

The Bright Idea Worksheet **Answers**

Objective: To use data from Renewable Energy Living Lab website to evaluate energy options and provide recommendations of energy sources suitable for various U.S. locations.

Materials: Work in groups of two or three students, with a computer to access the internet.

Engage: You have recently been hired by “The Green Company” as an engineering consultant to examine its energy use and source options. The chief executive officer (CEO), Mr. Envy, recently read an article describing how one of his competitors installed a photovoltaic system (solar panels) at its headquarters to generate 100% of their electricity needs. Mr. Envy wants to outdo his rival, so he assigned you the task of designing solar energy systems for each of his four facilities to generate 100% of the electricity needed for each facility. **Your task** as an engineer is to examine the science and technology behind the choice to use renewable energy and present the pros and cons of various options for each facility, including but not limited to feasibility (space, availability, etc.), cost and environmental impact. To solve this problem, you’ll use real-world data from the Renewable Energy Living Lab website.

Explore:

- Determine how much solar energy is available at each location, using information from the Renewable Energy Living Lab.
 - Begin by navigating to <http://www.teachengineering.org/livinglabs/index.php> > and clicking to enter the Renewable Energy Living Lab > then select the grades K-12 portal.
 - Explore the living lab data to become familiar with the interface.
 - Refer to the FAQs (bottom right of the map) if you have trouble finding the data you need.
- Determine the minimum size of the photovoltaic system required to meet the energy needs at the following four locations. The four facilities are identical three-story office buildings, each with 1,500 m² of available roof space on 10-acre lots, using an average of 2,800,000 kWh/year of energy.

Facility 1 in Longmont, CO = 1420 m²

Calculation:

From the Renewable Energy Living Lab map:

Potential PV solar energy in Longmont, CO = 5.4 kWh/m²/day.

This can be changed to kWh/m²/year by:

$$5.4 \text{ kWh/m}^2/\text{day} \times 365 \text{ days/year} = 1971 \text{ kWh/m}^2/\text{year}$$

To find the minimum size, or area, of the photovoltaic system required:

$$\text{Area required (m}^2\text{)} = \frac{2800000 \text{ kWh/year}}{1971 \text{ kWh/m}^2/\text{year}} = 1421 \text{ m}^2 \approx 1420 \text{ m}^2$$

Facility 2 in Utica, NY = 1830 m²

Calculation:

From the Renewable Energy Living Lab map:

Potential PV solar energy in Utica, NY = 4.2 kWh/m²/day.

This can be changed to kWh/m²/year by:

$$4.2 \text{ kWh/m}^2/\text{day} \times 365 \text{ days/year} = 1533 \text{ kWh/m}^2/\text{year}$$

To find the minimum size, or area, of the photovoltaic system required:

$$\text{Area required (m}^2\text{)} = \frac{2800000 \text{ kWh/year}}{1533 \text{ kWh/m}^2/\text{year}} = 1826 \text{ m}^2 \approx 1830 \text{ m}^2$$

Facility 3 in Cedar Rapids, IA = 1700 m²

Calculation:

From the Renewable Energy Living Lab map:

Potential PV solar energy in Cedar Rapids, IA = 4.5 kWh/m²/day.

This can be changed to kWh/m²/year by:

$$4.5 \text{ kWh/m}^2/\text{day} \times 365 \text{ days/year} = 1640 \text{ kWh/m}^2/\text{year}$$

To find the minimum size, or area, of the photovoltaic system required:

$$\text{Area required (m}^2\text{)} = \frac{2800000 \text{ kWh/year}}{1640 \text{ kWh/m}^2/\text{year}} = 1707 \approx 1700 \text{ m}^2$$

Facility 4 in Yuma, AZ = 1150 m²

Calculation:

From the Renewable Energy Living Lab map:

Potential PV solar energy in Yuma, AZ = 6.7 kWh/m²/day.

This can be changed to kWh/m²/year by:

$$6.7 \text{ kWh/m}^2/\text{day} \times 365 \text{ days/year} = 2446 \text{ kWh/m}^2/\text{year}$$

To find the minimum size, or area, of the photovoltaic system required:

$$\text{Area required (m}^2\text{)} = \frac{2800000 \text{ kWh/year}}{2482 \text{ kWh/m}^2/\text{year}} = 1145 \text{ m}^2 \approx 1150 \text{ m}^2$$

Explain: Compare the minimum size of the required photovoltaic system to the available space at each location. Is it reasonable to install the systems at these locations? Explain using data and your calculations.

Minimum size required:

Longmont, CO:	1420 m ²
Utica, NY:	1830 m ²
Cedar Rapids, IA:	1700 m ²
Yuma, AZ:	1150 m ²

Each location has a three-story building with 1,500 m² of available roof space. It would be the most reasonable to install photovoltaic systems in the locations in which the required area for the system is less than the roof space available. In these cases, none of the land would need to be taken up by the system. Based on this reasoning and the data and calculations shown above, Longmont, CO and Yuma, AZ are the two reasonable locations for installing photovoltaic systems.

Evaluate other energy sources for those same locations using the Renewable Energy Living Lab. How does the potential to use solar power compare to other renewable sources of energy in those locations? Use quantitative and qualitative data in your comparison.

Longmont, CO:

Wind – (Wind Power Class Onshore) – Class 2 (out of 7) – Low potential

Geothermal – Class 1.2 (out of 5, with 1 as the highest) – highest (and second to highest) potential range on map

Biomass – About 200,000 tons per year, in the middle range of biomass energy potential

Hydro – NPDs: No data in this area, FSPS: closest value: 1000 kW (average power)

Utica, NY:

Wind – (Wind Power Class Onshore) – Class 2 (out of 7) – Low potential

Geothermal – Class 5 (out of 5, with 1 as the highest) – Lowest potential range on map

Biomass – About 141,000 tons per year, in the second to lowest range of biomass energy potential

Hydro – NPDs: 1.2 MW, annual: about 5061 MWh, FSPS: No data available – low potential

Cedar Rapids, IA:

Wind – (Wind Power Class Onshore) – Class 2-3 (out of 7) – Low potential

Geothermal – Class 3 (out of 5, with 1 as the highest) – Medium potential

Biomass – About 400,000 tons per year, in the second to highest range of biomass energy potential

Hydro – NPDs: 2.3 MW, annual: about 11,500 MWh, FSPS: 1640 kW (average power)

Yuma, AZ:

Wind (Wind Power Class Onshore) – Class 2 (out of 7) – Low potential

Geothermal – IHS: 18.52 MWe, EGS: Class 1 – Highest level of geothermal energy potential shown

Biomass – 90,000 tons per year – within the lowest range of biomass energy potential

Hydro – NPDs: 25 MW, annual: 75,000 MWh, FSPS: 1000 kW (average power)

For Longmont, solar energy may be the best option, although Hydro power, Biomass, and Geothermal all present options. For Utica, solar energy potential was very low, while the potential for Hydro power is high and most likely that best option. For Cedar Rapids, solar energy potential was also relatively low, while Biomass presents the greatest potential. Yuma has extremely high potential for solar energy, so this seems to be the best option, but also has high potential for Geothermal energy and Hydro power.

Elaborate: As necessary, develop alternatives for Mr. Envy to consider in addition to his 100% solar power idea. Consider multiple sources (for example, 20% geothermal, 30% wind and 50% solar) or eliminating solar completely to be replaced by a different power source(s).

(Answers will vary, an example response is shown below)

I would recommend the following to Mr. Envy for each of the four locations:

Longmont, CO: 70% Solar, 30% Geothermal

Utica, NY: 100% Solar

Cedar Rapids, IA: 30% Solar, 70% Biomass

Yuma, AZ: 80% Solar, 20% Geothermal

Evaluate:

Summarize your research and analysis in the form of a feasibility plan that compares renewable energy options for four different facility locations. Prepare a final presentation for Mr. Envy. Have your presentation style (written or oral, individual or small group) approved by your teacher. Report

requirements:

- A summary of the preliminary data tasks.
- An analysis of Mr. Envy's original plan of 100% solar power at each location and your assessment of how successful this plan might be.
- Your evaluation of other power sources for each location.
- Your proposed alternative(s) for Mr. Envy.

Remember: Mr. Envy is a stubborn CEO who thinks this is the simplest thing he could do—just slap some solar panels on the roof and be done with it. If you want him to do something else, you must present a convincing argument. The **best presentations include:**

- An explanation of the problem (This is your chance to educate Mr. Envy; he is not a scientist or engineer so explain the science and technology to him with direct and accurate statements.)
- Quantitative and qualitative data to support your analysis of the problem
- An explanation of your recommendation(s)
- Data to support your recommendation (s)
- Use of graphics to clearly present data and concepts