## LESSON

History, How and Why?

## OVERVIEW

While the focus of this segment is about energy generation and transmission, this segment is also intended as a way to get to know the students in the class better as well as help assess their current understanding of the role of electricity in their life. This session can also be used to help understand students' current level of reading, writing, and comprehension. Lastly, the activities in this session will help build teamwork and bond students together.

## OBJECTIVES

- Create a personal connection to students in the class
- Understand the different personalities in the class
- Connect things that everyone loves to do to energy and demonstrate the large role electricity plays in everyone's life
- Intro to electricity generation, transmission, and distribution

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**How Does Electricity Play A Role In My Life?**

3 HOURS

## STANDARDS

### PA/SDP

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity with appropriate comprises in complex real-life problems.

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

**3.4.12.B2.** Illustrate how, with the aid of **technology,** various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.C2.** Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

## INSTRUCTIONAL

### TEACHING TOOLS

- **The Random Word Game - Overarching goal: demonstrate that it is difficult to use things you know well in new ways.**
  - Students pair off forming 2 parallel lines facing each other.
  - The rule is to say as many random words to each other as possible. The words cannot relate to each other in any way (so grass and then green are not allowed). For example: one person says "space" the other says "shoe"
  - You cannot repeat words nor can you say anything you see in the room
  - See how long students can go say random words to each other, game should last about a minute or a minute and a half
    - Ask students if it was hard?
    - Let them know that they know thousands of words and they use them everyday, but when asked to use them in a new way it became hard.
    - Did anyone come up with a strategy? Did anyone just ignore what the other person was saying

## KEY TERMS

Energy
Power
Electricity
Energy Conservation
Energy Efficiency
Multi-Meter
Loads
Teamwork
Fracking
Nuclear
Transmission
Distribution

## INSTRUCTIONAL (CONTINUED)

- **The Human Knot Game - overarching goal is teamwork and perspective.**
  - Have 6-8 students stand in a circle shoulder to shoulder.
  - Have each student put their hands in the middle of the circle
  - Randomly have students clasp hands so that arms are mixed above and below in the middle of the circle
  - Have students unknot their arms without releasing hands in under 3 minutes
    - Was anyone a leader?
    - Did the leader change throughout?
    - Did the physical perspective change the leader?

### TEXT/REFERENCES

https://theoatmeal.com/comics/tesla

https://www.fi.edu/benjamin-franklin/kite-key-experiment

https://www.youtube.com/watch?v=fsgqy5FYP2c (Centralia coal fire)

https://www.nih.gov/news-events/nih-research-matters/drop-coal-power-plant-emissions-associated-asthma-improvements

https://www.ucsusa.org/resources/coal-power-impacts#:~:text=Climate%20change%20is%20coal's%20most,the%20earth%20above%20normal%20limits

Solar Photovoltaic Basics - Chp. 3 Pg. 36 Electrical Transmission and Distribution Systems & Pg. 39 Figure 3.7 Electrical generation, transmission, and distribution

### MATERIALS

No additional materials are needed/required for this exercise.

### BACKGROUND/IN ADVANCE (TEACHER)

A strong understanding of teamwork, creative thinking exercises, and electricity generation and distribution is important. Being able to find a shared connection point with the students is helpful (both like the same music, both have been without power, both have some leadership qualities, etc.). It's important to have a strong understanding of electricity generation, transmission, and distribution.

## IMPLEMENTATION (LESSON PLAN)

### INTRODUCTION – OUR PERSONAL CONNECTION TO ENERGY.

- Introduce the role that energy plays in our everyday lives, like listening to music
- Let everyone name their favorite musician
- Tell everyone your favorite musician
- What device do you listen to music on?
- At its core what does that device need to work? ELECTRICITY!!!!
- Other interests outside of music, how do those relate to energy use?
- Connect current electricity production, particularly coal, to health impacts (asthma)
- What you love to do, listening to music, could be making you and your family sick (asthma), crazy right?!?! How do we solve this?
- Discussion about how we have solved how to generate electricity for most of the US, now we need to solve that problem in a way that does not make us sick. Solving already solved problems in a new way can be very difficult

PLAY RANDOM WORD GAME

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**How Does Electricity Play A Role In My Life?**

3 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### LECTURE & DISCUSSION

How is energy produced, where is it produced, and why?

- Benefits & drawbacks of coal generation
  - Benefits: Relatively inexpensive, well understood, lots of coal in PA, rural jobs.
  - Drawbacks: mining (tell story of Centralia, PA), pollution and health impacts (coal burning's relationship to asthma, coal burning's relationship to global warming), burning coal releases CO2, no urban jobs.
- Benefits & drawbacks of gas generation
  - Benefits: Relatively inexpensive, Marcellus Shale is abundant in PA, gas power plants are dispatchable, land lease money for farmers, rural fracking is out of site of most people, rural jobs.
  - Drawbacks: Fracking, Methane release from well heads, burning gas releases greenhouse gases (CO2), gas has become so inexpensive that they are stopping pumping and lease payments are stopped, no urban jobs.
- Benefits & drawbacks of nuclear generation
  - Benefits: Inexpensive, baseload power, long lifetime, zero CO2 emissions, rural jobs.
  - Drawbacks: No solution for nuclear waste, nuclear fallout from plant failures, no urban jobs.
- Centralized -vs- Distributed generation.
  - Centralized: https://www.epa.gov/energy/centralized-generation-electricity-and-its-impacts-environment
  - Distributed: https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts
- Discussion about global climate change and how our energy systems play a role in it.

PLAY HUMAN KNOT GAME

## MEETING INDIVIDUAL NEEDS

### STUDENTS WITH LEARNING DIFFICULTIES

The team building and verbal communication exercises typically appeal to a wide variety of learners. Getting students out of their seats and working together can assist students with learning difficulties.

### ADVANCED LEARNERS

Advanced learners can use the links provided to dive deep into the different energy sources. There are lots of advanced topics that can be discussed or used for independent learners around fracking, coal, and nuclear energy. Use the links provided and give to students encouraging them to do additional research.

## HOMEWORK

Homework 700-1

## TECHNOLOGY

The homework will require access to the internet for research.

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### TOPIC OF STUDY

**How Does Electricity Play A Role In My Life?**

3 HOURS

## LESSON

Roof Safety and Personal Fall Arrest Systems

## OVERVIEW

Safety the  top priority when working on construction sites. students will learn the safety requirements for working. These lessons will be woven into all times when working on the roof.

## OBJECTIVES

Students will:

- Identify types of ladders and when to use each type (when to use metal v. fiberglass)
- Inspect ladders for damage and label damaged ladders
- Demonstrate proper ladder safety techniques including, footing, rise over run, securing, height above roof line, and various support systems
- Demonstrate the use of personal fall arrest systems by correctly wearing and adjusting equipment

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## TOPIC OF STUDY

**OSHA Safety Requirements**

90 MINUTES

## TASK LIST SUBCATEGORY

**302** Demonstrate use of Personal Fall Arrest Systems (PFAS)

**303** Demonstrate the use of PPE

**304** Identify the causes of jobsite accidents

## KEY TERMS

personal fall arrest sytem
roof anchor
harness, lifeline
hitch clip
hard hat
gloves
eye protection

## STANDARDS

### PA/SDP

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity in complex real-life problems.

**3.4.12.B1.** Analyze ethical, social, economic, and cultural considerations as related to the development, selection, and use of **technologies**.

**3.4.12.C3.** Apply the concept that many technological problems require a multi-disciplinary approach.

**13.3.1.A.** (Career and Work) Evaluate personal attitudes and work habits that support career retention and advancement.

## INSTRUCTIONAL

### TEXT/REFERENCES

Solar Photovoltaic Basics, White. Chapter 2, pp. 13-22

### MATERIALS NEEDED

**Teacher Presentation:** PPE and Fall Protection Equipment (see #1 in Implementation list)

**Content:** OSHA web site

**Technology:** web browser to view videos

## IMPLEMENTATION (LESSON PLAN)

1. The first day of class layout fall arrest PPE and ask students to guess what each object is and how it works. Lay out the following items
   - *Harness*
   - *Lanyard*
   - *Lifeline*
   - *Roof anchor or hitchclip*
   - *Hard Hat*
   - *Gloves*
   - *Eye Protection (when drilling or cutting metal)*
2. Teacher demonstrates how to properly wear and adjust fall arrest systems. Allow all students to try on and adjust fall arrest PPE and set a rule that all students on the roof must be wearing PPE (Just like real life on a roof). (watch Home Depot video linked below if necessary). Teacher designates the flat roof and/or mock roof area as a location where all students must be wearing PFAS . Teacher should designate one student to serve as safety supervisor: this student monitors all classmates for proper use of equipment. The teacher should also assign pairs of students in a "buddy system" where each student always checks the proper use of the equipment by their partner.
3. Have students create a list of safety rules for working on or around roofs. Establish that OSHA regulations call for fall arrest to be worn whenever a person is in an unguarded area above 6 feet high. Be sure to include "don't walk backwards" and call out tripping hazards. The length of the lifeline cannot be greater than the distance to the ground. The lifeline should be adjusted to be as short as possible to perform the work while also maintaining the shortest possible fall off of the roof.
4. Discuss limitations of fall arrest systems (you can still fall and swing hard into a building, they are meant to save your life not necessarily prevent all injuries). Discuss why the lifeline must be attached to the back D ring on the harness (to absorb all shock properly). Discuss shock absorption system on lanyard.
5. Demonstrate proper installation of a roof anchor/hitch clip into a structural member of the roof. Discuss the use of screws or double headed nails. Discuss location of anchor/s on the roof and that many lifelines only extend 25' and thus you may need more than one. Also, no more than 2 people can be hooked into a single anchor (depending on rating). So a second anchor may be needed depending on the number of people on the roof. Have students install anchors.
6. Discuss tripping hazards created by lifelines and retractable lifelines (their benefits and drawbacks).
7. Demonstrate the proper use of hard hats, gloves, and eye protection. Discuss why all of these items are needed. Hard hats must be worn at all times, even on the roof. For example, when solar panels are being carried on the roof it is possible to hit a co-worker in the head with the panel.
8. Never put tools down on the roof. Wear a tool belt and have tools on lanyards to prevent tools from rolling off of the roof. Bring a tool bucket to the roof and harness it to a chimney to secure tools.
9. Ladder safety: The magic ratio is 4:1. For every 4 feet of rise there must be 1 foot of run. Basically when standing at the base of a ladder you should have your feet touching the ladder feet and if you can fully extend your arms and touch the sides of the ladder then it is set up properly. Ladders should extend 3 feet above the roof line. Fiberglass ladders are the only ladder type acceptable for electrical work. Metal ladders conduct electricity and can ground the person working on them making them susceptible to electrical shock.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**OSHA Safety Requirements**

90 MINUTES

## RESOURCES/LINKS

Home Depot Fall Protection

https://www.homedepot.com/p/Guardian-Fall-Protection-Rooftop-Safe-Tie-Bucket-Kit-00815-QC/202898758

Industrial Safety Products

https://www.industrialsafetyproducts.com/dbi-sala-retractable-horizontal-60-cable-lifeline-system-7605060/?gclid=Cj0KCQjwsZKJBhC0ARIsAJ96n3VCBKr5r-AQiT5SHHuN6KpyRQa8GFOzNmODx-UqM7_OnxctMDPA8qAaAjZaEALw_wcB

OSHA Ladder Safety

https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1053

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**OSHA Safety Requirements**

90 MINUTES

## LESSON

Ladder Safety and Mitigating Jobsite Hazards

## OVERVIEW

Ladder safety is critical for a safe work environment. Ladders seem straightforward to use, but when used improperly can easily lead to serious injury or even death.

## OBJECTIVES

Students will:

- Identify types of ladders and when to use each type (when to use metal v. fiberglass)
- Inspect ladders for damage and label damaged ladders
- Demonstrate proper ladder safety techniques including, footing, rise over run securing, height above roof line, and various support systems
- Evaluate the surface that ladders are being placed on for slippery conditions or other issues that may cause the feet to become unstable

BRIGHT SOLAR FUTURES

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### TOPIC OF STUDY

**OSHA Safety Requirements**

90 MINUTES

## TASK LIST SUBCATEGORY

**304** Identify the causes of jobsite accidents

**305** Recognize and mitigate hazards

**306** Evaluate and perform safe lifting and material handling

## KEY TERMS

3 points of contact
stabilizer
rungs
fiberglass
extension ladder

## STANDARDS

### PA/SDP

**3.4.10.A2.** Interpret how systems thinking applies logic and creativity in complex real-life problems.

**13.3.1.A.** (Career and Work) Evaluate personal attitudes and work habits that support career retention and advancement.

## INSTRUCTIONAL

### TEXT/REFERENCES

Solar Photovoltaic Basics, White. Chapter 2, pp. 13-22; ECA Energy Conservation Handbook, p. 43

Safety Toolbox Talks: Ladder Safety

https://www.youtube.com/watch?v=lqXYDlOSOOs

### MATERIALS NEEDED

#### MATERIALS

- Metal extension ladder
- Fiberglass extension ladder
- Optional all: muti-purpose ladder, A-Frame ladder, Step ladder

**Content:** OSHA web site

## IMPLEMENTATION (LESSON PLAN)

1. Bring out a fiberglass extension ladder (28′ preferred, 32′, or 38′ acceptable).
2. Have students inspect the ladder and lift it up to get comfortable with the ladder.
3. Have students break out into teams of 2. Tell pairs of students that they have to come up with a written step-by-step plan for how to set up the ladder.
4. Have the teams demonstrate their written plan
5. Whole class watches "Safety Toolbox Talks: Ladder Safety"
6. Students observe teacher giving a demonstration of how to properly use the extension ladder.
7. Teacher demonstrates again, asking students to describe and record each of the proper steps. Student initial student-generated description with the proper teacher-led method of ladder use.
8. Teacher asks students to on their own develop a list of key ladder safety guidelines. Upon completion class should compare their list with the following list of key takeaways:
    a. Ladder must extend 3′ above roof
    b. Never use top rung
    c. never use a ladder with bent rungs
    d. make sure footing is stable and not slippery
    e. 4:1 rise over run ratio
    f. Ladder stabilizer is a great tool to not only make ladder more secure but also protect against gutter damage
    g. Always tie off your ladder
    h. Never leave a ladder setup in high winds
    i. Always keep 3 points of contact when climbing a ladder
    j. To bring material to the roof use pulleys. Do not carry material up ladder as you cannot keep 3 points of contact
    k. Ensure any pulley system is properly secured. A falling pulley can injure or kill a worker
    l. Ladder carrying and setup technique. Always plan out how to get the ladder into the proper position. Be aware of overhead obstructions that could pose a safety threat (for example: trees, power lines, etc.)
9. Assessment: After the list of proper safety techniques is completed, ask each student to demonstrate their learning by correctly climbing the first 6′ of the ladder, focusing on maintaining three points of contact at all times.

## RESOURCES/LINKS

Safety Toolbox Talks: Ladder Safety

https://www.youtube.com/watch?v=lqXYDlOSOOs

OSHA Ladder Safety

https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1053

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

OSHA Safety Requirements

90 MINUTES

## LESSON
Emergency Action Plan (EAP)

## BIG IDEA(S)
All employees should be familiar with the OSHA-required Emergency Action Plan

## OBJECTIVES
Students will:

- Correctly demonstrate a variety of first aid skills.
- Identify the required elements of an EAP.
- Develop an Emergency Action Plan for a simulated site.

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**TOPIC OF STUDY**

**OSHA Safety Requirements**

90 MINUTES

## TASK LIST SUBCATEGORY
**307** Develop an Emergency Action Plan for a simulated site

**309** Demonstrate CPR and first aid skills

**310** Describe appropriate responses to job site emergencies

## OVERVIEW
OSHA requires that employers develop and keep at the workplace a site-specific emergency action plan (EAP). The EAP should be reviewed and revised on a regular basis. The EAP should include the following:

1. A description of all emergency escape procedures and routes.
2. Any procedures to be followed by designated employees who may remain to operate necessary functions before evacuating themselves.
3. Procedures to initially and periodically account for all employees during and after emergency evacuation.
4. Specific emergency rescue and medical duties for those employees trained, equipped and designated (in writing) to perform them.
5. Detailed and preferred means of reporting emergencies to the employer and emergency responders.
6. The names, positions and duties of designated in-house emergency personnel (Competent Persons), who will either respond specifically during an emergency or be responsible for the design, maintenance and overall implementation of the EAP.
7. The emergency alarm system(s) to be used on the construction site.

## KEY TERMS
OSHA
EAP

## STANDARDS
See PA Emergency Response Guidelines for Construction/Solar.

## INSTRUCTIONAL
### MATERIALS NEEDED
**Content:** Sample EAPs

**Technology:** Computers with internet access

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

OSHA Safety Requirements

90 MINUTES

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

1. Ask students to think about the rules and procedures for a school fire drill.
2. Ask students to think about other ways that they and their families might be prepared for emergencies at home (i.e. first aid kit, smoke detectors, flash light/candles, etc…)
3. Explain to students that OSHA requires all employers to have a written Emergency Action Plan (EAP).

### EXPLORE

- Have teams of 2-3 students work on developing a checklist of all of the things that should be part of the EAP.

### EXPLAIN

1. Ask teams to report out on their checklist items.
2. Provide students with an EAP from a Solar company such as Solar States

### EXTEND

1. In Year 2 and 3 student teams should develop and revise their own EAPs for use with their final capstone projects.
2. Have students complete a CPR and First Aid training through the school or a local YMCA or similar agency.

### EVALUATE

1. Teacher should grade checklists and plans looking for the OSHA minimum requirements.
2. Teacher may also create case studies and ask students to respond appropriately.

## RESOURCES/LINKS

OSHA Emergency Action Plans

https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.35

Roofing Contractor Emergency Preparedness

https://www.roofingcontractor.com/articles/84145-emergency-preparedness

Sample EAP From Texas

https://beaumonttexas.gov/wp-content/uploads/pdf/eoc/cob_bus_sample_eop.pdf

## LESSON

Hand and Power Tools

## BIG IDEA(S)

Tools are a critical part of the weatherization process.

## OBJECTIVES

Students will:

- Identify solar technology/weatherization tools and describe examples of their use
- Describe ways that a retrofit installer maintains tools and organizes them for job requirements and easy retrieval
- Describe tool safety for tools and tasks
- Read manufacturer's specification for a specific tool and understand directions

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Hand and Power Tools**

90 MINUTES

## TASK LIST SUBCATEGORY

**311** Recognize, identify and safely use hand tools and power tools

**415** Demonstrate knowledge of manufacturer specifications

**420** Demonstrate knowledge and use of time management strategies

**810** Use energy efficiency industry vocabulary

**811** Prepare and maintain tools and equipment used for energy auditing and weatherization tasks

## KEY TERMS

Maintaining tools
Manufacturer's Specifications

See pg. 55 of reference text for complete list.

## OVERVIEW

The purpose of this Lab is to introduce students to the tools that they will be using throughout the program. Instructor will assemble the tools and tasks to demonstrate, describe their use in weatherization and construction, and demonstrate how to use them safely. Students need to understand how keeping tools organized, ready to use, and selected for each job saves time and bother. The importance of reading the directions from manufacturers is also reviewed.

## STANDARDS

### PA/SDP

**CC.3.5.9-10.C.** Reading (Specific Anchor: Key Ideas and Details). Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

## INSTRUCTIONAL

### TEXT/REFERENCES

Energy Conservation Handbook. Pp.55-63

### MATERIALS NEEDED

**Teacher Presentation:** Assemble all tools that are to be demonstrated along with props and materials needed

**Content:** Year 1 Lesson 9 worksheet

SOLAR

TOPIC OF STUDY

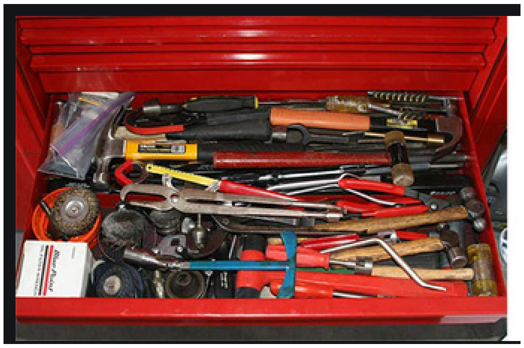
Hand and Power Tools

90 MINUTES

## IMPLEMENTATION (LESSON PLAN)

1. Organization of Tools

   In which drawer will you find the tool you need fastest?



   a. In the Shop or Truck: "Every tool in its place." Tools are often shared so be sure there is enough for everyone, and that they go back where everyone knows to find them.

   b. On the Job: Having tools ready for specific jobs in the order of need is a great idea. On p. 157, for this air sealing job of non-IC recessed light fixtures you would have ready the list of Tools, Consumables, and Safety Equipment ahead of time. Think about how they will be carried, loaded and unloaded, cleaned up, and returned. This is all part of the job.

2. Manufacturer's Specifications: It is very important to understand the technical aspects of a tool before using it. This is especially important for power tools which can be dangerous if not used properly. There are directions for things like changing blades and bits, safe operation, and limitations for the tool. Use the Table of Contents below to decide **what section** you would need to read to answer the questions about this circular saw:

   https://images.homedepot-static.com/catalog/pdfImages/b2/b236330b-101b-4751-a981-9c45537f3afa.pdf Full manual here for this circular saw to check the instructions.

TABLE OF CONTENTS



   a. What PPE should you use?

   b. When should the saw be disconnected from electricity?

   c. You suspect that the blade is not sharp and you need to change it?

   d. The saw stops working after using is correctly after 3 months.

   e. You are going to cut a ½" plywood board. How far down should the blade be?

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

3. Demonstrating the Tools (Approx. 45 minutes): The instructor should review demonstration of the procedures before-hand, setting sample jobs where warranted to save time. If any hands-on practice is planned, this lesson will take longer. Make a checklist for smoother sailing.
   a. Hand Tools
      i. Screw drivers are mostly flat or Phillips. There are other kinds and different sizes and lengths for getting into odd spots. If time, review when they come in handy. Also demo using a drill for screws with different bits.


      ii. Tool Belt. If you assemble a tool belt, you might want to put in tools for a specific job like making a drywall repair, or sealing an opening around a pipe.
   b. Power Tools: to consider time, demo just one of the saws but explain how the others work.

## HOMEWORK

Match the Tool to its Use (Year 1 Lesson 9 Worksheet)

## RESOURCES/LINKS

Straight Cuts with a Circular Saw

https://www.youtube.com/watch?v=99vUjwFIZuo

How to Use a Circular Saw

www.lowes.com/n/how-to/how-to-use-a-circular-saw

Miter Saw (7:52)

https://www.youtube.com/watch?v=7fjHvYy5lkg

Portable Band Saw

https://www.youtube.com/watch?v=iWXSkrhDMHo

BRIGHT SOLAR FUTURES

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TOPIC OF STUDY

Hand and Power Tools

90 MINUTES

## LESSON

Installation of Racking, Modules, Inverter, and BOS

- Installing Ballast Block Systems
- Wire Management
- Penetration Systems (flashing)
- Panels (modules)
- Grounding
- Inverters
- BOS

## BIG IDEA(S)

The installation of a solar system requires a series of specific steps beginning with flashing and ending with wire management and grid connection. A solar technician understands and is able to complete all the steps in this process as well as anyone pursuing the wide variety of career paths in the solar industry.

## OBJECTIVES

Students will be able to:

- Fluff shingles and install flashings as well as rails
- Understand when to use mechanical attachments vs. ballast weight
- Install ballast weight systems
- Perform wire management for DC and AC systems
- Install a junction box and/or a Soladeck
- Install PVC and EMT conduit
- Pull wire through conduit
- Install solar online monitoring systems
- Interconnect solar with the utility grid

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

**Solar Installation**

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## TASK LIST SUBCATEGORY

| | |
|---|---|
| **501** | Install roof flashings |
| **505** | Install racking, modules, inverter, BOS components |
| **302** | Demonstrate the use of Personal Fall Arrest Systems (PFAS) |
| **303** | Demonstrate the use of Personal Protective Equipment (PPE) |
| **306** | Evaluate and perform safe lifting and material handling |
| **311** | Recognize, identify and safely use hand tools and power tools |

## OVERVIEW

Students will learn about and get hands-on experience with all aspects of solar installation including: installing flashings, ballast weight racking, rails, wire management, stringing, branch circuits, junction boxes, Soladecks, PVC and EMT conduit, wiring, monitoring, interconnection. Racking system with flashing is recommended for the mock roof. Ballast system should also be demonstrated. Two of the most common ballast weight systems that are installed in Philly are Ecolibrium Eco 5D and Everest D-Dome both of which are self-squaring systems. Very little layout is required on the residential level as the system sizes are commonly within 20 panels).

**NOTE: SolaDeck** is a PV wire enclosure and seamless flashed product all in one. SolaDeck eliminates the multiple parts and respective labor typically needed to accomplish the roof penetration for a weather-tight wiring passageway into the home. Unique in the solar industry, SolaDeck is designed with a seamless flashing consistent with standard roofing practices for roof penetration. All SolaDeck models are third party tested by ETL to the UL50 Type 3R or UL1741 standards.

## KEY TERMS

flashing
ballast
rails
stringing
wire management
branch circuits
junction box
SolaDeck (see note)
PVC
EMT
monitoring
interconnection
din rail
grid connection
Wiley clips
crimping tools
Polaris connector
terminal blocks

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)

**11th grade:** 8-10 HRS (4-5 SESSIONS)

**12th grade:** 8-10 HRS (5 SESSIONS)

## STANDARDS

### PA/SDP

**3.4.10.A1.** Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity appropriately in complex real-life problems.

**3.4.10.B2**. Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies.**

**3.4.12.B2.** Illustrate how, with the aid of **technology**, various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.C2.** Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

**ETS1.B.** Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)

## INSTRUCTIONAL

### TEXT/REFERENCES

SEI Solar Electric Handbook ISBN#: 978-1-256-70166-8

How to install the Ecolibrium flat roof racking system

https://www.youtube.com/watch?v=NJFQ4y5PBbE

Overall racking training and certification program

https://www.ironridge.com/resources/on-demand-training/

### MATERIALS NEEDED

**Teacher Experience:** Performance of 3-4 solar installations

**Teacher Presentation:** Mock roof; Electrical wall; all installation tools and materials for installation

#### MATERIALS

- Drill and impact driver with bits
- Solar Panels
- MC4 connectors
- Microinverters and optimizers
- Enphase connectors
- Wiley clips
- Zip ties
- Junction box/Soladeck
- Din rail
- Terminal blocks
- Polaris connectors
- Wire strippers
- MC4 crimp tool
- Screw drivers
- Roof safety equipment

**Technology:** Video projection/display

## IMPLEMENTATION (LESSON PLAN)

### DAY 1: FLAT ROOF BALLAST WEIGHT SYSTEMS: SHINGLES, AND RAILS

#### ENGAGE

1. Review flashing installation and discuss non-ballast systems
2. Install racking system: Flat Roof Ballast Weight System: Ecolibrium EcoFoot 5D Installation
    a. Ecolibrium Eco 5D Racking System Description: Ecolibrium Solar unveils EcoFoot5D flat-roof racking solution
    b. When installing Ecolibrium eco 5D you would want a south line or a north line to follow as you build down the roof. Start by identifying an edge of the roof that is closest to the North (or South) edge of the roof.
    c. The layout process starts by obtaining the measurements of your modules (for example: 66 ⅜" X 39 ¼") and counting the number of EcoFoot bases in each row of bases on your planset, building North to South is the preferable method by most installers so you typically begin on the North side.
    d. Place a EcoFoot base in the north east corner of the array and move West placing a EcoFoot base every 66 ⅜" until you reach the number of bases for the row.
    e. Following rows, line up the bases with the row before.
    f. Now all of the bases are down it's time to move onto the next step: Slide the ballast trays into the bases.
    g. The ballast trays are coated in grease and very sharp, incorrect handling can lead to accidental penetrations of the roof so this part you must take care not to damage the roof as you attach the trays to the bases. Begin by placing a stack of trays close to the area of work, take one tray and slide one end in the base and secure the other side of the tray into the second base making sure the sharp edges do not touch the roofs' surface.
    h. Repeat until all bases are connected by ballast trays.
    i. Next, attach the panel clamp for the ballast tray.
    j. Attach this to the center of the ballast tray by sliding the two halves of the clamp under the tray and screwing a 9⁄16" bolt through the center. Do this on every tray.
    k. Then attach the 5D pressure clamps to the bases. Note: there are 2 clamps: a south clamp for the low end of the panel and a north clamp for the high end of the panel and they are almost identical, the slight difference is in the north clamp which has a bolt on the back end of it which is important for the final steps in installing this system (The Wind Deflector) so ensure you put the correct clamp on the correct base in the correct orientation.
    l. To do this take a 2 pack of clamps (north and south clamps bundled together with a rubber band) and set it on the roof in between the two rows of bases at each base, now the north clamp goes on the north base on the high end of the base and the open end of the clamp faces south, The south clamp goes on the low end of the south base with the open end facing north. do this at every base.

### DAY 2: PANELS, INVERTERS

#### EXPLAIN

1. Review the quick install guide as an overview of the entire installation process: Quick Installation Guide North America MAN-01-00025-3.2
2. Next you will run your Cable (PV Wire or Q Cable Field Wire) from your Junction box location to the ends of each string according to your planset.

SOLAR

TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

3. Setting panels.
   a. If you are using Microinverters:
      i. Plan your microinverter attachment method and wiring.
      - Attach microinverters to the panels using rocket clips
      - Mid-clamps with MLPE attachment spaces are also available (and preferred)
      - Plan your wiring run so that you do not exceed the maximum number of microinverters per branch circuit and so that the circuit ends as close to the junction box as possible.

   b. If you are using DC optimizers
      i. Plan your optimizer attachment method and wiring
      - Attach optimizers to the panels using rocket clips
      - Mid-clamps with MLPE attachment spaces are also available (and preferred)
      - Plan your positive and negative home run so that you land one end near the junction box and you have as easy a path as possible under the array and back to the junction box. Remember, both positive and negative leads will have to enter the junction box on the roof.

   c. Next, plan the order in which you set them. Work back to your ladder: if the ladder is set up in the south-east corner of the roof, the first panel (known as the keystone panel) will be set on the north-west corner of your array. The keystone is the most important panel because if it is not set plum to your north line, as you build you will run out of square with the roof, so take your time with this keystone panel.

   d. Once it is set, secure it so it does not move while placing the next panel, you'll place 3 block on the south end and 3 block on the north end so the keystone stays in place, from there you set the rest of the north row working toward the east and checking to ensure you stay on your north line, once the north row is set you weigh it down and secure the ballast trays to the panel with the ballast tray panel clamp you installed earlier. So now set the following rows working from west to east until all panels are set.

4. While laying panels you must map the solar array. Each microinverter or DC optimizer has a serial number sticker on it. Draw a map that reflects the design of the solar array and attach the serial number sticker in the location that the panel falls on the map. This will be used later on to build the online system monitoring and will allow the person building the system online to know where all of the microinverters or dc optimizers are in the solar array. Pro tip: take a phot of the map when done so if the map is lost or damaged you have a copy of it. If the array is built in the monitoring platform prior to installation both SolarEdge and Enphase have phone apps that can scan serial numbers and place the MLPE into the online map in the correct location.

5. Once all panels are set it is time to secure the wind deflector to the north end of the panels, you start by pushing the bottom of the wind deflector into the slotted channel on the 5D base you then push the top end of the deflector onto the bolt on the north clamp and fasten it with a ½" Flange Nut. Once this is done, you have finished.

### DAY 3: WIRING INVERTERS

1. Microinverters are a relatively new development in the industry. Rather than using high-voltage PV source circuits wired to a central string inverter, each module is paired with a single microinverter. .Microinverters mount to the rails underneath each module and haVE pre-wired connectors that mate with the module interconnects. The AC output of each inverter is then connected in parallel using special cable available from the manufacturer.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

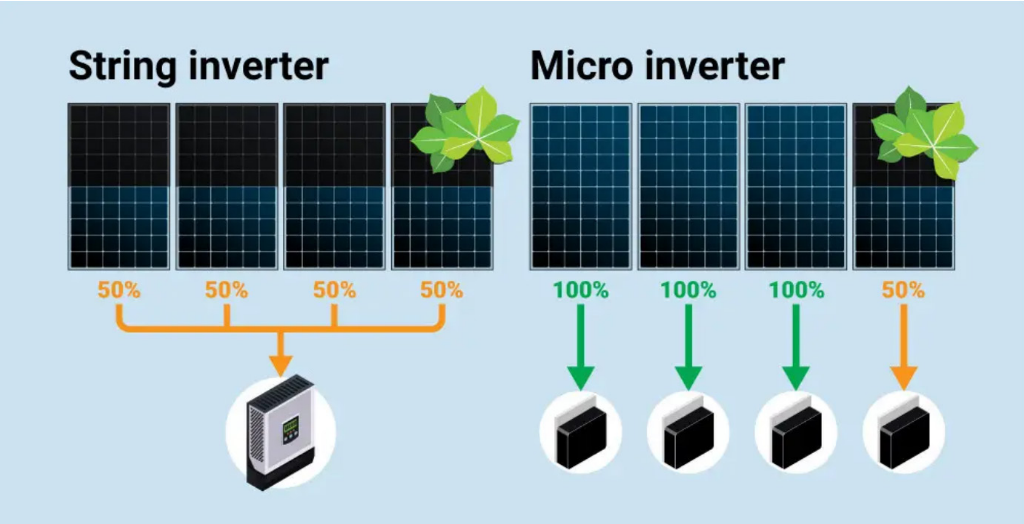
**Solar Installation**

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

a. Microinverters usually have a good data monitoring system which allows the owner or installer to view info about each module.

b. Inverter failure does not result in complete system shutdown, as in the case of string inverters




2. Here is a sample list of materials for wiring an array using microinverters.

   a. Enphase Q cable ( landscape or portrait) https://webshop.solarclarity.com/en/product/270077/enphase-q-cable-for-6096-cell-modules-

   b. Enphase IQ 7 microinverters https://enphase.com/installers/microinverters/iq7

   c. 6 enphase sealing caps

   d. Enphase terminator caps https://www.altestore.com/store/inverters/inverter-accessories/enphase-inverter-accessories/enphase-energy-sealing-cap-for-q-cable-connectors-p40743/?gclid=Cj0KCQjwrJOMBhCZARIsAGEd4VGa_QTWxV2DWuLLIig1fDaM97wTORc0xAaxs_4LJ-LzOoH254EFp18aAu-HEALw_wcB

   e. Engage cable clips Qty: 1 bag

   f. Qty: 20 each Enphase Male and Female field wireable connecters

   g. Qty: 5 - Enphase disconnect tools

   h. Qty: 3 - Breaker tie down kit

3. Teacher demonstrates how to approach the wiring task on the mock roof as the installation demonstration proceeds. The following may be used to prep for the install:

   EcoFoot MLPE Mounting Bracket

   Unirac Ecofoot2+ Universal Clamp Kit ES02+UNKTA

   How to install a soladeck - Soladeck install

### DAY 4

1. **Wiring the junction box to DC Systems** (Teacher demonstration)

   a. PVC junction boxes are commonly used, but if using a metal junction box remember to bond and ground the junction box. Double check your positive and negative home runs to be sure they are correct (reversing polarity will cause problems!). Remember, red is positive and black is negative (note: you can purchase red PV wire so that you do not have to label the wire with tape). If you have more than a single string of panels

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

you should label the wires with string numbers (ex. string 1 red and black should have a 1 labeled on it). Ensure that all positive and negative home runs have enough length to enter the junction box. Since the junction box is likely outdoors, ensure that you use a Heyco or similar connector to enter the junction box. Remember you will need a lock nut the same size as the Heyco connector to secure the Heyco connector to the junction box.

   b. Inside of the junction box you will transition from one wire type to another. A typical transition is from PV wire to THHN #10 wire. You transition the wires by stripping the end of each wire (about a quarter to half of an inch) and then wire nutting or Polaris Tapping the wires together. When finished, remember to tug test your wires! We transition to THHN because it is cheaper and easier to pull through conduit.
   c. Additionally you will need to make a hole in the junction box to bring in the equipment grounding conductor. This is usually bare copper wire and you will transition to green insulated wire. Use an irreversible crimp to merge these wires.
   d. If you are using a Soladeck with Din Rail you can use a wire termination block (that mounts to the din rail) to transition from PV wire to THHN. Usually the Soladeck comes with a ground bar (to transition the ground wire) and lug bonded to the case to bond the metal of the case to ground using a ground wire. Lastly, always drill a small hole in the bottom of a junction box (known as a weep hole) to allow water to drain should it somehow find a way into the box.

2. **Wiring the junction box for AC systems**
   a. PVC junction boxes are commonly used, but if using a metal junction box remember to bond and ground the junction box. If using Enphase Q cable use an Q Cable connector to enter the junction box. In this instance Black is L1 and Red is L2 (we are AC already so there is no positive and negative). If you have more than one branch circuit on the roof remember to label your circuits (example red and black pair are labeled branch 1, the next red and black pair are labeled branch 2).
   b. Inside of the junction box you will transition from one wire type to another. A typical transition is from Q cable to THHN #10 wire. You transition the wires by stripping the end of each wire (about a quarter to half of an inch) and then wire nutting or Polaris Tapping the wires together. When finished, remember to tug test your wires! We transition to THHN because it is cheaper and easier to pull through conduit.
   c. Additionally you will need to make a hole in the junction box to bring in the equipment grounding conductor. This is usually bare copper wire and you will transition to green insulated wire. Use an irreversible crimp to merge these wires.
   d. If you are using a Soladeck with Din Rail you can use a wire termination block (that mounts to the din rail) to transition from Q cable to THHN. Usually the Soladeck comes with a ground bar (to transition the ground wire) and lug bonded to the case to bond the metal of the case to ground using a ground wire.
   e. Lastly, always drill a small hole in the bottom of a junction box (known as a weep hole) to allow water to drain should it somehow find a way into the box.

3. **Pulling wire using a fish tape**
   a. Always use the ground wire to hook onto the fish tape (the goal is to never damage any wire, but if one wire should get damaged you want it to be the ground wire and not one of the hot wires!).
   b. Hook the ground wire to the fish tape and wrap electrical tape around the loop to keep the loop closed then continue taping down the ground wire and add wires every 3-4 inches. Make sure to stagger the wires when attaching them using tape so that you do not have a large bump. Wrap the tape tightly as you do not want wires to come off in the middle of a pull.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

c. If pulling a long distance, a tight pull, or there are a few turns you may want to use wire lube to allow the wires to slide through the conduit.

d. Lastly, you must have a pull point (an LB, junction box, something with a door on it) every 360º of turns. You cannot pull wire through more than 360º because you risk damaging the wire. In practice you should have a pull point at least every 270º of turns. All LB's, junction boxes, and pull points should have weep holes drilled into the bottom to allow water to escape should it enter the conduit.

   How to Attach Wire to a Fish Tape: How To Attach Wire To A Fish Tape

   Fish Tape Wire Pulling: Electrician Pro Tip: Fish Tape Wire Pull Prep

4. **Landing wires**

   a. DC Systems

      i. SolarEdge Installation Guide: How to Install SolarEdge | RENVU

      ii. Once you have pulled your wire from the junction box on the roof through to the inverters DC disconnect it is time to land the DC wires. Make sure to pull more wire than you will need into the DC disconnect. You will want to leave slack in the wire for expansion and contraction so do not pull wires tight. Keep your wires organized and tidy so if a service tech needs to come back and work inside the DC disconnect they will have an easy time determining what is what. Strip your wires about ¼" on the end. In a SolarEdge inverter there are DC terminal blocks. You will stick a small flat head screwdriver into the hole just above where the wire is to be landed and slightly twist the screwdriver. This will open the jaws on the terminal block. NOTE: Make sure you understand which terminals are for negative and which are positive, do not reverse the polarity! When the stripped end of the wire is in the terminal block remove your screwdriver from the top of the terminal block to close the terminal jaws on the wire. Tug test your wires to ensure they are installed correctly.

      iii. Interconnection

   b. AC Systems

      ENPHASE IQ Combiner Box + IQ Envoy Installation Manual

      Introducing the Enphase IQ Combiner Plus

      i. Once you have pulled your wire from the junction box on the roof through to the AC combiner box it is time to land the AC wires. Make sure to pull more wire than you will need into the AC combiner. You will want to leave slack in the wire for expansion and contraction so do not pull wires tight. Keep your wires organized and tidy so if a service tech needs to come back and work inside the AC combiner they will have an easy time determining what is what. Strip your wires about ¼" on the end. In an Enphase IQ AC combiner you are going to land the wires in 2 pole 20 Amp breakers. You will need to run the black wire (and ONLY the black wire) through the CT (the round doughnut) and then land them in the appropriate breaker. To land wire in the breaker strip the end about ¼" and screw it into the breaker. Make sure to tug test when done! Important: L1 and L2 matter! Make sure to follow the wiring diagram on the inside of the door of the IQ combiner. Black and red (L1 and L2) must remain the same throughout the install or the monitoring will show strange results.

      Wiring the AC disconnect: Installing a Solar AC Disconnect

      Wiring the interconnection: Solar panel wiring connection in house wiring diagram

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### DAY 5

**For Everest D-Dome East-West systems on a residential level** (informational, not for demo-install)

**Everest D-Dome Racking System:** Everest D Dome $R^2$ Quick Install Video (full demo of install in a lab setting)

Intro D-Dome: Everest D Dome $R^2$ System Introduction

1. Begin by popping east-west lines at the measurement of the width of a row of panels, 66 ⅜ strike them down the length of the array, let's say this array is 2 rows wide, strike three lines the length of the array that are parallel with each other and square to the roofs edge the array will be walking along.
2. Next place the base pads on the lines 39 ¼" from each other, as you place down the pads another crew member places down the bases.
   a. There are two bases for D-dome: the foot and the dome. They alternate foot, dome, foot, until the pads are filled.
   b. After the bases are placed they are connected together with the leg, a bar intended to slot into the base of the dome and bolt into the foot. This provides a place to attach the ballast bars for the racking,
   c. After all the legs are installed you must refer to your ballast plans to identify where and how many ballast block should be placed, you then walk around your array placing the ballast bars into the slotted channel on the legs and draw a number for how many block go in each ballasted section.
3. Once this is done you may load the number of blocks near each section for later and lay out your cable (PV Wire to homeruns or Q Cable Field Wire) to the projected ends of each string of panels.
4. Begin to set the panels: your Keystone panel is going to be the most important.
   a. With D-Dome you can use multiple panels as a keystone. To do this you can set four panels square to each other at either the east or west end of the array
   b. By doing this a larger keystone section is made and will run along a further distance on your east-west lines, ensuring a straight array.
   c. As you work down your array you'll need to wire manage and place block. Note: it is far easier to do this as you work down the array then to go back after all panels have been set and wire manage.
5. The final step is grounding your array. Everest requires one single ground lug as the array provides its own ground path, so you'll place a ground lug on the end of your array and run Bare #6 Cu from the lug to your Junction Box.

**Remember, a backfeed breaker must be installed on the opposite end of the bus bar from the main service disconnect.**

## RESOURCES/LINKS

https://unboundsolar.com/blog/step-by-step-diy-solar-installation

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### TOPIC OF STUDY

Solar Installation

**10th grade:** 4 HRS (2-3 SESSIONS)
**11th grade:** 8-10 HRS (4-5 SESSIONS)
**12th grade:** 8-10 HRS (5 SESSIONS)

## LESSON

Intro to Photovoltaic (PV) System Design

## OBJECTIVES

Students will:

- Identify the variables that impact PV system system design
- Identify which variables are a high priority for PV System Design

## BIG IDEA(S)

Photovoltaic system design utilizes knowledge from many disciplines. The PV system design process must take many different variables into consideration.

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### TOPIC OF STUDY

**Intro to PV System Design**

90 MINUTES

## TASK LIST SUBCATEGORY

Level 1 students will:

**401** Identify solar mechanical and electrical components

**402** Select appropriate components to design a solar system

**416** Use solar industry vocabulary

## OVERVIEW

Level 1 students will receive an introduction to design. This lesson will introduce students to the wide array of variables that impact PV System designs. These variables include roof characteristics, existing electrical systems, available components, manufacturers' specifications, and sun characteristics of the site.

## KEY TERMS

array size
string sizing
voltage drop
derate factors
kWh/KW/year
temperature coefficient

## STANDARDS

### PA

**3.4.10.A1.** Illustrate how the development of technologies is often driven by profit and an economic market.

**3.4.10.E7.** Evaluate structure design as related to function, considering such factors as style, convenience, safety, and efficiency.

## INSTRUCTIONAL

### TEXT/REFERENCES

Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013

### MATERIALS NEEDED

**Teacher Presentation:** Presentation 400-6

**Content:** Handouts, Installation Manuals, Plan Sets, Three Line Diagrams, Online Resources / Videos / Manufacturer's Websites, Books, PowerPoint Presentation, Installation Pictures, Lab / Hands-On, Field Trips

**Technology:** Computers with internet

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

- Ask student teams to brain storm all of the variables that might affect the design of a PV system on a client's roof.

### EXPLORE

1. In advance prepare a set of index cards for each group. On each card should be one of the variables from the presentation (i.e. client power consumption, roof type, roof condition, rafter spacing, fire code, roof tilt, shading, existing electrical panel, etc…).
2. Have each team sort through the deck and sort the variables into high priority and low priority. Which variables are deal breakers for the client? Which variables if not within a certain range prevent the installation? (i.e. roof structure, peak sun, etc…)

### EXPLAIN

- Have student groups explain their rationale to the class for their sorting choices.

### EXTEND

1. Student teams should revisit cards and come up with 2-3 key reasons each variable plays a role in the overall PV System Design.
2. Assign one variable to each team for further investigation. Have teams use internet to research their assigned variable.
3. Have students report back to whole group to teach each other what they learned.
4. Teacher wraps up class by going through the power point presentation as a review to bring it all together.

### EVALUATE

- Develop a short matching quiz for the variables and the reason for their importance.

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SOLAR

**TOPIC OF STUDY**

**Intro to PV System Design**

90 MINUTES

## LESSON

Manufacturers Specifications

## OBJECTIVES

Students will:

- Interpret manufacturer specifications for a PV inverter
- Use an installation manual for a PV inverter

## BIG IDEA(S)

It is important to adhere to manufacturer specifications.

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### TOPIC OF STUDY

**Intro to PV System Design**

180 MINUTES (2 SESSIONS)

## TASK LIST SUBCATEGORY

**415** Demonstrate knowledge of manufacturer specifications

**405** Identify the factors related to system sizing and production

**402** Select appropriate components to design a solar system

## OVERVIEW

Following manufacturers' guidelines can save time and money. Cutting corners and not following the directions may void a product's guarantee. During this session, the teacher should stress the importance of manufacturer specifications. The teacher should introduce students to this topic by reviewing a complete installation manual for a popular inverter.

## KEY TERMS

input voltage
maximum power point tracking (MPPT)
PV source circuit
Overcurrent Protection Devices (OCPD)
startup voltage

## STANDARDS

### PA

**CC.3.5.9-10.A.** (Specific Anchor, Key Ideas and Details) Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**CC.3.5.9-10.E.** Reading (Specific Anchor, Craft and Structure) Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, or energy).

**Construction Career Pathway (AC-CST)** Compare and contrast the building systems and components required for a construction project.

## INSTRUCTIONAL

### TEXT/REFERENCES

Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013

### MATERIALS NEEDED

**Teacher Presentation:** Solaredge Inverter Installation Manual

**Content:** Text Book - Chapter 12

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

- Ask students what the word specific means.

### EXPLORE

1. Ask pairs of students to each write out a set of directions for their partner for a simple task (i.e. build a small lego structure, make a peanut butter and jelly sandwich, etc…).
2. Have students complete the task exactly as their partner's direction state.

### EXPLAIN

1. Have students discuss what went wrong with the directions they were given.
2. Have students revise their directions to incorporate the feedback from their partners.

### EXTEND

- Student pairs should read through the Solaredge manual and create a checklist that includes items needed and things to be mindful of during the installation process.

### EVALUATE

- Students should present to the teacher their plans for installation of the inverter based on their interpretation of the manual.

## RESOURCES/LINKS

Solaredge Manual

https___www.solaredge.com_sites_default_files_se_hd_wave_inverter_SetApp_installation_guide.pdf

Why Contractors Need to Appreciate Manufacturers' Guidelines and Specifications

https://fixingpoint.com/news-and-press/why-contractors-need-to-appreciate-manufacturers-guidelines-and-specifications

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Intro to PV System Design**

180 MINUTES (2 SESSIONS)

## LESSON

Connectors, Wire Terminations, and Wire Management for Solar

## BIG IDEA(S)

Connectors are one of the most critical parts of a solar installation and also one of the most common points of failure when improperly installed.

## OBJECTIVES

Students will be able to:

- Explain the importance of connectors, wire termination, and wire management
- Make male and female MC4 & Enphase connectors
- Perform multiple wire termination methods
- Perform multiple wire management techniques

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Solar Installation**

3-4 HOURS (2 SESSIONS)

## TASK LIST SUBCATEGORY

**502** Demonstrate effective assembly of field-made connectors and conductor fabrication

**503** Demonstrate effective conductor termination and wire management techniques

## OVERVIEW

Students will learn how to make field made connectors and why it's necessary. Students will get hands-on experience making connectors of different types. Additionally, wire termination methods will be demonstrated and explained. Students will get experience terminating wires. Lastly, solar wire management will be demonstrated and explained. Students will have the opportunity to wire manage a solar array.

## KEY TERMS

MC4
backing nut
pin
connectors
Wiley clip
zip tie
nylon
terminal block
din rail
junction box
Enphase connector

## STANDARDS

### PA

**3.4.12.B2.** Illustrate how, with the aid of technology, various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.E7.** Analyze the technologies of prefabrication and new structural materials and processes as they pertain to constructing the modern world.

### NGSS STANDARDS

**HS-ETS1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

### COMMON CORE MATH

**HSG.MG.A.3**. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

## INSTRUCTIONAL

### TEXT/REFERENCES

What is a terminal block

https://www.electricaleasy.com/2018/03/terminal-block-types.html

## INSTRUCTIONAL - CONTINUED

How to crimp an MC4 connector

https://www.explorist.life/how-to-crimp-mc4-connectors/

Why is wire management important

https://www.solarpowerworldonline.com/2018/11/why-wire-management-is-important-to-solar-project-reliability-safety-and-life/

How to make enphase connectors

https://www.youtube.com/watch?v=aLMaE8n8KLk

### MATERIALS NEEDED

**Teacher Prep**: 502 & 503 - Field made connectors, terminations, wire management

### MATERIALS

- MC4 connectors
- Enphase connectors
- Wiley clips
- Zip ties
- Junction box
- Din rail
- Terminal blocks
- Polaris connectors
- Wire strippers
- MC4 crimp tool
- Screw drivers

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SOLAR

TOPIC OF STUDY

Solar Installation

3-4 HOURS (2 SESSIONS)

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE/EXPLORE

- We are at the point in installation where we need to connect components. Lets' look at the materials and tools we need to use to master the skills of connection. Show materials and tools in the lab, explain tool use and safety.
  a. If you do not have connectors stocked in your classroom you can show presentation: 502 & 503 - Field made connectors, terminations, wire management and videos referenced above.
  b. Take questions as you go through live.

### EXPLAIN

1. Impress upon the students that field made connectors and wire terminations are a common failure point in solar arrays. This is the number one reason for service and call backs. Performing these tasks is critical to a high quality and safe solar installation.
2. Loose connectors and terminations can cause arcing which can melt components and cause a fire (particularly when near dry leaves).
3. Pro tip: Keep wiley clips on the brim of your baseball hat so that they are easy to grab when you need them.
4. Use resources as needed to demonstrate techniques
   a. What is a terminal block: https://www.electricaleasy.com/2018/03/terminal-block-types.html
   b. How to crimp an MC4 connector: https://www.explorist.life/how-to-crimp-mc4-connectors/

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

c. Why is wire management important: https://www.solarpowerworldonline.com/2018/11/why-wire-management-is-important-to-solar-project-reliability-safety-and-life/
d. How to make enphase connectors: https://www.youtube.com/watch?v=aLMaE8n8KLk

### EXTEND

- After demonstrating crimping techniques, students break into pairs and crimp connectors.
  - One person working and the other performing quality control.
  - Repeat for wire termination and wire management.

### EVALUATE

- Provide roving conferences and demonstrate where needed to assure that students are using techniques properly. If this is a 12th grade Capstone team, provide very specific feedback.

## MEETING INDIVIDUAL NEEDS

- Presentation can be used for students who struggle using tools and hands-on learning.
- Students not comfortable using their hands for work can bring tools to the classroom and can organize tools and materials needed to return them to storage.
- Students can test other students' work by performing tug tests and other quality control tasks.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

Solar Installation

3-4 HOURS (2 SESSIONS)

## LESSON

Equipment Labeling for Commissioning and Certification

## BIG IDEA(S)

Buildings with PV systems need permanent labels located at each service equipment location to which the PV systems are connected or at an approved readily visible location and also at rapid shutdown initiation devices.

## OBJECTIVES

Students will be able to:

- Determine the max voltage, operating voltage, fault current, and operating current of the system by reviewing spec sheets and performing calculations
- In the classroom solar array setup, have students apply labels
- List the steps for a rapid shutdown procedure

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Solar Installation**

2 HOURS EACH LEVEL

## TASK LIST SUBCATEGORY

**510** Students will be able to properly label a solar array

## OVERVIEW

Students will be taught the importance of labels, that they are required by code, and understand the calculations needed to label voltage and current properly.

## STANDARDS

### PA/SDP

**3.4.12.B1.** Analyze ethical, social, economic, and cultural considerations as related to the development, selection, and use of technologies.

**3.4.12.B2.** Illustrate how, with the aid of technology, various aspects of the environment can be monitored to provide information for decision making.

**3.4.10.B1.** Compare and contrast how the use of technology involves weighing the trade-offs between the positive and negative effects.

## KEY TERMS

AC disconnect
DC disconnect
label
operating voltage
open circuit voltage
operating current
short circuit current
NEC
rapid shutdown

## INSTRUCTIONAL

### TEXT/REFERENCES

SEI Solar Electric Handbook, p. 250

NEC Articles 690.54, 690.56(B), 690.4(D), 690.13(B), 690.53, 690.31(D)(2), 690.15, 690.56(C)

### MATERIALS NEEDED

**Teacher Prep:**

NEC Articles 690.54, 690.56(B), 690.4(D), 690.13(B), 690.53, 690.31(D)(2), 690.15, 690.56(C)

https://www.purepower.com/blog/2017-nec-690.12-rapid-shutdown-important-changes

### MATERIALS

Label maker

Preprinted PV stickers (purchase at https://www.pvlabels.com/)

## INSTRUCTIONAL - CONTINUED

**Technology:**

NEC labeling guide

Solar Best Practices in Applying Labels

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TOPIC OF STUDY

Solar Installation

2 HOURS EACH LEVEL

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

- Review the Hellerman Titan labeling guide and watch the labeling video (11 minutes)

### EXPLORE/EXPLAIN

1. Have students determine the max voltage, operating voltage, fault current, and operating current of the system by reviewing spec sheets and performing calculations where necessary:
    a. Ex: Enphase micro inverters max output current is 1.1 amps. If there are 10 microinverters wired in parallel what is the max current? 10 x 1.1 = 11.
    b. Ex. Enphase systems are typically 240V systems so the operating voltage is 240V.
    c. If using DC optimizers the operating and max voltage can be found on the spec sheet and, when wired in series, the operating current is the current of the solar panel.
2. Have students print labels, it is a code violation to hand write on labels.
3. If your classroom has a solar array setup, have students apply labels as required.

### EXTEND

- Discuss Rapid Shutdown, why is it important? What does it do?
    a. https://www.purepower.com/blog/2017-nec-690.12-rapid-shutdown-important-changes
    b. Rapid Shutdown For Solar
        i. Rapid shutdown is to protect first responders from electrical shock.
        ii. It de-energizes a solar array at the panel level. Before rapid shutdown strings of panels would remain energized even when the disconnect was in the off position.
        iii. It only applies to roof mounted systems.

## HOMEWORK

Find the operating current and voltage for 9 Enphase IQ7+ microinverters wired in parallel.

## MEETING INDIVIDUAL NEEDS

Hands on learners can print labels and go around and stick them in the proper locations.

## RESOURCES/LINKS

Solar Installation Labeling Requirements for Permit Inspection. DIY solar installation

Solar Best Practices in Applying Labels

Solar Labeling Requirements

## LESSON

Understanding What Electricity Is, Terms, and Calculation

## BIG IDEA(S)

Electricity is a form of energy characterized by the movement of electrons. We can measure and describe the work done by electricity.

## OBJECTIVES

Students will be able to:

- Understanding what electricity is
- Know the units used to calculate electrical power
- Recognize and explain electrical symbols
- Describe the difference between power and energy

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## TOPIC OF STUDY

**Electricity Basics**

90 MINUTES

## TASK LIST SUBCATEGORY

**702** Recognize and use electrical concepts, terminology, relationships, and formulas

**102** Describe how energy is fundamental to our everyday lives

## OVERVIEW

At its most fundamental level, electricity is the movement of electrons between atoms. A long line of electrons bangs into each other, creating an electrical flow. When we move electrons we get electrical energy. Electricity itself is the name we give to the type of energy that comes from this electrical energy.We measure electricity and electrical units using several systems that are all interlinked.

## INSTRUCTIONAL

### MATERIALS NEEDED

**Technology:** Multimeters

## IMPLEMENTATION (LESSON PLAN)

### LECTURE & DISCUSSION

- Present Electricity Basics: https://docs.google.com/presentation/d/1N6W5EZ_L934YOsHsfBr3IzIW4sQw4uNZwrnhVTj_NwI/edit#slide=id.g742e3e7cd_1_16
- Discuss and present different ways to use Ohms Law Wheel to calculate volts, watts, amps, and resistance
- Electrical symbols
- Electrical units of measurement
- Ensure students have an understanding of the concept of power
- Ask students to calculate power
- Discuss energy and how it relates to power
- Ask students to calculate energy instead of power.

## KEY TERMS

amps
Ohm's Law
volts
watts
resistance
power
energy
multimeter
load

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### DISCUSSION

Why does it matter that power and energy are different?

How does all of this relate to solar energy?

### ACTIVITIES

- Use a multimeter to test voltage at a power outlet
- Use a multimeter to test amps of a plugged in load
- Use a multimeter to test
  - Students pair off forming 2 parallel lines facing each other.
  - The rule is to say as many random words to each other as possible. The words cannot relate to each other in any way (so grass and then green are not allowed). For example: one person says "space" the other says "shoe"
  - You cannot repeat words nor can you say anything you see in the room
  - See how long students can go say random words to each other, game should last about a minute or a minute and a half
  - Ask students if it was hard?
  - Let them know that they know thousands of words and they use them everyday, but when asked to use them in a new way it becomes hard.
  - Did anyone come up with a strategy? Did anyone just ignore what the other person was saying?

### HANDS ON EXERCISE

- How do you know when power is present? How can you measure it?
- What are electrical loads? What uses the most power in a home? – Introduce multimeters.
- Measure voltage at outlets in the classroom.
- Measure current of devices in classroom radio, fan, cell phone charger, AC, etc.

**Recap day's lessons learned.**

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TOPIC OF STUDY

Electricity Basics

90 MINUTES

## LESSON

Introduction to the National Electric Code (NEC) (Lesson 711 NEC)

- NEC Responsibilities
- NEC 690 Solar Definitions

## OBJECTIVES

Students wil:

- Explain the purpose of the NEC rules that govern how to safely install solar systems.

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**TOPIC OF STUDY**

**Electricity Basics**

1 HOUR

## BIG IDEA(S)

NFPA 70, National Electrical Code (NEC) is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards and includes rules for installing PV systems.

## TASK LIST SUBCATEGORY

**710** Explain the purpose of the National Electric Code

**711** Demonstrate how to use the National Electric Code Book as a reference guide

## OVERVIEW

The NEC is the book of rules that governs how to safely install solar systems. Remember, the NEC is the baseline for SAFETY when designing and installing solar systems. It is not about optimal design; those are two very different things.

The NEC is written by the National Fire Protection Association (NFPA, referred to as NFPA 70). It is the basis for most Authorities Having Jurisdiction (AHJ) codes and regulations. That said, every AHJ has its own rules that can supersede the NEC and utilities may have additional sets of rules and regulations that must be followed (For example there is the PECO Yellow Book, with rules governing cogeneration on the PECO distribution grid).

In the BSF Solar Technician program, the teacher will provide examples of how and when to use the NEC reference. For example, when teaching Power Tolerance and Nominal Voltage for PV panels, the teacher will demonstrate how to find the definition:

> *NEC defines nominal voltage in Article 100 as follows:*
>
> *"A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g. 120/240 volts, 480/277 volts, 600 volts). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment."*

**IMPORTANT NOTE:** The NABCEP Associate Exam does not include the NEC code. However, it is important to be aware of the Code's impact on PV installation since many of the rules must be followed for safety.

## STANDARDS

### PA/SDP

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

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**TOPIC OF STUDY**

**Electricity Basics**

1 HOUR

## STANDARDS - CONTINUED

### NGSS STANDARDS

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

- Provide several copies of the NEC reference (or provide on-line access. Have pairs of students explore the references and share comments about something they have found.

### EXPLORE

- Review the Table of Contents and demonstrate how something is researched. Call attention to sections that would be used to explore topics in solar installation. What topics or related components or procedures do students predict would be covered?

### EXPLAIN

1. The NEC is the book of rules that governs how to safely install solar systems. Remember, the NEC is the baseline for SAFETY when designing and installing solar systems. It is not about optimal design; those are two very different things. The NEC is written by the National Fire Protection Association (NFPA, referred to as NFPA 70). It is the basis for most Authorities Having Jurisdiction (AHJ) codes and regulations. That said, every AHJ has its own rules that can supersede the NEC and utilities may have additional sets of rules and regulations that must be followed (For example there is the PECO Yellow Book, with rules governing cogeneration on the PECO distribution grid).
2. The NEC book is very long and can be hard to understand. It deals mostly with topics that are not directly related to solar. It is important to try and read relevant sections even though you may not necessarily understand them. The more you read the code the more you will see how it's applied when you are in the field.
3. The NEC code book is updated every three years (for example: NEC 2011, 2014, 2017, 2020). It is very rare for the most recent code version to be approved by the AHJ, meaning that it is more likely the AHJ is using an older version of the NEC. For example, up until 2019 the City of Philadelphia was using NEC 2008, then in 2019 it approved NEC 2014 to be used with residential applications and NEC 2017 to be used with commercial applications. Usually Massachusetts adopts the most current version of the NEC and then all other states and municipalities follow after a number of years.

### EXTEND

1. The information about solar is mostly found in Article 690. 690.1 gives the scope of the entire article while 690.2 is about definitions. 690.3 is about "Other Articles" and basically says that if any other sections of the code conflict with Article 690 than Article 690 will supersede them. This makes Article 690 the authoritative location to find information about solar systems. In NEC 2014 Article 690 starts on page 623 and ends on page 638. It is very important that you read the entire article and have a firm understanding of the NEC as it pertains to solar.

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

2. Examples of Solar Rules in NEC:
   a. There are also a number of other articles and tables that are very important when it comes to solar energy:

      ***Table 310.1S(n)(3)(a) Adjustment Factors for More Than Three Current-Carrying Conductors:*** When there are more than 3 current carrying conductors in a raceway the ampacity of the conductor needs to be derated from what what is listed in Table 310.15(B)(16).

      **NOTE:** You may need to use multiple derate calculations on a single conductor. For example: if a conductor is used in 130ºF heat and there are 5 conductors in a raceway then the conductor will need to be derated for the ambient temperature as well as the increased temperature in the raceway due to the fact that there are so many conductors.

      ***Table 110.28 Enclosure Selection:*** This table deals with the enclosures and the minimum ratings for different use types. For example: NEMA 1 is for indoor use whereas NEMA 3R can be used outdoors. There are more classifications than you might think, so be sure to understand this table well.

      ***Section 352: Rigid Poly-Vinyl Chloride: Type PVC:*** This section deals with all of the rules when using PVC conduit.

      ***Section 358: Electrical Metallic Tubing: Type EMT:*** This section deals with all of the rules when using EMT conduit.

      ***Section 250: Grounding and Bonding:*** This section spells out the rules for safely grounding all electrical equipment including the equipment grounding conductor (EGC) and the grounding electrode conductor (GEC).

## RESOURCES/LINKS

NEC Scope 2020
https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Electricity Basics

1 HOUR

## LESSON

Electrical Safety

## BIG IDEA(S)

There are specific tools and techniques that are used to safely work with electrical systems.

## OBJECTIVES

Students will be able to:

- Understand the different types of electrical hazards
- Demonstrate basic electrical safety skills
- Connect things that everyone loves to do to energy and demonstrate the large role electricity plays in everyone's life
- Trace the pathway of electricity generation, transmission, and distribution

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### TOPIC OF STUDY

**Electrical Safety**

2 HOURS (2 SESSIONS)

## TASK LIST SUBCATEGORY

**305** Recognize and mitigate hazards

**311** Recognize, identify and safely use hand tools and power tools

**702** Recognize and use electrical concepts, terminology, relationships, and formulas

## OVERVIEW

The voltage of the electricity and the available electrical current in regular businesses and homes has enough power to cause death by electrocution. Even changing a light bulb without unplugging the lamp can be hazardous because coming in contact with the "hot", "energized" or "live" part of the socket could kill a person.

All electrical systems have the potential to cause harm. Electricity can be either "static" or "dynamic." Dynamic electricity is the uniform motion of electrons through a conductor (this is known as electric current). Conductors are materials that allow the movement of electricity through it. Most metals are conductors. The human body is also a conductor.

Electric current cannot exist without an unbroken path to and from the conductor. Electricity will form a "path" or "loop". When you plug in a device (e.g., a power tool), the electricity takes the easiest path from the plug-in, to the tool, and back to the power source. This action is also known as creating or completing an electrical circuit.

## KEY TERMS

arc flash
closed circuit
electricity
energy
power
electrocution
open circuit
insulator
loads

## INSTRUCTIONAL

### TEXT/REFERENCES

NFPA 70e Standard for Electrical Safety in the Workplace

Solar Electric Handbook, SEI, 2013. Pp. 346-348

### MATERIALS NEEDED

#### MATERIALS

Demo: electrically insulated gloves (rated for different voltages), arc flash rated hard hats, face shields, flame retardant clothing

## IMPLEMENTATION (LESSON PLAN)

1. Basic Rules
   a. To get a full understanding of the various hazards that exist in the workplace please reference NFPA 70e Standard for Electrical Safety in the Workplace: NFPA 70E requirements for safe work practices to protect personnel by reducing exposure to major electrical hazards.
   b. Only qualified persons are permitted to work on electrical equipment
   c. If at all possible (even if it inconveniences the client) a person should work on de-energized equipment or wiring. Working while no power is present can save lives! Additionally, always double check your work before energizing.
   d. Seeing an off sign or switch in the off position is NOT good enough! Just because a breaker says a circuit is off or a switch is in the off position does not mean the equipment you want to work on is safe. You must always use a voltage wand (non-contact voltage tester) or multi-meter in order to determine there is no voltage present.
   e. If you are working on a particular circuit, service, or piece of equipment and you have de-energized it but the switch for energizing is not within sight then you must use lock-out tag out. Lock out tag out is the industry standard for safely de-energizing equipment and ensuring it remains de-energized while work is being performed.
   f. When turning off larger electrical equipment understand the hazards and plan out how to mitigate them. For example: if a large knife switch needs to be thrown to open a circuit do not stand in front of the door of the knife switch just in case an arc blows the door off. The door exploding into you could potentially crush you.
   g. If you must work on a live circuit then you must wear rated electrical gloves (the rating of the glove must be higher than the voltage you are working with). Proper use of electrical gloves is very important. First you should put on a thin cotton glove to absorb sweat. Then put on the rated rubber electrical glove. Lastly place a leather glove over the rubber glove to protect from cuts or abrasions in the rubber gloves. Additionally, you should wear eye protection and an electrically rated hard hat. Class E (Electrical) Hard Hats are designed to reduce exposure to high voltage conductors.
   h. When working in an area where an arc flash is possible it is important to wear an arc flash suit.
2. Types of Hazards
   a. Electrical shock - Electrical shock occurs when electrical current enters the body. Electrical current can cause serious physical harm including damage to your heart. Electrical shocks can be fatal or lead to serious injuries.
   b. Arc Flash - Simply put, an arc flash is a phenomenon where a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. The results are often violent and when a human is in close proximity to the arc flash, serious injury and even death can occur. https://www.osha.gov/sites/default/files/2018-12/fy07_sh-16615-07_arc_flash_handout.pdf
3. Gear
   a. Electrical Gloves
   b. Electrical rated hard hat
   c. Glasses
   d. Arc flash suit
   e. Insulated tools
   f. Fiberglass ladder
   g. Voltage wand
   h. Multi-meter

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

Electrical Safety

2 HOURS
(2 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

4. Safety is everyone's responsibility

   Designate a student who is responsible for checking for electrical hazards and have them prepare a plan to mitigate the hazards.

## MEETING INDIVIDUAL NEEDS

### STUDENTS WHO NEED LEARNING SUPPORT

Students can try on various pieces of safety gear. Have students practice working with electrical gloves on so they can get used to the feeling.

### STUDENTS WHO HAVE DEMONSTRATED EARLY MASTERY

Advanced learners can deep dive into electrical safety and how to know when an arc flash hazard is present as well as the steps to mitigate it.

## LESSON

Mounting and Structural Considerations

## OBJECTIVES

Students will:

- Deep dive into racking manufacturer product specifications
- Identify components that comprise the racking

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SOLAR

### TOPIC OF STUDY

**Solar Project Management and Design**

4.5 HOURS (3 SESSIONS)

## TASK LIST SUBCATEGORY

**407** Describe the main types of solar mounting systems

**408** Identify the factors establishing structural suitability for solar panels

**409** Identify the impact of building design on solar installation

## OVERVIEW

Solar project management and design encompasses responsibility to design efficient solar systems. This is achieved through understanding the steps of a solar installation and what causes designs to fail.

## STANDARDS

### PA/SDP

**3.4.10.E7.** Evaluate structure design as related to function, considering such factors as style, convenience, safety, and efficiency.

**Pathway AC-CST:** Construction Career: Compare and contrast the building systems and components required for a construction project.

## KEY TERMS

rail
railless system
ballast
inter-row shading
mid-clamp
end-clamp
ballast mount
ground mount
single axis tracker
dual axis tracker
tracker

## INSTRUCTIONAL

### TEXTS/REFERENCES

Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013

### MATERIALS NEEDED

**Teacher Presentation:** 400-2 Presentation

**Content:** Handouts, Installation Manuals, Plan Sets, Three Line Diagrams, Online Resources / Videos / Manufacturer's Websites, Books, PowerPoint Presentation, Installation Pictures, Lab / Hands-On, Field Trips

## IMPLEMENTATION (LESSON PLAN)

1. Powerpoint - Review different types of racking. How do these differ from each other?
2. Supplement the class with product videos
    a. https://unirac.com/solarmount/

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

3. Review Chapter 9 - Mounting - *Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013*. This chapter provides students with a wider perspective of the different types of racking applications.
4. Review Chapter 10 - Roofing Systems - *Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013*. This chapter will help students understand the structural considerations of solar.

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SOLAR

TOPIC OF STUDY

Solar Project Management and Design

4.5 HOURS (3 SESSIONS)

## LESSON

Photovoltaic Career Pathways

## BIG IDEA(S)

There are numerous career pathways in the renewable energy industry.

## OBJECTIVES

Students will:

- Compare and contrast a variety of PV-related careers
- Design and implement a public service announcement showing PV-related careers aimed towards an 8th-9th grade audiences

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SOLAR

### TOPIC OF STUDY

**Photovoltaic Career Pathways**

90 MINUTES

## TASK LIST SUBCATEGORY

**203** Communicate the value of solar energy to different audiences

## OVERVIEW

There are numerous career pathways in the renewable energy industry and the field continues to grow.

## STANDARDS

### PA/SDP

**13.1.11.A.** Relate careers to individual interests, abilities, and aptitudes.

## KEY TERMS

career pathways

## INSTRUCTIONAL

### MATERIALS NEEDED

**Teacher Presentation:** NABCEP PV Career Pathways Brochure

**Content:** Internet resources listed below

**Technology:** Devices with audio and video recording software/apps

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

1. Show the following Solar Jobs video to students. Ask students to list all of the jobs mentioned during the video.
2. Review student answers as a whole class.

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

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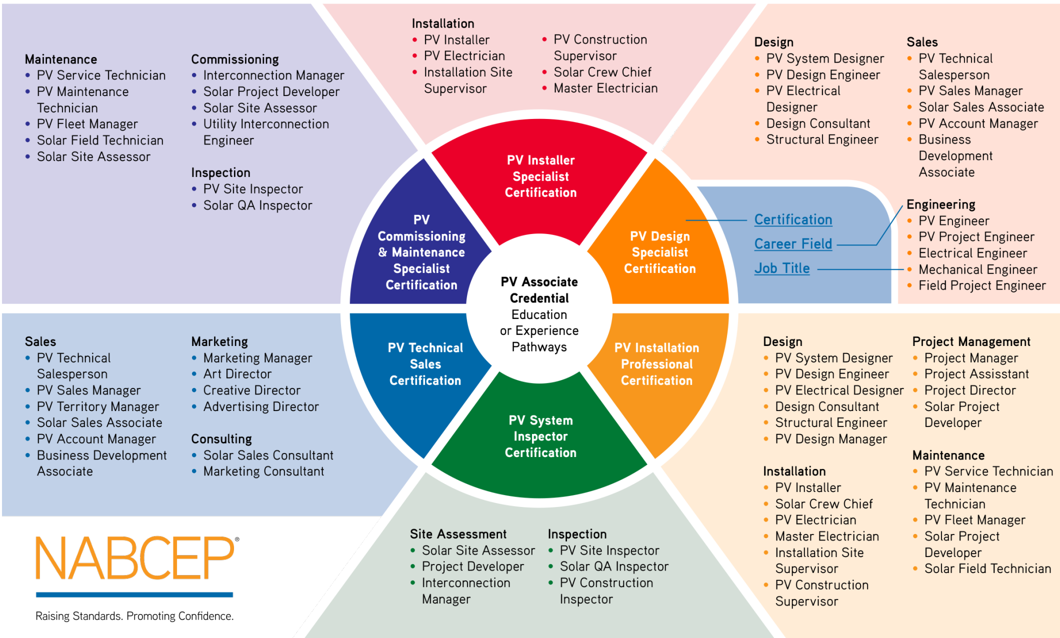
### EXPLORE

1. Provide students with a copy of the Solar Career Wheel from NABCEP pictured below.




2. Put students into teams of 2-3 individuals per group.
3. Assign each group one of the six sectors of the Solar Career Wheel.
4. Explain to students that they must research their assigned career sector and develop a public service announcement geared toward recruiting 8th or 9th graders to the program. (The teacher should select the format of the PSA based upon available time and technology - either a narrated powerpoint presentation or a 2-3 min video.).
5. Provide students with guidelines of what information to gather and include. Examples include: amount of education, salary ranges, day-to-day tasks, working conditions (indoor/outdoor), positive benefits, skills needed, etc…
6. Provide students with internet resources listed at the end of this lesson to help get them started on their research, including the IREC Career Map.

### EXPLAIN

- Student groups share their final presentations to the whole class, including a Q&A session.

### EXTEND

1. Students and teachers make arrangements to present to 9th grade classes at their home school.
2. If possible, have students also present to 8th grade classes at local middle schools.

### EVALUATE

- Teacher can assess students on both the accuracy and level of detail for the presentations and also on their overall communication skills with the 8th and 9th grade audiences.

SOLAR

**TOPIC OF STUDY**

**Photovoltaic Career Pathways**

90 MINUTES

## RESOURCES/LINKS

CareerWatch: Become a Solar Panel Installer in 2021
https://youtu.be/dzPLvdjBNEs

Interstate Renewable Energy Council
https://irecusa.org

IREC Solar Career Map
http://irecsolarcareermap.org

NABCEP PV Career Pathways Brochure
https://www.nabcep.org/wp-content/uploads/2020/11/Certification-Brochure-Career-Map-11.23.2020.pdf

Solar Jobs
https://youtu.be/-HsIeoJlcFg

## LESSON

Principles of Energy and Physics

## BIG IDEA(S)

The fundamental concepts of fundamental concepts of power and energy are important to understand for solar technicians and any career pathway related to energy efficiency.

## OBJECTIVES

Students will:

- Explain energy, its varieties, sources and behavior
- Explain the laws of thermodynamics and provide examples
- Explain examples of energy measurement including use of both Fahrenheit and Celsius scales
- Use entropy (Delta T) to explain how the stack effect works in a house

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

Energy Systems

90 MINUTES

## TASK LIST SUBCATEGORY

**101** The principles and physics of energy

## OVERVIEW

Power and Energy is covered in both the solar and weatherization fields. Kinetic and potential energy is reviewed as well as the important ideas of power and energy. For energy conservation measurement, Ohm's Law and forms of energy are important to understand since they are the big ideas that guide the work of a technician.

## STANDARDS

### PA

**3.2.12.B3.** Describe the relationship between the average kinetic **molecular** energy, temperature, and phase changes.

**3.2.10.B2.** Explain how the overall energy flowing through a system remains constant; Describe the work- energy theorem. Explain the relationships between work and power

**3.2.C.B3.** Describe the law of conservation of energy.

## FURTHER DEFINITION OF KEY TERMS

| | |
|---|---|
| Voltage: Electrical pressure (V or E) | Measured in Volts = V |
| Current: Electrical Flow | Measured in Amps = A |
| Power: Rate at which electricity is used (I) | Measured in Watts = W |
| Energy: amount of electricity used | Measured in Wh or kWh (Watt hours or kilowatt hours) |
| Power = Voltage x Current<br>W = V x A | Energy = Power x Time |

## KEY TERMS

current
energy
work
mass
inertia
kinetic energy
potential energy
mechanical energy
chemical energy
Ohm's Law
kW (killowatt)
voltage (V or E)
resistance

# INSTRUCTIONAL

## TEXTS/REFERENCES

Solar Photovoltaic Basics, Sean White, 2019, pp.23-30

Solar Electric Handbook: Photovoltaic Fundamentals, SEI, 2013. pp 40-46

## MATERIALS NEEDED

**Teacher Prep and Presentation:**

- Use the following resource to solidify lesson plan: Introduction to Energy
- Electricity Basics Lesson Plan
- Work and Energy: https://www.youtube.com/watch?v=pmOXi-My6ZI, up to 1:32.

**Content:**

### MATERIALS

- Balls of different sizes and weights to demonstrate energy principles
- Candle and matches to illustrate potential and kinetic energy; chemical, radiant, thermal energy; illuminated clear incandescent light bulb

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Energy Systems

90 MINUTES

# IMPLEMENTATION (LESSON PLAN)

## ENGAGE

1. Candle activity
   a. Use a candle and match to illustrate potential and kinetic energy, and bring in chemical (candle), radiant (light) and thermal (heat emission using a blown up balloon moving it closer to the flame to let it pop).
   b. Review the demo and ask for deeper explanations of potential and kinetic energy illustrated. Ask for a definition of each. Discuss the properties of the candle, light and heat, assessing student background knowledge. Use the chart to present the major kinds. You can build your own chart for students as you explore the main types of energy that can remain in the classroom for reference.
2. Additional Engagement/Intro
   a. Ask students to talk about what they think energy is in the normal conversational sense; what they think work is, what they think mass is, for all the vocabulary terms. Then tell them what the definitions are for each of these words within solar energy/physics Then show the two YouTube segments, stopping at minute 1:32 in the first. Have students ask questions, with both student and teacher responses. Bring in balls of differing sizes, place them on a surface and ask about their potential energy, kinetic energy. Then hold them above the surface asking the same questions.
   b. Next take the balls and push them gently to make them roll on the surface. Ask students which balls required more force to move and what would make them move faster. Which balls have the most kinetic energy when in motion? What happens when they strike one another?

BRIGHT SOLAR FUTURES

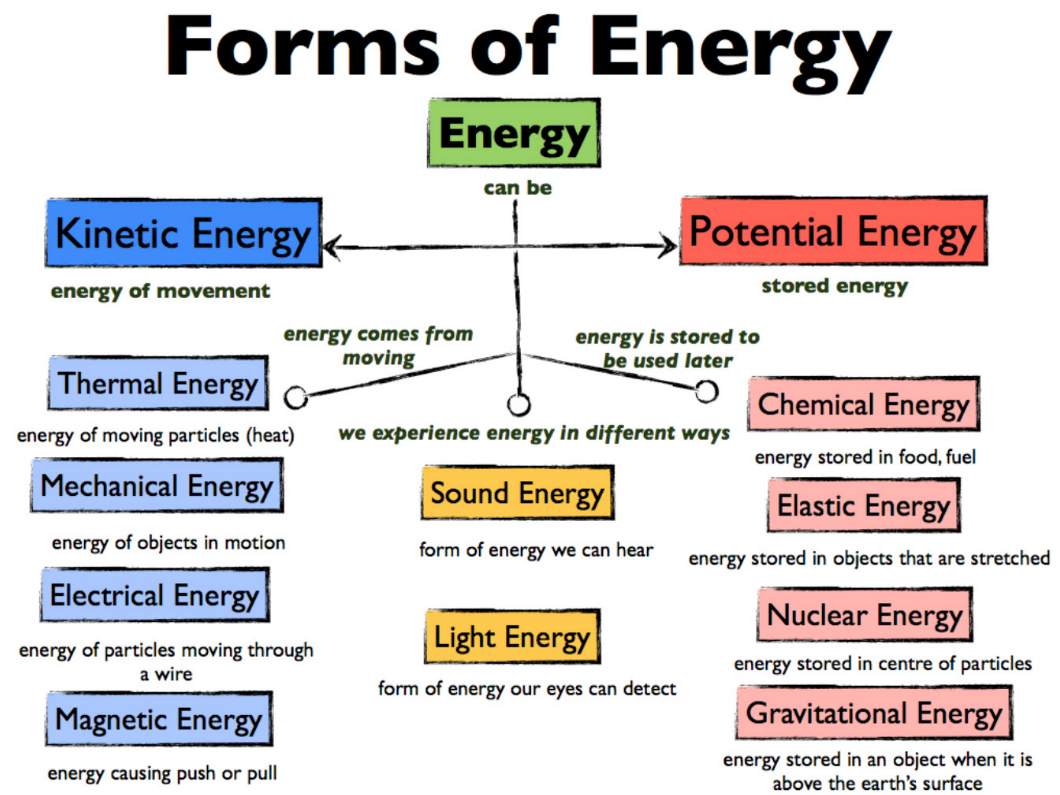
SOLAR

TOPIC OF STUDY

Energy Systems

90 MINUTES

3. Forms of Energy




## EXPLAIN

1. Use the following as a resource to explain the physics behind energy.
   a. We use terms in normal conversation such as work and energy and we know what they mean. But in Physics they have very specific definitions. Energy is defined as the ability to do work. And work is the application of a force over a distance. The more energy used the greater the work. The greater the distance covered, the greater the work. There are many sources of energy and energy can take many forms. For instance, when we light a fire, chemical changes happen to the fuel that releases heat energy. In turn, that heat energy can be used to boil water, and the steam from the water can power an engine. The engine converts the heat energy into mechanical energy. Mechanical energy is simply the ability to move things around.
   b. An interesting thing about energy is that it cannot be destroyed. When you accelerate in a car, the chemical energy driving the engine is converted to the mechanical motion of the car. And when you slow down the car using the brakes, the original energy that moved the car is converted into heat energy by the brakes. The energy simply moves from one type to another but is not lost.
   c. Energy is made available for use when there is more of it in one place and less in another. An example is how the energy of something hot will flow to a material in contact with it that is cooler. This is how we heat our houses. We take heat generated in various ways, transfer it to something like air moving through the house, or pipes filled with water, and then have that hot material transfer its heat to the air within the house that is cooler.
   d. One of the most basic principles of the universe is that energy flows from hot to cold but never in the opposite direction. And so there is an overall motion towards sameness as the amount of heat in things is equalized.

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

e. In physics, energy is divided up into kinetic energy and potential energy. This just means, we divide things into those that are moving (kinetic) and things that could move if allowed to (potential).

2. Review the formula information in the Vocabulary Section
3. Power: is measured in WATTS. Demonstrate how W = V x A, where Watts stay the same and voltage and current differ
   a. 120W = 120 V x 1A  and 120W = 12 V x 10 A
   b. Explain Watt and kilowatts
   c. Review larger units like gigawatt = one billion watts; a terawatt is one trillion watts
   d. Present Watts calculations for a PV array (SEI, p 43)

### EXPLORE

1. Review Ohm's law: Ohms Law Tutorial and Power in Electrical Circuits
2. Present simple algebra triangle formulas for power calculations and provide word problems for calculations.
   a. Example

**PROBLEM #1:**

A frying pan is connected to a 110-volt circuit. If the resistance of the frying pan is 10 ohms, how many amperes does the frying pan draw?

**Solution:** The voltage and the resistance are given, so we can just use the formula to find the current.

current = voltage resistance

current = 110 volts 10 ohms

current = 11 amperes.

Additional Problems: https://www.rcboe.org/cms/lib/GA01903614/Centricity/Domain/9473/03_08_18_ohms_law_worksheet_alt.pdf

### EXTEND

- Calculating Power and Energy in PV Systems
  - Demo the NREL PVWatts Calculator

## HOMEWORK

Have students look around their homes and make a list of all the different types of energy they see – examples of heat energy, mechanical energy, chemical energy etc.

## MEETING INDIVIDUAL NEEDS

Use of YouTube segments for visual learners. Avoidance of any complex mathematical formulas. Discussion of examples from everyday life.

## RESOURCES/LINKS

Basic Secondary Curriculum Unit: The NEED Project

Potential and Kinetic Energy Quiz: can be used to explain rather than assess.
Quiz: Potential And Kinetic Energy Questions!

Overview of Energy:
Introduction to Energy

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Energy Systems

90 MINUTES

## LESSON

How Energy Is Fundamental to Our Lives

## OBJECTIVES

To give students awareness of the many ways energy affects our lives, where that energy comes from and what the trends are in both the sources and uses of energy.

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Energy Systems**

90 MINUTES

## OVERVIEW

Think about the things that bring you pleasure in life and make life easier. Things like your phone and how it allows you to talk to anyone, listen to music and take pictures. Think about how cars make it possible to get places nearby or get to places that would have been many days away in the era of horse transportation. Or how about your air conditioner or refrigerator, or the lights that make it possible to see things at night. Forty percent of the energy we use is used in the home. But beyond the things we use personally we need to remember the planes, trucks, ships and trains that carry not only passengers but so many of the products we use and the materials to make those products. Even the making of basic products such as food, and steel is only possible because of our ability to use energy.

## KEY TERMS

heat energy
chemical energy
atomic energy
fossil fuels
electrical energy
wind power
solar power
hydroelectric power

## STANDARDS

### PA

**3.2.10.B6.** Explain how the behavior of matter and energy follow predictable patterns that are defined by laws.

**3.3.12.A1.** Classify Earth's internal and external sources of energy such as **radioactive decay, gravity,** and solar energy.

**3.4.12.A3.** Demonstrate how technological progress promotes the advancement of science, **technology**, engineering and mathematics **(STEM).**

## INSTRUCTIONAL

### TEXTS/REFERENCES

Various internet sites.

### MATERIALS NEEDED

**Teacher Prep:** Teacher to familiarize themselves with the various internet material used in advance.

**Technology:** Large monitor and computer

## IMPLEMENTATION (LESSON PLAN)

- Show images of different energy sources and energy uses (using images in lesson plan). Ask students how energy has made our lives different from those of people who lived 5000 years ago. Ask questions that have the students see how energy is used in the entire cycle of a vital commodity. Start with food. How does energy help in the growing of food (fertilizers, tractors, shipment, refrigeration etc.)? What are the different types of fertilizers (petroleum based and organic) and how do we get them?

# IMPLEMENTATION (LESSON PLAN) - CONTINUED

SOLAR

TOPIC OF STUDY

Energy Systems

90 MINUTES

- Then talk about household heating and cooling. Where does the heat energy of fire come from (the sun via photosynthesis and then the chemical reaction of burning - destructive distillation, the breaking down of chemicals to more fundamental parts, in this case mostly carbon and oxygen).

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

- How many ways did students use energy on the day they came to class? How is energy used in transportation?




- How has energy made our lives different than it was 200 years ago? Have students name some of the types of energy we use commonly – heat, chemical, atomic, renewable (wind, solar, geothermal) and talk about how they work. Look around the classroom – what ways is energy being used?



BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

Energy Systems

90 MINUTES

## MEETING INDIVIDUAL NEEDS

This lesson is almost entirely visual and conversational and so should be accessible to all types of learners.

## HOMEWORK

List all the kinds of energy present in each student's home. Find out how much energy use will increase by 2050 in the world and in the U.S. Where will the greatest growth happen? What kinds of energy will be most in demand.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Energy Systems

90 MINUTES

## LESSON

The Impact of Energy Systems - Social, Economic, Health, and Environment

## BIG IDEA(S)

The generation of energy for human consumption has impacts on individual health, the environment and the economy.

## OBJECTIVES

Students will be able to:

- Weigh the costs and benefits of the consumption of carbon-based fuels
- Students will share the advantages and disadvantages of energy transition

BRIGHT SOLAR FUTURES

**SOLAR**

## TOPIC OF STUDY

**Energy Systems**

60 MINUTES

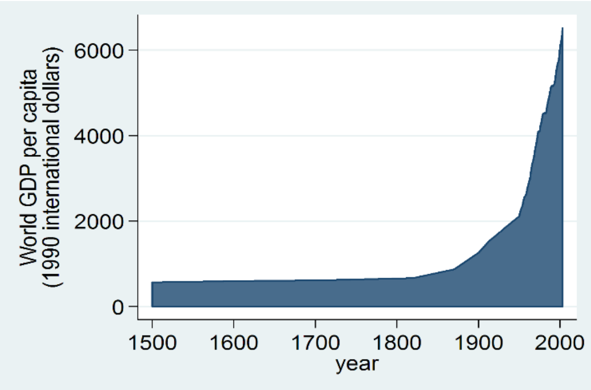
## TASK LIST SUBCATEGORY

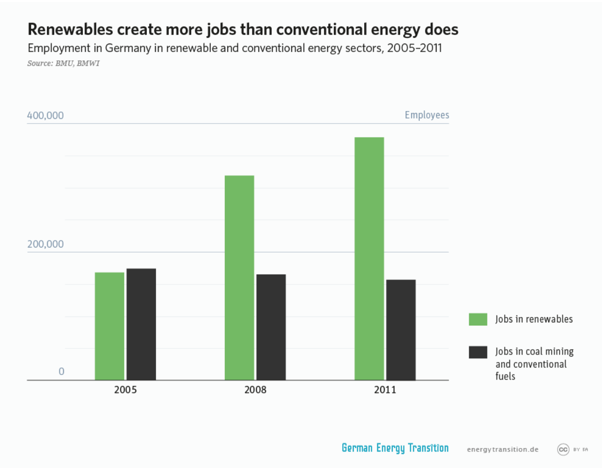
| | |
|---|---|
| **102** | Describe how energy is fundamental to our everyday lives |
| **104** | Describe sources and uses of energy |
| **106** | Describe the impact of energy systems (social, economic, health, and environmental) |
| **203** | Communicate the value of solar energy to different audiences |
| **416** | Use solar industry vocabulary |

## OVERVIEW

### JOBS

Originally, the use of wood fuel, coal, and petroleum products helped lead the way to an enormous expansion of human productivity and comfort. These power sources led to better forms of cooking, home heating, transportation (in the forms of trains, boats and cars) and electrification. Populations around the world, on average, gained much higher standards of living through their use.




But with the expansion of their use over time, they also produced harmful side effects. These include pollution, global warming and extreme weather events. The replacement of the fossil fuels infrastructure (oil and coal production and distribution) with renewables is known as the green economy. While jobs producing oil and coal will be eliminated, there will be a net gain in jobs when those losses are weighed against jobs created in the building out of the renewable infrastructure. These jobs include the production of solar panels, the installation of solar panels, the production of wind turbines, the installation of wind turbines, and the production and operation of nuclear power stations.

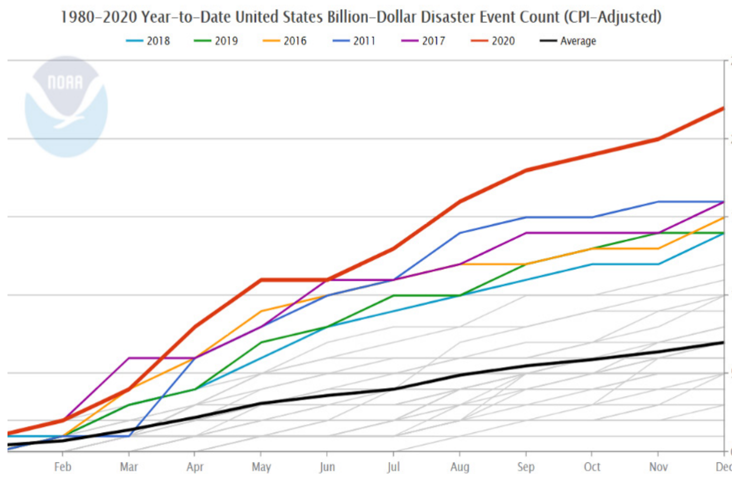
## KEY TERMS

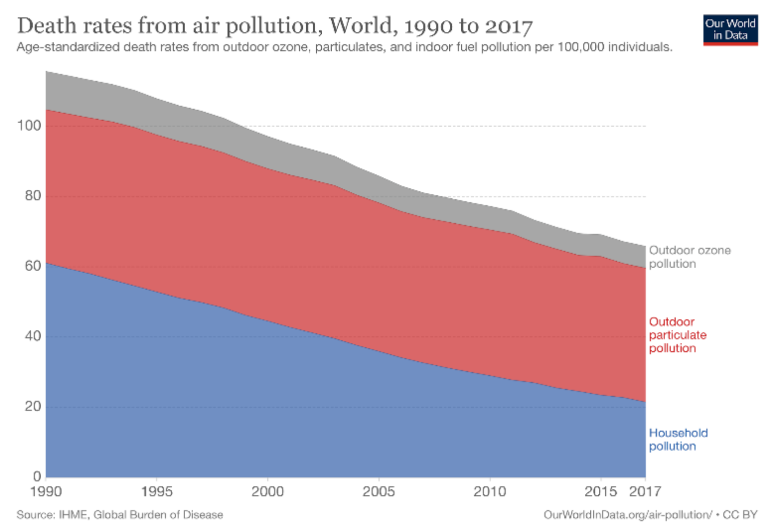
GDP (gross domestic product)
greenhouse gases
nitrogen oxides
per capita
global warming
fracking
fossil fuels
particulate pollution
emphysema
green economy
sulfur dixoide
cardiovascular disease
congestive heart failure

## OVERVIEW - CONTINUED

### REDUCTION OF EXTREME CLIMATE EVENTS

The scientific community is in almost complete agreement that rising temperatures resulting from greenhouse gas emissions (largely carbon dioxide and methane) has increased the occurrence of extreme weather events. These include tornadoes, hurricanes, flooding, droughts, fires, and dangerously high temperatures. In addition, global warming is leading to rising sea levels, which produce coastal flooding and erosion. The combined effect of extreme climate events and sea level rise not only causes damages in the hundreds of billions of dollars but directly leads to the loss of thousands of lives.




### POLLUTION

Fossil fuels contribute to both air and water pollution. Particulates are released into the air from smokestacks, forest fires but also take the form of tiny droplets formed from complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles. These kinds of particulates are harmful to both plants and animals (when they are breathed into the lungs). They cause lung and cardiovascular diseases (such as emphysema, asthma and congestive heart disease).

Coal production, gas and petroleum production through fracking, and the production of chemical products derived from petroleum also frequently results in the pollution of nearby sources of water. Government regulation has resulted in the lowering of pollutants from many sources. Various industries have pressured the government to relax the standards affecting them.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Energy Systems

60 MINUTES

## INSTRUCTIONAL

### TEXTS/REFERENCES

Materials from the overview

### MATERIALS NEEDED

**Teacher presentation:** Use material from the overview

**Content:** Review information referred to in overview and familiarize with the trends referred to. Prepare to explain gross domestic product per capita (total of all goods and services divided by the number of people).

**Technology:** Computer, projection device

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

Have students identify their favorite prepared food product. Have them map out the supply chain and resources necessary to get that food product into their hands.

### EXPLORE

Two thirds of the class will be placed into two teams where they will be tasked with developing a marketing campaign that either supports the expansion of electric car usage or reinforces the continued use of gas powered cars. A third team will develop the criteria for evaluating the other teams' presentations.

### EXPLAIN

Teacher will use the resources in the overview for the instructional conversation

### EXTEND

Students are to pick a source of energy related pollution and find articles that support opposing views regarding that source. They should be prepared to share their findings in a small group in class.

### EVALUATE

Students will choose one of the articles they found and explain how it is biased toward one point of view. They will be evaluated based on how their argument is supported by the text.

## LESSON

Tools for Evaluating Solar Equipment Performance

## BIG IDEA(S)

Use of a multimeter and pyranometer (light meter) are necessary tools when evaluation solar system performance.

## OBJECTIVES

Students will be able to:

- Demonstrate use of a multimeter and other basic OM tools.
- Perform basic diagnostic tests using these tools.

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Solar Maintenance and Operation**

4 HOURS

## TASK LIST SUBCATEGORY

**603** Demonstrate the use of testing and performance equipment

## OVERVIEW

This session covers the common tools used in O&M use. This will be somewhat of a review of introduction to tools in other lessons, but with special attention to how the tools are used in O&M work. Use of multimeter and pyranometer (light meter) is reviewed.

## INSTRUCTIONAL

### MATERIALS NEEDED

**Teacher preparation:** Be acquainted with content, prepare practice activities demonstrating the use of multimeter and other tools.

**Teacher presentation:** Links to Resources / Videos

**Content:**

### MATERIALS

- Multimeter
- Learning Lab devices to be tested:
  - modules
  - good and bad cables
  - good and bad fuses
  - inverter

**Technology:** Computer and monitor

## KEY TERMS

multimeter
volt meter
amp meter
continuity tester
pyranometer
Megger/insulation tester
infrared camera

## IMPLEMENTATION (LESSON PLAN)

1. Review Use of multimeter with attention to O&M procedures
2. Multimeter (best O&M tool is a 600 - 1000 Volt rated meter, with clamp on current meter, capable of testing AC and DC current)
   - AC volt meter
     - Typically used in O&M to:
       - Test presence of voltage for safety reasons
       - Confirm correct AC voltage from grid to inverter / microinveters

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

- Line to Line = 240, Line to Neutral & Ground = 120, Neutral to Ground = 0
- Verify phase consistency - two components that are on the same phase should have zero voltage difference
- Note: Polarity does not matter

- DC volt meter
  - Typically used in O&M to:
    - Test presence of DC string or inverter voltage for safety
    - Verify number of working modules on a string
    - Test whether a module is defective
    - Test whether an optimizer is defective
    - Check for short-circuits or open-circuits on a string
    - Narrow the search for the location of a problem on a DC string
    - Check polarity of DC wiring
    - Note: Polarity does matter. Red probe should be on the positive line, Black probe on the negative line. Otherwise result will be reversed (negative reading)
- Continuity tester (preferably with beep feature)
  - Used in O&M to:
    - Check for short-circuits / ground-faults
    - Check for open-circuits (broken wires, bad connections)
    - Check fuses
    - Check breakers and switches
    - Check phase consistency on de-energized devices
    - Note: Polarity does not matter
    - Note: Do not check continuity on a live or energized line - especially if there is a voltage difference across the leads. You will get an erroneous reading and/or damage the meter.
    - Note: Continuity is just a Yes / No test:
      - Beep and zero resistance = continuity. The leads are connected to a closed circuit (this can be good or bad)
      - No beep and OL (open line) = discontinuity. The leads are connected to an open circuit (this can be good or bad)
    - Note: there are other more advanced procedures involving resistance testing and diode testing beyond the scope of this course.
  - PRACTICE: test fuses
  - PRACTICE: short-circuit / open-circuit tests
- AC amp meter
  - Used in O&M to:
    - Confirm that line is producing power - and verify that the power is what it should be.
    - Example: Power (Watt) = Voltage (Volt) X Current (Amp). If a line should be producing 5 kW. 5,000 W / 240 V = 20.8 A
    - Line 1 and Line 2 from a PV system should carry equal current.
    - Current should be less than the fuse or breaker protecting the line.
    - Unusually high current can indicate an isolation fault.
    - Clamp direction usually does not matter

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**Solar Maintenance and Operation**

4 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

- DC amp meter
    - Make sure meter is set to DC current - and it is often necessary to calibrate the meter by holding the zero button - to set the meter to zero before taking a reading.
    - Used in O&M to:
        - Check module or string performance

3. Pyranometer (light meter)
    - Measures the irradiance of the sun in watts/meter squared.
    - Used to calculate expected power output to compare with measured performance.
4. Thermometer
    - Used in O&M to:
        - Check temperature of back of module to adjust performance expectations
        - Check modules or wire connections or devices for hot spots - indicating bad modules / cells, or bad wiring connections that are over-heating.
5. Other / Advanced (mention briefly)
    - Insulation Tester 'Megger' - tests for isolation faults (voltage 'leaks') indicating partially worn or damaged wire insulation even if there is not a total short-circuit.
    - Infra-red camera - hand-held or on a drone to test an array for hotspots. Can also check equipment for overheating connections.
    - Data cable tester - tests ethernet cables.
    - IV-Tracer - advanced expensive equipment to measure current and voltage relationships on a string.
6. Well-stocked truck
    - A variety of basic tools are common in O&M work. Keep commonly used items in service vehicle at all times. Anticipate needs and be prepared for site visits by bringing any additional items that may be needed.
    - PPE:
        - hard hat
        - fall protection
        - reflective vest, eye protection, ear protection, electrically insulated gloves.
    - General tools:
        - Multimeter
        - Impact driver, hammer drill, (bandsaw), (sawzall)
        - Driver accessories and screw drivers (including tiny 1/8", 3/16" for inverter disconnections and small data wire connections), all kinds of sockets, torx bits, hex bits, drill bits, hole saws, masonry bits
        - Wire strippers, wire cutters, utility knife, scissor snips, tin snips, channel lock pliers, needle nosed pliers
    - Basic parts and supplies:
        - PV stickers, string marking stickers, colored tape
        - Electrical tape - rubber and normal, Noalox, PVC glue, Geocell / silicon caulk
        - Fuses, Circuit Breakers, Breaker Blanks
        - Wire nuts, line tap connectors, ground lugs, romex connectors
        - PV wire, commonly used wires and cables
        - Screws, anchors, nuts & bolts, racking and mounting hardware
        - Squirrel guard (a few pieces for repairs / replacing small sections if cut for access…)
        - MC4 and Enphase connectors, crimping tools, splice crimping tool
        - Spare optimizers, microinverters, communication devices, CTs

## LESSON

Grounding

## BIG IDEA(S)

Connecting electrical systems to the earth is an important safety mechanism.

## OBJECTIVES

Students will:

- Describe the reasons for grounding
- Identify key components of system grounding
- Compare and contrast bonding and grounding
- Explain how to properly ground a PV system

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

Solar Installation

90 MINUTES

## TASK LIST SUBCATEGORY

**404** Describe relevant codes and requirements for permitting and interconnection

**702** Recognize and use electrical concepts, terminology, relationships, and formulas

**704** Describe the elements of an electrical service

## OVERVIEW

This session covers grounding in detail. Grounding is important for both design and installation. The *NEC* requires that all exposed or accessible PV equipment and circuits be properly connected to earth (grounded) using specified methods and equipment. As installed PV systems age, grounding issues emerge that impact system safety.

## STANDARDS

### PA

**3.4.10.A1.** Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.E7.** Evaluate structure design as related to function, considering such factors as style, convenience, safety, and efficiency.

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International; Pearson 2013*

### MATERIALS NEEDED

**Content:** Textbook and web sites listed in resources

**Technology:** Computer with access to YouTube

## KEY TERMS

equipment grounding conductor (EGC)
ground
ground fault protection device (GFPD)
ground fault
grounded
bonding
earthed
grounding electrode conductor (GEC)

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

1. Using think-pair-share method, ask students to answer the question, "why can a bird sit on a power line and not get an electric shock?"
2. Show video explaining the answer: https://youtu.be/rtnmCf2QFTc

### EXPLORE

1. Provide teams of students with a variety of electrical components including some metal junction boxes, metal conduit, pvc conduit, copper wire, etc.
2. Ask teams of students to layout the items so that they show a system that is bonded. Teams should raise their hand and show their work to the teacher.
3. Ask teams of students to layout the items so that they show a system that is grounded. Teams should raise their hand and show their work to the teacher.

### EXPLAIN

- Have student teams explain their work above and also explain the difference between bonding and ground a system.

### EXTEND

1. Provide a basic PV System diagram to each student.
2. Ask students to identify areas of the system which should be bonded and/or grounded.
3. Teacher should review the typical areas in the PV system where this occurs.

### EVALUATE

- Create an exit ticket with the following questions:
  - What is grounding and how does it occur?
  - How is the grounding process explained?

## RESOURCES/LINKS

Grounding (Physics): How Does it Work and Why is it Important?
https://sciencing.com/polarization-and-electric-induction-what-is-it-and-how-does-it-work-w-examples-13721176.html

Grounding - The Removal of a Charge
https://www.physicsclassroom.com/class/estatics/Lesson-2/Grounding-the-Removal-of-a-Charge

On the Grounding and Bonding of Solar Photovoltaic Systems
https://www.iaei.org/page/2021-01-grounding-and-bonding-solar-photovoltaic-systems

OSHA 10 Ground Fault Protection lesson
https://tools.niehs.nih.gov/wetp/public/Course_download2.cfm?tranid=2495

Photovoltaic System Grounding: Solar America Board for Codes and Standards
http://solarabcs.org/about/publications/reports/systemgrounding/pdfs/SystemGrounding_studyreport.pdf

To Ground or Not to Ground: That is Not the Question
https://www.solar-electric.com/lib/wind-sun/PV-Ground.pdf

Why don't birds get electrocuted on power lines?
https://youtu.be/rtnmCf2QFTc

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

Solar Installation

90 MINUTES

## LESSON

Introduction to Types of Solar Systems

## BIG IDEA(S)

It is important to be able to accurately describe all the necessary components of any type of solar system.

## OBJECTIVES

Students will be able to:

- Identify and describe the 3-4 kinds of solar systems
- Describe the components of each kind of system
- Explain how systems/configurations are best suited for specific situations
- Describe Grid Direct, Stand-Alone, and Hybrid systems are configured
- Explain the pros and cons of building integrated systems

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

**Solar Project Management and Design**

2 HOURS

## TASK LIST SUBCATEGORY

**401** Identify solar mechanical and electrical components

**402** Select appropriate components to design a solar system

**405** Identify the factors related to system sizing and production

**406** Differentiate the design of grid-tied, storage and off-grid systems

## OVERVIEW

There are three basic types of solar systems: grid direct, stand lone (off grid) and hybrid that this lesson explores. Some grid-tied have battery back-ups. For most people, a grid-tied solar system is a solid investment that provides security and predictability for their business, farm or home. The payback for a grid-tied solar system is shorter and there are fewer components that could need to be replaced in the future. An off-grid solar system is a good option for some cabins and more isolated areas, however at this time, off-grid systems struggle to compete with the payback and ROI of a grid-tied system.

## KEY TERMS

PV direct
DC standalone
grid-direct
grid-tied with battery back-up
batteries
AC load
stand-alone with AC loads
stand-alone with back-up
hybrid
building integrated solar

## STANDARDS

### PA/SDP

**3.4.10.A1.** Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity appropriately in complex real-life problems.

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

**3.4.12.A2.** Describe how management is the process of planning, organizing, and controlling work.

**3.4.12.B2.** Illustrate how, with the aid of **technology**, various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.C2.** Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Electric Handbook*, SEI, 2013. Pp. 55-79

*Solar Photovoltaic Basics*, Sean White, 2019. Pp. 83-90

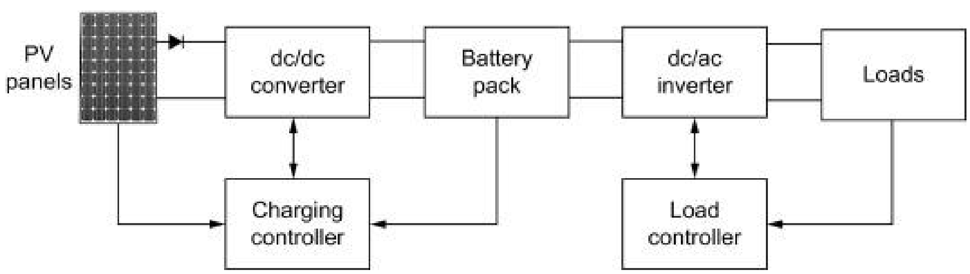
## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

What do you think all PV systems have in common? Why would different systems have different components? Discuss with students to assess background knowledge. They should at least understand that photovoltaic modules are what all systems have in common.

### EXPLORE

1. There are many types of solar systems. However, there are 3 systems that are most common:
   a. **Off Grid -** These systems require batteries or some other form of energy storage. The house is not connected to a power grid so all electrical power is generated from the solar system.
      - In this simple topology, the dc/dc converter between the battery and the PV panel is used to capture all the available power from the PV panel. In this system, battery pack acts as an energy buffer, charged from the PV panel and discharged through the dc/ac inverter to the load side. The charging controller determines the charging current of the battery, depending on the MPP of the PV panels at a certain time.
      - House have ac loads so the inverter is used to convert to ac from the PV panel




*Alireza Khaligh, Omer C. Onar, in Power Electronics Handbook (Fourth Edition), 2018*

https://www.sciencedirect.com/topics/engineering/stand-alone-photovoltaic-systems

   b. **Utility Interactive (Grid Tied or Grid-Direct) -** This is the most typical type of solar system. The homeowner stays connected to the utility grid and, when the solar is producing more electricity than the home needs, can feed electricity back to the grid. When the solar is not producing energy the home uses power produced by generation sources on the grid. There is no charge controller or batteries, and the grid must always be present.
      - **Net metered** systems are the most common type of grid direct. The single utility meter tracks the amount of energy purchased from the utility and the surplus PV energy sold back.

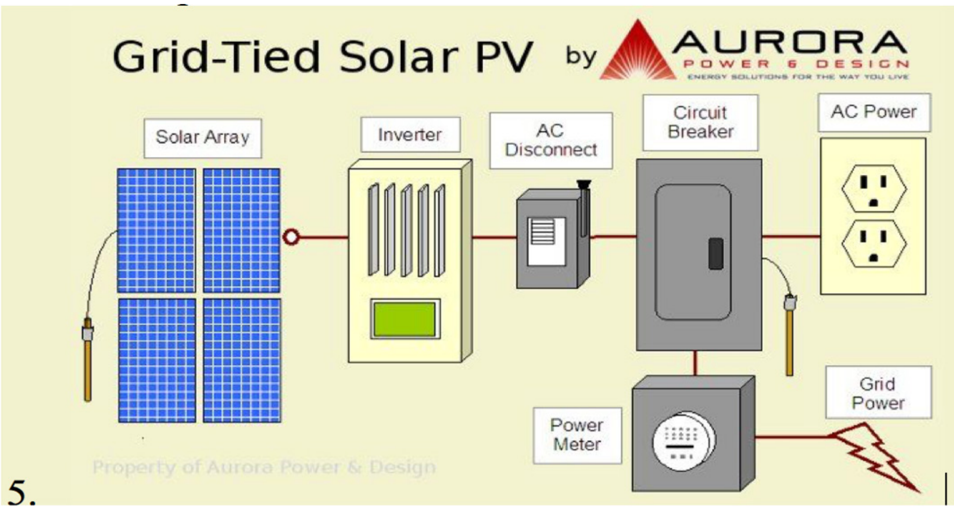
**SOLAR**

**TOPIC OF STUDY**

**Solar Project Management and Design**

2 HOURS

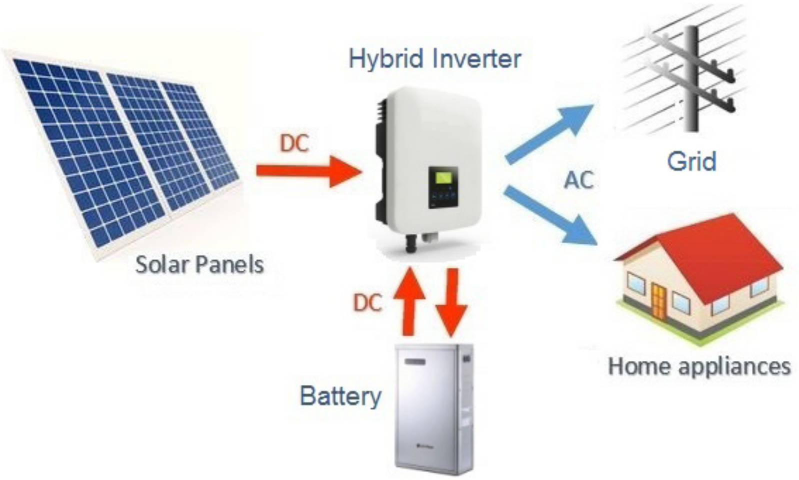
- **Feed-in tariff** systems include a second, utility style meter and is used to track all power that is generated by the PV system. A separate rate structure (incentive) applies to the energy that is sold vs. energy purchased from the utility.




5.

https://www.google.com/search?client=firefox-b-1-e&q=Grid-connect+solar+system+design#cobssid=s

c. **Hybrid systems -** This is the most complicated type of solar system. It involves solar and multiple power sources plus storage. For example, a house may be grid connected, with generator back-up, battery storage, and solar. These systems typically involved complex programming to ensure proper operation.




## EXTEND

1. For most people, a grid-tied solar system is a solid investment that provides security and predictability for their business, farm or home. The payback for a grid-tied solar system is shorter and there are fewer components that could need to be replaced in the future. An off-grid solar system is a good option for some cabins and more isolated areas, however at this time, off-grid systems struggle to compete with the payback and ROI of a grid-tied system.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Project Management and Design

2 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

2. Grid-Tied Pros and Cons
   a. Pros
      i. Grid-tied systems tend to be the less expensive option, due to not needing batteries and other equipment
      ii. This type of system is great for those who don't have the room or financing to install a solar system big enough to cover 100% of their energy usage. You can continue to pull electricity from the grid if needed
      iii. Net metering allows the electricity generated by a solar system to offset the electricity used from the grid during the night or cloudy days
      iv. The grid becomes your cost-effective, reliable storage solution
      v. In some regions, Solar Renewable Energy Credits (SRECs) allow owners of a grid-tied system to receive extra income by selling the SRECs their system produces
   b. Cons
      i. If the grid goes down your system will shut off, leaving you without power. This is required to prevent energy from back feeding into the grid to keep utility workers safe. Your grid-tied system will automatically shut off when the grid goes down, and will also automatically turn back on when power is restored
      ii. You're not completely independent from the grid
3. Off Grid-Solar System Pros and Cons
   a. Pros
      i. Completely independent from the grid
      ii. A great solution for remote locations and underdeveloped communities
   b. Cons
      i. They are more costly
      ii. Batteries are required to deliver electricity consistently throughout the day and night
      iii. It could require a lifestyle change to reduce energy consumption
      iv. Surplus energy production could go to waste
      v. Cannot rely on the grid at night or on cloudy days
      vi. Batteries require maintenance, have a relatively short lifespan, and degrade rapidly
4. Hybrid System Pros and Cons
   a. Pros
      i. Continuous power supply – The hybrid solar systems provide power continuously, without any interruption, as the batteries connected to them store the energy. So, when there is an electricity outage, the batteries work as inverters to provide backup. This is also the case during the evening or night time when there is no sun and energy is not being generated; batteries provide the back-up and life goes on without any interruption.
      ii. Utilize the renewable sources in the best way – Because the batteries are connected to the system to store the energy, there is no waste of the excess energy generated on bright sunny days. So, these systems make use of renewable energy in the best way, storing energy on a good day and utilizing the stored power on a bad day. The balance is maintained.

BRIGHT SOLAR FUTURES

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**TOPIC OF STUDY**

**Solar Project Management and Design**

2 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

iii. Low maintenance cost – The maintenance cost of the hybrid solar energy systems is low as compared to the traditional generators which use diesel as fuel. No fuel is used and they do not require frequent servicing.

iv. High efficiency – The hybrid solar energy systems work more efficiently than your traditional generators which waste the fuel under certain conditions. Hybrid solar systems work efficiently in all types of conditions without wasting the fuel.

v. Load management – Unlike traditional generators, which provide high power as soon as they are turned on, most hybrid solar power systems manage load accordingly. A hybrid solar system may have technology that adjusts the energy supply according to the devices they are connected to, whether it's an air conditioner requiring high power or a fan which requires less.

b. Cons

i. Complicated controlling process – With different types of energy sources in use, the systems require some knowledge. The operation of different energy sources, their interaction and coordination must be controlled and it can become complicated.

ii. High installation cost – Although the maintenance cost is low, the initial investment for the installation of a hybrid solar energy system is high as compared to a solar system.

iii. Less battery life – The batteries connected to the system may have a lower life as they are often exposed to natural elements like heat, rain, etc.

iv. The number of instruments connectable is limited – The number of devices you can connect to a hybrid solar energy system is limited and vary from system to system.

### EVALUATE

Working in 3 groups, have students create a drawing of each of the three kinds of solar systems.

## HOMEWORK

Do some research to find out what the most popular solar systems installed. Determine if choices are influenced by weather, wind, other natural resources,days of sun per year, etc.

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**TOPIC OF STUDY**

Solar Project Management and Design

2 HOURS

## LESSON

Home Wiring

## BIG IDEA(S)

Understanding the basics of safely and effectively navigating home wiring requires both broad and detailed knowledge of how home electrical systems work.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**Home Wiring**

3 HOURS (2 SESSIONS)

## OBJECTIVES

Students will be able to:

- Describe the 2 most common home service entrance sizes (100A & 200A)
- Know the most common service entrance wiring and sizes (#2 & 4/0 wire SEU cable)
- Understand the purpose and location of the main service disconnect
- Describe where & why neutral and ground are bonded (in the main service panel)
- Describe how branch circuits and OCPD function in a house
- Describe different cable types, wire, sizes, and why they are important (Romex, MC Cable, #10, #12,#14)
- Describe the purpose and grounding and bonding
- Demonstrate a broad understanding of how home electrical systems work

## TASK LIST SUBCATEGORY

**703** Read an electrical diagram

**705** Describe the elements of an electrical service

**708** Describe National Electrical Code wire sizing calculations with conditions of use factors

## KEY TERMS

amp
service panel
neutral
ground
branch circuit
low-voltage
breaker

## OVERVIEW

Electricity has become an essential part of contemporary life, energizing lights, appliances, heat, air conditioning, televisions, telephones, computers, and many other modern conveniences.

Electricity arrives at your house from your local utility company by a power line or underground through a conduit. Most homes have three-wire service—two hot wires and one neutral.

Throughout the house, one hot wire and one neutral wire power conventional 120-volt lights and appliances. Both hot wires and the neutral wire make a 240-volt circuit for large appliances such as air conditioners and electric furnaces.

An electric meter, monitored by your electric utility company, is mounted where the electricity enters your house.

The main panel is usually right next to or under the meter. This is the central distribution point for the electrical circuits that run to lights, receptacles, and appliances throughout the house.

A circuit, by definition, is a circular journey that begins and ends at the same place, and this is essentially how electricity works. Current begins at a power source, powers the appliance or device along the circuit, and then returns to the power source. Any interruption in this path will render the circuit dead.

## OVERVIEW - CONTINUED

A circuit consists of a hot (usually black) wire that goes from the main panel to a series of lights, receptacles, or appliances, and a neutral (usually white) wire that returns to the main panel. In addition to the neutral wire, a grounding wire also returns to the main panel and, from there, to the earth. The purpose of the ground is to divert electricity from any short-circuiting hot wires into the earth, preventing electric shock.

Subpanels in other locations of the house are connected to the main panel. These provide power to areas that have a number of different branch circuits or large appliances, such as the kitchen and laundry room. They also are equipped with a secondary set of circuit breakers.

Low-voltage electrical systems are also common in houses for powering doorbells, intercoms, sprinkler timers, outdoor lighting, and some types of low-voltage indoor lighting. With these, a transformer reduces the home's 120-volt electricity down to 12 volts. Relative to conventional voltage wiring, these systems are much safer for homeowners to work on.

## STANDARDS

### PA

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**ET S1.B.** Developing Possible Solutions.When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts **(HS-ETS1-3)**

Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. **(HS-ETS1-4)**

## IMPLEMENTATION (LESSON PLAN)

### DISCUSSION

- Our home electrical system as the "central nervous system" for the house.
  - How does electricity arrive at the house?
  - How is electricity brought into the house? From the meter using service entrance cables
  - Common service sizes are 200A and 100A. A home can go up to 400A (really 320A) with a single phase service. After that you have to move to 3 phase service.
  - The service size determines the wire size. 4/0 or #2 wire. Discussion of aluminum wire v. copper wire. Stranded v. solid

### LECTURE & DISCUSSION

- Grounding and bonding in homes. Why do we do it and how does it work?
- What is a main disconnect, how does it work and how many can there be?
- The main service panel is the central nervous system for electricity in your home.
- Describe the purpose and function of OCPDs

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

Home Wiring

3 HOURS
(2 SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### ACTIVITY

- Take apart and put back together a main service panel
  - Have students use common electricians tools to strip wires
  - Demonstrate how wire sizes relate to OCPD sizes
  - Show 2 pole (240V) breakers, single pole, twin breakers
  - Show the bonding of ground and neutral
  - Explain Noalox anti-oxidant and why we use it
  - Explain branch circuits and feeder circuits
  - Explain subpanels

## RESOURCES/LINKS

Understanding Your Home's Electrical System: The Main Panel
https://www.youtube.com/watch?v=0B0JK2FZ_tQ

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SOLAR

TOPIC OF STUDY

Home Wiring

3 HOURS
(2 SESSIONS)

## LESSON

Energy Storage

## BIG IDEA(S)

Understanding the capabilities of batteries is extremely important and is emerging globally as a critical technology for energy efficiency. Batteries are not a source of energy, but store energy and release energy stored within. A rechargeable battery, or a ban of multiple batteries, stores the daily PV production.

## OBJECTIVES

Students will be able to:

- Design and install an off grid solar and energy storage system.
- Prepare a battery sizing calculator with all house loads.
- Explain the difference between power and energy as it pertains to battery systems.
- Choose the proper inverter and batteries for a given situation.

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

**Solar Installation**

**Year 1:**
3 SESSIONS
(90 MINUTES EACH)
**Year 2/3:**
3 SESSIONS
(180 MINUTES EACH)

## TASK LIST SUBCATEGORY

**401** Identify solar mechanical and electrical components

**402** Select appropriate components to design a solar system

**405** Identify factors related to system sizing and production

**406** Differentiate the design of grid-tied, storage and off grid systems

**416** Use solar industry vocabulary

**507** Install energy storage equipment

## OVERVIEW

There are three types of battery-based PV Systems and several types of batteries. One is a stand-alone (off grid) system with batteries providing energy storage. Students will design and install an off grid solar and energy storage system. This will include battery sizing and choosing the appropriate inverter for a specific system.

## STANDARDS

### PA/SDP

**3.4.10.A1**. Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity appropriately in complex real-life problems.

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

**3.4.12.B2.** Illustrate how, with the aid of **technology**, various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.C2.** Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

**ETS1.B:** Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)

## KEY TERMS

flooded lead acid battery (FLA)
valve regulated lead acid battery (VRLA)
lithium cobalt
lithium iron phosphate
depth of discharge
state of charge
deep-cycle batteries
shallow-cycle batteries
battery bank
stand-alone DC load-only systems
stand-alone system (off-grid)
inverter/charger
grid-tied battery back-up systems

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Electric Handbook*, SEI, pp. 377-383

*Solar Photovoltaic Basics,* White: Chapter 6 System Components: Pages 88-90.

### MATERIALS NEEDED

**Teacher Prep:** New Enphase Battery Installation

**Content:**

- New Enphase Battery Installation
- https://www.tesla.com/support/energy/more/installers/installing-powerwall
- Tesla Electrical Time-lapse
- Enphase Ensemble first install
- Simple Solar Power System for an off grid Cabin

### MATERIALS

- Multimeter for measuring battery voltage
- Materials assembled for small groups to design and assemble a miniature off-grid system

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

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**Year 1:**
3 SESSIONS
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## IMPLEMENTATION (LESSON PLAN)

### SESSION 1

### ENGAGE

- You probably use batteries to power different devices every day, ranging from toys to TV remotes, without giving it much thought. Eventually the batteries will die and you have to replace them with new ones (or recharge them if they are rechargeable batteries). How much do you actually know about how batteries work?
  a. Batteries are not really a source of energy. They provide storage. Batteries used in PV systems are rechargeable, household batteries may or may not be.
  b. Batteries lose power at different rates when they are used. Rechargeable batteries last longer if they are recharged regularly and brought up to 100% capacity.

### EXPLORE

1. Battery Experiment #1 (10th Grade)
   a. Demonstrated household rechargeable appliances: electric shaver, remote, flashlight (non or rechargeable)
   b. Test the voltage in a flashlight battery. Turn on a flashlight at the beginning of class and test it periodically to assess how the load is lowering the voltage. Graph.
2. Battery experiment #2: Measure battery voltage accounting for internal resistance. Testing household batteries for voltage taking into account internal resistance

   How To Test Standard AA, AAA, D, C, and 9V Batteries with a Multimeter

### EXPLAIN

Understanding Batteries in System Design:

a. Understanding the capabilities of batteries is extremely important. The word battery is much like the word car in that there is a wide variety available with lots of different, and sometimes highly focused, capabilities. For example, some batteries can provide very high power (shallow cycle), but for a short period of time (think car battery). Other batteries are better at delivering smaller amounts of power, but over a long period of time (these are sometimes referred to as deep cycle batteries). Most home/business owners use deep cycle batteries. It used to be, with older battery chemistries, that draining a battery too far, past about 50% state of charge, could damage the battery and shorten its life. These older chemistries include flooded lead acid, absorbed glass mat, and gel batteries. New battery chemistries allow for almost 100% depth of discharge and they often carry warranties into the thousands of battery cycles (1 cycle = 1 complete discharge and recharge of the battery). Most modern batteries have warranties that go above 5,000 cycles (some even go to 10,000 cycles). These modern batteries use, almost exclusively, Lithium chemistry.

b. There are two main lithium chemistry batteries types on the market today: lithium cobalt and lithium iron phosphate.
   i. **Lithium cobalt** is cheaper and has better power density (so it is typically lighter/smaller than the other chemistry batteries). However, lithium cobalt is flammable and the fire creates a chain reaction that is extremely difficult to put out (maybe impossible).
   ii. **Lithium iron phosphate** is a bit more expensive and less power dense than Cobalt, but it does not have the same fire safety issues as cobalt. All lithium batteries are much more expensive, but last longer and store more energy, than lead acid batteries. Additionally Lithium batteries can be recharged faster than lead acid batteries.
   iii. Batteries are typically a low voltage, high current storage medium. Because there is no motion, instead of motion there is a chemical reaction involved with the storage of energy in batteries, they receive and will release DC current. Typical battery voltages are 12V, 24V, or 48V. Like solar panels, batteries can be strung together in series and/or parallel. When wired in series voltage is additive but current stays constant. When wired in parallel, current is additive but voltage stays constant. Batteries store energy chemically.
   iv. Show video: Different types of batteries and their properties. Best Batteries for Solar: Choose the Best for Your System

### SESSION 2: PREPARE A BATTERY SIZING CALCULATOR

1. Prepare a Solar Battery Sizing Calculator Solar Battery Bank Sizing Calculator for Off-Grid
2. How do you know the state of charge of a battery? Review the battery specifications/data sheet. State of charge will be determined by the voltage of the battery.
3. How do you wire Batteries to a solar system? There are two solutions:
   a. **AC coupled** - In this scenario the solar will have an inverter that inverts the solar's DC current into AC current and the battery will have a separate inverter that inverts the battery current from DC to AC and the two systems will be coupled in a AC combiner panel. Some batteries come with inverters prewired to them so they must be AC coupled (Tesla and Enphase batteries come with inverters so they can only be AC coupled). The advantage of AC coupled batteries is that they can be retro-fit to almost any solar system. The disadvantage is that AC coupled batteries tend to cost more money and are less efficient.
   b. **DC coupled** - This is the most efficient form of battery integration. A single inverter inverts both the battery and solar power. The solar is coupled directly to the batteries however, a charge controller may be needed to match the solar voltage to the battery voltage. Additionally, the charge controller can monitor the battery state of charge to

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

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ensure it is not over charging or depleting the battery to a harmful state. The downside of DC coupled batteries is it can be very difficult to retrofit DC coupled batteries to an existing solar system. See DC Coupled battery.pdf

4. Use cases for energy storage:
   a. Hybrid system: A Hybrid system has multiple power sources. Typically the power sources are the electrical grid, solar, and a gas generator. Solar is a variable power, meaning it goes up and down during the day based on the amount of sunshine available and it does not produce energy at night. In order to smooth out the variability of solar energy either another power source is required or  storage is needed. This is where batteries come in. Batteries can store excess energy that is produced by a solar system and can release that energy when the solar system is functioning at less than needed capacity for the home or if the solar is completely off. Hybrid systems require a transfer switch if a house is going to have power when the grid is off.
      i. Activities:
         1. Review the DocSet_Hybrid-Solar.pdf for how Hybrid systems are designed. Discuss the various components (Enphase Envoy Combiner, Enpower smart switch [transfer switch], Enphase Storage System [Encharge batteries], AC disconnect, etc.
         2. Review the spec sheets for the Enpower and Encharge devices. What is the peak current output of the Encharge batteries? What is the rated current output? Why does this matter? Peak and rated current relate to the amount of current that can be used at a single point in time. Understanding not only the energy devices use but also the power is critical.
         3. Have students use the Energy Use calculator to figure out how much energy their home uses. This will help students understand how to size batteries. Additionally you can discuss the smart Load-and-Solar-Circuit-Control-Technical-Brief.pdf document to talk about the need for load control so as to not overwhelm the batteries.
   b. There are a number of use cases for hybrid solar
      i. **Time-of-use rates**: Hybrid solar can help homeowners save money on their electricity bills where time-of-use rates are in place. Typically time-of-use rates have on peak and off peak rates. For example, in the PECO service area the highest rate is from 4PM - 6PM during weekdays. The kWh rate is about $.19 - $.21 per kWH. However, off peak rates are typically $.10 - $.12 per kWh. Then there is a third rate class named Late Night Rates that drops all the way down to $.06 per kWh. As one might guess, homeowners will want to use as little electricity as possible during the peak hours. However, that is a very hard time to avoid using electricity. It's around the time that people come home from work or school and need to start doing things around the house. This is where a Hybrid solar system can help people save money. The inverter can be programmed to allow the house to run off of solar energy and stored battery power during peak (and even off peak hours). If for some reason the solar is not able to fully recharge the battery because of high energy use during the day the inverter can be programmed to charge the battery during the very inexpensive Late Night Rate hours. By using electricity when it is cheap and not using it when it is expensive the homeowner can live their normal lifestyle while saving money because the solar and storage energy is offsetting the expensive peak electrical rates.
      ii. **Peak shaving**: Certain industrial users of electricity are billed based on their electrical demand (aka power, kW not kWh) as well as their energy use (kWh). The demand charges can be quite high. If they can stay below a certain demand level

BRIGHT SOLAR FUTURES

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TOPIC OF STUDY

Solar Installation

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then they can save a significant about of money. For ex. If the utility charges Acme Co. $1,000 for 50 - 99 kW of demand but will charge $2,000 if Acme goes up to and over 100 kW of demand then Acme can save $1,000 per month by staying under 100 kW of demand. Acme might find it financially prudent to install a smart building system that can signal a hybrid solar system to release battery power when the building hits 90 kW of demand. This will allow Acme to never go past the 99kW threshold and save them $1,000 per month.

iii. **Power grid issues**: Some areas of the United States (Hawaii for example) have high voltage issues with their power grid. This means it is illegal to backfeed solar into the grid. To be clear, a house can still use power from the grid to operate (or to charge batteries) but it is not allowed to feed any solar or battery stored power back into the grid. For this type of scenario hybrid solar systems with battery storage make a lot of sense. During the day, when the solar is over producing, power can be stored in batteries and then at night that power can be released as the house needs it (but no more than the house needs!). This way a homeowner can still use solar power without ever feeding it back into the grid.

iv. **Resilience**: There are businesses that require power 24/7/365 in order to function, such as hospitals. If a hospital goes without power it can lead to life and death issues. Additionally there are materials in hospitals that can be very costly to replace. Such as vaccines. If a hospital were to have a power outage and its vaccine refrigerators go off there could be many thousands of dollars of lost medicine. A hybrid solar power system with battery back-up can help to resolve this issue. The hospital could isolate the vaccine refrigerator circuit on a critical loads panel and have that panel fed by solar and batteries. If designed properly, should there be a power outage the solar and batteries will isolate themselves from the grid (through the use of an automatic transfer switch) and continue to power the vaccine fridges until the gird comes back. The same general idea is true for homeowners. Imagine there is a terrible storm and power is knocked out for many days (actually not so hard to imagine these days). Consider that the person living in the home may have life saving medicine in their refrigerator (such as insulin for diabetics). Having a hybrid system would allow the refrigerator to remain cold and some circuits in the house to function until the utility was able to restore power to the area. Resilience is a huge reason people opt for hybrid solar and battery systems.

c. Batteries in place of a generator

### SESSION 3

1. Off grid systems
   a. **Gardens or outdoor structures** - Sometimes gardens or other small outdoor structures need small amounts of power. It is not financially feasible to ask the electric company to hook up power for such a small site so a small off grid system may provide the perfect solution. ACTIVITY: Have students pick a small water pump and some LED lights for a garden and design a small off grid system to power them. The system should have at least 3 days of autonomy.
   b. **Construction signage** - One of the most common uses for off-grid solar. You may see these types of setups when driving down the highway and seeing a digital construction sign. Often these signs need power so they can be seen. They are in remote locations and only need to be in place for a temporary time period. It is easier to set up a few solar panels, batteries, and inverter (if needed) than it is to get any sort of power hookup to the location.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

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## IMPLEMENTATION (LESSON PLAN) - CONTINUED

c. **Off Grid homes**

i. **Houses** - *Electrically Designing an offgrid house will be the class's Capstone project. Students will need to use a load calculator to ensure all loads are considered. Students will need to understand the orientation of the house so that you can maximize the solar gain. Additionally, students will need to consider how to make the house itself as energy efficient as possible. While the students will be able to design with any solar and battery system they choose, Students will be able to use the battery system in the classroom to get hands-on experience building a DC coupled battery system.*

ii. **Tiny houses** - The tiny house movement is a new trend, but growing fast. Some tiny houses are completely off grid. Powering such a small space presents some challenges as there is not much room for solar panels or battery storage. Off-The-Grid Tiny House Is Pure Design Genius

iii. **Buses or RVs** - Another new trend is converting old school busses (sometimes called Skoolie's) into living spaces or adding solar panels and batteries to RV's. This allows for mobile, off grid living. The Most Cleverly Designed School Bus Conversion - A True Apartment On Wheels

iv. **Earthships** - Earthships are intentionally designed off grid houses that try to use as little energy and resources as possible. They are often built using old tires for walls and as much recycled material as possible. They can be built into the ground so that they use the natural temperature of the earth to stay warm in the winter and cool in the summer. Since Earthships are so energy efficient they do not need much in terms of solar power and battery storage to operate. Some Eathships need as little as 5 solar panels and 4 batteries to operate off grid.

- Incredible Small Off-Grid Earthship Home
- New Earthships capture more energy, water & food at lower cost

2. Design and Assemble a Small Off-Grid System in the Lab

## HOMEWORK

1. Find your home electrical bill and examine it. What are the charges on it? Will solar offset all of the charges on your bill? Are there any demand charges? When you add up all of the kWh rates on the bill what is your effective electrical rate? When you add up every single charge on your bill (you will need to spread non-kWh charges over the total number of kWh charges) what is your electricity kWh rate?
2. What materials could you recycle locally if you were going to build an earthship where you live. How many solar panels would you need?

## MEETING INDIVIDUAL NEEDS

The Capstone project will involve hands-on wiring and assembling of batteries, inverters and solar panels. There are also lots of video resources available for visual learners.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

**Year 1:**
3 SESSIONS
(90 MINUTES EACH)
**Year 2/3:**
3 SESSIONS
(180 MINUTES EACH)

## RESOURCES/LINKS

Different types of batteries and their properties.

Best Batteries for Solar: Choose the Best for Your System

What is a hybrid solar system? — Clean Energy Reviews

Making Sense of Demand Charges: What Are They and How Do They Work?

We build Earthships and retrofit houses — Earthship Biotecture michael reynolds

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

Solar Installation

**Year 1:**
3 SESSIONS
(90 MINUTES EACH)
**Year 2/3:**
3 SESSIONS
(180 MINUTES EACH)

## LESSON

Fundamentals of Solar Energy

## BIG IDEA(S)

Solar energy can be captured and converted into other forms of energy in biological and man-made systems.

## OBJECTIVES

Students will be able to:

- Recall and share basic information about the history of solar power
- List and explain the differing ways that solar power is captured (fossil fuels, passive shelter design, and solar panels)
- Explain how electrons are involved in solar energy transformations
- Compare the possibilities and limitations of using solar energy

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Energy Systems**

2 HOURS

## TASK LIST SUBCATEGORY

**102** Describe how energy is fundamental to our everyday lives

**104** Describe sources and uses of energy

**107** Describe the fundamentals of solar energy

**702** Recognize and use electrical concepts, terminology, relationships, and formulas

## STANDARDS

### PA/SDP

**3.2.12.B3.** Describe the relationship between the average kinetic molecular energy, temperature, and phase changes.

**3.2.10.B2.** Explain how the overall energy flowing through a system remains constant; Describe the work- energy theorem. Explain the relationships between work and power

**3.2.C.B3.** Describe the law of conservation of energy.

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Photovoltaic Basics*, Sean White, 2019, pp.1; 43-59

*Solar Electric Handbook: Photovoltaic Fundamentals*, SEI, 2013. pp 40-46

### MATERIALS NEEDED

**Teacher Presentation:** Instructor will deliver a talk based on the resource information provided below

**Content:**

- Use of solar panels and inverters in the lab
- How solar panels work:
  How do solar panels work? (Physics of Solar Cells)
- Overview:

**Technology:** Teacher computer, projection device, student computers and telephones as needed

## KEY TERMS

solar power
solar energy
sunlight (irradiance)
arrays
panels
silicon
solar radiation
pyranometer
cells
electrons
valence
AC and DC
photons
semiconductors
inverters

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

- In pairs, have students draw a diagram of the sun's rays, how they think they might be collected, how they are changed into electric power. Explain that they should make up any explanation and that this is a way to make strong connection to the material (prediction, recall of knowledge, synthesis) **AND/OR**
- Pictures of pieces of bread, a cell phone, and an e-bike will be shown to students. They will have to choose one to explain how that thing gets the energy that is stored inside. Choose volunteers to explain their reasoning for each and get class input to come up with the best agreed upon explanation.

**SUN ENERGY:** Provide background information as appropriate

- The sun is the main source of the energy that powers life on earth. It gives the energy necessary for plants and food to grow. It provides the temperature environment that makes life possible. During the past three hundred years, humans have experienced a huge improvement in the standard of living for most people. This improvement was powered by carbon based energy sources such as wood, coal, and petroleum. Even these fuels are essentially stored forms of solar energy, where the solar power used to create the plants they came from is released when they are burned. They are sometimes called fossil fuels since the plants that formed them were crushed beneath the earth and compressed for millions of years, in order to form the fuels we then mine from the earth.
- Solar energy is also utilized in well designed homes and buildings through the use of what is called passive solar design. We experience the greatest amount of heating from the sun when it is highest in the sky, during the middle of the day. At that point the sun is seen to be in the south. Buildings utilizing passive solar design are positioned so that sunlight comes in through south facing windows and the heat from it is captured by materials such as stone that can store it and radiate it back into the building's interior. Well designed passive solar buildings also are well sealed and well insulated to keep the solar heat gain from escaping the structure to the outside air.
  - Solar Power is measured in power per unit area and most often in watts per square meter
  - Solar Energy. Since power x time + energy, then solar power x time = solar energy

### SOLAR HISTORY

- Over the last 130 years, however, another method of using the energy from the sun has been developed. In 1883, an American inventor named Charles Fritts developed the first solar panel. By taking a layer of the element selenium and coating it with a very thin layer of gold he was able to generate a small electrical current when the material was placed in the sun. These first solar panels were not at all efficient. They could only convert about 1% of the energy hitting them into electrical energy.
- Then in 1941, Russell Ohl used silicon for the basis of panels that were 5% efficient. Since then, many improvements have been made and now the average solar panel sold operates at about 17% efficiency and they are still improving.

### EXPLORE

Show this YouTube segment on solar panels twice - once all the way through and then stopping as students have questions. Students should be cautioned that they won't necessarily understand every bit of the video but that is ok. Instructor will show the YouTube segment explaining inverters. Instructor will point out the parts of the actual solar panel and inverter. How Do Solar Panels Work? (Physics of Solar Cells)

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

Energy Systems

2 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Energy Systems

2 HOURS

### EXPLAIN

- Here is a more in depth description of **how solar panels work**. Light is a form of energy. The particles that carry the energy of light are called photons. In certain materials, the electrons in the outermost shell of their atoms can be made to escape from the atom if they are hit by photons. Other materials are in need of electrons in their outer shells. The difference between the two can be utilized to cause an electric current flow. We can tell which elements tend to need electrons and which tend to lose electrons by their position on the periodic table. Elements on the periodic table are organized according to the number of electrons they have in their outer shells.
- Phosphorus and boron are typical materials that have the tendencies just described. In a solar panel, thin layers of silicon, which is a poor conductor, are coated or doped on differing sides with these two types of materials. When hit with light, the silicon becomes an area where electrons traveling between the two doping elements collect and can be tapped off as current.
- These techniques are used to produce small solar cells. Solar cells are then combined to make solar panels. And finally, for most large scale uses, many panels are wired together into a solar array.
- Solar panels produce direct current. As we learned in the unit on power generation and transmission, alternating current more easily allows the voltage to be stepped up for transmission over long distances and household use. To make this change, a device called an inverter is used. It converts the DC power produced by solar panels into AC power.

### EXTEND

- Extend the lesson by presenting how a power inverter works https://www.youtube.com/watch?v=iIqhAX0I7lI
- Teacher will use the solar panel and inverter project supplied by SolarStates
- There are many practical considerations involved in constructing a solar array. The panels need to be oriented at an angle that takes best advantage of the sun's rays. In addition, attention must be paid to any sources of shade that might block the sun at various points during the day. Some solar panels are mounted on supports that move to stay aligned with the sun as it changes position in the sky. In actuality it is not the sun that is moving but the fact that the earth rotates that makes the sun appear in different positions in the sky.
- Until recently solar energy couldn't compete with electricity generated by different means. Solar panels used to be much more expensive than they are now and had the disadvantage of not producing power during the night or during periods of the day when the sun was blocked by clouds. Now batteries can help store power from solar panels to bridge times when current isn't being generated. Solar panels are particularly advantageous during the daylight hours of peak electrical demand, when traditional sources of electricity are most expensive. Also, solar power does not require an expensive and potentially unreliable transmission grid to bring centrally produced power to dispersed users. But perhaps the biggest advantage of solar is that, unlike fossil fuels, it does not produce $CO_2$, the greenhouse gas responsible for global warming.

## LESSON
System Sizing

## OBJECTIVES
Students will:
- Explain the importance of system sizing parameter
- Perform calculations using Ohms law for sizing strings

## BIG IDEA(S)
Knowing the minimum and maximum number of modules in a PV is critical for performance.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**Solar Project Management and Design**

180 MINUTES

## TASK LIST SUBCATEGORY
**415** Demonstrate knowledge of manufacturer specifications

**405** Identify the factors related to system sizing and production

**402** Select appropriate components to design a solar system

## OVERVIEW
In this session, students will learn to identify the factors related to system sizing and production and by able to select appropriate components to design a solar system.

## KEY TERMS
series
PV source circuits
parallel
homeruns
PV output circuits

## STANDARDS
### PA/SDP
**3.2.10.B4.** Describe quantitatively the relationships between voltage, current, and resistance to electrical energy and power.

**3.2.10.B6.** Explain how behavior of matter and energy follow predictable patterns that are defined by laws.

## INSTRUCTIONAL
### TEXTS/REFERENCES
*Solar Electric Handbook: Photovoltaic Fundamentals and Applications; Solar Energy International;* Pearson 2013

### MATERIALS NEEDED
**Teacher Presentation:** Presentation 400-5

**Content:** Chapter 6 and Chapter 13 of text

**Technology:** Access to Google sheets

## IMPLEMENTATION (LESSON PLAN)
### ENGAGE
- Ask students to list in their notebooks or on the board the pros and cons of 60 cell modules and 72 cell modules.

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### EXPLORE

- Teacher goes over powerpoint presentation 400-5.
- Students complete a string size calculator spreadsheet.

### EXPLAIN

- As a whole class discuss the answers to the string size calculator spreadsheet.

### EXTEND

- Review the Mayfield Energy PV String Size web site.
- Teacher provides parameters for new calculations.

### EVALUATE

- Collect student work and provide feedback. Review areas of weakness or misunderstandings.

## RESOURCES/LINKS

Calculating String Size
https://solardesignguide.com/calculating-string-size/

How to Calculate PV String Size
https://www.mayfield.energy/blog/pv-string-size

SolarEdge String Rules video
https://youtu.be/YP5ik77b_v4

String Sizing Guide
https://unboundsolar.com/blog/string-sizing-guide

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Project Management and Design

180 MINUTES

## LESSON

Sun Path

## OBJECTIVES

Students will:

- Explain the impact of the path of the sun and its seasonal changes on solar array placement
- Evaluate site placement with an instrument like a solar pathfinder

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Earth Science Basics**

**Level 1:**
2 HOURS
**Level 2:**
2 HOURS
**Level 3:**
3 HOURS

## BIG IDEA(S)

Solar production relies heavily on the intensity and position of the sun. By combining the site-specific shading data of an instrument like the Solar Pathfinder™ with the published global weather data, an accurate solar site analysis can be made. This insolation data, on an hourly and monthly basis can then be applied to solar site analysis and positioning.

## OVERVIEW

Solar production relies heavily on the intensity and position of the sun. The position of the earth during the year changes, can increase shading and the angle that the sun hits the location. This all needs to be predicted and helps make placement decisions for the solar array to capture the maximum amount of solar energy.

## STANDARDS

### PA/SDP

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity with appropriate comprises in complex real-life problems.

**3.4.12.B2.** Illustrate how, with the aid of technology, various aspects of the environment can be monitored to provide information for decision making.

### NGSS

**HS-ESS3-4** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

## KEY TERMS

winter solstice
summer solstice
equator
sun angle
solar pathfinder
shading
latitude
longitude

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Photovoltaic Basics,* Sean White, 2019. Pp 43-63

Solar Pathfinder Demonstration

### MATERIALS NEEDED

**Teacher Preparation:**
https://news.energysage.com/whats-the-best-angle-for-my-solar-panels/

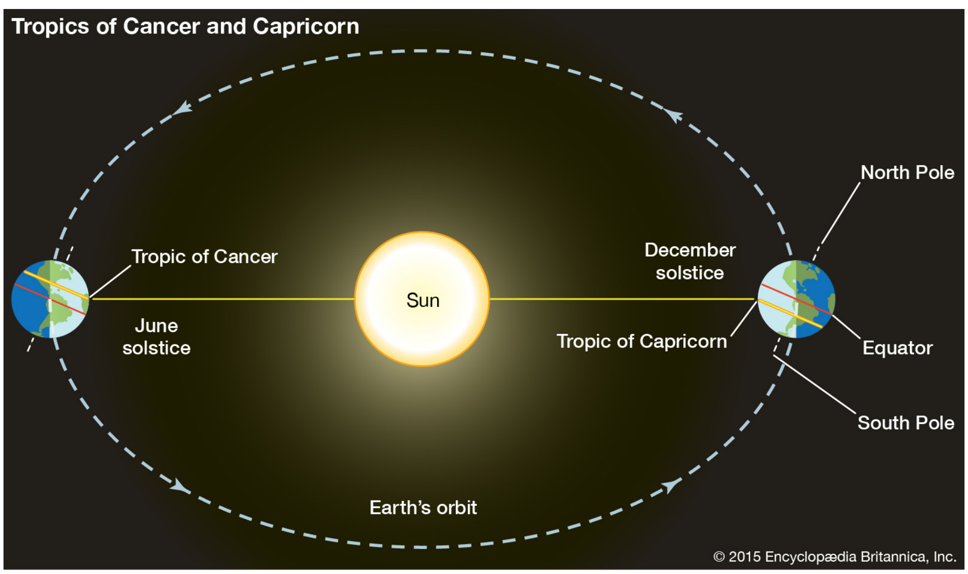
**Teacher Presentation:** Solar Pathfinder - Solar site analysis

**Content:**

- Solar Pathfinder Demonstration
- Pathfinder Overview

## IMPLEMENTATION (LESSON PLAN)

1. Solar production relies heavily on the intensity and position of the sun.
2. The sun always rises in the east and sets in the west. Depending on what hemisphere you are in and how close you are to the equator the Sun can also mostly be in the southern or northern sky. Since Philadelphia is in the northern hemisphere the sun is mostly in the southern sky as it moves from east to west (remember, the sun is not actually moving, Earth is rotating). Earth rotates from west to east and makes the sun appear to move from east to west.
3. Did you know that Earth is actually closer to the sun in the winter time than in the summertime? Yes, it's true. The reason the temperature is colder in the winter is not because of the earth's proximity to the sun, it is because of the angle the sun's rays hit Earth. During the summer the sun's rays hit the earth at close to a 90º degree angle. During the winter the sun's rays can hit the earth at around a 45º.
4. So, the sun not only moves from east to west every day, but it also slightly changes the angle that the rays hit Earth. When the sun is at its lowest point in the sky it's called the winter solstice. When the sun is at its highest point in the sky it's called the summer solstice. When the sun is exactly between its highest and lowest points its called the equinox.
5. The equator is an imaginary line around the center of the earth and is considered zero degrees latitude. Traveling north or south from the equator will result in the degrees of latitude increasing. For example, Philadelphia is at about 39º latitude. This means it is 39º from the equator.
6. The Tropic of Cancer (or Northern Tropic) is about 23º north of the equator and the Tropic of Capricorn (or Southern Tropic) is about 23º South of the equator.




7. If you live in the Northern Hemisphere then the June solstice is the summer solstice (the longest day of the year) but if you live in the southern hemisphere then the June solstice is the winter solstice and it is the shortest day of the year. All of this is a result of the fact that while Earth is constantly rotating it is also tilted on its axis in respect to how it faces the sun. The tilt of Earth and its orbit around the sun creates different angles that the sun's rays hit the earth throughout the year which in turn creates the seasons.
8. The closer you get to the equator the hotter it gets because the sun angle remains more consistently close to 90º.

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**Earth Science Basics**

**Level 1:**
2 HOURS
**Level 2:**
2 HOURS
**Level 3:**
3 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

9. At the equator a solar system should be laid flat as the Sun will be in the northern sky for half of the year and in the southern sky for the other half of the year.
10. The closer you are to the equator the greater the sun hours per day. For example, Miami has more daily sun hours than Philadelphia because Miami is much closer to the equator than Philadelphia.
11. Peak sun hours (PSH) is the term solar professionals use to describe the number of hours with bright sunlight. It is typically average. So on a cloudy day you may get 2 peak sun hours as a result of all of the light that hits the earth for the entire day. Philadelphia averages about 4.5 PSH per day.
12. More PSH means more solar energy! So the closer you get to the equator, the more energy a solar panel will produce. For example, a 400W panel in Philadelphia will create 1.6kWh of energy per year whereas that same panel in Miami will produce a little over 2.0 kWh per year.
13. A sun path chart shows the position and altitude of the sun throughout the year at a given latitude.
14. A solar path finder has a sun path chart and allows you to look at a reflection of the surrounding physical environment overlaid on that sun chart so you can determine if an obstruction is going to shade your solar system and, if so, at what points in the year the shade will affect the solar array
15. DEMO: Solar Path Finder.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Earth Science Basics

**Level 1:**
2 HOURS
**Level 2:**
2 HOURS
**Level 3:**
3 HOURS

## LESSON

STC and the Impact on Solar Production

## BIG IDEA(S)

STC (Standard Test Conditions) are how PV modules are tested and are the conditions under which the module performance is measured.

## OBJECTIVES

Students will:

- Evaluate the output of a solar panel
- Explain when solar panels can perform at their best
- Explain the following solar fundamental terms
  - Standard Test Conditions (STC)
  - Voltage open circuit ($V_{OC}$)
  - Amperage max power (Ipmax)

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

**Solar Fundamentals**

**Level 1:**
2 HOURS
**Level 2:**
3 HOURS
**Level 3:**
3 HOURS

## TASK LIST SUBCATEGORY

**601** Demonstrate ability to monitor system

**603** Demonstrate the use of testing and performance equipment

**607** Analyze monitoring results for solar power systems

## OVERVIEW

STC (Standard Test Conditions) are how PV modules are tested and are the conditions under which the module performance is measured.

## STANDARDS

### PA/SDP

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

**3.4.12.A2.** Describe how management is the process of planning, organizing, and controlling work.

**3.4.12.B2.** Illustrate how, with the aid of **technology,** various aspects of the environment can be monitored to provide information for decision making.

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Photovoltaic Basics,* White, 2019. p. 44

*Solar Electric Handbook,* SEI, 2013. Pp. 96; 102; 104-5

### MATERIALS NEEDED

**Teacher Preparation/Presentation:**

https://www.pveducation.org/pvcdrom/properties-of-sunlight/air-mass

Understand how to use an Amprobe Solar 100 irradiance meter

**Content:** How to use an irradiance meter for successful solar inspections

## KEY TERMS

standard test conditions (STC)
voltage
current
irradiance
insolation
solar radiation
voltage open circular ($V_{OC}$)
Amperage short circuit ($I_{SC}$)
Ipmax
Vpmax

## INSTRUCTIONAL - CONTINUED

### MATERIALS

- Irradiance meter
- Thermometer (infrared)
- Multimeter

## IMPLEMENTATION (LESSON PLAN)

1. Standard test conditions (STC) refers to the circumstances in which a solar panel will produce its rated wattage output (Pmax). STC has the following characteristics
   a. 1,000 W per meter squared of light irradiation
      i. Use an irradiance meter
      ii. Ensure the meter is measuring irradiance using the $W/M^2$
   b. 1.5 Air Mass (AM)
      i. Air Mass is difficult to measure. Usually you are very close to 1.5 AM unless you are in an area with elevation or some other special circumstance.
   c. 25º C / 77º F
      i. Use a weather app to check ambient temperature
      ii. Use an infrared thermometer
2. Understanding STC is very important. All calculations on the performance of solar panels is based on STC. If the ambient weather conditions do not match STC one has to determine how great the difference is between the actual conditions and STC and then derate the solar panel output by that amount.
3. Voltage appears with the presence of very little light. So even in low light conditions you will get significant voltage from a solar panel.
4. However, in order for current to flow a solar panel needs intense light. So current will not flow without bright, direct light.
5. When measuring the light also measure voltage open circuit ($V_{OC}$) and amperage short circuit ($I_{SC}$) so that all readings will be coordinated.
6. Remember, if you are at STC then a solar panel should be able to achieve it's Ipmax, Vpmax, and Pmax ratings.
7. Solar time reflects the sun's position in the sky. For example solar noon is when the sun is highest in the sky. When measuring solar output it is good to be as close to solar noon as possible. Measuring PV output in low light conditions can be very difficult.
8. ACTIVITY: Take a solar panel outside and measure the temperature and solar irradiation. Using a multimeter measure Voc and Imp. Do the results match up with what you would expect? https://www.pveducation.org/pvcdrom/properties-of-sunlight/air-mass
9. Understand how to use an Amprobe Solar 100 irradiance meter

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Fundamentals

**Level 1:**
2 HOURS
**Level 2:**
3 HOURS
**Level 3:**
3 HOURS

## LESSON

Solar Site Analysis (Optimum Array Orientation and Placement)

## BIG IDEA(S)

How much sun will be at a given location determines how productive it will be. After looking at seasonal differences in energy delivery, it is important to understand how specific techniques and tools work for optimal solar array placement.

## OBJECTIVES

Students will:

- Determine azimuth and altitude angles using a sun chart
- Determine magnetic declination for a given site
- List the variables needed to analyze the amount of sunlight available for a particular solar window
- Explain the process of using tilt angle and orientation to provide maximum energy production for a given site
- Demonstrate solar site analysis tools and procedures

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

**Solar Fundamentals**

3 HOURS

## TASK LIST SUBCATEGORY

| | |
|---|---|
| **107** | Describe the fundamentals of solar energy |
| **405** | Identify the factors related to system sizing and production |
| **411** | Use current technology to determine site suitability |
| **415** | Demonstrate knowledge of manufacturers specifications |

## OVERVIEW

The sun changes position constantly and solar technicians need to define the sun through azimuth and altitude angles and how to find its position. This lesson will cover:

- Finding sun position using a sun chart
- Measure Azimuth and Altitude angles to determine sun position
- Determine magnetic declination
- Utilizing an Inclinometer & Compass

## STANDARDS

### PA

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity with appropriate comprises in complex real-life problems.

**3.4.12.B2.** Illustrate how, with the aid of technology, various aspects of the environment can be monitored to provide information for decision making.

### NGSS

**HS-ESS3-4** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

## KEY TERMS

azimuth altitude
peak sun hours
magnetic declination
true south
orientation
tilt angle
shading
solar noon
sun chart
inclinometer
irradiance
solar window
insolation
Solmetric SunEye
sun path

elevation angle: the vertical tilt of your panels

azimuth angle: the horizontal orientation of your panels (in relation to the equator, in this case)

## INSTRUCTIONAL

### TEXTS/REFERENCES

*Solar Photovoltaic Basics,* White, 2019. p. 44

*Solar Electric Handbook,* SEI, 2013. Pp. 96; 102; 104-5

### MATERIALS NEEDED

**Content:**

- Calculating the Sun's Path and Solar Array Orientation - Page 3
- Photovoltaic Tutorial: Calculating the Sun's Path and Solar Array Orientation

### MATERIALS

SolMetric

- SunEye
- PV Analyzer
- Other solar test and measurement equipment

Solar Pathfinder

SOLAR

TOPIC OF STUDY

Solar Fundamentals

3 HOURS

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE

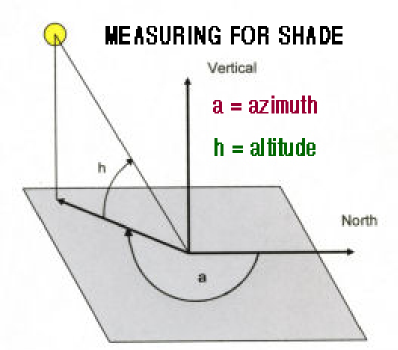
1. Brainstorm: What effects getting the maximum energy in a solar system? (Think-Pair-Share) Have students jot down their thoughts and share with a partner, then report out. Add ideas from all groups.
2. If possible, have students complete the azimuth task in the following lesson plan: Lesson 8: "Watt's" Your Angle?

### EXPLORE

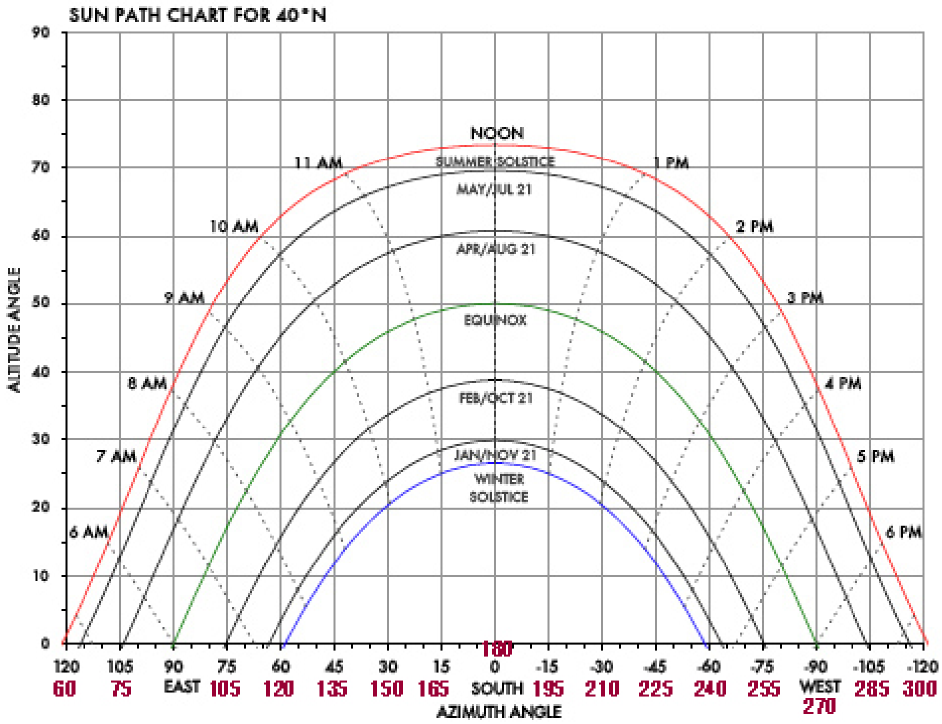
- Review tutorial Photovoltaic Tutorial: Calculating the Sun's Path and Solar Array Orientation and Calculating the Sun's Path and Solar Array Orientation - Page 3

### EXPLAIN

1. Steps in Determining Array Orientation, Shading, etc.
   - Step 1: Generate a **sun path diagram** online for your latitude.
   - Step 2: Next, go outside to the site of your potential solar array and take a compass bearing to determine the azimuth angle and width of each potential obstruction.
   - Step 3: Record the altitude angle of all the same obstructions.
   - Step 4: On the sun path diagram, plot the coordinates for each potential obstacle.
   - Step 5: Analyze the data to determine how much shading will occur.
2. Azimuth and Altitude: How to Measure a Year's Worth of Shade by Hand
   - A shadow will be cast across an array if an object's elevation or altitude angle is the same or greater than the sun's when they share the same compass bearing—that is, from the perspective of the array. This bearing is called an azimuth angle.



## IMPLEMENTATION (LESSON PLAN) - CONTINUED




- A sun path diagram provides the track of the sun over a year's time for your local latitude and time zone. Diagram adapted from solardat.uoregon.edu.
- The solid curving lines on the graph represent the sun's path on one day for each two months out of the year (e.g. April and August), except on the solstices, which represent one day. Although there's a white space between each curved line, it's assumed that the sun will gradually track through these spaces over the course of 30 days. The horizontal axis of the graph charts the azimuth angle (compass orientation), while the vertical axis charts the altitude angle.
- The vertical dotted lines plot the time of day in relation to the azimuth and altitude angles. Remember, it's only between the hours of 9 a.m. and 3 p.m. that shading across an array is counted. For this particular chart, any obstruction located outside the compass range of 100 degrees (close to due east) and 265 degrees (close to due west) does not even need to be measured. The top azimuth scale, incidentally, uses the reference-to-due-south system

3. Magnetic Declination: The difference between true and magnetic north varies by location. This is important for panel orientation and calculations. Declination for a given location can be found on the NOAA website in the National Geophysical Data Center: www.ngdc.noaa.gov/geomag

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Fundamentals

3 HOURS

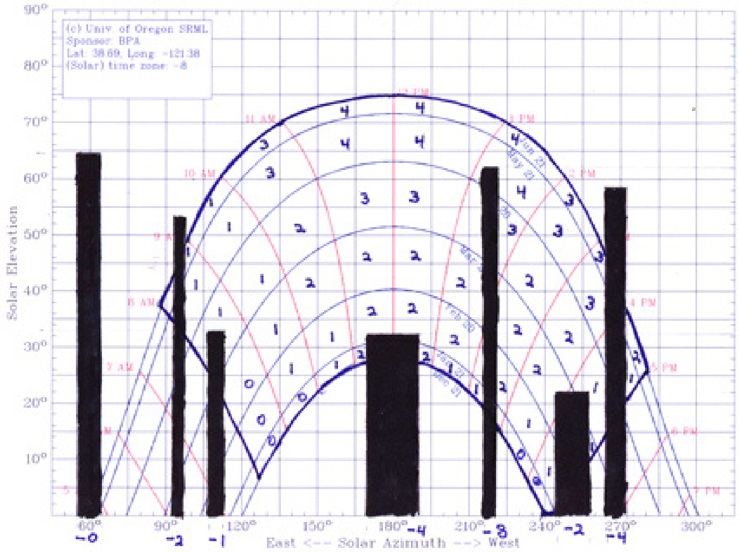
SOLAR

TOPIC OF STUDY

Solar Fundamentals

3 HOURS

4. Shading
   a. The chart will tell you if an obstruction will eclipse the sun as it shines on the array. It will also tell you how long the shade will occur. As you can see, a sun path diagram is a simple line graph with X and Y axes.




   b. Plot each set of coordinates in pencil (i.e. the two azimuth measurements and one altitude angle), one by one. Mark the points near the axes lines on the chart. Now draw and fill in a vertical bar shooting up from the Azimuth axis. Once that's done, you can erase the horizontal line emanating from the Altitude axis.
   c. Repeat the process for all the other objects you measured. And if you took readings from more than one location, repeat the tasks -- one sun path chart per location.
5. Array Tilt Angle and Orientation: A surface perpendicular to the sun receives the most irradiance. However, for fixed-mount-grid-direct systems, a 30-degree array tilt angle maximizes annual production. (Review SEI pages 141-145). Demonstrate the Inclinometer https://www.youtube.com/watch?v=7thWAa0xXsU
6. Solar Window: the time the solar array is free of shade
   a. Data that pertains to the solar window: demonstrate how a solar window is determined. Draw a border along the following lines: the 9 a.m and 3 p.m. dotted lines between the uppermost and lowermost curved sun path line; and the curved sun path upper and lower lines, stopping at the 9 a.m. and 3 p.m. borders.
   b. Demonstrate how this is provided by a Solar Pathfinder Solar Pathfinder - Solar site analysis

**Solar Obstruction Data**

| Month | Actual Solar Rad w/o Shading Azimuth=180.0 Tilt=0.0 KWH/m² /day | Actual Solar Rad w/ Shading Azimuth=180.0 Tilt=0.0 KWH/m² /day |
|---|---|---|
| January | 5.85 | 4.95 |
| February | 6.61 | 5.98 |
| March | 7.26 | 6.86 |
| April | 8.82 | 8.48 |
| May | 8.33 | 8.15 |
| June | 7.64 | 7.64 |
| July | 7.33 | 7.27 |
| August | 7.28 | 7.09 |
| September | 6.65 | 6.46 |
| October | 6.76 | 6.36 |
| November | 6.13 | 5.52 |
| December | 5.53 | 4.08 |
| **Totals** | **84.19** | **78.84** |
| | **Effect: 100.00%** | **Effect: 93.64%** |
| | **Sun Hrs: 7.02** | **Sun Hrs: 6.57** |

The chart is excerpted from a report by the Solar Pathfinder software and provides the month by month impact of shading on a proposed solar array. The photo on the right

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

shows another module placement scheme designed to avoid a year round obstruction - the chimney.

7. Shading remedies:If your assessment produces more than 10% shading, you can take a variety of steps to improve that number. Moreover, any amount of shade -- even one percent! -- can cause a loss of voltage that affects all modules wired in the same series string. In addition to changing the placement or orientation of an array, you can and should try to mitigate its impact within the electric circuit.
    a. Here are the most common adjustments solar designers employ to address shading over an array site:
        i. Move the site farther down the roof (or off the roof).
        ii. Use a non-rectangular configuration.
        iii. Leave an empty space within the array to avoid an obstruction.
        iv. If possible, arrange for a tree removal or seasonal pruning.
        v. Raise the array's height so that the object altitude angle is lower than the sun's altitude/elevation.
        vi. Use a module model with extra shade mitigation features.
        vii. Use several microverters instead of one central inverter, or some form of DC optimization, so that shaded modules won't affect the production of non-shaded modules.
        viii. Run separate cables to the central inverter for each module string so that a lower voltage in one string won't affect the voltage of the others.
        ix. Use a tracking system instead of a fixed arraymount.
8. Peak Sun Hours: the daily amount of sun available on average is given in peak sun hours. The irradiance element of a peak sun hour (1,000 W/m2) is the solar radiation component of Standard Test Conditions.

### EXTEND

- Site Analysis Tools
    a. Inclinometer
    b. www.solarpathfinder.com
    c. www.solmetric.com

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Fundamentals

3 HOURS

## LESSON

Interconnection and System Commissioning

## BIG IDEA(S)

Interconnection standards dictate how renewable energy systems can be legally connected to the electricity grid. They are a set of requirements and procedures for both utilities and customers.

## OBJECTIVES

Students will:

- Explain the interconnection process at the site to utility.
- Explain the interconnection application for your local jurisdiction.
- Interpret line drawings distinguishing load-side and line-side interconnection scheme.
- Explain the purpose of system commissioning.

BRIGHT SOLAR FUTURES

SOLAR

## TOPIC OF STUDY

Solar Installation

3 HOURS

## TASK LIST SUBCATEGORY

**505** Install racking, modules, inverter, BOS, conduit, interconnection

**508** Identify the fundamentals of system commissioning

## OVERVIEW

The majority of US residential and commercial PV systems are *grid-interactive* (or *grid-tied*), which means that they are designed to be able to export excess power to the utility grid. Export occurs when the power generated by the solar system is greater than the power used by the loads on site. A photovoltaic system will be given permission to interact with the power grid only after a formal approval has been issued by the utility. The process through which a utility verifies a solar system's compliance to its technical and administrative requirements is commonly referred to as the interconnection process. There are two main types of PV interconnection: Load-Side and Line-Side.

## KEY TERMS

interconnection
load-side
authority having jurisdiction (AHJ)
line-side
busbar
interconnection agreement
system commissioning

## FURTHER DEFINITION OF KEY TERMS

A **busbar is a rigid conductor used for connecting together several circuits.** The system for monitoring partial discharge is connected in parallel with a busbar between a generator and an electric network. A busbar is a metal strip in a distribution box that provides one connection point for all the circuits.

**Commissioning** is the process of assuring that all systems and components of a PV plant are designed, installed, tested, operated, and maintained according to the operational requirements of the project's owner or final client. To ensure building code compliance, an inspection will verify proper material selection, soundness of structural support, and secure attachment to the roof or ground. Inspection of a solar PV installation's electrical system often focuses on wiring methods, circuit protection, grounding, and safety signage.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

3 HOURS

## STANDARDS

### PA

**3.4.10.A1.** Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity appropriately in complex real-life problems.

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies**.

**3.4.12.B2.** Illustrate how, with the aid of **technology,** various aspects of the environment can be monitored to provide information for decision making.

**3.4.12.C2.** Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

**ETS1.B:** Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)

## INSTRUCTIONAL

### TEXTS/REFERENCES

PV Interconnection: Load-Side vs. Line-Side

*Solar Electric Handbook*, SEI, 2013. P 27

## IMPLEMENTATION (LESSON PLAN)

### ENGAGE/EXPLORE

- Using the Lab electric wall set-up, have students share how connection to/from the utility works. How would this take place safely? Who do you think has jurisdiction to permit this connection in your town/city?

### EXPLAIN

1. General Standards for interconnection: Although interconnection standards are not consistent across states and utilities, many states adopt engineering and safety requirements based on IEEE 1547 and UL 1741 standards. Additionally, state interconnection standards are increasingly modeled after FERC's SGIP (see Background section above). Interconnection standards can also vary by:
   a. Net metered vs. non-net metered systems
   b. System capacity requirements
   c. Eligible technologies
   d. Eligible sectors (e.g., commercial, residential)
   e. Fees
   f. Insurance requirements.
2. Review the PECO brochure for the interconnection process and the steps involved. PECO Interconnection Brochure
3. Is there another licensing entity that needs to be involved in your area? How is an agreement handled?

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

**EXTEND/DEMONSTRATE:** Doing the Interconnection

4. There are **2 types of residential solar interconnections** (otherwise known as the point-of-interconnection, POI). Line/Supply side and load side. The type of interconnection is determined by where the solar is meeting the grid.
    a. If a backfeed breaker is installed then that breaker is on the **load-side** of the main service disconnect and thus is a load side connection. ***Load-side tap connection*** is applied when there are no circuit breaker slots available. The wires are connected directly to the existing wires, between the electrical panel and (on the *load side* of) the main breaker.
    b. If the solar power is joining the grid between the main service disconnect and the utility meter then it is a l***ine/supply side connection*** because it is on the line/supply side of the main service disconnect.This method requires that the wires from the inverter are connected to the service wires on the line side of the circuit breaker. Utilities usually require that the design for this connection and the installation are approved by a professional electrician.
    c. Once the utility engineers have approved the line side tap connection, it is necessary that a transformer power shutdown is scheduled, to allow the electrical contractor to perform the connection on wires that are otherwise connected to the utility grid.
5. Feedback Breakers
    a. The NEC 120% rule: How big of a backfeed breaker are you allowed to insert into the main service panel in the house? This is where the 120% rule applies. Here are the basics, take the rating of the bus bar and multiply it by 120% (1.2). Then subtract the size of the main service disconnect and that will result in the size of the largest backfeed breaker that can be installed in a main service panel. Sample calculation:
        i. Busbar rating 200A
        ii. Main service disconnect 200A
        iii. Calculation: busbar = 200A x 120% (12) = 240, 240 - 200 (Main service disconnect)= 40. So a 40 amp breaker is the largest backfeed breaker that can be installed.
        iv. Remember, a backfeed breaker must be installed on the opposite end of the bus bar from the main service disconnect.
    b. The overcurrent protection devices below are the main circuit breaker and the PV backfeed circuit breaker in the electrical panel.

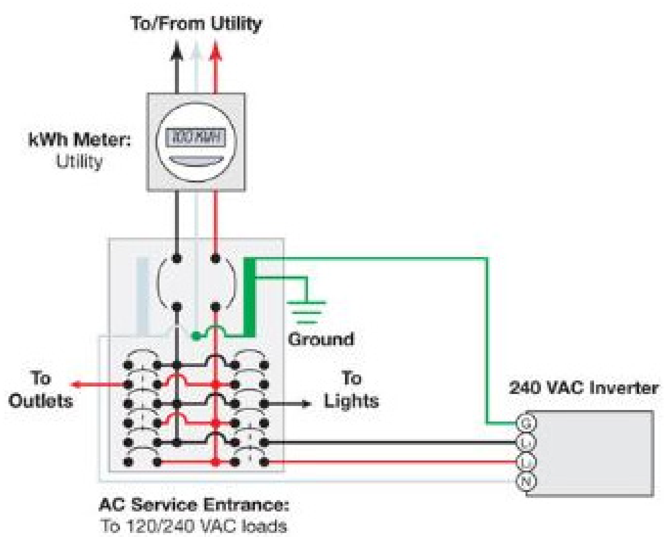



Image courtesy of Home Power Magazine

SOLAR

TOPIC OF STUDY

Solar Installation

3 HOURS

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

c. The overcurrent protection device is the PV *fused* AC disconnect.

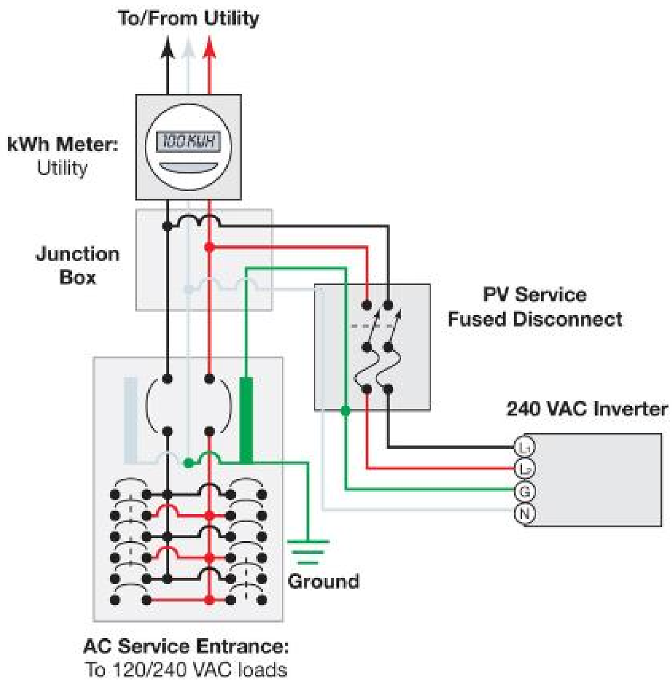



Image courtesy of Home Power Magazine

6. Interconnection and Utility Companies
   a. During the interconnection process, utilities certify that a PV system meets the following general requirements:
      i. The power exported to the grid is measurable and compliant with the grid's standards in terms of voltage, frequency, power quality. that the equipment used is certified
      ii. The AC side of the PV system (between the inverter and the utility meter) meets the utility's safety requirements (labeling, location of equipment, connection to electric panel)
      iii. The power and energy generated to meet the net metering program requirements
   b. Utilities usually require that an interconnection application is submitted to their interconnection department to gather the necessary information about the proposed system, The application may be submitted by the account holder or, when properly designated, by the contractor that designs and installs the PV system. The interconnection application usually includes professional technical drawings, such as site plans and an electrical diagram.
   c. Once the utility has received the approved final permit, it will schedule an inspection of the installed system. During the site visit, performed by qualified utility personnel, the solar system will be tested, and, if necessary, revenue meters installed and/or replaced. When the system is approved, the utility will notify the account holder and the installer, which will then be able to turn on the system and export power to the utility grid.

### EVALUATE

- Have working groups provide an oral demonstration at the power wall to walk through the actual interconnection process.

## LESSON

Fixed Tilt and Dual Axis Tracker Systems

## BIG IDEA(S)

Previously students learned how flush mount or ballast weight solar installation work. Fixed tilt solar is very similar to these roof mounted systems, however, when they are installed over empty ground instead of on existing buildings, they are called ground mount, fixed tilt systems.

## OBJECTIVES

Students will be able to:

- Explain the advantages and disadvantages of fixed tilt and tracker based racking systems
- Demonstrate the concepts of how to install both styles of systems
- Describe how tilt is established based on seasonal need, location, distance from energy use, and angle of the sun.

BRIGHT SOLAR FUTURES

SOLAR

### TOPIC OF STUDY

**Solar Installation**

**Year 1:**
6 HOURS
(FOUR 90-MINUTE SESSIONS)
**Year 2/3:**
6 HOURS
(TWO 180-MINUTE SESSIONS)

## TASK LIST SUBCATEGORY

**506** Describe fixed tilt systems as compared to single and dual axis tracker systems

## STANDARDS

### PA/SDP

**3.4.10.A1.** Illustrate how the development of **technologies** is often driven by profit and an economic market.

**3.4.10.A2.** Interpret how **systems** thinking applies logic and creativity with appropriate comprises in complex real-life problems.

**3.4.10.B2.** Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies.**

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**ETS1.B:** Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)

## INSTRUCTIONAL

### TEXTS/REFERENCES

3D Technical Animation - Dual Axis Solar Tracking System

Worksaver Skid Steer Post Hole Digger

PD10 Pile Driver | Vermeer

PST 2AL Dual Axis Tracker

*Solar PV Engineering and Installation* (Sean White)

*Solar Photovoltaic Basics* (Sean White)

## KEY TERMS

single plane
inter-row shading
dual axis
single axis
trigonometry
fixed tilt
zenith
brownfields
power density
ground screw
pile driver
skid steer
ground mount

## INSTRUCTIONAL - CONTINUED

### MATERIALS NEEDED

**Teacher Preparation:**

*Solar PV Engineering and Installation* (Sean White) Chapter 7 Solar trigonometry

*Solar Photovoltaic Basics* (Sean White) Chapter 9 PV System Mechanical Design

**Content:**

#### MATERIALS

- Lights
- Cardboard
- Dark room Lights

**Technology:** Review the spec sheets provided (Ironridge; Soltec)

## IMPLEMENTATION (LESSON PLAN)

### FIXED TILT SYSTEMS

### ENGAGE/EXPLORE

1. Most of what has been discussed so far is Flush mount or ballast weight solar installation. This is a form of fixed tilt solar however, when most people talk about fixed tilt solar systems they are referring to ground mounted solar.
2. What do you know about ground mount systems? What is different about installation of this kind of system? Provide a presentation based on background knowledge of ground mounted solar vs. roof mounted solar
    a. Roof mounted solar is installed in already used spaces
    b. Roof mounted solar is very efficient because it generates energy right where it's being used. There is not a long distance for the energy to travel.
    c. Ground mounted solar requires land space
        i. Is all land space the same?
        ii. Farm land, can solar and farming co-exist?
        iii. House backyard or other land related to housing
            1. Discuss trenching to house, do you have to go under anything (driveway, wall, etc.)?
        iv. Brownfields and contaminated land: there are lots of areas where the land is contaminated or otherwise unusable. Can they be good for solar?
            1. Discuss what might happen if a capped brownfield is drilled into. Contamination might leak
            2. Discuss advantages of ballast weight ground mount installation when installing on a brownfield site
    d. Orientation is important for a ground mounted solar
        i. In the northern hemisphere you want to face south
        ii. Avoid shading or obstructions
        iii. Mark the perimeter of the solar array using strings (class activity, on the floor design a solar array and then place strings on the floor around the room to mark the perimeter).

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

**Year 1:**
6 HOURS
(FOUR 90-MINUTE SESSIONS)

**Year 2/3:**
6 HOURS
(TWO 180-MINUTE SESSIONS)

## IMPLEMENTATION (LESSON PLAN) - CONTINUED

### EXPLAIN

1. Digging and Mounting Systems
   a. Always call the local Dig Safe authority before digging in the ground!
   b. Soil conditions
      i. Soft sandy soil (not good uplift strength)
      ii. Harder clay-like soil
      iii. Rocky soil (depending on the size of the rocks you may not be able to dig deep enough) Be careful using an auger with a Skid Steer in rocky soil, you can flip the Skid Steer!
   c. Digging tools
      i. Hand dig using a shovel
      ii. Ditch Witch trenching tool
      iii. Skid Steer with digging attachments (different types of attachments available: bucket shovel, auger, shovel of different widths)
      iv. Mini-excavator
      v. Excavator
   d. Ground mount racking systems that penetrate the earth
      i. Ground Screw
      ii. Concrete sono tube
      iii. Pile Driver installed piles
      iv. Vibration installed piles
   e. Figuring out how much solar can be installed using a fixed tilt system
      i. Discuss land area available for solar
      ii. Are there local AHJ requirements about ground mount solar (Does it need to be fenced in? How close to the property line can it go? Etc.)
      iii. Are there any land use issues to be considered
         1. Will animals be using the same space? If so, what types? NOT GOATS! Cows can work.
         2. Will plants be grown underneath? If so how, will they be maintained and cut back?
         3. If plants are not wanted how will the ground be treated to prevent plants from growing? Using tarps or other covers such as mulch or stone.
         4. How will water run-off be collected? Does it need to be?
      iv. Will the solar fit in a single row of panels that are all coplanar? Or will there need to be multiple rows?
      v. What is the ideal tilt angle for the solar? Ideal production tilt is always your latitude. However, if there are multiple rows you must consider inter-row shading!
         1. Discussion of Trigonometry and how you can calculate inter-row shading. Reference Solar PV Engineering and Installation Chapter 7 (pg. 99).
         2. IN CLASS ACTIVITY. Have students cut out to scale versions of solar panels using cardboard (1"= 1'). Use toothpicks, cut straws or other methods to angle the cardboard up on a surface. hang a light a known height and distance away from

BRIGHT SOLAR FUTURES

SOLAR

**TOPIC OF STUDY**

**Solar Installation**

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## IMPLEMENTATION (LESSON PLAN) - CONTINUED

the cardboard. Can you calculate the length of the shadow? Shine the light and turn off all other lights. Measure the shadow.

3. Could you get more power out of the area available by sacrificing the ideal tilt to allow for more panels to fit in the area (Lower tilt shrinks the inter-row shading and allows for greater power density!)

### SINGLE AND DUAL TRACKER SYSTEMS

### EXPLAIN

What is a single axis tracking system? What is a dual axis tracker and how does it work?

a. Single axis tracker:
   i. Advantages: A single axis tracker is a solar racking system that tracks the sun in a single direction. Sometimes, single axis trackers track east to west throughout the day if they are motor powered (but this is rare). Single axis trackers can be installed with driven piles and do not necessarily require concrete footers.
   ii. Functionality: Most single axis trackers adjust the tilt of the panels manually or with a very simple motor. This means there is little to no maintenance. If using a single axis manually powered tracker the tilt adjustment typically happens twice per year. A sharper angle in the winter and a flatter angle in the summer. This allows you to gain solar production throughout the year.
   iii. Disadvantages: Even with very few moving parts there are still moving parts and potentially motors involved. These create points of failure. Also, since the solar is only tracking in a single axis some potential solar energy gains are being lost. They are not as efficient as dual axis trackers.
b. Dual axis tracker:
   i. Advantages: Dual axis trackers allow for the most possible solar energy production because they are always optimizing the angle of the array to be perpendicular to the sun. They are good to use in environments where there is not a lot of sun throughout the year. They are also good to use in environments prone to storms as they will move to a flat position for protection when wind speeds get above a set threshold.
   ii. Functionality: The dual axis tracker moves east to west throughout the day and also slightly adjusts the angle of the panel throughout the year to match the height of the sun. These types of trackers usually have an electric motor and there can be a special solar panel on the tracker that is used to charge a battery that powers the tracker. Additionally, since in the winter they can be at a very steep angle, dual axis trackers usually have wind speed indicators on them. If the wind speed gets too high they will move to the flat position in order to shed wind load.
   iii. Disadvantages: As with anything with moving parts there is a higher probability of something breaking. Most dual axis trackers require some sort of regular maintenance. Dual axis trackers usually require a concrete footer that goes at least six feet deep (and perhaps much more) in order to counter strong wind and snow loads. Lastly, the spacing between trackers can be quite large as they need space to move in every direction and lay flat (don't forget that we don't want them to shade each other!)

### EXTEND

Utility Scale solar: Almost all VERY large solar systems (10 MW and above) are ground mount systems. A 10 MW solar system may consist of 30,000+ solar panels and this requires a lot of space. These types of systems are usually fixed tilt and located in the southern areas of the United States. Solar Developers look for big, wide open, unused spaces that are near utility infrastructure so the power can be transmitted to urban areas where it will be used.



**TOPIC OF STUDY**

Solar Installation

**Year 1:**
6 HOURS
(FOUR 90-MINUTE SESSIONS)
**Year 2/3:**
6 HOURS
(TWO 180-MINUTE SESSIONS)

## MEETING INDIVIDUAL NEEDS

Do in-class activities to demonstrate how inter-row shading works. Allow visual learners to watch YouTube videos in resources.

## HOMEWORK

Look for a piece of land (big open space or backyard) where you could design a ground mount solar system. What would work best in this location: Fixed tilt? Single axis tracker? Dual axis tracker? Remember the further north you go the more important it is to optimize power output when the sun is shining since there will be fewer sun hours per year as compared to southern locations.

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

**Solar Installation**

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