Chapter 2
Units of Measure

Abstract *Units of measure* is the language of home energy information. We talk about our energy consumption in terms of specific units used to measure the consumption. Measuring is a vital part of the home energy information cycle. It is what guides us toward the actions we need to take in order to conserve energy and protect the environment. The ability to express those measurements in standard units has long been a benefit in understanding energy consumption. Each type of fuel such as electricity, natural gas, propane, fuel oil and others all have their own specific units associated with respect to measuring their consumption. Other environmental factors such as outside temperature affect our energy consumption. We measure these as part of the home energy information cycle and they also have specific units associated with them. We *derive* other values from the measurements to express consumption in ways that are convenient to make comparisons over time and from one location to another.

2.1 Electricity Units

Kilowatt-hours (kWh) is the standard unit of measure for electricity. It is not the easiest to understand primarily because it describes electric consumption over time. In other words, it is a *rate* of electric consumption. This is how the electric companies charge us for the electricity we use. They track the number of kilowatt-hours of electricity we use over the whole month and then charge us a standard rate (usually 10–20 cents) per kWh. We derive the unit kilowatt-hour from the unit of measure called a *watt*. Electric power expressed in watts is the rate electric energy moves through a circuit. One watt is equal to one joule per second. And 1000 W is equal to 1 kW.

The watt was named after James Watt, a British engineer and inventor. He lived from 1736 to 1819. The work of James Watt with respect to power resulted in the steam engine that powered the industrial revolution [6]. However, most of what we know today about electricity comes from Benjamin Franklin, a noted statesman and inventor who lived from 1706 to 1790. Franklin's experiments in positive and negative electrical charges resulted in the electrical lighting we enjoy today [7].

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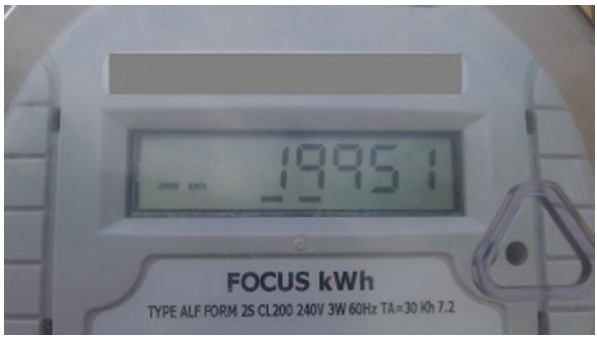


Fig. 2.1 Home electric meter

The manufacturing industry rates light bulbs in terms of watts. A 100-watt bulb is brighter than a 40-watt bulb and it also consumes more electricity. If we left a 40-watt light bulb on for 30 days continuously it would consume 28.800 kWh of electricity. My electric company charges about 10.9 cents per kWh. So, it would charge me $ 3.14 just for leaving that light bulb on.

- $30 \text{ days} \times 24 \text{ h} = 720 \text{ h} \times 40 \text{ W} = 28,800 \text{ watt-hours}$
- $28,800 \text{ watt-hours} / 1000 = 28.8 \text{ kWh} \times \$0.109 = \$3.14$

Newer LED light bulbs produce the same amount of light but consume much less electricity. The 40-watt light bulbs I have produce 465 lumens of light compared to the 450 lumens of light my 6.5-watt LED light bulbs produce. This could amount to a considerable savings in energy and money over time. Using the example above, if I left my LED light bulb on for 30 days continuously it would only consume 4.68 kWh of electricity and only cost me $ 0.51.

- $30 \text{ days} \times 24 \text{ h} = 720 \text{ h} \times 6.5 \text{ W} = 4,680 \text{ watt-hours}$
- $4,680 \text{ watt-hours} / 1000 = 4.68 \text{ kWh} \times \$0.109 = \$0.51$

One way to watch your home's electric consumption in real-time is to watch your electric meter. Most electric meters show your electric consumption in kWh. This could be a time consuming task. Depending on what is happening in your home it could take several minutes to consume even one kWh of electricity (Fig. 2.1).

There are other devices available that you can use to watch the electric consumption of small appliances in real-time. Watching your electric consumption in kWh can help you be more aware of how much energy your home uses each day.

2.2 Natural Gas Units

The therm is the standard unit of measure for natural gas. Natural gas meters actually record the consumption by volume as 100s of cubic feet (CCF). But, gas companies usually charge us by the *therm.* 100 CCF is equal to approximately one

therm. The word "*therm*", derived from British Thermal Units (BTU), represents the potential heat generated from the fuel. One *therm* is 100,000 BTUs [8].

Converting the CCF from the meter to therms on your gas invoice is a little tricky. The exact conversion factor depends on the mix of hydrocarbons in the natural gas. This factor can vary from month to month. So, the gas company will likely show the conversion factor, called *thermal factor*, on your invoice as well. Then they calculate therms as CCF divided by the thermal factor to get therms. Here's an example of the calculation portion of a typical natural gas invoice.

CURRENT BILL ITEMIZED
In 32 days you used 57 therms
07/19/2005 reading ACTUAL 61105
06/17/2005 reading ACTUAL 61050
CCF Used for METER# xxxxxxxx 55
Thermal Factor × 1.0448
Total therms used 57

Then of course the gas company charges you a certain amount for each therm used. This amount varies by company and depends a great deal on availability of natural gas in the region where you live.

Since it is difficult to relate the readings on your gas meter to your gas bill, another great way to track your energy consumption is to use the information on your invoices. Both electric and gas companies usually include a "use history" section that shows how much you have consumed in previous months. This is how you can compare your consumption from month to month. It's important to keep in mind that billing months may have a different number of days. Table 2.1 is an example of use history in therms for a natural gas invoice.

Watching your gas consumption month to month makes it easy to spot the increased consumption during the colder winter months. This is an excellent example of how the environment effects our energy consumption. Reducing consumption amounts to a battle against the environment. If you live in an area with extreme outside temperatures, either cold or hot, you have "extreme challenges" in reducing your energy consumption.

2.3 Propane and Fuel Oil Units

Gallons are the standard units of measure for propane and fuel oil. These liquid fuels are contained in a tank until you consume them. Replenishment occurs much like the fuel in the gas tank of your car. When you get low on fuel you fill the tank up again. This likely doesn't occur on a regular basis. So the service companies will likely not send you an invoice on a regular basis like with electric and gas. How-

Table 2.1 Gas use history

Gas use history		
Bill date	Days	Therms
Jul 05	32	57
Jun 05	31	141
May 05	32	179
Apr 05	29	386
Mar 05	29	1058
Feb 05	28	1358
Jan 05	34	1174
Dec 04	29	509
Nov 04	28	380
Oct 04	30	120
Sep 04	32	56
Aug 04	31	55
Jul 04	32	69

ever, the propane and fuel oil providers charge you a set rate per gallon of fuel just like the other providers. The rate per gallon is dependent on availability of the fuel in your area.

Since your invoice arrives at varying intervals it is not much help in tracking your consumption on a monthly basis. You have to rely on the gauges attached to the tanks themselves along with the amounts (in gallons) added on each delivery.

You can still make an attempt to track your propane and fuel oil use by the month by using a systematic method of checking the gauge on your tank regularly. For instance, check the gauge at the same time of day on the first day of each month and record the gallons in the tank. You also must record the gallons in the tank just prior to each time your provider fills it along with the number of gallons added during the fill. Propane tank gauges like in Fig. 2.2 show the volume of liquid in the tank as a percentage. So you must know the total capacity of the tank to calculate the gallons available. The gauge in Fig. 2.2 attached to a 100-gallon tank has 80 gallons of propane inside. If this were a 400-gallon tank it would have 320 gallons of propane inside.

Fuel oil gauges show that the volume in the tank in gallons. Figure 2.3 shows what a typical fuel oil tank gauge might look like for a 200-gallon tank.

The Table 2.2 shows how to record these values in a log and determine your consumption in gallons for each month.

Using the Propane Use Log in Table 2.2 you can see that this home used 77 gallons in January, 56 gallons in February, 55 gallons in March and so on. Keeping track of your propane and fuel oil consumption in this manor will help you insure that your consumption is not outside the normal range. An abnormally high usage during any one month might signal a problem with your heating equipment or a leak in the tank or lines.



Fig. 2.2 Propane gauge



Fig. 2.3 Fuel oil tank gauge

2.4 British Thermal Units

The great thing about British Thermal Units (BTU) is that we can convert any of the units we talked about previously to the BTU. That is because they all involve transfer or release of heat when consumed. Scientists initially defined the BTU as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. However, they found that it depended on the initial temperature

Table 2.2 Propane use log

Propane use log			
Date	Gallons in tank	Gallons added	Gallons used
1/1/2014	152		
2/1/2014	75		77
2/10/2014	49	120	26
3/1/2014	139		30
4/1/2014	84		55
4/15/2014	66	100	18
5/1/2014	155		11
6/1/2014	146		9

of the water. So, since 1956 its definition has been approximately equal to 1055 J or 252 g calories [9].

The BTU has become a standard for measuring energy consumption because we can convert the consumption measurement for any fuel to BTUs. This allows us to combine the consumption of different fuels and arrive at a value that represents the consumption for the whole home. The best web site I've found for converting these values is: http://www.onlineconversion.com/energy.htm [10]. On this web site you can find the following conversion factors:

- 1 KWh = 3412.1414799 BTU
- 1 therm = 100,000 BTU
- 1 gallon [U.S.] of LPG = 95,500 BTU
- 1 gallon [U.S.] of #2 fuel oil = 138,874.15823 BTU

My home uses electricity and propane. So, in order to find the total number of BTUs my home used in a particular month I would use the following calculations.

- Electric use (kWh) × 3,412.1414799 = Electric BTU
- Propane use (gallons) × 95,500 = Propane BTU
- Electric BTU + Propane BTU = Total BTU

This represents the total energy consumption for my entire home for one month. This is a giant leap forward in arriving at our home energy index (HEI). We still have environmental factors that effect our home's consumption in BTUs. My propane fireplace burns a lot in the winter time so that will obviously raise the number of BTUs consumed during those months. During the spring and fall neither my fireplace nor my heat pump runs. This lowers my consumption considerably.

2.5 Degree Days

Degree Days (DD) is an important factor in calculating our HEI. It is what helps us see how energy efficient our homes are no matter what the outside temperature. So when we compare months to months throughout the year we can get more consistent and meaningful values.

DD is a measure of how many days and degrees the Mean Daily Temperature was above or below a base temperature, usually 65° Fahrenheit (F). In our case we add those values up for the whole month. During colder months the degree days are called "heating degree days" because it requires heating to raise the temperature back up to the base temperature. During hotter months they are called "cooling degree days" since it requires cooling to lower the temperature down to the base temperature.

In warmer or cooler months when the number of degree days is high we can expect to use more energy to cool or heat our homes. During months when the outside temperature is near 65 °F then the number of degree days is low and we can expect to use less energy to cool or heat our homes. So, in order to eliminate the confusion

of tracking our energy efficiency during different weather conditions we could track our energy consumed per degree day as BTU/DD. Here's an example for my home during the month of January.

- January Electric (kWh) = $1,678 \times 3,412.1414799 = 5,725,573.2$ BTU
- January Propane (gallons) = $52 \times 95,500 = 4,966,000$ BTU
- January Degree Days (heating) = 1301
- $(5,725,573.2 \text{ BTU} + 4,966,000 \text{ BTU}) / 1301 \text{ DD} = 8,217.9654 \text{ BTU / DD}$

Anyone can find the degree days for their location for any month at the BIZEE Degree Days web site (http://www.degreedays.net). Now, let's do this same calculation for my home in April when I have very little (if any) heating or cooling energy consumption.

- April Electric (kWh) = $805 \times 3,412.1414799 = 2,746,773.8$ BTU
- April Propane (gallons) = 0
- April Degree Days (heating) = 337
- 2,746,773.8 BTU / 337 DD = 8,150.664 BTU / DD

As you can see the BTU/DD values for January and April are nearly the same even though the outside temperature where I live in January is very cold, sometimes way below 0 °F. In April, it's very mild averaging near 60° F. So, by using degree days as a factor in tracking our energy consumption we can get a consistent value to compare our energy efficiency month to month no matter how cold or hot the outside temperature is where we live.

2.6 Living Area Units

It's fairly obvious that homeowners measure the living area of their homes in *square feet* (SF). This represents the area serviced by the energy consuming appliances and equipment. The exact value may vary from utility to utility. For instance certain areas of a home may not be heated with natural gas but still have electricity for lights and appliances.

We define the living area of the home or a single room by the multiple of its length and width dimensions. We can measure homes serviced completely by all utilities by multiplying the length of the home by the width to arrive at an area value for each floor. If it is a two-story home, we multiply that result by two. This gets complicated for split-level homes and homes that do not provide utility services to all rooms. Another method is to calculate the area of each room and add them all together. The goal is to arrive at a living area value expressed in *square feet* (SF) for each utility provided to the home. So, if a home is all electric you just have one living area value. For a home serviced by both electric and natural gas there are two values, electric living area and natural gas living area. Also, since the size of our home could change, we need to record the living area(s) each month along with our energy consumption values.

We use the living area values to further refine our definition of the HEI. Just like the environment, the *size* of our home effects how much energy we will use. In general, large homes use more energy and smaller homes use less energy. So in order to compare our HEI with others to see how well we are doing we need to factor in the effects of size, similar to the way we factored in the effects of temperature using degree days. Ultimately, we want to find an energy consumption value for our home in BTU per DD SF. We multiply the DD and the SF values together. Let's add the living area of my home to the previous example for degree days to arrive at a January Electric Energy Index (EI) for my home.

- January Electric (kWh) = $1,678 \times 3,412.1414799 = 5,725,573.2$ BTU
- January Electric Living Area (SF) = 2218 SF
- January Degree Days (DD) = 1301 DD
- January Electric EI = $5,725,573.2 / (2218 \times 1301) = 1.9841757$

I can calculate the same EI for propane for my home and arrive at a Propane EI. If I add the Electric EI and the Propane EI together I have the Home Energy Index (HEI) for my home. This is a close approximation to the true energy efficiency of my home. It is a value I can use to measure how well I'm doing with regard to conserving energy. I can compare these values month to month to help me detect appliances and equipment that may not be as efficient as they should be. I can also compare my HEI with other homes to inspire a dialog with others on how to save energy.

Using these standard units of measure we've arrived at a value that represents our home energy efficiency. Each utility provided has its own specific units of measure. We use these units to record consumption values each month. Degree days values help normalize the effects of weather on our energy consumption values. Living area values normalize the effects of the size of the home on our energy consumption values. Together these units of measure allow us to create an Energy Index (EI) for each utility provided to the home. Adding the EI of each utility provided gives us the HEI for our home. The HEI is just one of the tools we need to continuously measure, conserve and monitor our energy consumption and participate in the Home Energy Information Cycle.



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Green, D.
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