

Solar Power at Vernier Software & Technology

Having an eco-friendly business is important to Vernier. Towards that end, we have recently completed a two-phase project to add solar panels to our building to help reduce our carbon footprint. On our web site, www.vernier.com/solar, you can see a live camera view of the roof solar panels (Phase 1), our weather station data, and a live display of the power production of the panels. There are also tables and graphs you can use to investigate the energy production of the panels over time. It is our hope that you will be able to use this information to facilitate the study of solar energy production.

Background Information

Solar panels were added to the Vernier building in two different phases. In 2006, 68 of the 208 watt Sharp polycrystalline solar panels were installed on the roof of the building. In January 2008, 60 of the smaller 60 watt Kaneka amorphous silicon solar panels were installed on the front of the building as an awning. The total power rating of our system is 17,744 watts.



View of the roof panels that made up Phase 1. In the background is Mt. Hood.

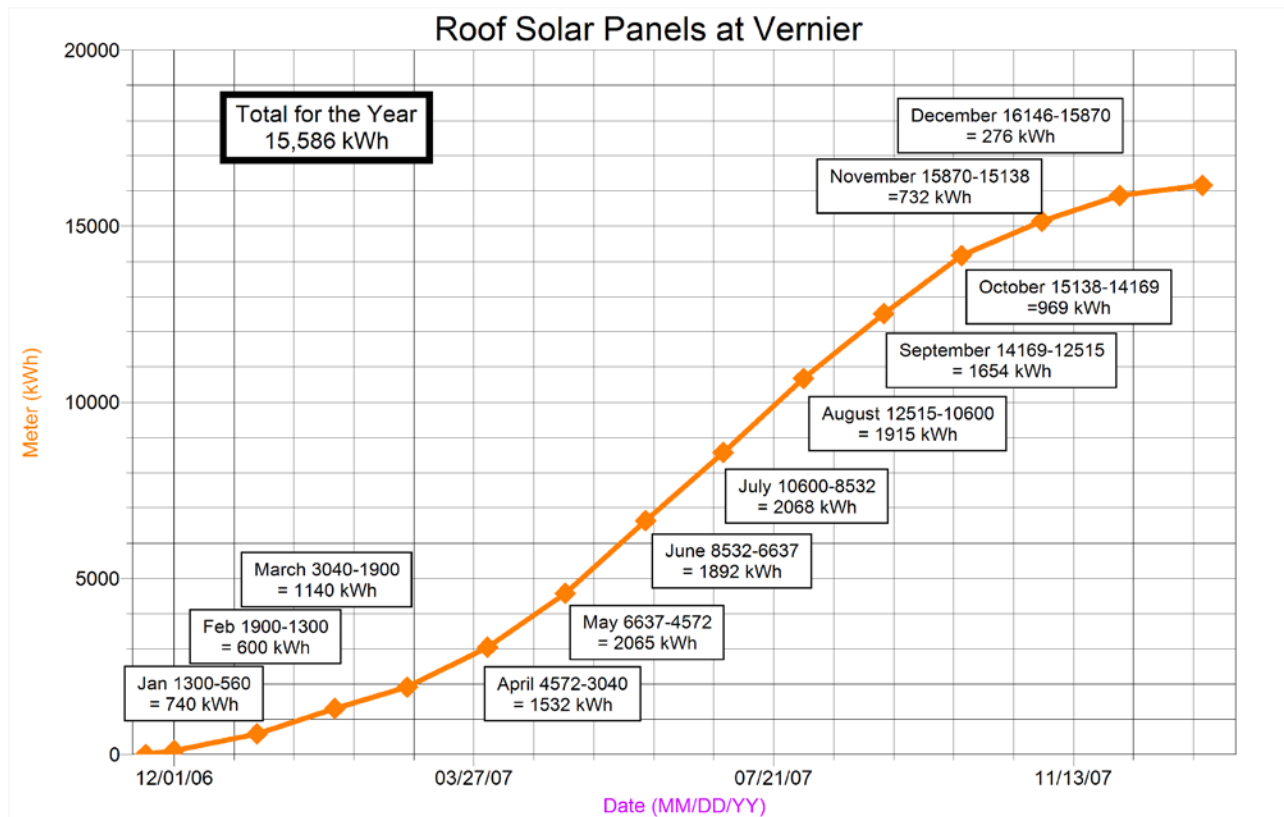
Phase 1: 68 Solar Panels on the Roof

These 68 panels are Sharp polycrystalline solar panels, each rated at 208 watts. The panels are arranged in three arrays of 22 (east), 24 (center), and 22 (west). Each of these arrays drives a PV Powered 4600 inverter, feeding a 3-phase sub panel. The Sharp PV modules are made in Tennessee and cost about \$1000 each. Additional costs include mounting hardware, electrical connections, installation labor, and inverters to convert the DC electricity from the solar panels to AC for use.

Energy Production Data and Financial Information on the Roof Panels

Number of panels	68
Installation completed	December 2006
Power rating (watts)	14,144
Energy expected per year in Oregon (kWh)	15,000
Energy actually produced in 1st year (kWh)	15,586
Cost of PV panels	\$66,560
Area of each panel	0.993m x 1.641m = 1.63 m ²
Total Cost of Project	\$102,195
Energy Trust of Oregon incentive	\$17,680
Green tags payments (over 2 years)	\$1,559
Oregon Business Energy Tax Credit in 2007	35% (taken over 5 years)
Federal Tax Credit	30%

Below is a graph of the total energy production for the Phase 1 panels from November 2006 through January 2007.



Phase 2: 60 Panels on the Front of the Building

For Phase 2, we installed a different type of solar cell—amorphous silicon solar panels. We chose a different type so we could do comparisons of the production of the two different types of panels under the same sky and temperature conditions. As these panels are visible to the public, we wanted to make them an attractive addition to the front of our building. The mounting structure is made out of stainless steel, which made the total cost of the project abnormally high.



View of the front awning panels that made up Phase 2.

Energy Production Data and Financial Information on the Front Awning Panels

Number of panels	60
Installation completed	January 2008
Power rating (watts)	3600
Energy expected per year in Oregon (kWh)	3886
Energy actually produced in 1st year (kWh)	Not yet available
Cost of PV panels	\$20,927
Area of each panel	0.99 m x 0.96 m = 0.95 m ²
Total cost of Project	\$84,062
Energy Trust of Oregon contribution	\$5,400
Green tags payments (over 2 years)	\$388 (estimated)
Oregon Business Energy Tax Credit in 2008	50% (taken over 5 years)
Federal Tax Credit	30%

Comparing the Different Photo Cells

Here are some comparisons between the amorphous silicon photovoltaic cell (used in Phase 2) and the polycrystalline silicon solar cells (used in Phase 1).

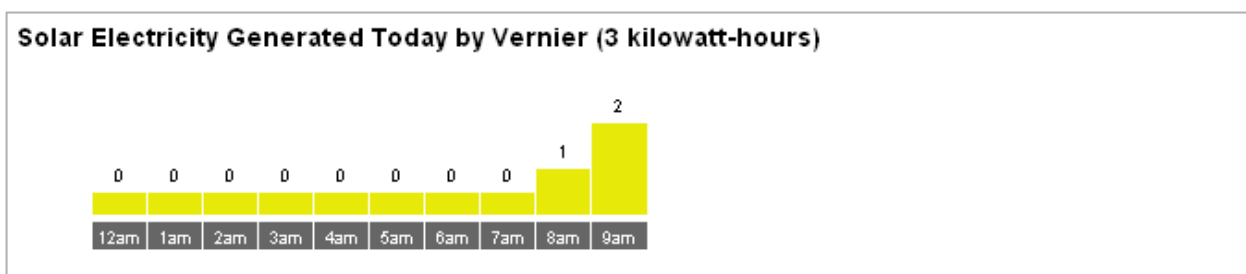
- The amorphous silicon photovoltaic panels are guaranteed to produce at least 90% of their rated power for 12 years and 80% of their rated power for 25 years.
- Amorphous silicon solar panels claim to continue to produce energy at a high rate, even when they get hot. The energy production of polycrystalline silicon solar panels drops off more when they get hot.
- Amorphous silicon has a higher band gap than crystalline silicon, which means that amorphous silicon absorbs more strongly in the visible part of the spectrum than the infrared.
- Amorphous silicon has an ecological advantage over crystalline silicon solar panels in their manufacturing. The energy used to produce them is less than what they will produce in two years. This time period is somewhat longer for crystalline solar panels.

Using vernier.com/solar

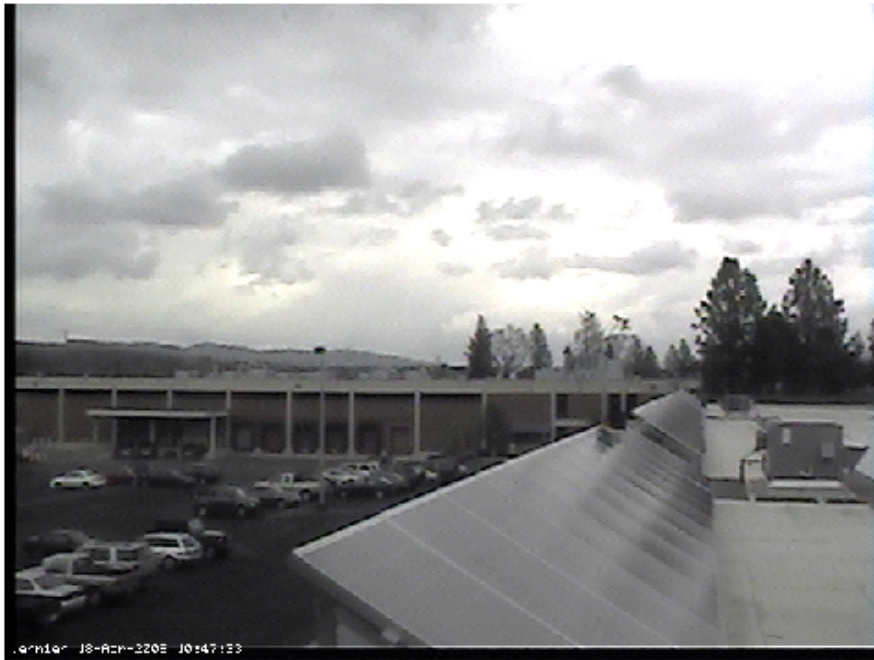
We have created www.vernier.com/solar as a place you can go to investigate solar power production using data from our solar panels. This web site has live readouts of the output from the Vernier photovoltaic panels, along with pertinent weather information you can use to study solar energy production.

The Solar Power Dashboard

When you go to www.vernier.com/solar, the dashboard displays the current power data. This includes a simple graph of energy production per hour. Additionally, there is a camera view of the roof panels and sky conditions. Current power production coming from each of the arrays is displayed, along with the monthly solar energy production for the past year.



View From Our Rooftop Webcam



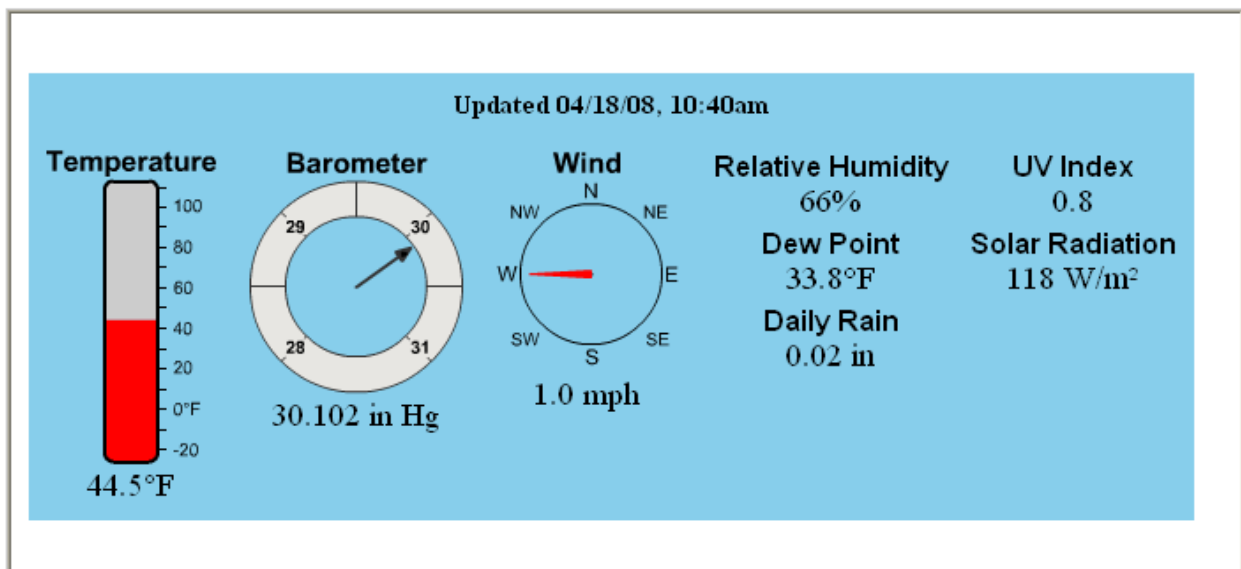
[View larger image »](#)

Current Power Readings	
Inverter	AC Power (W)
West	377
Center	437
East	400
Front	249
Total	1463

Solar Energy Production	
Month	kWh
March 2007	1140
April 2007	1532
May 2007	2283
June 2007	1954
July 2007	2149
August 2007	1963
September 2007	1710
October 2007	1008
November 2007	761
December 2007	297
January 2008	626
February 2008	1148
March 2008	1553

The East, Center, and West arrays are on the roof and they are all polycrystalline solar panels. The East and West arrays have 22 panels each and the center array has 24 panels. The Front array is for the 60 smaller amorous silicon panels.

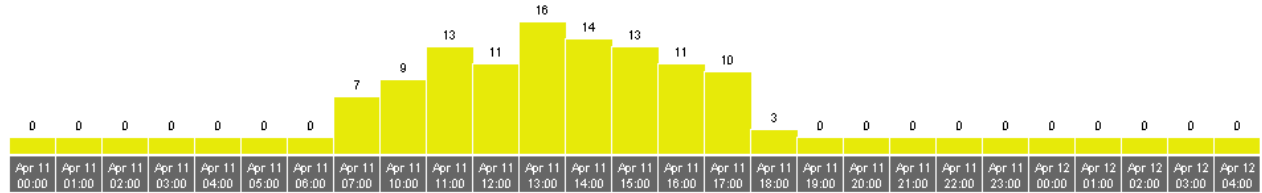
There is also weather station data, updated every 5 minutes. The weather station readout has a sensor reading solar radiation (in watts per square meter).



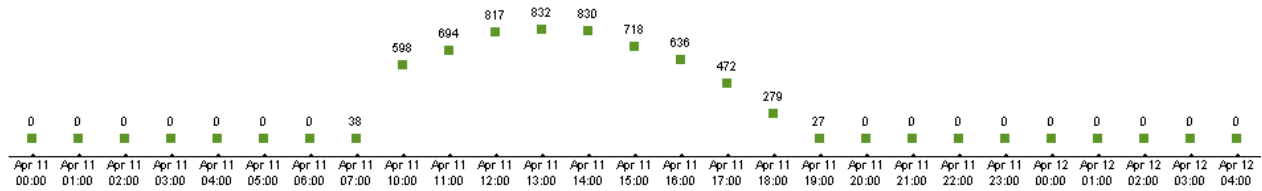
Vernier Solar and Weather Graphs

You can use the **Solar and Weather Graphs** link to view simple graphs of solar energy production and weather conditions on past days.

Energy Produced per Hour (kWh)

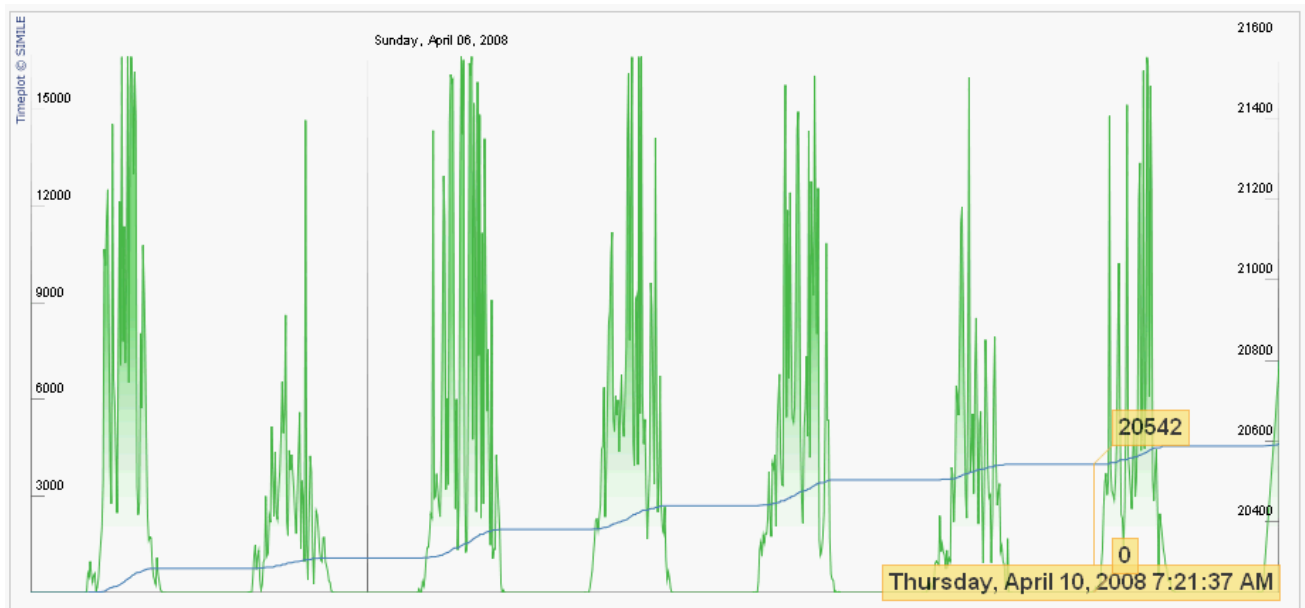


Solar Radiation (W/m²)



Solar Power Graphs (beta)

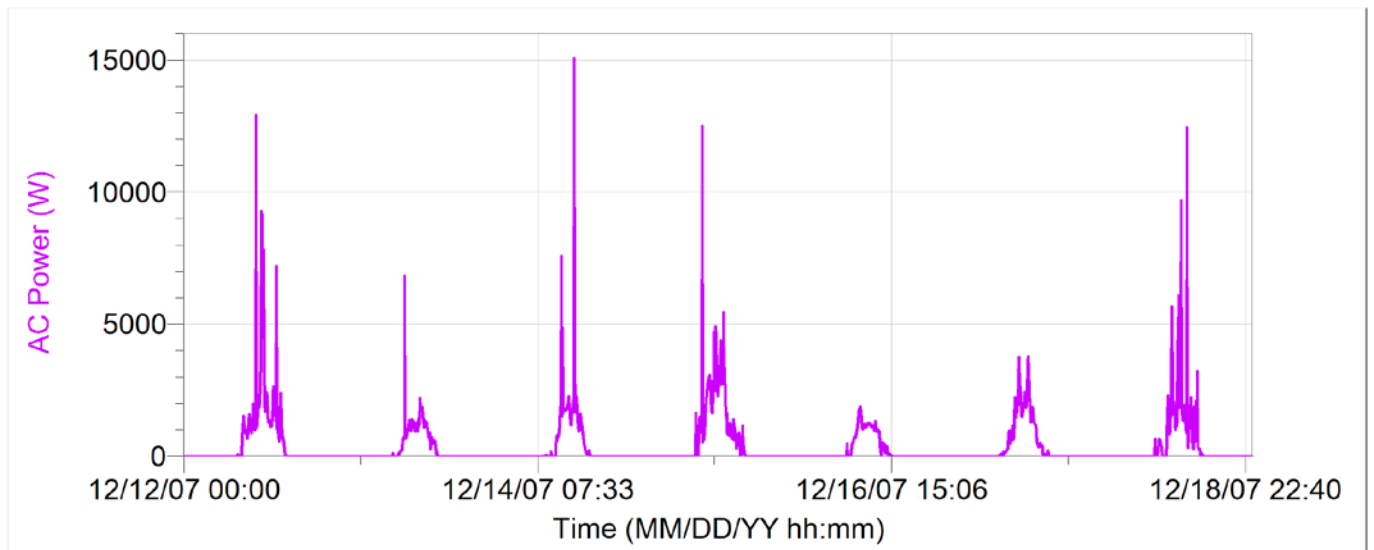
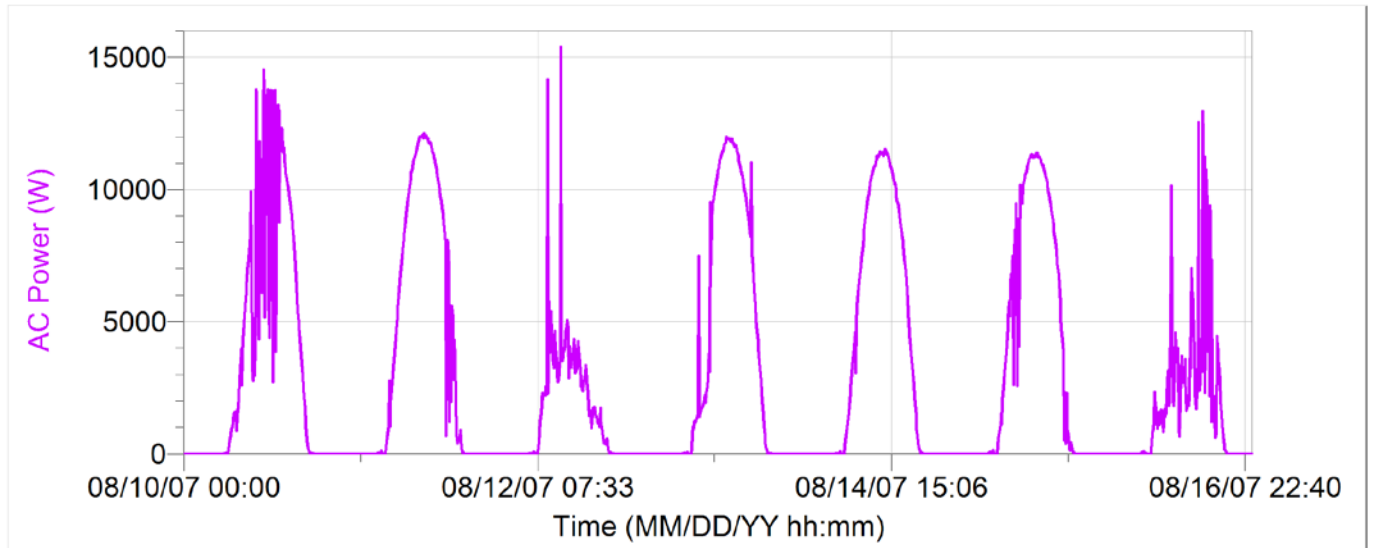
If you are using Firefox, or a Gecko-based browser, you will have the option to view more detailed graphs like the one shown below.



This graph uses MIT's SIMILE Timeplot (see <http://simile.mit.edu/timeplot>)

Export Solar and Weather Data to Logger Pro

Another way to view historical data is to download the data as a Logger *Pro* or text file. Logger *Pro* allows you to do things like plot different days on one screen and integrate the power graph over time.



2008 Solar Update

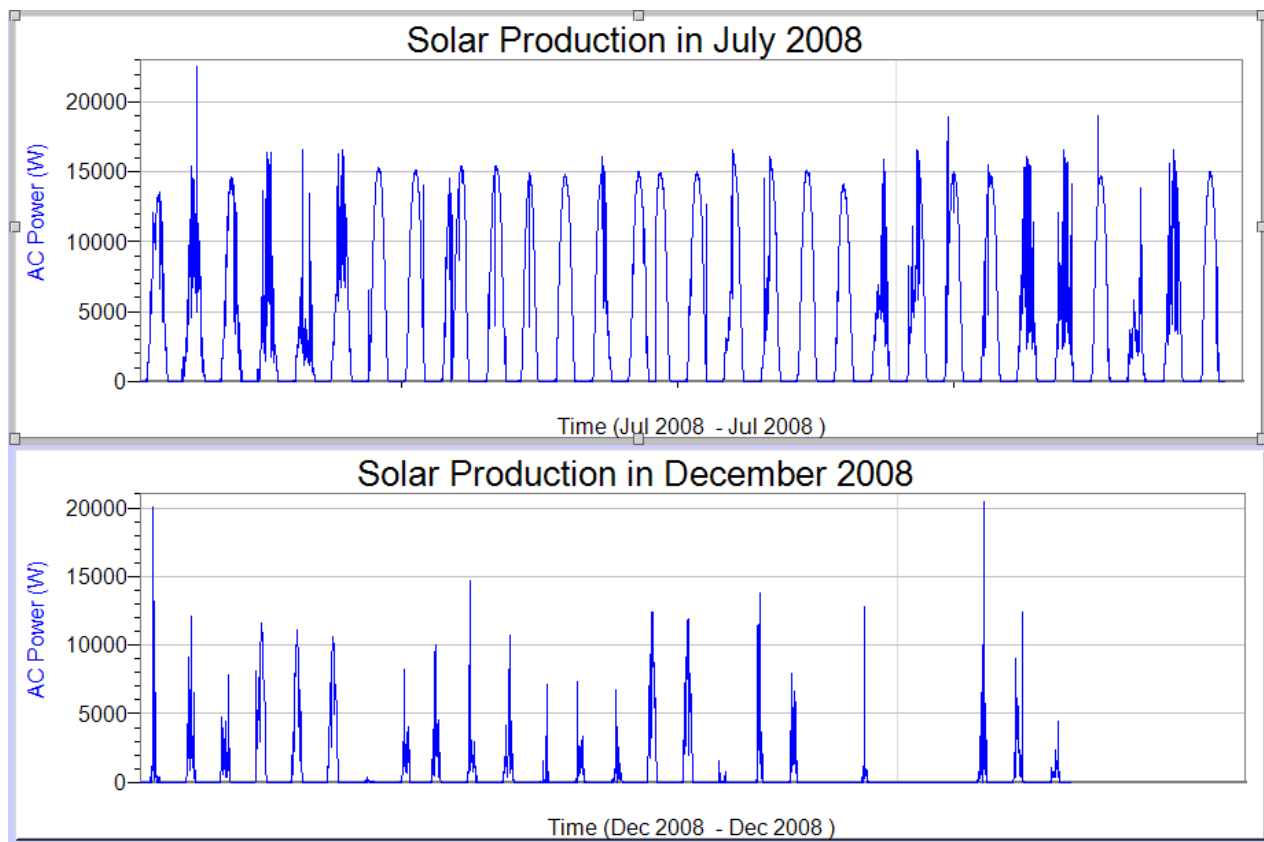
Here is an update on our solar energy production for 2008. Note that our front solar panels were installed in mid January, so effectively they were available for almost all the 2008 solar energy. Here is a graph of our 2008 production:

Note that we produced 19,504 KWH of electricity in 2008, compared with 15,586 KWH in 2007. Here is data on the production for the year from the four different arrays:

West: 5227 KWH
Center: 6016 KWH
East: 5215 KWH
Front: 3402 KWH

This means that our roof, polymorphic silicon panels, rated at 14,144 KW, produced a total of about 16,458 KWH and our front awning, amorphous silicon panels, rated at 3600 KW, produced 3402 KWH.

As you would expect, there was a huge difference in winter and summer solar energy production. Below are graphs of the energy production for the best and worst months. Both graphs have the same vertical axis scale. They were made by importing the data into *Logger Pro*.



Energy Production for the Best and Worst Months of 2008

Part 1: How Well Does it Work?

Note to Teachers

This document is intended to give information about our solar installation and to generate ideas as to how the data from our site could be used for instruction or inquiry in your classroom. The levels of the questions that follow are suitable for middle school and high school students. Feel free to modify the questions to fit your needs.

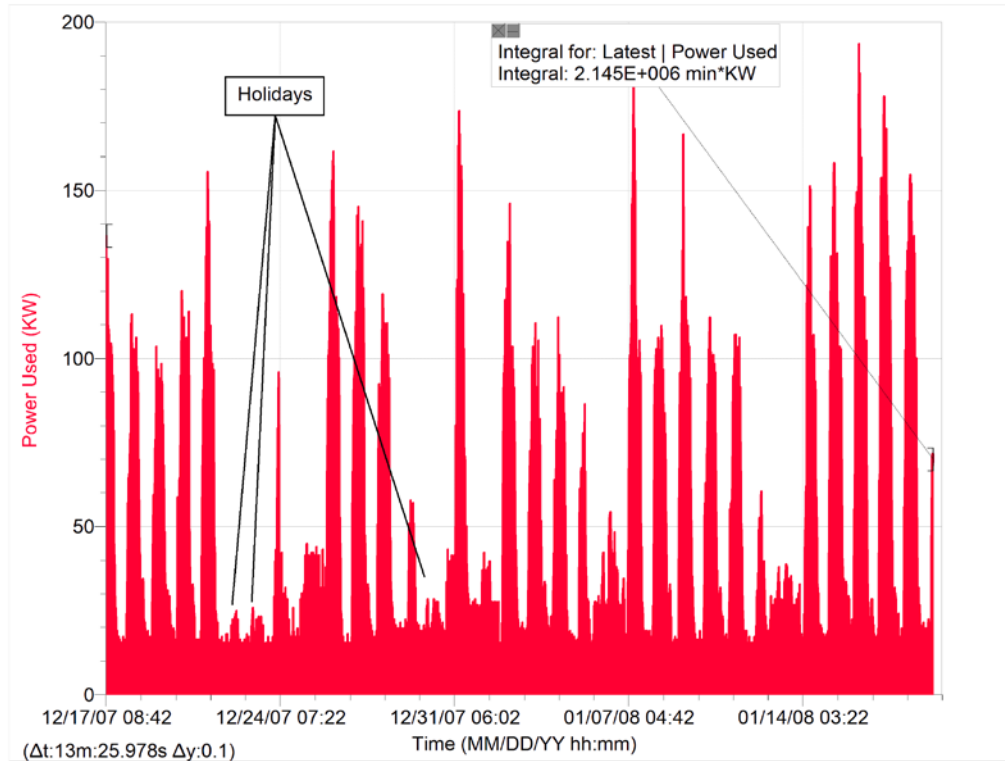
Questions to Consider

Part 1: How Well Does it Work?

1. What is the peak power production from the Vernier solar panels (Phase 1 and Phase 2)?
2. At this point, how many 17 watt compact fluorescent lamps could the Vernier solar panels power? How many 1000 watt hair dryers could it power?
3. Use the month-by-month solar energy production data available at www.vernier.com/solar to determine the average solar energy production at Vernier over a year. In winter? In summer?
4. Compare the length of time the panels are producing energy and the maximum energy produced for the weeks of August 10 – 16, 2007 and December 12 – 18, 2007. (Note: These weeks were chosen as they had relatively few clouds and not much rain.)
5. Compare the average power production during the day for the weeks of August 10 – 16, 2007 and December 12 – 18, 2007.
6. Oregon is famous for having cloudy, rainy winters. Do the solar output numbers match with this reputation?

Some Additional Information about our Building

The Vernier building is a LEED-EB green building. It used 294,720 kWh of electricity in 2007 and 282,880 kWh in 2008. This electricity cost \$27,932 in 2007 and \$27,359 in 2008. Electricity does most of the heating and cooling of the building. We have a few small gas heaters, but they only cost about \$2000 per year to run. It is a 30,000 square foot building with about 80 people working in it. With mostly electric heating and air conditioning, the electrical energy use is normally highest in the winter months. Spring and fall have the lowest electrical energy use.



Logger Pro graph of the Vernier building energy use

7. What fraction of the electricity use for a year will the solar panels be able to produce now that Phase 2 is complete?
8. The Vernier photovoltaic panels are connected to the “grid.” That means that the power produced can go directly to the local power company. If the panels create more energy than the building uses, the electric meter would run backward. Do you think the Vernier electric meter will ever run backward? What time of year would that be most likely? What would you guess a specific day might be? Explain your reasoning.

Comparing the Different Solar Panels

Compare the output of the amorphous silicon solar panels on the front of the Vernier building and the crystalline silicon panels (on the roof).

9. Which type of panels is producing more energy per square meter?
10. Which type of panel is producing more energy per dollar of its cost?
11. Is there a difference in the answers above for times with a lot of sun vs. times with minimal sunlight?

Comparing Other Solar Sites

There are a lot of other solar installations that have their power output displayed on the internet:

www.google.com/corporate/solarpanels/home (This is a huge project and a web site with lots of good information.)

www.fatspaniel.com/live-sites/index.html (This site has links to many solar panel project web sites with energy output data.)

www.sunviewer.net/ (This site has links to many solar panel project web sites with energy output data.)

12. Find a site with photovoltaic panels in your area, if you can. If not, use the Google site. Compare the output of this site with the Vernier site. Note the weather conditions and the time of day (Vernier and Google are both in the Pacific time zone).
13. Vernier Software & Technology is located at about 45.5 degrees North Latitude. What are the implications of this northerly latitude with regard to solar power production? Why?
14. See if you can find a site in Arizona or New Mexico to compare to the Vernier site. How does the energy production compare per square meter of panel?
15. The proper positioning of solar panels relative to the ground depends on latitude, since the height to which the sun rises depends on latitude. In Beaverton, Oregon, the Vernier solar panels are mounted at 30 degrees from horizontal. How does that angle compare with the angle of mounting of other solar panels? Can you come up with a rule for the optimum angle for mounting solar panels as a function of latitude?

Efficiency

Let's define the efficiency of a solar cell as the electrical energy produced per square meter divided by the incident solar energy per meter. Many weather stations, including the one at Vernier, list the solar radiation number. Several factors will affect this efficiency, including type of solar cell, temperature of the solar panel, and orientation of the panel to the sun.

16. How many square meters of panels are in each phase of the Vernier solar project?
17. If it is daylight in Beaverton, Oregon, go to www.vernier.com/solar and check the energy production of the Vernier solar panels at this time. Also, check the solar radiation (watts/m) available from the weather station data at the same site. Compare the amount of energy produced by the solar panels per square meter with the solar radiation (amount available from the sun per square meter). Compare these efficiency figures with solar cell efficiency numbers you find on the internet.
18. Compare the efficiencies of the crystalline and amorphous silicon solar panels at Vernier.
19. Download data from the Vernier site over different periods of time and estimate the average solar panel efficiency in the summer and in the winter. See if you can see a difference in efficiency between the summer and the winter. What happens to the sun angle relative to the fixed mounting angle of the solar panels between summer and winter? Is this the only effect here?
20. See if you can support the hypothesis that the efficiency of the panels depends on temperature.
21. One way to assess photovoltaic panel energy production is to calculate their peak-equivalent hours per day. So, for example, using the best month of 2008, July for this calculation: Vernier produced 2900 KWH of energy, or about $2900/31 = 93.5$ KWH per day. The system is rated at 17.744 KW, so it would have taken $93.5 \text{ KWH}/17.744 \text{ KW} = 5.2$ hours to generate this much energy at peak production. Determine the peak-equivalent hour per day calculation for the Vernier facility averaged over the whole year. For comparison, an article in the July 2008 *Physics Today* lists the average peak-equivalent hours per day in San Diego is 5.7 hours and in Seattle as 3.7 hours.
22. The peak-equivalent hours per day figures from the *Physics Today* article in the previous question assume that the solar panels are permanently mounted at the best angle for the latitude of the site. According to the article, adjusting the tilt of the panels to match the seasonal path of the sun increases energy production by about 8%. Do some calculations and consider whether this adjustment might be worthwhile. How much money would it save per year?
23. The U.S. produces about 10^{12} watts of electricity daily. How much land area would need to be covered to produce this much energy with solar panels? Ignore the whole issue of energy storage in this calculation.

Part 2: What does it really cost?

Consider the financial side of the solar panel project. In Oregon, the following incentives are offered to businesses to promote the purchase of photovoltaic panels:

- Oregon Energy Trust (<http://www.energytrust.org/solar/index.html>) pays up to \$1.50 per watt for business photovoltaic projects. The Energy Trust pays the money directly to the contractor at the completion of the project.

- An Oregon Business Energy Tax Credit is giving Vernier a 35% tax credit distributed over five years. 10% of the cost of the project can be taken off our state income tax bill in each of the first two years after the completion of the project, and then 5% can be taken off the next three years. In 2008, this incentive was increased to 50% (10% of the cost of the project for each of five years).
- In 2008, anywhere in the U.S., businesses can take advantage of a 30% Federal Income Tax Credit for Solar projects. In addition, solar projects can be depreciated on business tax returns over a short 5-year period. According to some reports, this can save as much as 25% of the cost of the project (see for example *The Oregonian* newspaper, March 16th, 2008 or <http://rebeeco.com/content/view/11/11/>). See also <http://en.wikipedia.org/wiki/Depreciation> .

For the following questions, assume a cost of electricity of \$0.08 per kWh.

1. One common way to express the cost of electricity generating systems is to calculate the cost per delivered kilowatt. Ignoring all incentives, what was the cost per kilowatt for the Vernier solar project? What was the cost for Phase 1? For Phase 2?
2. How much did the Vernier solar project really cost when the incentives (Oregon Energy Trust, Oregon Business Energy Tax Credit, federal tax credit, and depreciation advantages) are taken into consideration?
3. How much money is saved by Vernier on electric energy because of the energy produced by the solar panels?
4. Considering the incentives above, what is the cost per delivered kilowatt of the Vernier solar project?
5. In a simplified calculation (not taking into account the lost interest on the initial money invested), how long would it take Vernier to pay for their solar panels with the money saved on electricity?
6. What would you expect to happen to the cost of electricity from the power company in the next few years?
7. Does the whole idea of solar panels in Oregon make sense?
8. As mentioned above, at the start of 2008, the Oregon Business Energy Tax Credit for solar installations went up from 35% over 5 years to 50% over 5 years. How much money would Vernier have saved if they delayed their roof top solar panel project so that it was on the 2008 tax form?
9. What are the advantages, other than financial, for a company when considering installing solar panels?
10. What are the disadvantages of the state and federal government giving tax breaks for people installing solar panels?
11. What are the tax incentives for solar power projects in your state? Sometimes the incentives are different for residential projects and businesses. Check for both. A useful site for such comparisons is <http://www.dsireusa.org/>
12. If the Vernier solar power project had been done in your state, how much different would the financial situation be, assuming that the cost of materials and construction was the same?
13. If the Vernier solar panels keep producing at about the same level for 20 years, and require essentially no maintenance, what would the cost of per KWH work out to be? Do this calculation two ways, once including incentives and once not.