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Name: *_____

Date: *____ / ____ / ____ Class Hour: *____

Center for Renewable Energy Advanced Technological Education

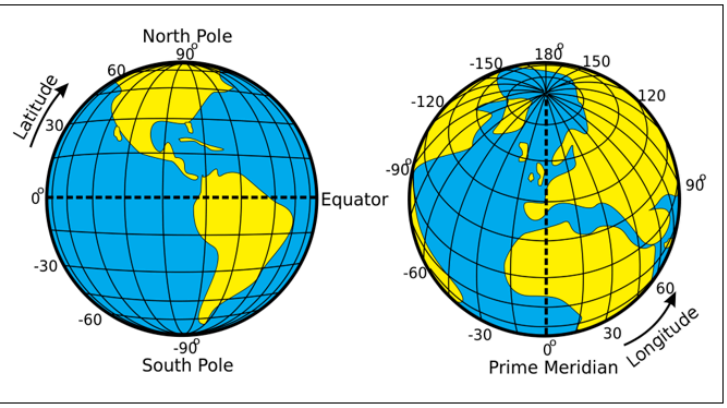
SOLAR LOCATION ANALYSIS: THE PV WATTS CALCULATOR

Student Response Guide

Place written responses and graphs into this document where you see the asterisk, *. Your written answers should appear in bold-faced type. If they don't, bold them yourself.

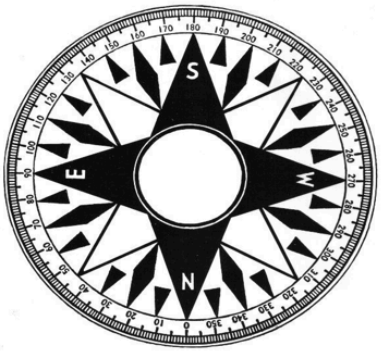
After you complete this document, but before you submit it, go through it to organize it for easy reading by your teacher.

Activity, Part 1 Critical Definitions

Definitions for:	
Latitude **Longitude** Figure 1.	

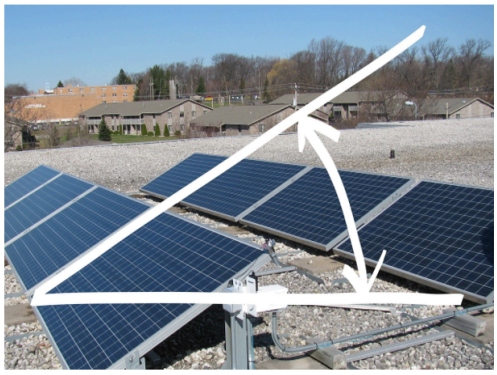
Latitude: *

Longitude: *

Definitions for: **Solar azimuth** **Solar altitude or solar elevation** Figure 2.	

Solar azimuth: *

Solar altitude or solar elevation: *

Definition for: **Solar tilt angle** Figure 3.	

Solar tilt angle: *

Show What You Know

Place graphs and written responses into this document where you see the asterisk, *****. Your written answers should appear in bold-faced type. If they don't, bold them yourself.

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1. Produce two graphs. Use the graphing function within your **PV Watts Student Spreadsheet** to produce three plots on each of the following two graphs:
   - Annual Energy Production as a function of changing solar Tilt Angle (refer to this as **Graph 1**)
   - Annual Energy Production as a function of changing solar Azimuth Angel (refer to this as **Graph 2**)

On each graph include:

1. a plot for your location (**Location 1**)
2. a plot for Quito (**Location 2**)
3. a plot for the location you chose (**Location 3**)

Snip or Copy and then Paste the two graphs into this document, below. Include a legend below each graph that identifies the location of each plot.

Graph 1:

Location 1: *	**Location 2: ***	**Location 3: ***

Graph 2:

Location 1: *	Location 2: *	Location 3: *

Write full and complete answers in paragraph form to questions 2, 3, and 4 that follow. Make regular and appropriate references to one or both of your graphs to support your answers. It's recommended that you use words in your writing that read like this: "As you can see in **Graph 2**..."

It's important to keep in mind that while working with PV Watts you only surveyed PV systems that were fixed in position. Similarly, each of the following questions refer only to PV systems that are fixed in their location.

2a. Compare the effect of tilt angle among your three locations (**Graph 1**). Explain meaningful similarities, differences, connections, or relationships you observe among your three location plots

*

2b. In general, what is the effect of tilt angle on the energy production of a solar PV system? Is there a generalization or "rule of thumb," you can apply for the best tilt angle selection for any location?

*

3a. Compare the effect of azimuth among your three locations (**Graph2**). Explain meaningful similarities, differences, connections, or relationships you observe among your three location plots.

*

3b. In general, what is the effect of azimuth on the energy production of a solar PV system? Is there a generalization or "rule of thumb," you can apply for the best azimuth selection for any location?

*

4a. From your data, identify the combination of azimuth and tilt angle that appear to be ideal for each of your 3 locations. Place your answers in the table below.

Location	Azimuth	Tilt Angle
1: *	*	*
2: *	*	*
3: *	*	*

4b. Explain how you determined the best combination of azimuth and tilt angle for each location.

*

4c. Consider the ideal tilt angle and ideal azimuth selections for each of your three locations. How does the **Annual kWH Produced** differ for the three locations? Explain the differences you observe. Why is the best location the best for producing PV electricity? Why is the worst location the worst?

*

5. For this question, you'll make estimates on the long run significance of installing a well-placed, residential-size solar PV system at your location (**Location 1**). To do this, you'll locate necessary source information. You'll enter that information into appropriate boxes (**Boxes 1-4**) just above the table that follows (**Summary Table 1**).

Then you'll make several estimates that are not as formal and accurate as professional calculations. However they are sure to be better than "back of the envelope" estimates. [Back of the envelope estimates are usually quick calculations, often done by hand on the back of a spare envelope. They are usually more accurate than a guess, but never as accurate as a formal, professional investigation.]

Once your estimates are complete, you'll follow up by commenting on the significance of those estimates.

Instructions:

5a: Instructions for completing **Box 1. Annual Electricity Offset.** This number represents the kWh of electricity offset from the electricity you now generate (with your own solar PV system and no longer buy from the energy utility).

1. Use the link below to return to the National Renewable Energy Laboratory (NREL) **PV Watts Calculator** web page.

https://pvwatts.nrel.gov/

2. As you did previously, enter your school's zip code in the **Get Started** box. Then click **Go**.

3. Click on **Go to system info**.

4. Enter these values into three of the SYSTEM INFO boxes:

- **DC System Size (kW):**….. **6 kW** (roughly the current American residential average sized PV system installed)
- **Tilt (deg):**……. Ideal tilt angle from your location; the tilt angle that produced the greatest **Annual kWh** of electricity from **Location 1**.
- **Azimuth (deg):**…….. Ideal azimuth from your location; the azimuth that produced the greatest **Annual kWh** of electricity

from **Location 1**.

- Don't change the values in the other 3 boxes. You are installing standard modules on an open, fixed rack, with the expected system losses indicated in the table.

5. Click on **Go to PV Watts results**.

6. The number expressed at the top of the page in **kWh/Year** is also this system's **Annual Electricity Offset**. Enter this number where you see the ***** in **Box 1**.

7. Enter the same number in the 1 year electricity offset box in **Summary Table 1**, just below **Box 1.** They are the same number.

5b: Instructions for completing **Box 2. Cost Offset/kWh.** This number represents the dollar cost offset for each kWh of electricity you no longer buy from your energy utility (with the electricity you generate with your own solar PV system).

1. Use the link below to connect with the United States Energy Information Administration (US eia) **US Electricity Profile** web page for the current year.

http://www.eia.gov/electricity/state/

2. Locate the Average retail price for electricity for your state (cents/kWh).

3. Divide this number by 100 to convert it from cents/kWh to $/kWh.

4. Where you see the ***** in **Box 2**, enter the quotient in **dollars / kWh**.

Note: It's important to recognize this number represents a statewide average. It will probably not be the same as your local rate. For greater accuracy, your teacher may have you use your local rate instead.

5c: Instructions for completing **Box 3. CO_2 Emissions Offset/kWh.** This number represents the CO_2 air emissions offset for each kWh of electricity you no longer buy from your energy utility (with the electricity you generate with your own with solar PV system).

1. Use the link below to connect with the United States Environmental Protection Agency (US EPA) **Power Profiler** web page.

https://www.epa.gov/egrid/power-profiler#/

2. In the light blue **Power Profiler** box on the left, enter your zip code.

3. Click the dark blue **Go** button. This will connect you with a web page providing CO_2 emission rates for the electricity fuel mix specific to your region of the United States.

4. Locate the lbs/MWh of CO2 emitted in your region in the light blue box.

5. Divide this number by 1000 to convert it from lbs of CO_2/MWh to lbs of CO_2/kWh.

6. Where you see the ***** in **Box 3**, enter the quotient in **lbs CO_2/kWh**.

5d: Instructions for completing **Box 4. Coal Resources Offset/kWh**. This number represents the coal resources offset for each kWh of electricity you no longer buy from your energy utility (with the electricity you generate with your own solar PV system).

1. Use the link below to connect with the United States Energy Information Administration (US eia) Greenhouse Gas Equivalencies Calculator.

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

2. Click the **Energy data** button under **Step 1 – Enter and convert data**.

3. Under **Enter Data**, click the **Kilowatt-hours avoided** button.

4. Also under **Enter Data**, enter the number **1** in the **Amount** box..

5. Click the blue **Convert data** button. Information will now appear under **Step 2 – View Results**.

6. Scroll down your screen to **pounds of coal burned**. The number you see is the average mass of coal—and only coal—that would have to be burned to produce 1 kWh of electricity.

7. Where you see the ***** in **Box 4**, enter the number in **lbs Coal/kWh**.

5e: Using a little math reasoning, a calculator, and your offsets in **Boxes 1-4**, estimate your offsets of electricity, cost, emissions, and resources, over 1 year, 10 years, 20 years, and 30 years. Enter your estimated values where indicated in **Summary Table 1**.

Box 1.	Box 2.	Box 3.	Box 4.
Annual Electricity Offset *** kWh/ year**	**Cost Offset/ kWh** *** / kWh**	**CO_2 Emissions Offset/ kWh** *** lbs. CO_2/ kWh**	**Coal Resources Offset/ kWh** *** lbs. Coal/ kWh**

Summary Table 1.

Length of Time **(years)**	**Electricity Offset** [Fixed, 6 kW PV system installed at your location (ideal azimuth and tilt angle)] **(kWh)**	**Cost Offset** [Electricity that did not have to be purchased from the energy utility] ($)	**Emissions Offset** [Mass of CO_2 emissions that were not released into the atmosphere] **(lbs. CO_2) and tons CO_2)**	**Resources Offset** [Energy resources that were not taken from the ground and burned] **(lbs. Coal and tons Coal)**
1 year	*	*	* and *	* and *
10 years	*	*	* and *	* and *

20 years	*	*	* and *	* and *
30 years	*	*	* and *	* and *

5f. Summarize and comment on the long run <u>financial</u> significance of installing a well-placed, residential size solar PV system at your location. Make references to the estimates in **Summary Table 1** in your answer.

*

5g. Summarize and comment on the long run <u>environmental</u> significance of installing a well-placed, residential size solar PV system at your location. Make references to the estimates in **Summary Table 1** in your answer.

*

5h. The long term cost offset of this PV system can be large and appear impressive. But it cannot be taken at face value. Plainly, the initial cost of the PV system was not taken into account and subtracted from it.

With that in mind, explain why we cannot take the emissions and resources offsets at face value, either.

*

6. You want to install a solar PV system at your location. Assume you will be able to install it at the best combination of tilt angle and azimuth for maximum performance. What other issues--site specific variables--usually have to be taken into account in order to get the best performance from a solar PV array? Describe at least three and explain how each one can negatively affect the performance of a solar PV system.

6-1. *

6-2. *

6-3. *

7. Describe the most important idea, concept, principle, or fact you learned while completing this this part of the lesson. Explain why it is important for you (and probably other people) to know and understand.

*