UNDERSTANDING ENERGY UNITS

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Musings of an Energy Nerd

Contemplating residential energy use

UNDERSTANDING ENERGY UNITS

Don't confuse energy and power — it's important to know the difference between Btu and Btu/h, as well as kW and kWh

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If you've ever been confused by the difference between 500 Btu and 500 Btu/h, you probably can use a handy cheat sheet to explain energy units. As a guide through the thorny thickets of energy, power, and the units used to measure them, I've assembled some questions and attempted to answer them.

Energy units can be confusing. Should the annual electricity production of a power plant be reported in megawatts or megawatt-hours? Hmmm... let me think...

What's the difference between energy and power?

Energy is the amount of heat or work that can be obtained by burning a certain amount of fuel. Energy is measured in a variety of units, including kilowatt-hours (kWh), Btu, and joules. A quantity of energy can also be expressed in terms of barrels of oil, gallons of gasoline, or cords of firewood.

A unit of energy can be bought or sold. For example, electricity is usually sold by the kWh. Your electric bill includes a monthly tally of the number of kWh you used. If you are charged $80 for 800 kWh, then each kWh costs you 10¢.

A Btu (British Thermal Unit) is the amount of heat necessary to raise one pound of water by 1 Farenheit degree. A joule is the work done by a force of one newton for a distance of one meter.

Power is different from energy. Power is the *rate* at which energy is burned or used (or, more precisely, the rate at which energy is converted from one form to another). In other words, power is a measure of how quickly work can be performed; Power = Energy/Time, and Energy = Power × Time. Power is measured in watts, kilowatts, horsepower, Btu/h, tons of cooling, and foot-pounds/minute.

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What's the Difference

Appliances are usually rated by their power consumption. When we talk about a 100-watt light bulb, we are describing it by its power rating. Furnaces also have power ratings — for example, a furnace can be rated at 40,000 Btu/h. If the power rating is high, the appliance uses energy at a fast rate; if the power rating is low, it uses energy at a slow rate. So we can say that a 20-horsepower tractor is more powerful than a 12-horsepower tractor; we can also say that a 2,000-watt hairdryer is more powerful than a 1,000-watt hairdryer.

If you turn on a 1,000-watt hairdryer for one hour, you've used a kilowatt-hour. While it's possible to buy a kilowatt-hour, you can't buy a kilowatt.

When dealing with electricity, Power (in watts) = Current (in amperes) × Voltage. One watt is the power from a current of 1 ampere flowing through 1 volt. (An ampere is the unit used to measure the flow of electricity, or current. Amperes measure the rate of electron flow.)

Lots of people are confused by energy and power units. Don't be one of them — or you'll risk ending up on the Power and Energy Hall of Shame. Remember, there is no such thing as kilowatts per hour or watts per hour.

Can you provide some analogies to clarify these energy units?

Yes. Here's one: energy is a measurable quantity and can therefore be compared to distance. In this analogy, power (which is a rate) is like speed.

I especially like plumbing analogies, because I was a plumber before I was an electrician. If you are comparing electricity to piped water, here's how the analogy works:

Kilowat-hours (energy) are like gallons of water.
Kilowatts (power) are like gallons per minute.
Voltage is like water pressure.
Wire gauge is like pipe diameter.

A tap that delivers a generous flow of water is like an appliance using a lot of watts. A tap delivering a trickle of water is like an appliance using few watts.

So, if you need 10 gallons of water per minute, you can deliver it with a fat pipe operating at low pressure, or with a skinny pipe operating at high pressure. Similarly, you can obtain 1,000 watts of electric heat from a low-voltage appliance with a large-gauge wire or from a high-voltage appliance with a small-gauge wire.

How do I convert energy units?

Here are some handy conversion factors for energy units:

1 kWh = 3,413 Btu

1 kWh = 3,600,000 joules

1 joule = 1 watt-second

1 Btu = 1,055 joules

1 Therm = 100,000 Btu = 29.3 kWh

1 calorie = 4.184 joules

1 Btu = 252 calories

Note: Try to avoid using the abbreviation MBtu, since this unit has two definitions. One MBtu can mean either 1,000 Btu or 1,000,000 Btu; that's reason enough to stay away from MBtu.

How do I convert power units?

Here are some handy conversion factors for power units:

1 watt = 1 joule/second
1 watt = 3.413 Btu/h
1 Btu/h = 0.2931 watt
1 kW = 1,000 watts
1 megawatt (MW) = 1,000,000 watts
1 kW = 3,413 Btu/h
1 ton of cooling = 12,000 Btu/h
1 horsepower (electric) = 746 watts

What's the energy content of common fuels?

A gallon of propane isn't equivalent to a gallon of fuel oil, because fuel oil packs more Btu per gallon than propane. To compare different fuels, use this handy guide.
Natural gas: 1,000 Btu/cu. ft.
Propane: Between 91,333 Btu/gallon and 93,000 Btu/gallon
Fuel oil: Between 138,700 Btu/gallon and 140,000 Btu/gallon
Kerosene: Between 120,000 Btu/gallon and 135,000 Btu/gallon
Gasoline: Between 114,000 Btu/gallon and 125,000 Btu/gallon
Coal: 25,000,000 Btu/ton
Seasoned dense hardwood firewood: Between 21 and 26 million Btu/cord
Seasoned pine firewood: Between 14 and 16 million Btu/cord
Here are some useful conversion factors used for measuring natural gas:
1 ccf ("centi- cubic feet") = 100 cubic feet
1 cubic foot of natural gas = 1,000 Btu = 0.01 Therm
1 Therm = 1 ccf of natural gas = 100,000 Btu = 29.3 kWh

What about air pressure units?

The question is a little off-topic, but why not address it anyway? Here are some conversion factors:
1 atmosphere = 14.7 lb./sq. in. = 760 mm. of mercury = 406.78 in. of water = 101,325 Pascals
1 Pascal = 0.00401 in. of water
1 lb./sq. in. = 6,894.76 Pascals
1 lb./sq. ft. = 47.88 Pascals
According to the formula in C. Donald Ahrens, *Meteorology Today*, wind speed in miles per hour multiplied by itself and then by 0.004 gives the wind's pressure in pounds per square foot.

What about converting units used to measure fan performance?

Here are some conversion factors:
1 cubic foot/minute (cfm) = 0.472 liter/second
1 liter/second = 2.12 cfm
1 liter/minute = 0.03531 cfm
1 cubic meter/hour = 0.588 cfm

What's the difference between "site energy" and "source energy"?

Site energy is the amount of electricity and fuel consumed at a building. For example, in one year a house might require 12,000 kWh of electricity and 500 gallons of fuel oil. These quantities represent the amount of site energy consumed by the house; if we convert both types of energy to Btu, the house used 40,956,000 Btu + 69,500,000 Btu = 110,456,000 Btu of site energy.

Source energy is a calculation of the amount of fuel required to produce the energy consumed at a given site. Of all of the fuels, electricity has the biggest discrepancy between site energy and source energy — that is, the biggest "site/source ratio" — because most fuel-burning power plants require 3 or more units of fuel to produce 1 unit of electricity. (The energy that isn't converted to electricity is lost as waste heat.) Different power plants have different conversion efficiencies, so calculating source energy can be tricky; the site/source ratio for electricity varies by state and even by time of day.

When primary energy (for example, fuel oil or natural gas) is consumed at a house, the conversion to source energy must account for losses that occur during storage, transport, and delivery of the fuel to the building. The site/source ratios for natural gas and fuel oil burned in a building are much lower than the site/source ratio for electricity produced at a fuel-burning power plant.

In the case of the house that uses 110,456,000 Btu of site energy each year (the example given above), it might require 40,080 kWh of coal (in other words, 136,793,000 Btu of coal) to generate 12,000 kWh of electricity for the house. Moreover, it might require 70,195,000 Btu of energy to deliver 69,500,000 Btu of fuel oil to the house. So the house in this example used 136,793,000 Btu + 70,195,000 Btu = 206,988,000 of source energy. That's considerably more source energy than site energy.

The Energy Star program assumes the following site/source ratios (based on national averages): grid electricity, 3.34; natural gas, 1.047; and fuel oil and propane, 1.01. In other words, it takes 1.047 units of source energy to deliver 1 unit of natural gas to a building.

Another source provides the following site/source ratios for the U.S.: grid electricity, 3.365; natural gas, 1.092; fuel oil, 1.158; propane, 1.151.

Average energy use per person

A nonprofit group in Switzerland, the 2,000-Watt Society, has calculated that the current level of worldwide energy use amounts to 2,000 watts per capita. This is the total amount of energy used continuously, on average, by one person, as long as the person is alive. The amount includes energy used for industry, commercial buildings, residential buildings, municipalities, and transportation — everything.

Per capita energy use in the U.S. is significantly above the world average, of course. The average American uses about 12,000 watts — six times the world average. In Bangladesh and sub-Saharan Africa, on the other hand, the figure is well under 500 watts per person.

It's hard to understand the quantity of the energy used by a typical U.S. family, but here's a mental exercise that helps: how big a photovoltaic array would be needed to meet all of the energy used by the average American?

Let's assume the American lives in Chicago. A person using 12,000 watts requires 288 kWh/day or 105,120 kWh/year. In Chicago, that much energy could be produced by a 90-kW PV array. The cost to install such a PV system would be about $405,000. A family of three would require an array costing $1.2 milllion.

Of course, this PV array would produce enough energy to cover every aspect of one's life, including one's transportation and a personal share of the energy used for U.S. manufacturing.

Last week's blog: **"Joe Lstiburek Discusses Basement Insulation and Vapor Retarders."**

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