So How Much Electricity Is That?

A practical explanation of units of electrical energy and power.

Regarding electric cars and renewable energy, questions are often asked about electrical power and energy. A solar installation is rated at 10 kW; people ask, “How much electricity is that?” Or an electric car has a 20 kW·h battery, “How much electricity is that?” Is 10 kW of solar power enough to power a house? Or will an electric car with a 20 kW·h battery double an electricity bill? Many people are unfamiliar with kilowatts and kilowatt-hours. This is an explanation of these terms and with the perspective of the electricity used by a typical house.

Kilowatt-hour, abbreviated kW·h, is a measure of electrical energy used or produced. It is a quantity, analogous to a gallon or a kilogram. Kilowatt, abbreviated kW, is a measure of electrical power. Power is the rate that energy is used. Power and energy are not the same thing, but they are related. A gallon bucket full of liquid is an amount of that liquid, like kilowatt-hours is an amount of electricity. A bucket can be filled or emptied with a big stream or a small trickle. So too can you have a big ‘stream’, many kilowatts, or a small ‘stream’, few kilowatts. Electrical power is like a stream of electricity. With few kilowatts of power it takes more time to get to a kilowatt-hour of electricity. With many kilowatts of power it takes less time to get to a kilowatt-hour. So, kilowatt-hours and kilowatts are related by time, but they are not the same thing by themselves. Power for a certain length of time is equal to energy. Or energy divided by a certain time is power. The ‘kilo-‘ prefix for both means one thousand (1000). KW·h and kW are relatively large units made up of, watt-hours (W·h) and watts (W), respectively.

For the solar installation, it can produce electricity under full sun conditions at the rate of 10 kW; a measure of it’s power, or the rate it can produce electricity. That is the size of the electrical ‘stream’. How much electric energy it produces is also a function of time. Latitude, season, and time of day all influence the ability to produce electricity from sunlight. To be specific, in Texas, 5.5 hours per day is the yearly average for full sun condition. It will be less than that during the winter, and more in the summer, but on a yearly average, it’s 5.5 hours per day of full sun (there is sunshine for more than that time, but early and late in the day sunlight is not as bright. The standard is based on $1kW/m^2$ of insolation.) So, based on an average day, the solar installation can produce 10 kW for 5.5 hours, for a total amount of electricity per day of 55 kW·h.

Most single-family houses use between 500 kW·h to 2000 kW·h of electricity per month. Selecting 1200 kW·h, as a typical house for this explanation, and since there are, on average, 30 days in a month, a typical house would consume on the average 40 kW·h per day. The 10 kW solar installation can produce 55 kW·h on a standard sunny day in Texas, so it would seem adequate to supply a typical house with the amount of electricity that is used on a daily average.

This is not the whole story. Both energy and power are important. Since the solar installation only produces electricity during the day, and assuming the house gets electricity only by solar, some form of energy storage is needed to save energy when the sun is shining brightly so that it can be released as needed when the sunlight is not as bright and during the night.

If we assume the energy storage system smoothes the rate of electricity (power) provided to the house to a constant rate, this would be 2.3 kW. (55 kW·h / day divided by 24 hr / day ≈ 2.3 kW). Electric utility companies consider a typical house to require 4 kW of electrical power (rate of electrical energy). This is a standard used for planning the electricity needs of many houses. It implies that the solar installation with storage would be unable to power a typical house because 2.3 kW from the solar and storage is less than 4 kW for the house. The house will frequently exceed the power provided by the solar and storage, even if just for a few minutes each day.

If the solar installation were the only source of electricity, the power capability of the storage system, although not necessarily the amount of storage, would have to be increased. Then the storage system could store, or delivering, a bigger stream (power) than just the average 2.3 kW. The power of the storage system would have to be at least 4 kW, and probably 6 kW or 7 kW to meet peak demands. To precisely match the power of the storage system to the power required by the house, the time and power of peak demands and production would have to be determined. Precise matching of solar to the house can be avoided if the house remains grid connected and solar generation only supplements electrical usage of the house.

Considering the electric car (EV); 20 kW·h is the size of the battery. The battery is the electrical storage, or think of it as the fuel tank. The tank can hold 20 kW·h , but the amount that needs to be put into the tank is a function of how far the car is driven. Every trip doesn't empty the battery. Most EVs get 4 or 5 miles to 1 kW·h. Assume the car is driven 30 miles per day, this driving uses about 6 to 8 kW·h per day. Since the "typical" house uses 40 kW·h per day, this would only be about a 15% to 20% increase in the electric bill per month, if the bill were linear with usage, which it may not be.

Interestingly, even though most EVs only use an amount of electricity equal to 15% to 20% (caveat: mileage may vary) of the electricity used in a house, the EV is capable of using electricity at a much larger rate. It does this usually when accelerating. Typical houses use electricity at a 4 kW rate, but many EVs are capable of 100 kW of power. So more total electricity is used in a typical house than a typical EV even though it is used in the house at a lower rate, but the house uses electricity 24/7. The EV can use electricity faster, but does this only briefly, so the total is less than a house. For many applications with electricity, both total quantity (kW·h) and power (kW) are important.

It is more efficient (both energy and cost), for the electric requirements of many houses, EVs, and businesses to be combined and supplied from a much larger than 10 kW renewable energy source. By combining many users of electricity, the variations in the individual demands average out and the average power required is closer to the time average of the quantity of electricity generated. This is the advantage of grid electricity.

Unlike traditional electric generation, solar electric generation can be cost effective with smaller sources and located physically closer to where the electricity is used. Generating electricity near where it is used eliminates the long distance transmission of the electricity and the accompanying costs and losses. This is <u>distributed renewable electric generation</u> and if done at comparable costs to existing electric generation it can be applied to the grid, just as wind generated electricity and hydro generated electricity. Together these can provide sustainable national energy sources.