Proposal for a New Construction Management Emerging Trends Elective Course: Principles of Solar Construction

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California Polytechnic State University (Cal Poly) prides itself on its learn by doing motto which encourages students to participate in hands-on projects and choose elective courses about topics they are interested in. This project is an outline for an Emerging Trends elective course that aims to fill the gap between what students learn in school and what they see in the field. Over the past decade, the use of on-site solar energy generated has skyrocketed in the commercial and residential sectors. The purpose of this course is to inform students about solar requirements and to lay the groundwork for students to understand the steps that go into constructing a solar project. This elective course is designed to be taught in one hour increments twice a week in which students will have one class for instruction and one class to work on the correlating section of the class project. As a result of this class, students will have designed and analyzed their own solar projects and be able to understand the basic fundamentals of how solar energy can be created and utilized to help sustain an environment.

Key Words: Solar, Green Energy, Power Generation, Photovoltaic, Emerging Trends

Introduction

The Cal Poly Construction Management program consistently produces some of the industries most prepared and well-rounded graduates year after year. In order to hold this as true, the curriculum is continually updated to include relevant information for graduating students. This course is designed to meet the needs of a two-unit technical elective that aims to inform students about photovoltaic energy production and show them how solar can be used to benefit to any given jobsite. The class is scheduled to meet twice a week in one hour class periods for ten weeks. Additionally, the curriculum follows along with the requirements and the deliverables for the Department of Energy’s Solar District Cup competition with the intent to recruit students who show interest in the subject and want to further their education about solar energy.
Background

Cal Poly Construction Management students are often encouraged to participate in various competitions sponsored by the department. These competitions range in size from small single afternoon competitions on campus to the large Associated Schools of Construction (ASC) competitions that draw thousands of students each year. One of the niche competitions I was encouraged to compete in through the Cal Poly NECA club was the Solar District Cup. The Solar District Cup is an annual competition of construction and electrical engineering students sponsored by the US Department of Energy. The competition asks students to design and analyze a solar layout for a multi-building development in differing places across the county each year. Participating in this competition furthered my knowledge in the electrical field, but also introduced me to a new sector of solar construction. The construction management curriculum has little focus on solar construction, and with the faculty moderator for the Solar District Cup Team I became interested in designing a course to mimic the skills learned through the competition, and raise awareness of the industry for other students making their way through the curriculum.

Purpose

The purpose of this project is to create a course for the construction management department to implement as an option for students who are interested in the subcontractor field. More specifically, this course is targeted at students who are anxious to learn more than what is taught in our current curriculum about the electrical or solar industries. In my discussions with industry members, leaders in the solar field were hard to come by, especially those with a construction background and knowledge. The outcome of these conversations with industry and faculty members is a course that is aimed to challenge students while also teaching them valuable information. The goal of every graduating student is to become the best new industry professional, with access to as many new technologies as possible. In order to assist students in achieving this goal, this course will teach students the most important facts about the solar industry as well as allow them to apply their knowledge in a group setting. This attainment of new knowledge will be achieved through weekly readings about relevant material and an extreme focus on the class project which will implement key information from each module, ensuring each student has a grasp on that particular subject before moving on.

Process

The first step that went into creating a course was deciding what information needed to be covered. There are entire disciplines centered around solar engineering, and keeping a broad spectrum of important materials for a Construction Management student was my main priority. After talking with my Senior Project SME, I decided on a 10-week course instead of adding a module to a pre-existing class, so that I would have more flexibility with timing and knowledge. I then spoke with several industry members of the solar and electrical fields, to learn what they seemed to be the most relevant information in their day to day work. This was very helpful getting two different points of view as one industry member came from a CM background and the other from an engineering background. Based off the important information these industry members provided, and the requirements for the Solar District Cup, I narrowed the information down into sizeable chunks that would each fit one module.
After each of the 10 topics were narrowed down, I had to find reference materials for each module. This reference material could be used as readings or in the form of a video that students could watch to have an understanding of the topic before coming to the next class period. After extensive searches through the Cal Poly Library’s database, I found one textbook that contained enough viable information to coincide with a majority of my modules, and other resources to fill in the gaps of what I was missing. These materials will be presented with this final project. After my resources were determined, I moved on to creating the class project, and project deliverables that would relate to each module. As this class project was the basis of grading for most of the class, ensuring they related to the class information was pertinent. I also at this point had to decide how to assign individual assessments to each module, which I decided upon discussion posts each week based off of the weekly readings.

The final step I took to creating this project was creating a course outline and course syllabus. To complete this, I had to come up with what I wanted my student outcomes to be, and how I wanted to arrange the 10 modules. After discussion with my SME about how Cal Poly looks at new courses, and learning about Bloom’s Taxonomy, I went ahead and created my course learning outcomes. I then analyzed these course learning outcomes, compared them to the setup of the book, and created a schedule which I deemed to be logical in order. I moved some of the chapter reading in the book around to create what I felt to be the most comprehensive schedule possible. With my new schedule, I then took a look at other Cal Poly course syllabuses to create my own.

**Project Deliverables**

At the completion of my Senior Project, I will have produced an interactive course that is ready to implement into the Cal Poly curriculum. It will be a great first step into the nuances of the solar industry for those that are interested, and I will have completed:

- A course syllabus breaking down course objectives
- A comprehensive schedule that works alongside the schedule of the Solar District Cup
- Project guidelines and weekly project deliverables coinciding with class materials
- Weekly readings or video tutorials to supplement the in-class materials

A list of the course modules with information about the goal of each module will follow.

**Course Goals**

This course is designed to introduce photovoltaic technology, as well as discuss the issues related to installing and planning a solar grid. There will also be a brief introduction to several technologies that help in the management, estimate, and design of solar construction projects.
Course Learning Outcomes

As a result of this class, each student should be able to:

- Create an efficient solar layout using modules and inverters
- Evaluate whether the system is beneficial using a cost-benefit analysis
- Analyze productivity of using a battery backup system
- Understand the power grid and current power generation techniques
- Remember the main equipment and materials used in Solar Construction
- Understand project financing, and who the financial players are
- Learn about NECA, and the student chapter at Cal Poly

Course Modules

Module 1: Basics of Electricity

The initial module will be used as a course introduction, as well as a brief introduction of electrical theories and basics. This information will be review and refresher module for students who have previously taken the Specialty Construction Class at Cal Poly (CM 411), and a brief intro to key vocabulary and concepts for students with no prior electrical knowledge. The basis of this module is to set groundwork about terminology for the rest of the class so that students understand what the professor is talking about. The key points of this module include:

- Measurement and Quantification of Electricity Vocabulary
- Commonly Used Electrical Equipment
- Basic cost of Electricity
- Study of Ohm’s Law
- The difference between AC and DC power

The project deliverable for this module includes a small paper (1-2) pages about the specific buildings that each group will be analyzing throughout the quarter. These buildings will be determined by which use case Cal Poly is/was assigned for the Solar District Cup that competition year.

Module 2: Power Supply and Traditional Power Generation

This second module will delve into the current method for creating power and why the current method is unsustainable for a growing US population. Alternative methods will be mentioned with their pros and cons. Additionally students will study how transmission lines work to transport power from the power plant to individual neighborhood load centers. The basis for this module is to create a reasoning
as to why advancements in solar power generation are important and to show how extra generated power is redistributed back into the grid. The key points of this module will include:

- How Electricity is Generated through Coal and Natural Gas Power Plants
- Alternative types of Power Generation in the US and around the World
- Elements of the Power Grid
- Understand how to Read a Bill from the Power Company
- Understand On/Off Peak Power Purchasing

The project deliverable for this module will be to diagnose energy bills provided for the project, determine what the On-Peak vs Off-Peak costs are, and create a monthly spreadsheet to determine what the buildings average costs are by week, month, season, and year.

**Module 3: Distribution System Sizing and Analysis**

Now that students understand distribution systems, power transformation, and power transmission, they will be taught how to properly engineer the buildings existing distribution system to ensure that the system will not be overloaded with the addition of solar. Ideally, this course will be taught by a guest lecturer from the Electrical Engineering department or by a local solar contractor. Additionally, there are video resources provided by the Department of Energy on how to use their analysis software, OpenDSS. The key points of this module include:

- Understand how an energy upgrade affects an existing building
- Learn to analyze existing systems
- Create a distribution system model

The project deliverable for this module will include a model of the distribution system and an explanation of the system analysis that is run. Grading for this module will be less graded upon accuracy, and more on how well the student is able the concepts.

**Module 4: Understanding Solar Energy**

This fourth module will be the first introduction into actual concepts of solar energy. All previous mention of solar will have been to set a groundwork as to why it is important. This module will not focus on the chemistry of solar energy production, but rather on how the suns energy reaches the earth. In this module, students will understand the costs of installing solar and how these costs have evolved over time (see figure 1.). The key points of this module include:

- What is Rated Capacity?
- Costs of a Solar Panel vs costs of a Solar Project
- Understanding Solar Radiation and Irradiance
- Determine Peak Sun and Sun Azimuth

The project deliverable for this module will include a report as to what solar panel the group decides to use. They will go through options given by the Solar District Cup, compare those specifications
with the resources on standard pricing published by NREL (the National Renewable Energy Laboratory) and determine a price per kilowatt for their system.

![Price per KW in 4 Industry Categories (inflation adjusted), 2010-2018](image)

**Figure 1.** Price per KW in 4 Industry Categories (inflation adjusted), 2010-2018

**Module 5: Energy Creation and Transformation**

This module is when students will start to delve into how solar works and the chemical reactions that makes solar power possible. The goal is that by the end of this module students will understand what photovoltaic cells are and how they work to create energy. Additionally, this module will discuss inverters and how DC power can be inverted into AC power for commercial or residential use. The key points of module 5 include:

- How Photovoltaic Cells Work
- Different types of Photovoltaic Cells
- How to size a PV system
- What an Inverter is and how it Works
- Different types of Inverters

The project deliverable for this module will be a similar activity to the previous module, but with inverters rather than solar panels. Students will decide what inverter type they will use, compare its connectivity to the solar panel they chose, and then use NREL historical data to estimate a cost. Students will provide a cost estimate for both a string inverter and for a micro-inverter, and write a description as to which technology they will use for their project and why.
Module 6: System Design

Module 6 will be one of the most interesting and most hand-on modules of the entire class. This module is when students will finally get to use the Aurora Solar software on their project, to put everything together. However, before students get to design they will discuss different mounting methods for solar. This will help them create the best possible design. Key points include:

- Photovoltaic Panel Mounting Types
- Review of Azimuth Angles and Panel Spacing
- Training on Aurora Solar Technology

The project deliverable for this module will include a presentation on the Aurora Solar design. Student designs will revolve around the choices they made in the previous two modules. Once again, grading will be on the grasp of the subject, rather than on the accuracy or feasibility of the design.

![Figure 2. Aurora Solar design of 2019 Solar District Cup Use Case](image)

Module 7: Permits and Building Codes

This module was encouraged by my industry help. In their eyes, the largest setback to learning was often the time it took to learn about codes and how to understand code. Both industry members told me that the largest thing to consider was the Authority Having Jurisdiction (AHJ) and how that would affect each and every project. That is why this module aims to brief students about AHJ’s and building codes. Unlike codes in other sectors, the National Electric Code is updated every three years as new developments are made. This rapidly changing code book is difficult to stay on top of, so instead students will be taught major codes, as well as how to work with the AHJ for any additional information. The key points of this module include:

- Understanding that a code is a minimum requirement and what a code aims to do
- Understand AHJs and how to Determine a Project’s AHJ
- Steps Needed to get a Solar Project Permitted
- Difficulties with Connecting a Solar Project to the Grid
The project deliverable for this module will be to determine the AHJ for the assigned district case. After the AHJ is decided, each student will individually find an important governing code that is specific to that AHJ, or a new law passed in either California or wherever their project is located.

**Module 8: Project Financing**

In module 8, students will learn about financing a solar project. A good solar design and idea is nothing if there is no way to pay for it. In this module students will analyze the break-even point to see if the project is even worth going through with. Additionally, students will learn about a power-purchase agreement (PPA), and how they can be used to subsidize the cost of power for a campus type project. The key points of module 8 are:

- Debt vs Equity (Loanership vs Ownership)
- Who the players are in financing a project
- Tax and Cash Incentives for Completing a Solar Construction Project
- How to Run and Analyze a Break-Even Simulation

The project deliverable for this part of the class will be a short (1-2 Pages) paper about Power Purchase Agreements, and how they can be a beneficial investment for an owner. Additionally, students will run a financial analysis on their project to determine the break-even point of the project. To complete this, students will be encouraged to find tax incentives available in the project region to make their project breakeven.

**Module 9: Battery Systems and Energy Storage**

Module nine discusses new up-and-coming technologies in the industry. Solar is often looked down upon as a method of energy production because of its lack of productivity when the sun isn’t shining. As this problem was raised, battery and energy storage systems arose. In this module students will learn about current battery storage systems and why their ability to store power overnight can be useful to a solar project. The key points of this module include:

- The makeup of a battery
- How batteries are used to store solar energy
- Costs vs Benefits of using a battery system to coincide with solar
- Tax Incentives and payoffs for installing a battery system

The project deliverable for this final bit of the project asks students to estimate the cost of a battery backup system and re-run their financial analysis. Student groups will be asked to decide whether their project would benefit from implementing this system or not. They will then have to write a summary of their findings and what their approach to the problem was.
Module 10: NECA Club and Executive Summaries

The final module will primarily be used as a time for students to finish up their presentations about their project and write an executive summary. My hopes for this module are for representatives from the NECA club and from the Solar District Cup team to come and give a presentation about what they do. Students who were interested by the class can get to know the teams and ideally sign up for the Solar District Cup or any of the other things NECA concerns itself with. Key points include:

- What is Cal Poly NECA
- What projects/competitions are they involved in
- Contents of an executive summary
- Final Project Deliverables

The project deliverables in this final module are to put all of the deliverables together in an orderly fashion, and attach an executive summary. Additionally, groups will be presenting their findings from each section and whether they as an ownership team would go through with the project or not.

Conclusion

Through each of these ten modules students will have learned new information about the solar industry that is not present in any other curriculum of the construction management major. This course has been designed to give any student who is interested in learning about the subject at hand a well-rounded and a leg up when they enter the workforce. This course sets a ground layer of knowledge for the electrical and solar industry, and allows each student to participate in a project that reinforces the information that he/she learns throughout the process of these 10 modules. The idea behind this course is to be academically rigorous, while also spurring interest in the subject for students who want to do additional research on their own time. Each module was designed to give introductory knowledge about a different sector of the industry and provide sufficient additional resources to teach each student about why it is important that we as a society and an industry pursue solar energy. This project was tough to accomplish for many reasons, but the main being the state of Cal Poly at the time of this project. At the beginning of the quarter it was announced that classes at Cal Poly would be cancelled due to the outbreak of the 2019 Novel Coronavirus. This was challenging as it limited my interaction with my SME and with important industry members. However, despite all the troubles caused by Covid-19, I believe this is a full course that would be extremely beneficial to implement into the Cal Poly Construction Management curriculum.
Appendix – Syllabus, Schedule, and Module Resources

California Polytechnic State University, San Luis Obispo
Construction Management Department

Course Number
Emerging Trends: Solar Construction Management
Quarter and Year

<table>
<thead>
<tr>
<th>Instructor:</th>
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<tr>
<td>Email:</td>
<td><a href="mailto:instructor@calpoly.edu">instructor@calpoly.edu</a></td>
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<td>Class Days / Times:</td>
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<td>Prerequisite(s):</td>
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Course Description
This course is designed to introduce photovoltaic technology, as well as discuss the issues related to installing and planning a solar grid. There will also be a brief introduction to several technologies that help in the management, estimate, and design of solar construction projects.

Required Texts/Reading

Solar Electricity Basics - A Green Energy Guide by Dan Chiras
Published 2010. ISBN 978-0-86571-618-6

Wind Energy Essentials: Societal, Economic, and Environmental Impacts
First Edition. By Richard P. Walker and Andrew Swift
Published 2016 by John Wiley & Sons, Inc. ISBN 978-1-11887-789-0

***PDF of Both Texts Provided for Student Use***
Course Learning Outcomes

As a result of this class, each student should be able to:

- Create an efficient solar layout using modules and inverters
- Evaluate whether the system is beneficial using a cost-benefit analysis
- Analyze productivity of using a battery backup system
- Understand the power grid and current power generation techniques
- Remember the main equipment and materials used in Solar Construction
- Understand project financing, and who the financial players are
- Learn about NECA, and the student chapter at Cal Poly

Grading Rubric

<table>
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<th>Description</th>
<th>Points</th>
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<tr>
<td>Participation and Attendance</td>
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<td>Weekly Reading Discussions</td>
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<td>Weekly Project Deliverables</td>
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<tr>
<td>Project Presentation</td>
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<td>Final Project and Executive Summary</td>
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<td>Total</td>
<td>1000</td>
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Weekly Reading Discussions

In Canvas, each student is responsible for creating a 200-word response to that week’s reading or video, in addition to 100-word comments on two other students’ posts. These posts will be due at the beginning of the class period following the assignment of that week’s reading.

Project Deliverables

Working with the same team throughout the quarter, each week a new deliverable will be due. These deliverables will help keep the project teams focused and on track towards the final deliverable which will terminate the class.

Executive Summary

In place of a final examination, each student will INDIVIDUALLY create an executive summary highlighting every deliverable for the project. Individual students should be able to demonstrate their knowledge of each module and their understanding of each deliverable. There will be two classes to work on this in class during the final module.
### Class Schedule

<table>
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<tr>
<th>Week</th>
<th>Topic</th>
<th>Reading</th>
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<tr>
<td>1</td>
<td>Class Introduction, Project Introduction, and Basics of Electricity</td>
<td>WEE Chapter 2</td>
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<tr>
<td>2</td>
<td>Power Creation and Distribution</td>
<td>Energy Creation Articles</td>
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<td>3</td>
<td>Distribution System Analysis</td>
<td>OpenDSS Training Videos</td>
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<tr>
<td>4</td>
<td>Basics of Solar</td>
<td>SEB Chapters 1&amp;2</td>
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<td>5</td>
<td>Photovoltaics and Inversion</td>
<td>SEB Chapters 3&amp;6</td>
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<td>6</td>
<td>System Design and Aurora</td>
<td>SEB Chapter 8</td>
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<td>7</td>
<td>Codes and Permitting</td>
<td>SEB Chapter 9, NEC Article 690</td>
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<td>8</td>
<td>Solar Project Financing</td>
<td>Heatspring Lesson 5</td>
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<td>9</td>
<td>Battery Backup Systems</td>
<td>SEB Chapter 7</td>
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<td>10</td>
<td>NECA and Executive Summaries</td>
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### Project Schedule

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<th>Project Activity</th>
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<tr>
<td>1</td>
<td>Introduction to the Project Location</td>
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<tr>
<td>2</td>
<td>Analyze Current Energy Usage and Bills</td>
</tr>
<tr>
<td>3</td>
<td>Distribution System Analysis - OpenDSS</td>
</tr>
<tr>
<td>4</td>
<td>Choose Solar Panels and Estimate a Cost</td>
</tr>
<tr>
<td>5</td>
<td>Choose Inverters and Estimate</td>
</tr>
<tr>
<td>6</td>
<td>Design System in Aurora Solar</td>
</tr>
<tr>
<td>7</td>
<td>Determine AHJ and Unique Codes</td>
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<tr>
<td>8</td>
<td>Break-Even Analysis</td>
</tr>
<tr>
<td>9</td>
<td>Analyze a Battery Backup System</td>
</tr>
<tr>
<td>10</td>
<td>Create an Executive Summary and Presentation</td>
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</table>
Module Resources:

Module 1 – Basics of Electricity

Main Resource
• Chapter 2: Wind Energy Essentials (pages 34-47)

Additional Resources
• https://www.youtube.com/watch?v=IYZUXV-v71Y - Voltage and Circuits Explained
• https://www.youtube.com/watch?v=vN9aR2wKv0U - AC vs DC explained

Module 2: Power Supply and Traditional Power Generation

Main Resources
• How Electricity is Generated - US Energy Information Administration
• How the Electricity Grid Works - Union of Concerned Scientists
• Reading your Electricity Bill - Aurora Solar

Additional Resources
• https://www.youtube.com/watch?v=20Vb6hlLQSg - Electricity Generation
• https://www.youtube.com/watch?v=HGVDu1z5YQ8 - What is a Power Plant
• https://www.youtube.com/watch?v=v1BMWczn7JM - How does the Power Grid Work
• https://www.youtube.com/watch?v=LvoRK2OwQtE - Understanding Electricity Bill
• https://www.youtube.com/watch?v=9joPVlsarqg - What is a Peak Hour Usage Charge

Module 3: Distribution System Sizing and Analysis

Main Resources
• Lesson 3: Heatspring Presentation from NREL
• https://www.youtube.com/playlist?list=PLcOap2oqW_gEMEVH9dg2HoXJ4NvydfsZM
  • Open DSS training videos

Module 4: Understanding Solar Energy

Main Resource
• Chapters 1 and 2 - Solar Basics (Page 1 - 36)
Module 5: Energy Creation and Transformation

Main Resource
- Chapters 3 and 6 - Solar Electricity Basics

Additional Resources
- https://www.youtube.com/watch?v=L_q6LRgKpTw - How do solar cells work?
- https://www.youtube.com/watch?v=ln9VZI8rVs - How inverters work

Module 6: System Design

Main Resources
- Chapter 8 of Solar Electricity Basics
- Conceptual System Design - Dr. Andy Walker

Additional Resources
- https://www.youtube.com/watch?v=COm6zuD4qwc - Aurora Demonstration

Module 7: Permits and Building Codes

Main Resources Available
- Chapter 9 - Solar Electricity Basics
- Article 690 - National Electrical Code
- Permitting Presentation - NREL

Additional Resources
- Planning and Zoning for Solar Energy
  - List of municipal codes and resources

Module 8: Project Financing

Main Resource Available
- Solar Project Finance Presentation by Travis Lowder (NREL)

Additional Resource
- https://www.youtube.com/watch?v=wy9hhd2ZuK4 - Power Purchase Agreement
Module 9: Battery Systems and Energy Storage

Main Resource Available
- Chapter 7 - Solar Electricity Basics

Module 10: NECA Club and Executive Summaries

Main Resource Available
- Presentation by NECA
- https://www.youtube.com/watch?v=dJF8zdpV_a8 - Michael Klee Ghana Video