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Lesson Title: **SOLAR SITE ANALYSIS: HELIOSCOPE**

Grade level: High School/College

Lesson length: 3-5 hours, depending on coverage and emphasis

Author: Jennifer Clemons

Created: March 2021

Instructor's Guide

Learning Goals:

- Students will understand that the electricity produced with a solar photovoltaic system is generated renewably.
- Students will understand how to use a standard solar industry tool--the Helioscope
- Students will use Helioscope to design a PV system on a given location.
- Students will collect and analyze relevant data to draw valid conclusions.
- Students will design a PV system at a given location.
- Students will select panels and inverters for a designed PV system.
- Students will model potential shading issues, such as trees and other obstructions.
- Students will create a financial analysis for a PV installation
- Students will create a single line diagram of electrical components required for a PV installation. This may be requested for permitting.

Materials, Resources, and Technology Required:

- Computer with internet connection for class project purposes (or students in computer lab or students with laptop computer)

- Students need to sign up for a free trial of helioscope at <https://www.helioscope.com/>. Free trial is good for 30 days.
- Presentation unit and screen
- Instructors can get free access to the software by contacting helioscope directly. See instructions below.
- This example uses a residential style building on the Delaware Tech campus. My students are familiar with this building, as we have used it as an example for other class assignments. I suggest you use a building or property that is familiar to you and students or nearby. For parts 1 and 2, you want to choose a property that would be reasonably good for solar, with an unshaded south facing roof. A flat roof would be acceptable. For parts 1 and 2, you will want everyone to be working on the same location, so everyone should get about the same sized system.

Signing up for Helioscope:

Helioscope is a design tool which allows the user to create quality reports in a matter of minutes. It allows users to select panels, inverters and helps model potential shading issues like trees. However, it is rather costly, especially for educators.

If you reach out to them directly, they will extend an educator license for free. However, you will have to provide information about the course, including submitting a syllabus. Their customer service is quite good, and all issues are usually resolved within about a day. The chat function usually works well, and gets you answers quickly. However, they are a small company and on the west coast, so responses come later in the day (if you are on east coast).

Reach out directly to support@folsonlabs.com, requesting educator subscription with information on your class/program.

Once you have an educator's license, it is only good for a semester. This is a change from past offerings. They will give you a discount (50%) on an annual fee. They will extend the educators license for the semester, but it needs to be during the semester. They will ask for verification that the class is currently in session and want a copy of the syllabus.

Additionally, they will extend the student's free trial for the entire semester if you request. Before you request, have each of your students sign up for a free trial using their school email. Reach out to the same email as above, and they will extend the trial for students. Customer service with this company is very good, and usually the licenses have been extended in a matter of hours.

Introduction to the activity:

I use this program after the students have been exposed to other solar design tools, such as solar pathfinder and PV Watts. The students are already pretty well versed in good locations for solar and have done several remote site assessments using PV Watts.

For our first attempt at using the Helioscope software, I like to do a property that we have already done in PV Watts. On our campus (100 Campus Drive, Dover DE 19904), there is a residential style building that we use for several projects in the solar program. The students are very familiar with the orientation of this building, as we have used it for both Solar Pathfinder activities and PV Watts. For our first attempt at using Helioscope we model a solar system on this building together as a group. I have included here an example report of this building.

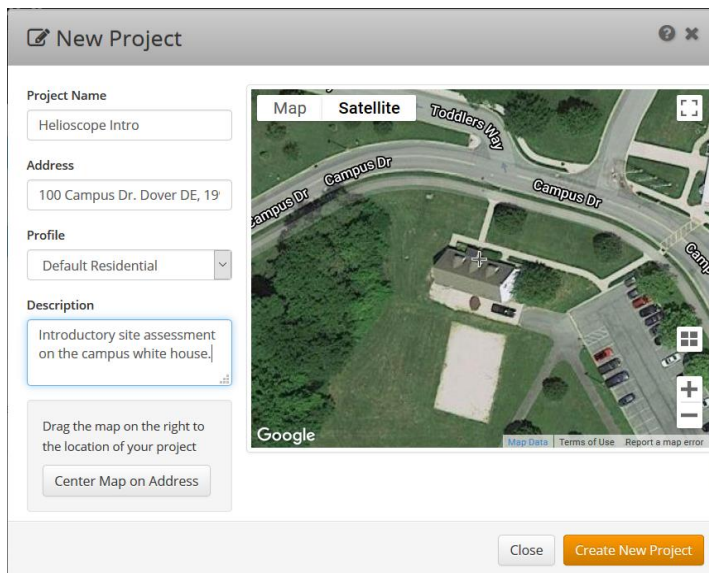
Helioscope will allow the students prepare professional looking designs. The students will be able to model shading from trees and other obstructions. They will have the opportunity to select their equipment (panels and inverters) and create single line diagrams of the electrical system. This tool is best used after the students have a very good understanding of the components, so they can properly select appropriately sized equipment.

Helioscope does a lot of webinars and training. You can assign some of the videos/trainings for your class to complete. Or, if you have a larger group, you may be able to request a training during your class time. All the trainings/webinars are about 60 minutes.

Activity, Part 1: Known Property, as a group.

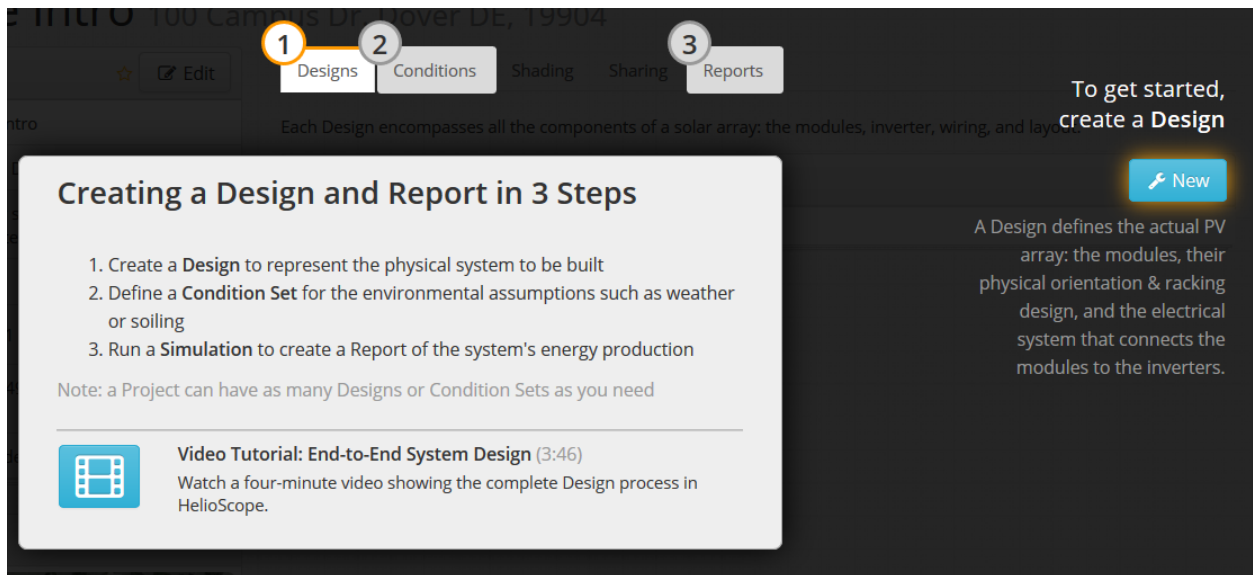
For this activity, I assign my students do the “White House” on our campus. As previously mentioned, it is a property on campus they are familiar with and have done several previous assignments on.

1. Once all the students have created an account, have them login as a class.
2. Fill in the project name, address, and description.
 - a. Note you will have to move the image to find the house after typing in the address.
 - b. After filling out the information, click “Create New Project.”
 - c. Select the type of system, which defaults to Residential, but you can also choose ground mount or commercial.

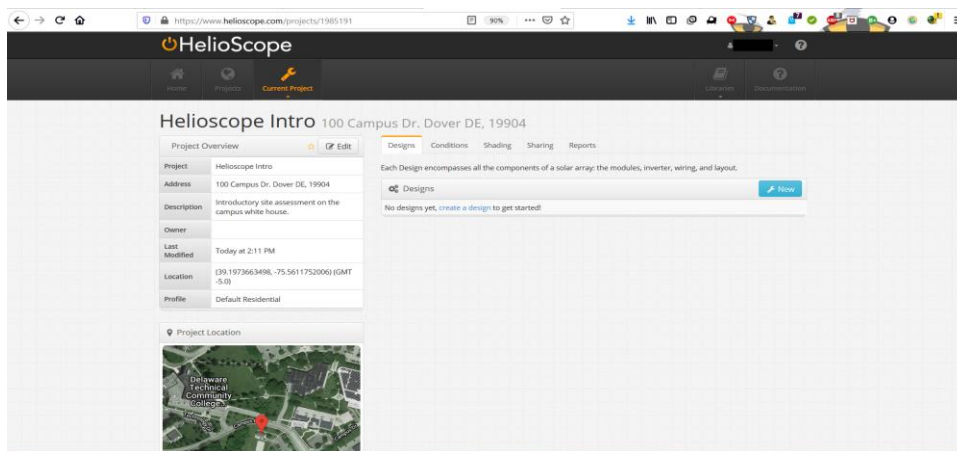


The screenshot shows the 'New Project' interface. On the left, there are input fields for 'Project Name' (filled with 'Helioscope Intro'), 'Address' (filled with '100 Campus Dr. Dover DE, 19'), 'Profile' (a dropdown menu set to 'Default Residential'), and 'Description' (filled with 'Introductory site assessment on the campus white house'). Below the description field is a button labeled 'Center Map on Address'. To the right of the form is a satellite map showing a campus area with a yellow pin. The map has labels for 'Campus Dr' and 'Toddlers Wy'. At the bottom of the map are links for 'Map data', 'Terms of Use', and 'Report a map error'. At the bottom of the entire form are two buttons: 'Close' and 'Create New Project'.

3. Before you start your project, Helioscope will give you the quick hints seen below to help you get started.
 - a. There is also another link to the 5 min intro video.
 - b. After you are done reading click in the empty space to see the rest of the page



4. This is the Current Project page. Here you can see the project overview, project location, and several tabs relating to the project.
 - a. Under "Project Overview", you can click edit to change any of the listed information.
 - b. Go under "Designs" and click "create a new design".

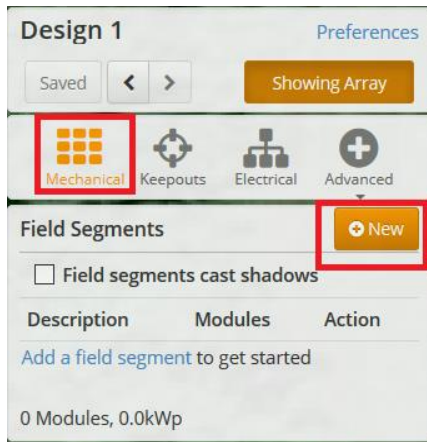


5. The Design page looks like the image below.
 - a. The white house for the project is in the red circle below.
 - b. The blue box on the left is the design controls

- c. The green circle is the compass
- d. You can zoom in and out with the scroll wheel.
- e. You may have to zoom move around to find the correct property for the example shown here. (The 100 Campus Drive address is for the entire campus.)

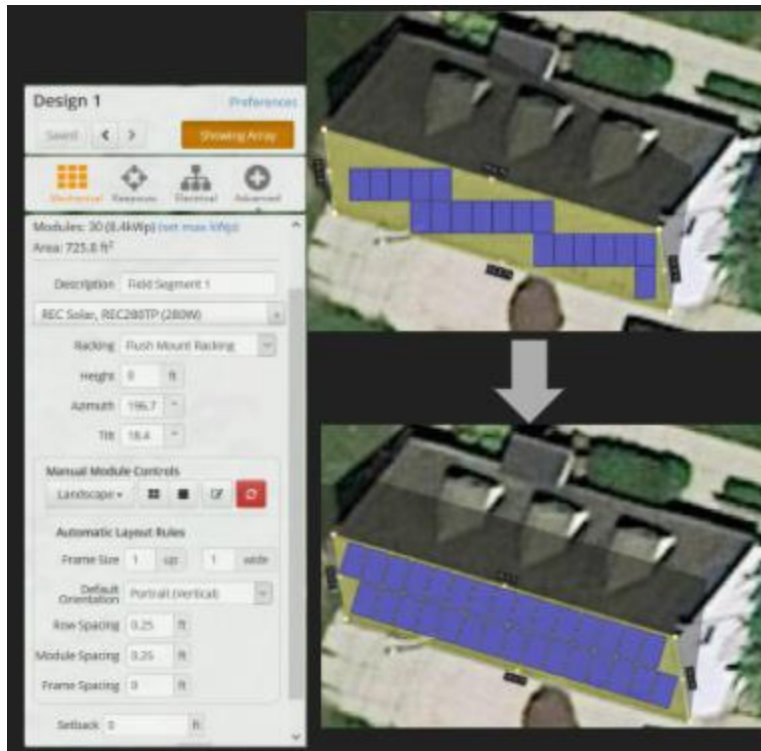


6. To begin designing your system, click on “Mechanical Under the design controls to create a new field segment.
 - a. Outline the back portion of the roof as shown by clicking each corner.
 - b. When you finish your last corner, double click on that dot to complete the drawing of the field segment.
 - c. The outline can be edited after you finish if you make a mistake.
 - d. You can see estimates distance of the roof space you selected.



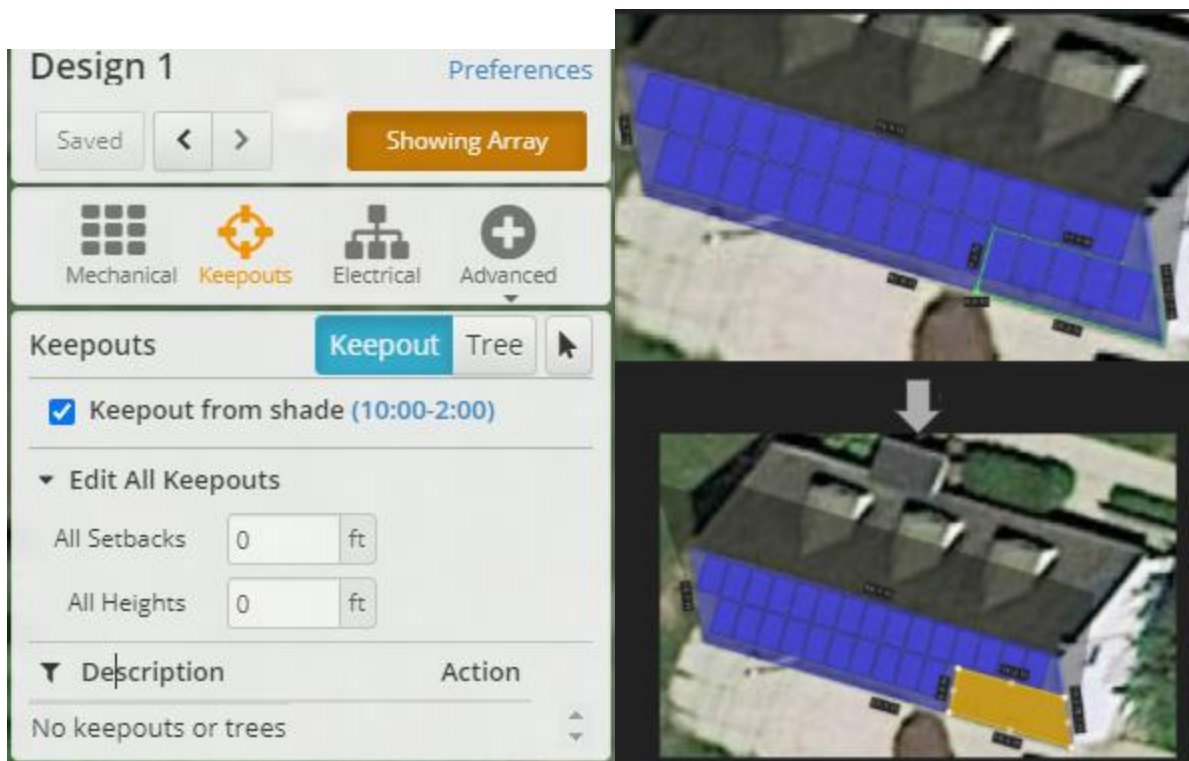
7. Field Segment

- a. When you right click on the modules, you can select “align modules on click” to straighten the modules as shown in the image below.
- b. After creating the field segment, right click on the midpoint of any line and align your panels to the top or bottom edge.
- c. In the design box you can set the azimuth, tilt, spacing, and setback of your modules.
- d. You can change the orientation of modules from portrait to landscape.
- e. Right click, “align modules on click” will change the layout. Click around the roof to get the alignment you like.
- f. You can click on a module and move it to have a cleaner look. (Right click, remove module).
- g. The modules will default to REC Solar REC280TP, but you can change to many different types. Start typing in module box and you see the different brands and sizes of modules available.



8. Keepouts

- a. Next to mechanical, there is an icon for Keepouts.
- b. Here you can select areas in the field segment where you do not want panels or to identify obstructions.
- c. In this example, the roof has a few protrusions that prevent you from using the entire area. In this case it is the plumbing and heating system that are in one small area of the roof.
- d. You can select the area to “keepout” by drawing the area just like you did for the field segment.



9. Keepouts (Trees)

- a. The keepout button under the design controls also has an option for trees.
- b. Click on the center of the tree, then move the cursor out from the center until the circle matches the size of the tree
- c. You can also set the height and radius of the tree keepout in the controls
- d. You can adjust the time you wish to keepout from shade. The default is 10:00-2:00



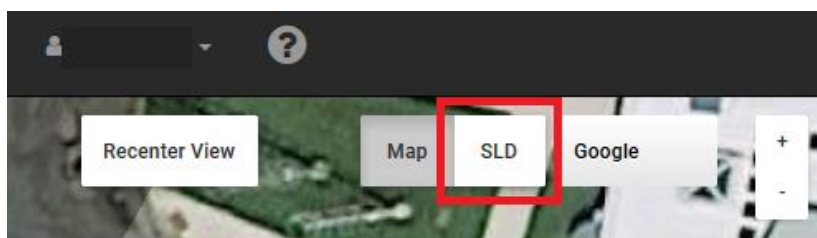
10. Electrical

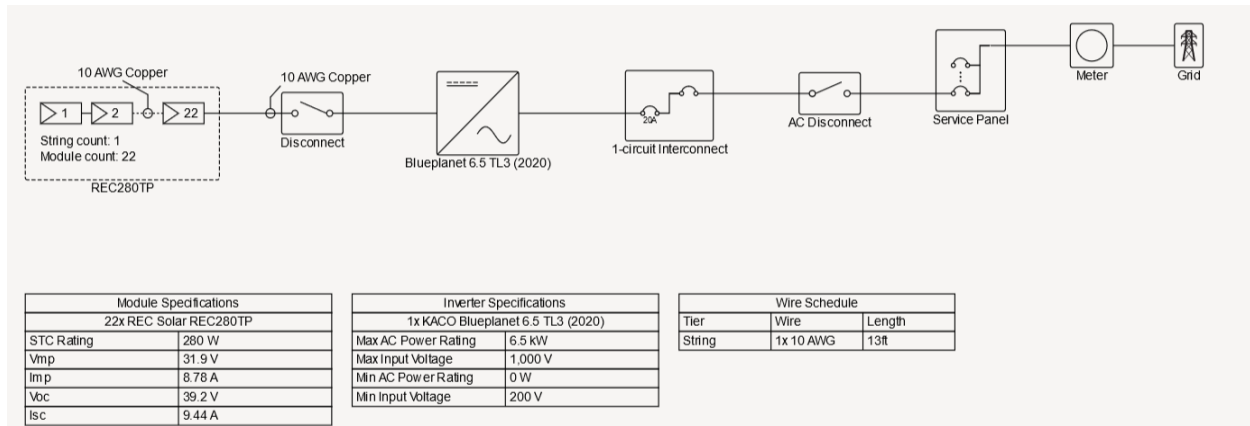
- a. Under the electrical tab you can select your inverter (and how many).
- b. You can move the location of the inverter. (This may be important for wire length.)
- c. Inverters are represented on the design by blue circles that can be moved if necessary.
- d. Users can select the brand and type of inverter.
- e. Optimizer can also be added.
 - i. If you choose a solar edge optimizer, you must then select a solar edge inverter.



11. Electrical

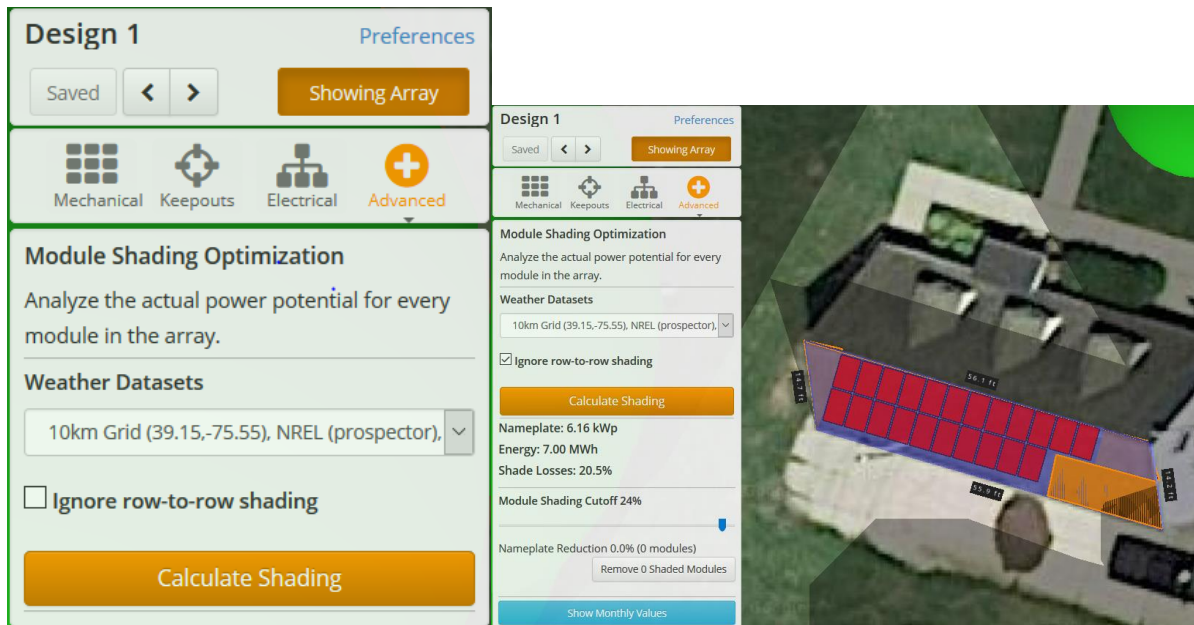
- a. Once you are happy with your design and inverter select you can see the single line diagram, or export as an dxt file.
- b. In the top right of the design window you can click the “SLD” button to view a single line electrical diagram of your array. line diagram of the system.
- c. This is useful (and required) for permitting.





12. Electrical

- Under “Advanced” in the controls you can perform a shading analysis of your array and remove panels shaded over a set percentage.
- Select a weather data set, check the box to ignore row-to-row shading, then click “calculate shading”.



13. Wrapping up

- After finishing your array design, click “Save and exit” to return to the projects page.

b. Design tab:

- i. If you click on the project again, you can get a summary of the components needed for system, including length of wire and wire size, along with inverter(s) and modules.

Components		
Component	Name	Count
Inverters	SmartRE 3000 (OutBack Power Systems)	2 (12.0 kW)
AC Home Runs	8 AWG (Copper)	2 (256.6 ft)
Strings	10 AWG (Copper)	10 (265.5 ft)
Module	REC Solar, REC280TP (280W)	30 (8.40 kW)

c. Conditions Tab

- i. This tab gives you an overview of the weather data set used for solar irradiation.
- ii. Additionally, this tab gives you information on the temperature model parameters.

d. Shading Tab

- i. This tab allows you add your own shading analysis to the system from a Solmetric Suneye file or PVSyst Horizon.

ii. I have not used this.

e. Sharing Tab

- i. This tab allows you to share your work with another user.
- ii. Administrators can manage users or update project metadata.
- iii. If you share your project with another user, they have access and can edit it.
- iv. New users can be deleted by the administrator.

- v. All edits are saved to the latest version, no matter who made them.
- vi. Administrators can lock designs- so that users can no longer make edits

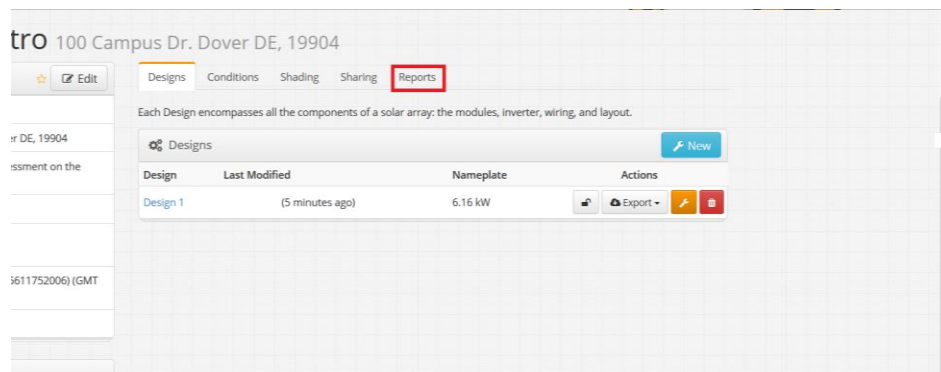
Share Your Project

To share your project simply copy and paste this link and send it to any other user of HelioScope:

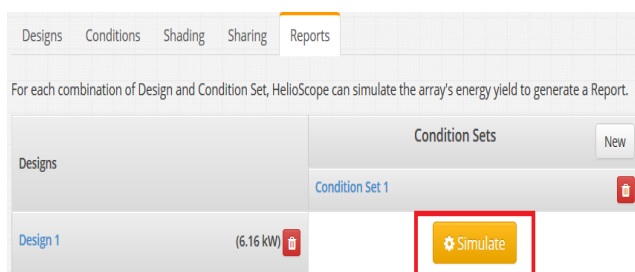
<https://www.helioscope.com/projects/share/gTer6DjIzqxb88uNkjuOrsGzCcEjdglt>

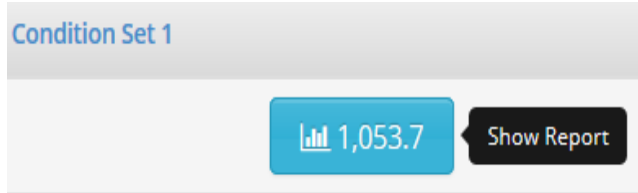
Warning! Anyone with this URL (and a HelioScope account) will be able to see all resources associated with this project. Only the project administrator can add or remove users. This URL will expire once it has been used.

a. Reports tab

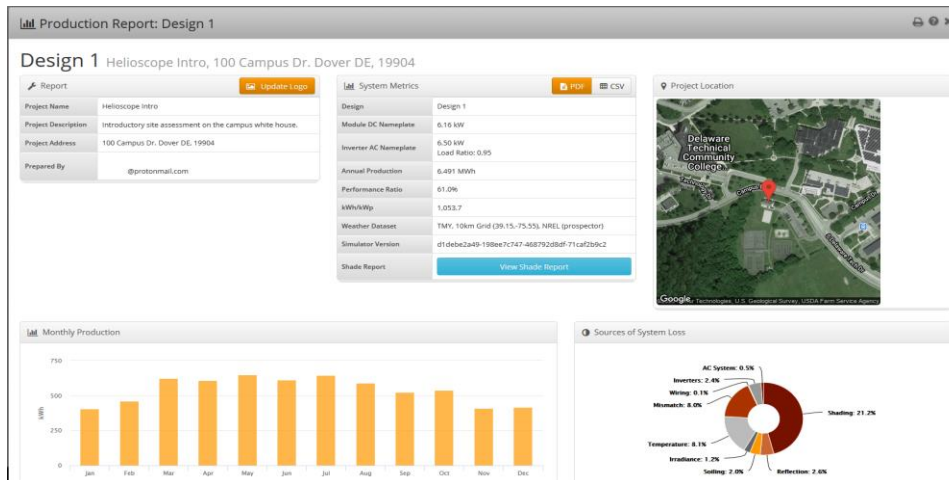


- i. In the Reports tab find your project and click “Simulate” and wait for the program to finish loading.
- ii. After the program finishes loading there will be a blue button you can click to view your report.






b. Below is an example of your report.



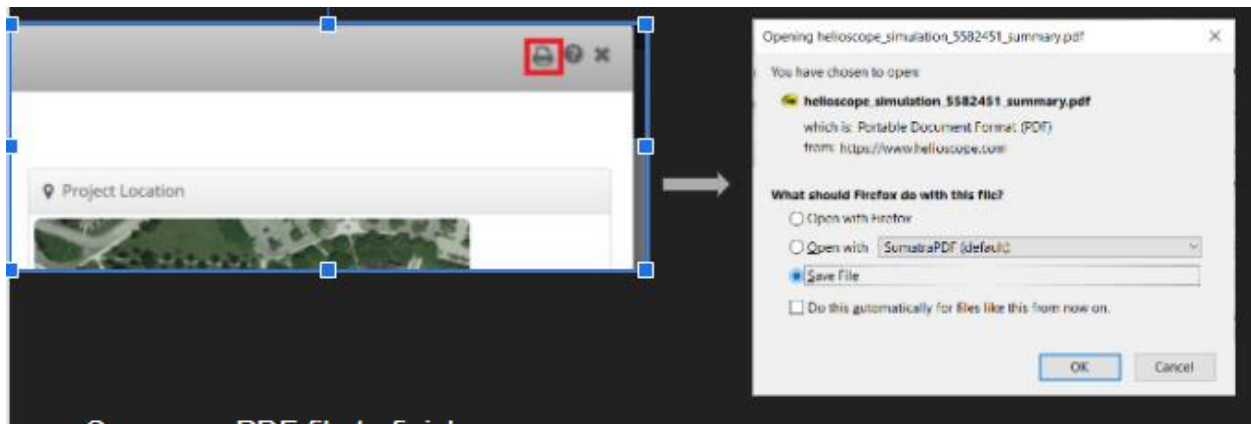
c. You can update your logo in the upper left side, yellow button “Update Logo”. This will remove the helioscope watermark and allow you to include your own (business/school) logo.

Report

Project Name	CREATE example
Project Address	100 Campus Drive DOVER DEL
Prepared By	Jennifer Clemons jclemons@dtcc.edu

 **Center for Renewable Energy
Advanced Technological Education**
Working to Advance Energy Technology Educational Programs

- d. To download your report from Helioscope click the print icon in the top right of the report. Your report will be downloaded as a PDF.



- e. You can also download the report as a CSV, which will contain all of the TMY data and hourly production data for one year of the system. This information could be useful if students want to create their own graphs. Be aware, since it is TMY data, it contains 8760 data points. Pivot tables would be the best tool for working with this data.

Activity: Part 2 Annual Production Report

Once the system design report has been created and exported, there is a lot of useful information that can be used or discussed. After you simulate the system (as done in part 1), the following information is available.

1. Module DC Nameplate: This is amount of PV panels in your system design.
2. Inverter AC Nameplate: This is the inverter(s) used in your design. The Load Ratio may give you an indication if your inverter is too big or too small.

In this example, the size of the PV system installed in 9.8 kW, however the inverter AC name plate is 8.4kW. This means that the inverter is smaller than the maximum production in the PV system. The load ratio for this system is listed at 1.17, or $9.8\text{kW}/8.4\text{kW}$.

Module DC Nameplate	9.80 kW
Inverter AC Nameplate	8.40 kW Load Ratio: 1.17

Helioscope will let you choose any inverter you like, but it would be important to look at this number when you export your report. In the “Sources of System Loss” you can see increased losses from the Inverter and AC system if your inverter is undersized.

Below is a different example with a slightly better match between your PV system size and inverter. In this case the DC Nameplate module is 6.16 kW, while the inverter is 6.5kW. The load ratio in this case is 0.95.

Module DC Nameplate	6.16 kW
Inverter AC Nameplate	6.50 kW Load Ratio: 0.95

Again, the helioscope program allows you to choose the inverter you like. It does not say if it is a good or bad choice. It is up to the designer to decide.

It may make sense to undersize an inverter if there is a lot of shading and are not expecting to get the maximum production. The load ratio number should be examined to see if it is reasonable for the design. If the number is larger than 1, that means your inverter is smaller than the PV system. If the number is much lower than 1, it means your inverter may be oversized for your design. There may be reasons to oversize or undersize your inverter. Helioscope does not evaluate the sizing but allows you to make that choice. The Load Ratio just gives you a sense of how closely the inverter and modules are sized. Just remember, PV modules can overproduce on cold sunny days, so sizing the inverter perfectly to PV system may not be the best design.

3. Performance Ratio- This is essentially the ratio the energy to the grid (kWh)/maximum theoretical production based upon the module nameplate.

$$\frac{\text{Energy to Grid (wh)}}{\text{POA Irradiance (wh/m}^2\text{)} * \frac{\text{DC Nameplate (w)}}{\text{STC (1000 w/m}^2\text{)}}}$$

This value will be less than 100% based upon a number of factors that may be out of your control, including shading, weather, temperature and location of system.

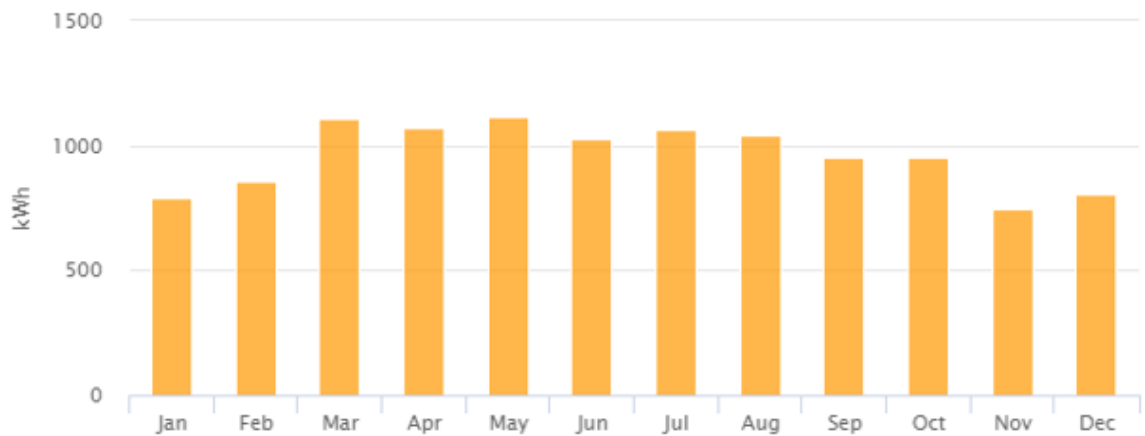
4. kWh/kWp This is ration of the annual energy generation divided by the system DC nameplate power.

Module DC Nameplate	6.16 kW
Inverter AC Nameplate	6.50 kW Load Ratio: 0.95
Annual Production	6,491 MWh
Performance Ratio	61.0%
kWh/kWp	1,053.7

In this case, it is 6491 kWh/ 6.16kW = 1053.7

5. Monthly Production- This chart shows the expected production of the system by months. You can access this data as a table before you export to PDF.

Monthly Production



[Show table](#)

[Hide table](#)

Month	GHI (kWh/m ²)	POA (kWh/m ²)	Shaded (kWh/m ²)	Nameplate (kWh)	Grid (kWh)
January	63.3	111.1	111.0	891.7	792.0
February	83.2	123.3	122.8	985.6	855.3
March	133.2	165.1	163.9	1,316.1	1,107.5
April	158.4	164.6	163.8	1,310.1	1,072.0
May	188.3	172.7	171.9	1,367.7	1,115.3
June	185.8	163.3	162.9	1,293.3	1,025.7
July	194.4	172.1	171.5	1,363.1	1,067.2
August	170.2	169.5	168.8	1,346.3	1,044.1
September	129.6	149.4	148.6	1,190.2	953.1
October	102.8	144.6	144.3	1,159.2	955.3
November	67.3	108.8	108.8	874.6	743.8
December	61.7	115.7	115.6	931.5	807.7

With the table exported, you can make your own graphs to compare the energy use of the property, or any other figure of interest.

All this data can be exported as a CSV as well, in hourly data.

6. Sources of System Loss- There are many sources of system loss, which may not be possible to completely eliminate.

7. I recommend asking the students to use the information in this report to write a remote site assessment for the property. This is the same type of assignment as listed in part 3, but everyone is doing the same property. This makes it much easier to determine if the student is making a significant mistake, such as under or oversizing the system (since you know the property).

Potential Assessment Questions

Q1. What does TMY stand for? Why is it needed for a solar design? How many data points does it require?

A: TMY stands for “typical meteorological year” and is used to assess the weather conditions at any given location over a period of time. It is needed in solar design to give an estimate of the temperature and amount of irradiance at a location. Together, the TMY data and tilt angle are used to estimate the production from a PV system. A TMY data set has 8760 data points, amounting to 1 point/hour for 365 day. $8760 = 24 \text{ hours/day} \times 365 \text{ days/year}$.

Q2: What are some of the types of system losses that may occur? Explain how/why they occur? What are some ways you can reduce these losses? What is a reasonable percentage of loss to expect in a PV system?

A: Shading - obstructions from trees or nearby buildings: Reflection, Soiling- can occur due to dirt, pollen or snow on modules, Temperature losses occur from module being too hot; Mismatch, Wiring: Inverters: AC system

You can reduce the shading by positioning your PV system in a location with no potential shading, or trim back trees to keep from shading.

You can reduce your Inverter and AC system losses by sizing your inverter to more closely match the solar production.

The Temperature losses will be difficult to eliminate on a roof mount system, but may be less with a rack that is higher off the roof. (roof color plays a big role in temperature loss) Also the temperature losses could be less with a ground mount system. However, the temperature losses may not be able to be eliminated in most locations due to weather conditions.

Q3: Your design has a load ratio of 0.5, what if anything, should you do?

- A. This indicates that the inverter is too large for your system. You may want to consider replacing the inverter with a smaller system.

Q4: Your design has a load ratio of 2.5, what if anything should you do?

- A. This indicates that your system is much too large for your inverter. You may want to add another inverter or look for a different one that its more closely sized to your system.

Q5: Your design has a load ratio of 0.95, what if anything should you do?

- A. This inverter is well sized for your system. You probably don't need to do anything.

Q6: What might be wrong if you don't get any output from your system design.

- A.** Check your system losses. Your inverter might be undersized. If it is too small you won't get any production. Check and make sure the inverter size the correct units (e.g. Is it in Watts instead of kilowatts?).

Part 3: Pick a location and create a remote site assessment

A remote site assessment (or preliminary proposal) is used in the industry once homeowner has expressed interest in solar. This is a useful tool and can usually be prepared for potential client very quickly. Using modeling tools, the students can determine very quickly if a site is suitable for solar, and get an estimate of how many watts of modules could be installed. For this part of the lesson, the students will use helioscope to collect data and write a remote site assessment to give to a potential customer.

After the students have experience with Helioscope on a known location, I have them design a system for a location of their choosing. I usually let them design one for their home or any property they prefer. Sometimes students live in apartments or do not have a property suitable for solar, so I let them choose any location they are familiar with, such as a family members home, or place of business.

This assignment is a little more challenging to evaluate, since the instructor is not familiar with the property, however, google maps can give you a lot of information with just an address.

Have the students design a PV system and model any potential obstructions to the facility. I have my students do an evaluation of their choosing (it can be their house) and do a remote site assessment on the property. This is an assignment we can also do with PV Watts.

The information I require my students to include in a remote site assessment include the items below: Most of these are taken directly from the NABCEP Technical Sales Job Task Analysis.

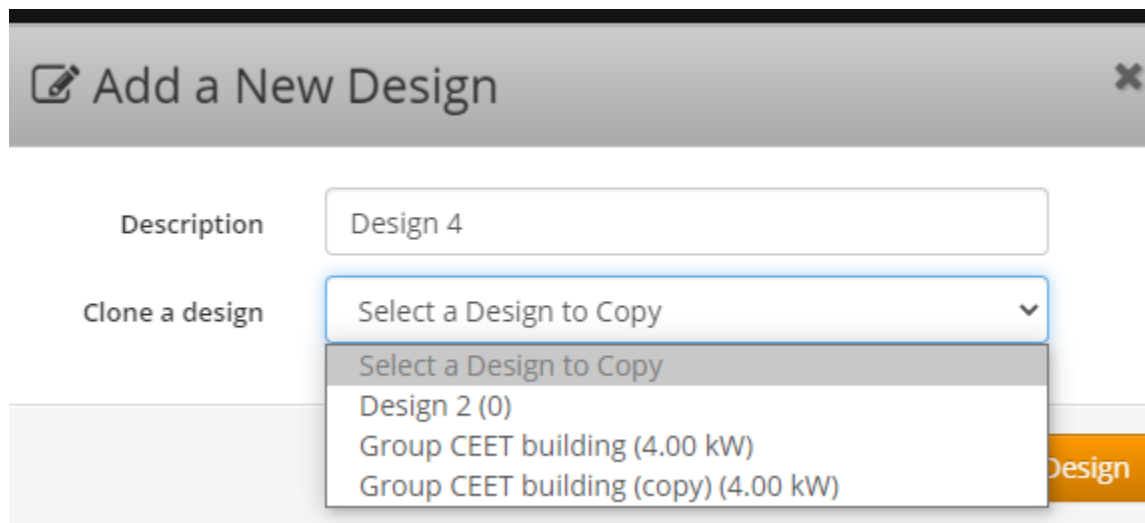
- Description of the property
- Determine house orientation
- Determine roof tilt/angle, available area
- Determine shading
- Evaluate obstructions
- Inquire about type and condition of roof
- Determine ownership status
- Determine type of property (residential commercial, non-profit)
- Estimate the solar production
- Identify any shading issues and make recommendations.
- Identify if this property is a good candidate for solar.
- Include pictures

Sample Rubric for Remote Site Assessment

	Beginning	Developing	Acceptable	Accomplished
Property Description	No description of property included.	Some property description provided.	Property description is accurate, but not clear to someone unfamiliar to location	Property description is accurate, and understandable to someone unfamiliar to location
Roof Tilt Estimated	Tilt angle of roof is not within 20% of correct value.	Tilt angle of roof is within 20% of correct value.	Tilt angle of roof is within 10% of correct value.	Tilt angle of roof is accurate.
Determine house orientation and roof space available	Orientation is not correctly determined. Usable roof area is not within 20% of correct value.	Orientation is not correctly determined. Usable roof area is within 20% of correct value.	Orientation is correctly determined. Usable roof area is within 10% of correct value.	Orientation is correctly determined. Usable roof area is correct.
Identify potential Shading and Obstruction Issues	Some potential shading and obstruction issues identified. No recommendations given.	Most potential shading and obstruction issues were identified. No recommendations given.	Most potential shading and obstruction issues were identified. Some recommendations given.	All potential shading and obstruction issues were identified. Recommendations given.
Installation Capacity determined using appropriate software (PVWatts/Helioscope)	Installed capacity sizing calculation not done using a software program.	Major errors in installed capacity sizing from software program.	Minor errors in installed capacity sizing from software program.	No errors in installed capacity sizing from software program.
Professional Writing Quality	More than 4 grammatical mistakes and not written in professional tone.	4-7 grammatical mistakes or not written in professional tone.	3 or fewer grammatical mistakes.	Virtually no grammatical errors, or very minor. Written in professional tone.
Identifies the next steps- follow up on solar inquiry (sales)	No next steps given, does not mention incentives, does not sell it.	Gives client a list of next steps, but is negative about the property for PV. Does not mention Incentives.	Gives client some next steps, positively sells PV. Does not mention incentives.	Gives client a list of next steps or follow up. Positively "sells" solar system. Mentions the potential incentives available to client.
Visual aids	No visual aids given.	Too few visual aids used.	Too many visual aids used.	Visual aids are helpful and add to the report.

Part 4: Have students solve design problems



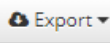











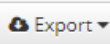



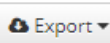


- a. Create a system and share with your students.
- b. Make one project design, for this assignment I will purposely insert some mistakes, such as have the wrong inverter/module configuration, or design so that there are lot of system losses.
- c. Under the same project, you can make multiple designs. To copy the same one select New (blue button), and then “select a design to copy.”



The screenshot shows a dialog box titled "Add a New Design" with a close button (X) in the top right corner. Below the title bar, there are two main sections. The first section is labeled "Description" and contains a text input field with the value "Design 4". The second section is labeled "Clone a design" and contains a dropdown menu. The dropdown menu is currently open, showing a list of options: "Select a Design to Copy" (with a downward arrow), "Select a Design to Copy" (highlighted), "Design 2 (0)", "Group CEET building (4.00 kW)", and "Group CEET building (copy) (4.00 kW)". To the right of the dropdown menu, there is a blue button labeled "Design".

- d. Share the system with the class or students to make improvements. (Sharing instructions found in Part 1: e.) You can share via link.
- e. Have the students edit the system as you request, such as select new inverter/module configuration. Or just give them a system with problems and ask them to fix up.
- f. Could also have the students edit the system to try and reduce the system losses as much as possible.
- g. Another problem could be putting the keepouts in the wrong place, or modeling a tree incorrectly (too small, in wrong spot).
- h. The students could solve or correct any number of problems you insert.

- i. All students have editing rights to each design, so maybe identify them by initials or names. See below, I added student initials so they know which one to edit.

 Designs New			
Design	Last Modified	Nameplate	Actions
Group CEET building	Jennifer Clemons (2 days ago)	4.00 kW	  Export ▼  
Group CEET building (copy)	Jennifer Clemons (a day ago)	4.00 kW	  Export ▼  
Group EB	Jennifer Clemons (a day ago)	4.00 kW	  Export ▼  
Group Gj	Jennifer Clemons (a day ago)	4.00 kW	  Export ▼  
Group ID	Jennifer Clemons (a few seconds ago)	4.00 kW	  Export ▼  

- j. This activity would be a nice opportunity for students to share with the class what works in their module/inverter configuration. They can see that there are many possible solutions to the same problem.
- k. Have the students identify as many problems with your original design as they can find. They will likely find problems that you did not intend.
- l. Some possible questions for the students to answer
 - i. What changes did you make to inverter and/or module? Why did you make those changes? What affect did those changes have on your AC output?
 - ii. What changes did you make to the keepouts or trees from the original system? Why did you make those changes? What affect did those changes have on your AC output?
 - iii. Did you add or remove any modules from the original design? Why or why not? Defend your decision.