **Midterm:** The midterm and the final exams will be open notebook. The tests will include short answer, multiple choice, problem sets, and essay questions. However, you will not have access to any electronic devices (other than a calculator). You must bring a calculator to the examinations. To study for the tests, you should review the readings, course lecture notes, homework, and learning objectives well in advance of the test date. The midterm will include material covered during the first portion of the class. We will include both multiple choice and problems related to the scientific principles of energy, heat, and work. You are encouraged to review the problems sets before the midterm.

20% **Final Research Project & Presentation:** Students will develop a group research project related to solar energy technologies. More details on this assignment will be available on the course website.

20% **Comprehensive Final Exam:** There will be a comprehensive final exam.

Course Grading

The course grade will be determined based on a total 100 possible points. Accumulated points that fall within the grade scale below determine your semester grade.

A+ 97–100	A 92–96	A- 89–91	B+ 86–88	B 81–85	B- 79–80	C+ 76–78
C 72–76	C- 69–71	D+ 67–68	D 64–66	D- 60–64	F < 60	

University policy on academic integrity

Your commitment as a student to learning is evidenced by your enrollment at San Jose State University. The University's Academic Integrity policy requires you to be honest in all your academic course work. Faculty members are required to report all infractions to the office of Student Conduct and Ethical Development website.

Instances of academic dishonesty will not be tolerated. Cheating on exams or plagiarism (presenting the work of another as your own, or the use of another person's ideas without giving proper credit) will result in a failing grade and sanctions by the University. For this class, all assignments are to be completed by the individual student unless otherwise specified. If you would like to include your assignment or any material you have submitted, or plan to submit for another class, please note that SJSU's Academic Policy S07-2 requires approval of instructors.

Campus policy in compliance with the American Disabilities Act

If you need course adaptations or accommodations because of a disability, or if you need to make special arrangements in case the building must be evacuated, please make an appointment with me as soon as possible, or see me during office hours. Presidential Directive 97-03 requires that students with disabilities requesting accommodations must register with the Accessible Education Center to establish a record of their disability.

Other Campus Resources

- **Computer labs** for student use are available in the **Academic Success Center** located on the 1st floor of Clark Hall and on the 2nd floor of the Student Union. Additional computer labs may be available in your department/college. Computers are also available in the Martin Luther King Library. A wide variety of audio-visual equipment is available for student checkout from Media Services located in IRC 112.
- The **Learning Assistance Resource Center (LARC)** is located in Room 600 in the Student Services Center. It is designed to assist students in the development of their full academic potential and to inspire them to become independent learners. The Center's tutors are trained and nationally certified by the College Reading and Learning Association (CRLA). They provide content-based tutoring in many lower division courses (some upper division) as well as writing and study skills assistance. Small group, individual, and drop-in tutoring are available. Please visit the LARC website.
- The **SJSU Writing Center** is located in Room 126 in Clark Hall and is staffed by professional instructors and upper-division or graduate-level writing specialists from each of the seven SJSU colleges. Writing specialists have met a rigorous GPA requirement, and they are well trained to assist all students at all levels within all disciplines to become better writers. The Writing Center also has resource on their website.
- The **Peer Mentor Center** is located on the 1st floor of Clark Hall in the Academic Success Center. The Peer Mentor Center is staffed with Peer Mentors who excel in helping students manage university life, tackling problems that range from academic challenges to interpersonal struggles. On the road to graduation, Peer Mentors are navigators, offering "roadside assistance" to peers who feel a bit lost or simply need help mapping out the locations of campus resources. Peer Mentor services are free and available on a drop –in basis, no reservation required. The Peer Mentor Center website is located at http://www.sjsu.edu/muse/peermentor

The schedule and content is subject to change with fair notice.

Date	*Topic, keywords, concepts*	*Read before class*	*Assignments*
8/20	Course introduction and overview		
8/25	History of PV, Sustainability Science	Hawken, P. et al. 1999. The next industrial revolution. Natural Capitalism. Rocky Mountain Institute, Snowmass, CO. McDonough, W. and M. Braungart. 2002). "Eco-Effectiveness." Cradle to cradle: remaking the way we make things. New York, North Point Press.	
8/27	Solar Energy Physics I: Solar Radiation, Absorption and thermal utilization	Crabtree & Lewis. 2007. Solar energy conversion. http://authors.library.caltech.edu/7721/1/CRApt07.pdf Nelson, 2003, Ch 1	
9/1	Solar Energy Physics II: Solar thermal electricity, PV effect, bandgap, p-n junctions	Physics of Solar Cells, Chapter 21	Assignment #1 Due
9/3	Solar Energy Physics III: semiconductors, color and band gap	Sanderson 2008 "the Photon Trap" Nature 452: 400–2. http://www.nature.com/news/2008/080326/full/452400a.html	
9/8	PV economics I: LCOE, grid parity, break-even point,	Denholm, P., et al. 2009. Break-Even Cost for Residential PV in the US: Key Drivers and Sensitivities. NREL Technical Report.www.nrel.gov/docs/fy10osti/46909.pdf Branker, Pathak, & Pearce, 2011. A Review of Solar Photovoltaic Levelized Cost of Electricity, *Renewable and Sustainable Energy Reviews*, 15: 4470–82. http://dx.doi.org/10.1016/j.rser.2011.07.104	Assignment #2 Due
9/10	PV economics II: Discount rate, amortization	Timilsina, G. R., L. Kurdgelashvili, et al. 2012. "Solar energy: Markets, economics and policies." *Renewable and Sustainable Energy Reviews* 16(1): 449-65. http://dx.doi.org/10.1016/j.rser.2011.08.009	
9/15	PV Economic III: EPBT, EROI,	Borenstein, S. 2012. "The Private and Public Economics of Renewable Electricity Generation", *Journal of Economic Perspectives* 26 Winter.	
9/17	PV and public policy I: FIT, net metering, pigouvian taxes	Poullikkas et al. 2013. A review of net metering mechanism for electricity renewable energy sources. International Journal of Energy and Environment. 4(6): 975–1002. http://ijee.ieefoundation.org/vol4/issue6/IJEE_06_v4n6.pdf Jacobs, D. & B. Sovacool. 2012. Feed in Tariffs and Other Support Mechanisms for promotion. P. 74–79 & 83–106. Comprehensive Renewable Energy, Volume 1 doi:10.1016/B978-0-08-087872-0.00104-9	
9/22	PV policy II: TOU pricing, solar investment tax credit, PACE		Assignment #3 Due
9/24	Industrial and innovation policy	Deshmukh, R., R. Bharvirkar, et al. 2012. "Changing Sunshine: Analyzing the dynamics of solar electricity policies in the global context." *Renewable and Sustainable Energy Reviews* 16(7): 5188-98. http://dx.doi.org/10.1016/j.rser.2012.04.020 Buchanon, 2013. "Where the iPhone came from" *The Breakthrough Institute* June 21, 2013 http://thebreakthrough.org/index.php/programs/economic-growth/where-the-iphone-came-from Rodrik. 2013. The Right Green Industrial Policies. *Project Syndicate* Jul 11, 2013. http://www.project-syndicate.org/commentary/the-right-green-industrial-policies-by-dani-rodrik	
9/29	Solar Energy Policy in California	Taylor, M. 2008. "Beyond technology-push and demand-pull: Lessons from California's solar policy." *Energy Economics* 30(6): 2829–54. http://dx.doi.org/10.1016/j.eneco.2008.06.004 Hobbs et al. 2013. Improving Solar Policy: Lessons from the solar leasing boom in California. Climate Policy Initiative.http://climatepolicyinitiative.org/publication/improving-solar-policy-lessons-from-the-solar-leasing-boom-in-california/	

		NYT debate on California solar energy policy http://roomfordebate.blogs.nytimes.com/2010/04/21/californias-solar-scorecard	
10/1	Natural Resource Requirements for PV	Zweibel, K. (2010). "The Impact of Tellurium Supply on Cadmium Telluride PV." *Science* 328(5979): 699-701. *Optional*: Feltrin, A. and A. Freundlich 2008. "Material considerations for terawatt level deployment of PV." *Renewable Energy* 33(2): 180-185. Wadia, C., A. P. Alivisatos, et al. 2009. "Materials Availability Expands the Opportunity for Large-Scale Photovoltaics Deployment." *Environmental Science and Technology* 43(6): 2072-7. USGS National Minerals Information Center. 2011. "Tellurium." 1-2.	
10/6	PV recycling and cradle to cradle stewardship and design	Prior to class watch: "12 Sustainable Design Ideas from Nature." Janine Benyus. TED Talks. Feb 2005. 16 May 2009. 23 minutes. Larsen, K. 2009. End-of-life PV then what? *Renewable Energy Focus.*	Abstract & Research Plan for Final Group Project Due
10/8	ecological impacts, energy sprawl, Environmental impact assessment of solar farms	Lovich, J. E. and J. R. Ennen. 2011. "Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States." *BioScience* 61(12): 982–92.	
10/13	Public Acceptance of Solar Farms; Cultural and ecological resource impacts;	Devine-Wright. 2007. "Reconsidering public acceptance of renewable energy technologies: a critical review." in: Jamasb T., Grubb, M., Pollitt, M. (Eds), Delivering a Low Carbon Electricity System: Technologies, Economics and Policy, Cambridge University Press. Hunold, C. and S. Leitner (2011). "'Hasta la vista, baby!' The Solar Grand Plan, environmentalism, and social constructions of the Mojave Desert." *Environmental Politics* 20(5): 687-704.	Assignment #4 DUE
10/15	PV farms on agricultural lands, Williamson Act, direct and indirect land use change	Elkind, E. (2011). Harvesting Clean Energy. Berkeley, UC Berkeley School of Law's Center for Law, Energy & the Environment (CLEE).	
10/20	**MIDTERM**	All materials assigned prior to this date will appear on the midterm exam. Open notebook.	
10/22	Globalization of Solar Energy Commodity Chains, solar energy trade dispute, OEMs, SOEs	Bradsher, K. On Clean Energy, China Skirts Rules. *New York Times.* 9/8/2010. *Optional:* The Kearny Alliance. 2012. *China's Solar Industry and the U.S. Anti-Dumping/Anti-Subsidy Trade Case.* Coalition for US solar manufacturing http://www.americansolarmanufacturing.org Center for American Progress. 5 Myths and Realities About U.S.-China Solar Trade Competition. http://www.americanprogress.org/issues/2012/05/china_solar.html	
10/27	PV sustainability metrics, ecological footprints, Life Cycle Analyses: EPBT, EROI, GHGs, criteria pollutants, heavy metal emissions, Water & chemical use	Fthenakis, V., H. C. Kim, et al. 2008. "Emissions from Photovoltaic Life Cycles." Environmental Science & Technology 42(2): 2168-2174. Fthenakis, V. 2002. "Could CdTe PV Modules Pollute the Environment?" National Photovoltaic Environmental Health and Safety Assistance Center, Brookhaven National Laboratory, Upton/USA.	Assignment #5 DUE
10/29	Life Cycle Assessment, Continued.	Fthenakis & Kim. 2010. PV Life Cycle Analyses. Solar Energy. International Energy Agency. 2012. Life Cycle Inventories and Life Cycle Assessments of PV systems.	
11/3	Worker safety issues in PV manufacturing;	Mulvaney 2013 Opening the Black Box of Solar Energy Technologies: Tensions between Innovations and Environmental Justice. *Science As*	

	Environmental Justice, Supply chain sustainability, Corporate Social Responsibility	*Culture* 2(2): Biello, D. (2010). "Explosive Silicon Gas Casts Shadow on Solar Power Industry." *Scientific American* Retrieved April 4, 2010, from http://www.scientificamerican.com/article.cfm?id=explosive-gas-silane-used-to-make-photovoltaics. SolarWorld: GRI Reporting. http://www.solarworld.de/index.php?id=360&L=1 First Solar: Carbon Disclosure Project Report; http://www.firstsolar.com/Sustainability/Environmental SunPower: Sustainability Report http://us.sunpowercorp.com/about/sustainability/ SEIA:http://www.seia.org/policy/environment/sustainability/solar-industry-environment-social-responsibility-committment SVTC. Scorecard. Life Cycle of PV http://svtc.org/solarlifecycle/ www.solarscorecard.org	
11/15	Estimating DG PV resource potential	Denholm, P. and R. M. Margolis. 2008. "Land-use requirements and the per-capita solar footprint for photovoltaic generation in the United States." *Energy Policy* 36: 3531–43.	Annotated Bibliography for Final Group Project Due
11/10	DG & Storage	Toldeo et al. 2010. "Distributed photovoltaic generation and energy storage systems: A review" *Renewable and Sustainable Energy Reviews* 14: 506–11. http://dx.doi.org/10.1016/j.rser.2009.08.007	
11/17	PV and Distributed Power Generation (DG), Challenges in grid integration, policy considerations	Hondo, H. and K. Baba. 2010. "Socio-psychological impacts of the introduction of energy technologies: Change in environmental behavior of households with photovoltaic systems " Applied Energy 87: 229–35. Winner, L. 1986. Do Artifacts Have Politics? The whale and the reactor: a search for limits in an age of high technology. Chicago, University of Chicago Press, pages 19-39.	
11/24	Energy poverty challenges & solutions, meeting Millennium Development Goals with PV	Sovacool, B. 2012. "The political economy of energy poverty: A review of key challenges." *Energy for Sustainable Development* 16(3): 272–82. in press). http://dx.doi.org/10.1016/j.esd.2012.05.006 Guruswamy, L. 2011. "Energy Poverty." *Annual Review of Environment and Resources* 36: 139–61. http://www.annualreviews.org/doi/abs/10.1146/annurev-environ-040610-090118 Optional Adkins, E., S. Eapen, et al. 2010. "Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi." *Energy Policy* 38(2): 1087–97.	
12/1	Final Group Projects	Group A, B, C	Presentations
12/3	Final Group Projects	Group D, E, F	Presentations
12/8	Final Group Projects	Group G, H, I	Final project due
12/10	**FINAL EXAM 7:15am–9:30am**		