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Student Objective
The student:
- given the size of their school's photovoltaic array, the amount of available sunlight and a fixed rate for electricity, will calculate the monetary savings to the school daily, monthly, and yearly
- given their family's electricity usage, will calculate the array size needed for their home to be a "zero energy" home
- can explain steps that can be taken to make a home "net zero energy."

Key Words:
conservation
energy efficiency
kilowatt hours
zero energy home

Time: 1 class period for lesson
Homework: retrofit and energy efficiency research
1 class period for presentations (optional)

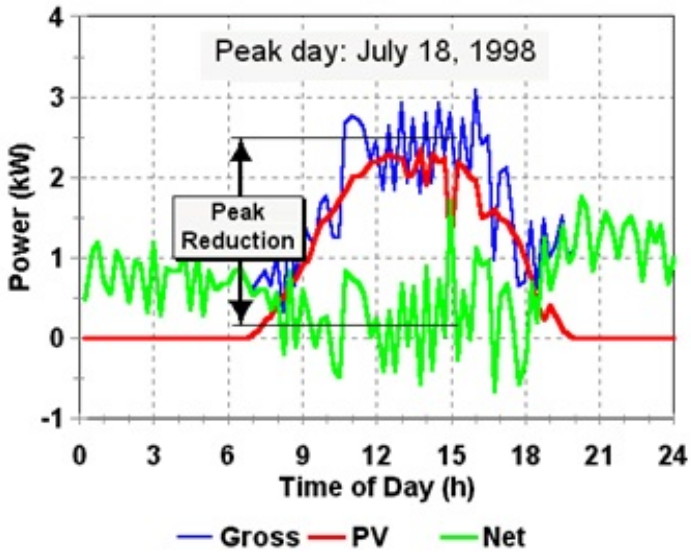
Materials:
- computer with internet access
- Insolation charts for your latitude/climate pattern (charts from the *Good Day Sunshine!* activity may be substituted)
- electricity bill and online access to family's electricity usage

Background

A "net zero energy" building or home is one that produces as much electricity as it uses over the course of a year. Most zero energy homes are also connected to the utility grid. When this is the case, it is not important that the energy produced equals the energy used in a minute-to-minute situation, or even on a daily basis. Electricity is purchased from the utility when the system isn't producing enough for the home's demand (nighttime for example), and then sold back to the utility when the system is producing more than the building needs (when the sunlight is intense, when no one is home, or on very sunny days). This averages out the production and the usage to equal zero or near zero. The graph below from the first "zero energy" home research in the United States, done by the Florida Solar Energy Center in Lakeland Florida, demonstrates this fact.

In the graph below you can see that when the Sun isn't shining in the morning and evening, the homeowners are buying their power from the power company (green line). But

during the day when the sunlight is bright and the photovoltaics are producing power (red line), the homeowners are actually "selling" power back to the utility (green line dips below zero).



The interesting thing for Florida homeowners is the near match that the output from a photovoltaic array (red line) makes with the energy consumption of the house (blue line). When the most electricity is needed for air conditioning, the systems are also producing the most power. More information from this study, can be found on the Florida Solar Energy Center's building research section (the link is listed in Internet Sites section).

Because of the size and cost of photovoltaic systems, it is advantageous to improve the energy efficiency of a building before buying and installing enough photovoltaics to make the building "zero energy". Research has shown that doing the energy retrofits listed below will reduce energy usage in a home by 56%. In the order from the easiest and most cost effective to the larger retrofits are:

- Install a programmable thermostat
- Fix leaky ductwork
- Replace incandescent lightbulbs with compact florescent or LED lighting
- Insulate hot water storage tank
- Upgrade ceiling insulation
- Replace old refrigerator with an Energy Star model (and get rid of the old refrigerator in the garage!)
- Install a solar thermal hot water system
- Install a energy efficient air conditioner

In Florida, 51% of our electricity is used by our homes. By reducing the amount of conventionally produced electricity needed to power our homes we can dramatically decrease the amount of pollution, and other harmful environmental effects.

Procedure (prior to class)

1. Send a note home advising the parents that the students will be learning how to calculate

their family's electrical use with the goal of energy conservation and saving money. Request that a copy of the family electric bill (or a printout of energy use from the utility website) be brought to school by the student.

2. For students that are unable to obtain their family's bill, have copies of an anonymous bill available for them to use.
3. If your school does not have a photovoltaic system, have ready some "typical" system information for the students to use, such as: System Size = 10.8 kW; Tilt angle = 28º.

Procedure (during class)

1. If necessary, divide the students into groups according to how many computers are available to them.
2. **Engage:** Lead a review discussion on their findings during the Good Day Sunshine! activity. Tell the students that now they have all the tools they need to be able to predict how much electricity their school's system will produce next month, and also how much money the system will save the school in electricity that will not have to be bought from the power company.
3. **Explore:** Students should complete their Laboratory Manual.
4. **Elaborate:** Have the students go to the research page for the Lakeland Florida Zero Energy Home listed in their Laboratory Manuals. Tell the students to imagine that they have at their home the same size array as the one used in the Lakeland house research. They are to figure out if that size array would be enough to power their house. If that would not be enough power for their family's yearly electricity needs, they are to come up with a realistic plan for conservation and retrofits--with a budget of $1000 total--to cut their family's electrical usage to match (or get as close as possible to) the output from the panels. *(Note: Most likely, the 5180 kWh yearly will not be enough to power their house currently. If you have a student who is currently that energy efficient, give them an alternative assignment of creating a brochure of effective energy efficiency upgrades and conservation for under $1000)*.
5. Tell the students they are to research conservation and retrofit options and price out these costs and energy savings until they have a plan for their family to make their home a zero energy home. Students are to document their research and their final plan, including websites (or stores) used for conservation, cost and energy use numbers. The method of documentation is left up to the student; computer programs such as Excel, PowerPoint are acceptable, as well as paper balance sheets. What is most important is that the students research what savings will be realized with each conservation method and how much each retrofit will cost and judge whether the source of this information is a reliable one. Assign a reasonable amount of time for the students to complete the project.
6. If desired, the student's zero energy household plans can be shared with the group.

Answer Key

1. Students should be able to calculate the output of the system using their knowledge from the *Good Day Sunshine!* lesson, multiplying the system size by the peak sun hours for the month and then multiplying by the number of days in the month.
2. The answer from question 1 should be multiplied by .12.

3. Students should calculate each month separately as in question 1 then add them together. Common mistakes are not accounting for the difference in peak sun hours each month or not realizing that the months are of differing lengths.
4. Students should use the yearly total output (Question 3) to calculate the offset of CO_2.
5. Students should figure the cost by multiplying the nameplate rating of the system by 5.25, then divide that by the total electricity cost they calculated in question 2.
6. There are several different problem solving strategies that can be used. Check for problem understanding, and appropriate unit conversion.

Key Words & Definitions

- **conservation** – the preservation and careful management of natural resources
- **energy efficiency** – the process of doing more with less
- **kilowatt hours (kWh) –** the standard unit used to describe electricity usage over time
- **zero energy home** – a home that produces as much energy as it uses when averaged over a year

Further Research

1. Research other Zero Energy Homes. Start with the other locations that have been studied by the Florida Solar Energy Center, then expand the search to other states. Prepare a presentation or a flyer on two zero energy homes in different regional climates. **http://www.fsec.ucf.edu/en/research/buildings/zero_energy/index.htm**
2. Research local builders that are building and marketing "energy efficient" homes. What construction techniques are they using in their homes?
3. Find out what local building codes would apply for someone wanting to add photovoltaics to their house.
4. Are there any rebates and/or incentives available for homeowners who want to do energy efficient retrofits, or add photovoltaics to their homes? Be sure to check for state, local and national tax rebates, as well as any incentives provided by the utility or manufacturer.

Internet sites

https://www.fsec.ucf.edu/go/zeh/

Florida Solar Energy Center's original Zero Energy Home research in Lakeland Florida.

https://www.fsec.ucf.edu/go/priorities/

Florida Solar Energy Center list of priorities to reducing energy usage in new and existing buildings.

http://energy.gov/energysaver/articles/estimating-appliance-and-home-electronic-energy-use

U.S. Department of Energy site to estimate and home electronic use. Includes typical wattages of various appliances.

https://www.energystar.gov/index.cfm?fuseaction=HOME_ENERGY_YARDSTICK.showGetStarted

U.S. Environmental Protection Agency's Energy Star Home Energy Yardstick. The site assesses the energy efficiency of your home through a question answer format.

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Florida NGSS Standards & Related Subject Common Core

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 1	SC.912.N.1.	X																			
Standard 4	SC.912.N.4		X																		
Standard 6	SC.912.E.6						X														
Standard 17	SC.912.L.17.											X									
Language Arts Standards		**Grades 9 & 10:** LAFS.910.RST.3.8, LAFS.910.RST.3.9, LAFS.910.WHST.3.7, LAFS.910.WHST.3.8 Grades 11 & 12: LAFS.1112.RST.2.4, LAFS.1112.RST.3.9																			
Mathematics Standards		MAFS.K12.MP.2.1																			

Science–Standard 1: The Practice of Science

- SC.912.N.1.1- Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 6) use tools to gather, analyze, and interpret data, and 7) pose answers, explanations, or descriptions of events.

Science–Standard 4: Science and Society

- SC912.N.4.2 - Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Science–Standard 6: Earth Structures

- SC.912.E.6.6 - Analyze past, present, and potential future consequences to the environment resulting from various energy production technologies.

Science–Standard 17: Interdependence

- SC.912.L.17.11 - Evaluate the costs and benefits of renewable and nonrenewable resources, such as water, energy, fossil fuels, wildlife, and forests.

Language Arts–Reading Standards for Literacy in Science and Technical Subjects

- LAFS.910.RST.3.8 - Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
- LAFS.910.RST.3.9 - Compare and contrast findings presented in a text to those from other

sources, noting when the findings support or contradict previous explanations or accounts.

- LAFS.1112.RST.3.7 - Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.
- LAFS.1112.RST.3.9 - Synthesize information from a range of sources into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Language Arts–Writing Standards for Literacy in Science and Technical Subjects

- LAFS.910.WHST.3.7 & LAFS.1112.WHST.3.7 - Conduct short as well as more sustained research projects to answer a question or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- LAFS.910.WHST.3.8 & LAFS.1112.WHST.3.8 - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; and assess the usefulness of each source in answering the research question.

Mathematics – Mathematical Practice

- MAFS.K12.MP.2.1 - Reason abstractly and quantitatively.

National Next Generation Science Standards

Earth and Human Activity

- HS-ESS3-2 - Evaluate competing design solutions for develping, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- HS-ESS3-4 - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Engineering Design

- 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.

Note: Related Common Core Mathematics Standards are listed in the Florida section above.

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1. How much electricity will your school's photovoltaic system produce this month (assuming that this month is an "average" month)? Hint: Start by calculating the expected kWhrs per day.

2. How much money is the school saving this month by producing some of the electricity being used by photovoltaics rather than buying it from the electric company? (Use 12¢ per kilowatt hour for electricity cost)

3. How much money will the school save each year? (Remember–each month has a different number of peak sun hours).

4. Calculate how many lbs of CO_2 were not released into the atmosphere last year by using the electricity your SunSmart photovoltaic array produced versus the average coal fired power plant. (Note: to calculate CO_2 emissions, use 2.3 lb CO_2 per kWh of electricity)

5. If the system at your school (or the one you have been using) cost $5.25 per watt (hardware and installation), how long will it take to have the system pay for itself with its savings? Note: use 12¢ per kWhr for electricity cost.

6. If the cost of electricity increases ½ cent per year, how long will it take to have the system pay for itself?