

Reality Math

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Photovoltaic Electricity

1. How Much Energy Does the Sun Provide to Earth?

Photovoltaic panels convert sunlight directly to electricity. The light from the sun can provide **1 kW of energy per square meter** when the sun is at its maximum.

Remember that US households need an average flow of 1 kW twenty-four hours a day, or 24 kWh every day. So one square meter of photovoltaic panel would be enough to power an average US household if the sun was always available at its maximum potential and if the photovoltaic panels used to convert the sunlight to electricity were 100% efficient.

2. Taking PV efficiency into Account

However a very good 1 m² PV panel might be only 20% efficient. That means only 20% of the sun's 1 kW of energy would be turned to electricity.

1. (a) What **fraction** of the sun's energy can a very good PV panel convert to electricity?

(b) A 20% efficient 1 m² PV panel would provide a flow of how many watts of electricity when sunlight is at a maximum? (Remember 1 kW = 1000 watts.)

(c) How many square meters of 20% efficient PV panels would be needed to provide 1 kW steadily when sunlight is at its maximum?

3. Taking Available Sunlight into Account.

How much of the time does the sun shine anyway? This is an interesting question. Sometimes it is dark, so no sunlight. But sometimes the sun is low in the sky. And what about cloudy days? And locations far from the equator? What if it is winter?

<http://www.altestore.com/howto/Solar-Insolation-Data-USA-Cities/a35/>

There are many sites on the web in general agreement about “solar *insolation*,” which is the number of hours of “peak sun” available in various locations. “Peak sun” on a sunny day in an optimal latitude around noon provides 1 kW of energy per square meter. If the location is poorer, the day is cloudy, the time of day is earlier in the morning or later in the afternoon, then only a portion of “peak sun” energy will be available. Much monitoring of sunlight has been done over the past decades and solar insolation data

provides us with the hours of peak sun equivalent coming from the many more hours of less than optimal solar energy.

El Paso, Texas has, everything taken into account, 6.72 hours of peak sun on the average every day all year long. Remember

$$\mathbf{kW \times hrs = kilowatt-hours (kWh)}$$

2. In El Paso, a 10 kW PV system would produce about how many kWh of electricity
 - (a) per day?
 - (b) annually?
3. The average cost of electricity in Texas is 11.68¢/kWh. Estimate the value of the electricity generated by a 10 kW system in El Paso
 - (a) per day.
 - (b) annually.
4. Estimate the annual revenue from selling the electricity generated by a 20 MW solar farm in El Paso at the average retail rate. 1 MW = 1000 kW

4. Buying a PV System

You could buy a 5 kW photovoltaic system. Such a system would provide 5 kW when the sun was at maximum power. So, in El Paso with 6.72 hours of peak sun daily, the 5 kW system will produce

$$\mathbf{5 \text{ kW} \times 6.72 \text{ hours} = 33.6 \text{ kWh}}$$

on average every day. Remember that average US households need about **24 kWh/day** of electricity. So a 5 kW system would provide more than enough electricity for an average household in El Paso.

Generally PV systems are connected to the grid so that surplus energy is fed into the grid during peak sun hours and needed electricity can be drawn out of the grid on cloudy days or at night.

5. In El Paso, would each system provide enough electricity for an average household connected to the grid?
 - (a) a 4.5 kW system
 - (b) a 3.6 kW system
 - (c) a 2.5 kW system

5. Would It Pay to Buy a 5 kW PV System for \$20,673 Installed?

In 2019 the Federal Government gives a tax credit of 30% of cost.

Cape Hatteras, North Carolina receives 5.31 hours of peak sun per day on average all year long.

Suppose you live on Cape Hatteras and purchase a 5 kW PV systems for \$20,673 installed. Your utility will install a two-way connection to the grid, so you draw off power when you aren't producing enough for your household, at night for example. The utility keeps track of what you put into the grid and what you draw out of the grid. If you draw out more than you put in they charge you about 10¢/kWh in North Carolina. If you put in extra, in NC, they don't reimburse you.

6. (a) How much Federal tax credit will you get?

(b) What will the system end up costing you?
7. (a) About how many kWh/year will your 5 kW system generate in Cape Hatteras, NC?

(b) What is the dollar value of one year of electricity from your system at 10¢ per kWh?

(c) How many years will it take to payback the cost of the system?

(d) If the system lasts for 25 years and the price of electricity doesn't increase, estimate the profit you will make off your PV system.

(e) If the price of electricity rises, will your profit increase or decrease?

6. Powering the World with PV alone

It is possible to convert all the energy provided by the barrels of oil, tons of coal, and cubic meters of natural gas used by the world into petawatt-hours. Petawatt-hours are a really big energy unit. The world needs about **150 PWh** annually of energy from all sources combined (coal, oil, natural gas, nuclear, renewables)

http://en.wikipedia.org/wiki/World_energy_consumption

petawatt-hours	1 PWh = 1000 TWh
terawatt-hours	1 TWh = 1000 GWh
gigawatt-hours	1 GWh = 1000 MWh

8. 1 PWh equals how many

- (a) TWh?
- (b) GWh?
- (c) MWh?
- (d) kWh?

The Sahara Desert has area 9.4 million square kilometers. Each square km is 1000 meters by 1000 meters = 1,000,000 square meters.

At the beginning of this unit we determined that taking the 20% efficiency of PV panels into consideration, 5 square meters of land could provide 1 kWh of electricity during 1 hour of peak sun.

9. What flow of electricity could PV all over the Sahara Desert supply during peak sun?

- (a) kW
- (b) MW
- (c) GW
- (d) TW
- (e) PW

10. With 6.3 hours per day of peak sun for the Sahara Desert,

- (a) How many PWh of electricity could PV all over the Sahara Desert supply daily?
- (b) How many PWh of electricity could PV all over the Sahara Desert supply annually?
- (b) How many times total world energy from all sources could be supplied by PV all over the Sahara Desert?
- (d) PV on what percent of Sahara Desert land could provide all the energy for the world?