San José State University
Mechanical Engineering
ME 172 Alternative Energy Resources
Fall 2022

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Office Hours: Friday 8:30-9:30 AM

Class Days/Time: Friday 9:00 to 11:45 AM

Prerequisites: ME 114 or CHE/ME 109 or CHE 190 with a C- or better

Faculty Web Page and MYSJSU Messaging

Course materials such as syllabus, handouts, notes, assignment instructions, etc. can be found on Canvas Leaning Management System course login website at http://sjsu.instructure.com. You are responsible for regularly checking with the messaging system through MySJSU at http://my.sjsu.edu to learn of any updates.

Course Description

Essentials of Alternative Energy. Theory and Applications of Solar thermal, Photovoltaics, Biomass biogas and biofuels, Fuel cells, Wind, Geothermal Energy, Marine Energy and Electric Vehicles.

Course Goals

This course is focused on sustainable energy conversion and storage to prepare young engineers to the opportunities of the up-coming Energy Transition towards a Carbon Neutral Economy. The prospect of producing clean, sustainable power from renewable energy sources is fast raising interest worldwide. Driven by increasing concerns over the environmental impact and sustainability of traditional fossil fuels, and stimulated by recent technological developments, alternative energy sources have grown from marginal 10 years ago to commonly used today and most surely dominant in only few decades. The course aims to describe the different technological options and how to apply engineering tools to compare performance and identify possible improvements. The integration into the complex energy mix of developed and emerging countries is also

presented. The course covers a broad range of technologies to offer a comprehensive assessment: photovoltaics, electric vehicles, biomass, biogas, biofuels, hydrogen, fuel cells, thermal solar, wind, tidal, wave, geothermal energy, and Carbon Capture Utilization and Sequestration.

Course Learning Outcomes (CLO)

Students who complete all of the course assignments, including attending lectures, preparing homework problems, reading assignments, and completing student projects, should be able to…

Introduction to renewable energy

1. Compare energy consumption across different sectors in the US and internationally.
2. Compare available energy sources on earth.
3. Distinguish between force, energy, exergy, heat, and power.
4. Discuss factors causing global warming.
5. Understand global warming modeling including Radiative Forcing and Global Warming Potential.
6. Beyond CO2 and energy describe the climate impact of other Greenhouse Gases and sources.
7. Describe the evolution of regulations to address global warming.
8. Discuss the energy transition from fossil fuel to carbon free energy sources: how it transforms the energy sector and affects international trade and alliances.
9. Describe the levers of energy transition and the trends and the challenges related to them.

Solar Resource

10. Understand the nature of solar radiation.
11. Calculate declination, hour angle, and days of sunlight based on location.
12. Know irradiance standards used in solar cell testing.
13. Calculate the irradiance on a surface based on location, geometry of surface, time of day and season.
14. Know typical average insolation around the globe
15. Understand the concept of Capacity Factor
16. List factors that influence actual solar irradiance that are not accounted for in simple calculations.
17. Understand differences between trackers, concentrators, and fix panels.
18. Develop calculators of solar irradiance to apply to solar panels.

Photovoltaics

19. Understand the physics of photovoltaic effect
20. Utilize physics of a PN junction to explain the IV plot for a PV device.
21. Label open circuit voltage, short circuit current, maximum power, and fill factor.
22. Describe how the properties of the cell change in series and parallel.
23. Define n-type and p-type semiconductor.
24. Describe the drift and diffusion of carriers across a junction.
25. Explain built in voltage and analyze what happens to it under different biases.
26. Calculate minority carrier lifetime and diffusion length of carriers and relate their significance to PV performance.
27. Analyze fabrication steps in a basic single crystalline Si PV device based on their importance for device performance.
28. Explain limitations on conversion rate in PV devices including the Schokley-Queisser principle.
29. Describe how a PV cell is designed to minimize loss.
30. Distinguish between first, second, and third generation PV technologies.
31. Design a PV array for a specific application and evaluate the limitations based on cost, location, etc.
32. Design a solar panel system and calculate its annual electricity generation
33. Understand the concept of Balance of System
34. Analyze costs of the installation of a photovoltaic system
35. Discuss different incentive programs and the integration of distributed solar system in the electricity grid
36. Compared distributed solar systems and utility scale solar power plant.
37. Discuss intermittency and integration with storage and hydrogen production.

Solar Thermal

38. Compare different solar water heater designs including thoughts on cost, maintenance, and effectiveness.
39. Apply thermodynamic concepts to solar collectors: understand the Carnot efficiency significance.
40. Identify the influence of location effect (solar irradiance, outside temperature, wind speed) on effectiveness of water heater.
41. Distinguish between radiation, convection, and conduction and give examples in solar water heaters.
42. Calculate the convective heat transfer coefficient based on location and design.
43. Define absorbance, transmission, and emittance.
44. Calculate the time to heat a system or the maximum temperature based on design parameters and location.
45. Know the concept of Trombe wall
46. Calculate the temperature change in a forced circulation system.
47. Discuss the advantages and disadvantages of using a concentrator.
48. Calculate the influence of a concentrator on the effectiveness of a water heater.
49. Know and compare the different types of concentrated Solar Power plants
50. Know the history of concentrated Solar Power plants and new developments

Windpower

51. Describe the physical sources of wind on earth, explain effect of terrain.
52. Discuss wind speed measurement techniques and their applications during the project development phase of a wind farm
53. Calculate the energy contained in the wind.
54. Evaluate impact of turbine height on wind resource.
55. Describe the components of a wind turbine.
56. Calculate the maximum energy efficiency of wind turbine (Betz's law).
57. Design a wind blade based on aerodynamics equations.
58. Compare and contrast different turbine designs.
59. Calculate the optimum speed and pitch of a blade.
60. Calculate the force (thrust), torque, and power.
61. Discuss design trends and optimization.
62. Calculate the capacity factor.
63. Describe off-shore wind turbine design
64. Discuss wind power markets for on-shore and off-shore locations
65. Understand environmental impact of wind power.
66. Design a wind power system to maximize power generation for a given scenario.
67. Discuss intermittency and integration with storage and hydrogen production.

Geothermal

68. Describe the advantages and disadvantages of geothermal power from engineering, economic, environmental, and societal perspectives.
69. Describe the geological conditions needed to create useable geothermal resources on earth.
70. List the types of geothermal power plant cycles and their uses.
71. Calculate the performance of different geothermal power plant cycles.
72. Analyze geothermal power plants in California and in the world.
73. Describe geothermal heat pumps for buildings and calculate performance compared to traditional heating and cooling systems.
74. Practice the use of refrigerant fluid properties through lnP-h diagrams.
75. Describe the impact of refrigerant fluid impact on the environment and the regulation mitigating this impact.

Biomass, Biogas and Biofuels

76. List examples of biomass, biogas and biofuel processes.
77. Classify biomass processes into categories: thermochemical, biochemical, and agrochemical (extraction).
78. Compare the different processes in each category of biofuels.
79. Understand the physical, bio-chemical and chemical phenomena involved in the production of bio-fuels.
80. Assess the potential of biofuel production from different sources.
81. Discuss the use of bi-fuels for electricity generation.
82. Know the steam turbine cycle (Rankine Cycle), the gas turbine cycle (Brayton Cycle) and combined cycle turbines (CCGT and ICGT)

83. Compare the properties of bio-fuels to similar products using fossil feedstocks (Gasoline, Diesel, Heavy Crude Oil, Kerosene)
84. Know the Otto and Diesel cycles used in gasoline and diesel vehicles and calculate their performance.
85. Understand the chemical pathways to produce different type of bio-fuels: ethanol, bio-diesel, renewable diesel, bio-methane, methanol, bio-oil, hydrogen.
86. Discuss the markets and the market drivers including incentives for bio-fuels around the world.
87. Calculate the heat of reaction, fuel consumed, and CO_2 produced for different combustion reactions.

Hydrogen, Electrolyzers and Fuel Cells

88. Compare traditional and emerging techniques to produce hydrogen.
89. Assess the challenges of transportation storage and use of hydrogen compared to other fuels.
90. Discuss the use of hydrogen as an energy carrier and elementary chemical compound.
91. Define anode, cathode, and half-cell reaction.
92. Understand the electro-chemical process involved in a fuel-cell and an electrolyzer.
93. Describe the different types of electrolyzers
94. Know the history of the development of electrolyzers
95. Discuss the different techniques of production of hydrogen
96. Describe the advantages and disadvantages of fuel cells from engineering, economic, environmental, and societal perspectives.
97. Describe different examples of fuel cells including the materials used to make them, the half-cell reactions, fuel used, and by products created, and advantages and disadvantages of the system.
98. Discuss challenges and opportunities of the hydrogen economy in the context of a zero-carbon energy supply.

Electric Vehicles

99. Describe the advantages and disadvantages of electric vehicles from engineering, economic, environmental, and societal perspectives.
100. Compare losses in a gasoline and in an electric vehicle
101. Characterize battery operation.
102. Understand impact of electric vehicle charging on utility systems.
103. Comparing electric cars available on the market in the USA and internationally.
104. Assess battery charging technologies and business models to assure equitable access
105. Discuss challenges and opportunities of deployment of electric vehicle.
106. Discuss challenges of extension of electrification to medium and heavy duty trucks, trains, ships, and aircrafts

Tidal Energy

107. Describe the advantages and disadvantages of tidal power from engineering, economic, environmental, and societal perspectives.

108. Describe the physical processes that cause tides on earth.
109. Identify the components of a tidal power facility.
110. Describe factors to measure and average the height of a tide.
111. Discuss the link between tide and currents.
112. Calculate the power generated from a tidal site.
113. Describe resonance and calculate the size on an estuary needed for resonance.
114. Design a tidal current system.
115. Design a tidal power system to maximize power for a given scenario.
116. Discuss intermittency and integration in power systems to reduce the need for energy storage.

Wave Power

117. Describe the advantages and disadvantages of wave power from engineering, economic, environmental, and societal perspectives.
118. Describe the physical forces that cause waves on earth.
119. Compare and contrast different wave energy conversion technologies.
120. Calculate the amplitude, height, period, frequency, velocity, and power of a wave.
121. Describe methods of measuring and averaging the wave height and power.
122. Calculate the energy and power of a wave front and group of waves.
123. Design a wave power system to maximize power and energy for a given scenario.

Towards Carbon Neutrality

124. Understand the requirements of a carbon neutral economy.
125. Identify needs and solutions for carbon removal from the atmosphere
126. Discuss challenges and opportunities of Carbon Capture Utilization and Sequestration
127. Conclude on the importance of energy diversification and integration for long term sustainability.

Required Texts/Readings

The field of alternative energy is permanently changing; therefore the class does not follow a specific text book and is up-dated every year in function of new technologies, regulations and market conditions.

There is No required text book.

Here is a list of books that may be used by students to review or learn more about some concepts presented during the class:

Alternative Energy Sources by Efstathios E. Stathis Michaelides at Springer-Verlag Berlin Heidelberg in 2012, ISBN 978-3-642-20950-5

Photovoltaic Systems Engineering, Third Edition by Roger Messenger and Jerry Ventre at CRC Press in 2010, ISBN 1439802920

Wind Power Plants Fundamentals, Design, Construction and Operation by Robert Gasch and Jochen Twele at Springer-Verlag Berlin Heidelberg in 2012, ISBN 978-3-642-22937-4

Bioenergy Biomass to Biofuels by A Dahiya at Academic Press in 2014, ISBN 9780124079090

Fuel Cells From Fundamentals to Applications by S Srinivasan at Springer US in 2006, ISBN 978-0-387-25116-5

Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors by Vladimir S. Bagotsky, Alexander M. Skundin, Yurij M. Volfkovich at Wiley in 2015, ISBN: 978-1-118-46023-8

Electricity from Wave and Tide: An Introduction to Marine Energy by Paul A. Lynn, at Wiley in 2014, ISBN 978-1118340912

Course Requirements and Assignments (Required)

Students are required to complete:

- One homework for each class session: homework must be submitted by the start of class period.
- One Mid-term exam in class
- Two mini-projects (by groups of 3-4 people)
- One Final Exam

You are invited to actively participate in class to discuss the concepts and the elements presented during the lecture. Homework is reviewed and discuss during the class. The best benefit is captured by students who come well prepared.

Grading Information

Course Element:	%
Homework	20%
Projects	20%
Midterm	30%
Final Exam	30%
Total	100%

Total Course Score	Letter Grade
>= 100	A+
90-99	A
85-89	A-
80-84	B+
70-79	B
65-69	B-
60-64	C+

50-59 45-49	C C-
20-44	D
< 20	F

University Policies

Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs' Syllabus Information web page at http://www.sjsu.edu/gup/syllabusinfo/"

Course Schedule

Date	**Lecture**
1: 8/19	Introduction
2: 8/26	Introduction (2)
3: 9/2	Solar Resource
4: 9/9	Photovoltaics
5: 9/16	Photovoltaics, Solar Thermal
6: 9/23	Wind Power
7: 9/30	Wind Power
8: 10/7	Guest Speaker, Electric Vehicle
9: 10/14	**Midterm** Biomass
10. 10/21	Biogas, Biofuel
11: 10/28	Hydrogen and fuel cells
12: 11/4	Geothermal Energy
13: 11/11	Holiday
14: 11/18	Tide and Wave Energy
15: 11/25	Holiday
16: 12/2	Towards Carbon Neutrality
18: 12/13	**Final Exam 7:15 – 9:30 AM - Tuesday**