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Power, Energy, and Efficiency

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1 Introduction

We are often asked questions about power and energy such as how much energy our LFC uses, how much power the SRA can save, or what is meant by a gain in efficiency. Often the questioner doesn't understand our answer. This application note defines each of these attributes and should make the answers clearer. While the emphasis is how these parameters relate to Power Knot products, the principles apply equally to any physical machine.

2 Power and Energy

Power is the rate of doing work and is measured in Watt (W) or kilo-Watt (kW).[1] [2]

Energy is the total amount of work that is done and is measured in kilo-Watt-hour (kWh).[3] [4]

3 Explaining Power

Suppose I have a simple 1 kW electric heater. When the heater is running it uses 1 kW of electricity and it puts out 1 kW of heat.

If I turn it on for ten seconds, the power it uses at any time during those ten seconds is 1 kW. If I turn it on for one hour, the power it uses at any time in that hour is 1 kW. If I leave it on for a year, the power it uses at any time during that year is 1 kW. It is a 1 kW heater and no matter how long it is on or off, it remains a 1 kW heater.

If I turn on that same heater for five minutes and turn it off for 15 minutes, when it is on, the heater uses 1 kW and when it is off it uses 0 kW. If I am going to power this from a generator (or solar panel) I need to be able to provide a maximum power of 1 kW. If I repeat this cycle (on for a quarter of the time), then in an hour the heater would be on 15 minutes

1. Units in common use in the USA for power include the horsepower, BTU/h, and refrigeration ton, RT. These are explained in other application notes from Power Knot.
2. 'k' denotes kilo, or 1000. This should not be confused with 'K' to describe 1024, used to measure, for example, memory sizes (640 KB).
3. Strictly speaking, the unit of energy is the Joule which is a Watt-second. But as explained above, we are defining these terms in relation to Power Knot's products. The Joule is a small amount of energy and not applicable to the LFC or SRA.
4. Note the proper capitalization: 'k' and 'h' are lower case; 'W' is upper case because the name is from a person.

and off for 45 minutes. When the heater is on it uses 1 kW and when it is off it uses 0 kW. The average power will be 0.25 kW.

A heater that is 2 kW is more powerful. It has twice the power of a 1 kW heater. If I turn on the 2 kW heater, it will heat the room twice as fast as if I had used the 1 kW heater. The electrical circuit that feeds my 2 kW heater must be capable of supplying more power than a circuit that feeds a 1 kW heater.[5] In any given period of time, the 2 kW heater will use twice the energy as the 1 kW heater.

4 Explaining Energy

The energy used is the multiplication of power and time. If I leave my 1 kW heater on for one hour it will consume 1 kWh of energy. The electricity company will bill me for that 1 kWh. Here in Silicon Valley, our electricity is supplied by PG&E, and for that 1 kWh, PG&E will bill us about 14¢.

If I turn on the 1 kW heater all day, the energy used is 24 hours x 1 kW = 24 kWh. We would pay $3.36 for that.

Reconsider the example where I turn on my 1 kW heater for 5 minutes and off for 15 minutes, and I repeat this for an hour. Then the total energy used in that hour will be 0.25 kWh. If I repeat this all day, the total energy used in a day is 6 kWh. I have not changed the heater, the power is still 1 kW, the energy used is less because it is on for less time.

If I turn on my 2 kW heater all day, it will consume 48 kWh, and that is what the electricity company will bill us for. If I turn that same heater on for 15 minutes and off for 15 minutes, it is on for half the time. If I repeat this throughout the day the energy used is:

$$\frac{1}{2} \times 2\ \text{kW} \times 24\ \text{h} = 24\ \text{kWh} \qquad \text{(EQ 1)}$$

This is the same as if I had had the 1 kW heater on all day and our bill would again be $3.36.

Remember that for electrical energy it is meaningful only when you know the time period in question. If I tell you that my heater uses 24 kWh, that tells you nothing unless I add that is the amount of energy used in a hour, a day, a week, or some other time period.

5. In practice this means that if the voltage remains the same, the current will be twice as much and the copper conductors (wires) are twice as fat.

5 Looking at the Specifications for the LFC

On the data sheet for the LFC, it lists a maximum power and energy per day. Consider the LFC-200, one of Power Knot's most popular models:

- Maximum power: 1.6 kW
- Energy per day: 9.6 kWh

The power comprises a motor (1.2 kW) and a heater (400 W). So when these are both on, the total power is 1.6 kW. This allows the electrician to size the circuit, to decide how thick the electrical conductors need to be and the appropriate current rating (Amps) for the circuit breaker or fuse.

In most installations, the heater is not used. It is used when the LFC is installed in a cold environment or when cold water is supplied to the machine. Usually, the only power is that used by the motor. The motor on the LFC turns for a quarter of the time (typically on for 5 minutes and off for 15 minutes). Even though the heater is not normally on, let us consider that the heater is also on for a quarter of the time. Then the energy per day is:

$$\text{energy each day} = 1.6\text{ kW} \times \frac{1}{4} \times 24\text{ h} = 9.6\text{ kWh} \qquad \text{(EQ 2)}$$

In those cases where the heater is not on:

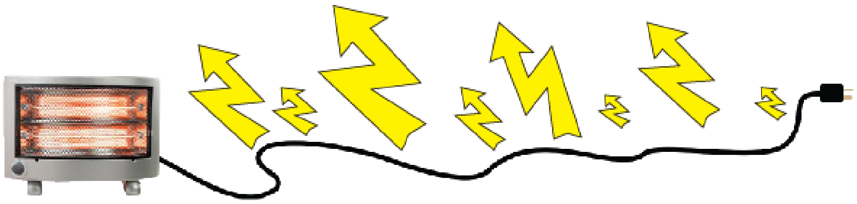
$$\text{energy each day} = 1.2\text{ kW} \times \frac{1}{4} \times 24\text{ h} = 7.2\text{ kWh} \qquad \text{(EQ 3)}$$

So, the typical energy consumed is 75% of that listed on our data sheet.

6 Energy Efficiency

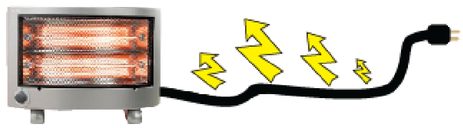
Energy efficiency is a ratio of the amount of energy that is usefully used compared with the total energy input to obtain that useful output.

As an example, consider my 1 kW electric heater. Suppose I power that from a very long power cord so that the power cord dissipates much energy because of its high resistance.



Imagine that this circuit still takes 1 kW, but that 200 W is dissipated in the long wire and only 800 W is dissipated in my heater. That wasted power is lost and my system is operating at an efficiency of 80% (800/1000). Over any given time period, the system is operating at an energy efficiency of 80%.

Suppose I exchange my long extension cord for a shorter one, or one that is fatter.



This will have less resistance and will dissipate less power. If this circuit still takes 1 kW, but now only 100 W is dissipated in the power cord and 900 W is dissipated as usable energy in my heater, my system is operating at an energy efficiency of 90%.

7 False Units of Measurement

There is no such measurement as kW/h (kW per hour). Regardless how long I turn on my 1 kW heater, the power it uses is still 1 kW. The energy the heater uses is the multiplication of power and the time it is on (kW times hours = kWh).

As a specification for an electrical machine, this is meaningless:

Electrical Consumption: 1.2 kWh (or worse, 1.2 kwh)

The reason this is meaningless is that the energy consumption can only be known if the time period is specified. So, does this really mean that the average power is 1.2 kW (so that in a day the total energy is 1.2 kW x 24 h = 28.8 kWh)? Or does it mean that in a day the energy consumed is 1.2 kWh (so the average power is 1.2 kWh / 24 h = 50 W)? Or does it mean that in a week the energy consumed is 1.2 kWh (so the average power is 1.2 kWh / 24 h / 7 = 7.1 W)?

In any case, a company that states this as the specification for their device is either trying to hide something or doesn't understand what they are doing. On the other hand, Power Knot is a totally green company dedicated to reducing your carbon footprint so the data we publish can help you to make an informed decision about our products.

8 Review Questions

8.1 Energy Consumption

8.1.1 Question

I have a room that needs to be heated and I use a 1 kW heater which I turn on all day. The next day I substitute the 1 kW heater with a 2 kW heater and I turn it on for 5 minutes and off for 5 minutes throughout the day. If the conditions inside and outside the room are the same from one day to the next: (a) will the room on average be warmer, colder, or the same on the second day? (b) will the electricity company bill me less, more, or the same on the second day?

8.1.2 Answer

The amount of energy used is the same in both cases. We assume that the electrical heater is 100% efficient so the amount of heat energy in the room in either case is the same. So, for both questions, the answer is that the temperature will be the same and the cost will be the same.

8.2 Cost Of Operation

8.2.1 Question

A company needs to stop discarding waste food in the trash and is considering the use of either an LFC-300 or a drying machine. The drying machine heats waste food to a benign powder (not true compost) that can then discarded.

Here are key advantages and disadvantages of these machines:

	Advantages	Disadvantages
Drying machine	No water, Powerchips, or Powerzyme required	Uses large electrical energy; batch process
LFC from Power Knot	Low power, continuous process	Need to supplement Powerzyme and change Powerchips

Assume the cost of the two machines is the same. The cost of the Powerchips and Powerzyme over a five year period for the LFC-300 is $900 per year. Water costs 0.75¢ per gallon and electricity costs 14¢ per kWh. What is the cost to operate the LFC-300 over a five year period?

The drying machine is a batch process. It heats the waste food for eight hours, and then it cools for four hours. The heater is 30 kW. If this is used once per day, what is the cost to operate the LFC-300 over a five year period?

8.2.2 Answer:

From the data sheet, the LFC-300 uses 15 kWh of electricity per day and 210 gallons of water per day. The cost to operate the LFC per day is therefore:

$$(15 \times \$0.14) + (210 \times \$0.0075) = \$3.675 \quad \text{(EQ 4)}$$

The cost over five years for utilities is:

$$\$3.675 \times 365 \times 5 = \$6{,}706.88 \quad \text{(EQ 5)}$$

The Powerzyme and Powerchips cost $900 per year or $4500 for five years, so the total operating cost is:

$$\$6{,}707 + \$4{,}500 = \$11{,}207 \quad \text{(EQ 6)}$$

For the drying machine, the heater is on for eight hours, so the energy used per day is:

$$30\ \text{kW} \times 8\ \text{h} = 240\ \text{kWh} \quad \text{(EQ 7)}$$

The cost per day is:

$$240 \times \$0.14 = \$33.60 \quad \text{(EQ 8)}$$

The total operating cost over five years is:

$$\$33.60 \times 365 \times 5 = \$61{,}320 \quad \text{(EQ 9)}$$

In other words, the drying machine costs $50,113 more to use over five years than the LFC.

8.3 Energy Efficiency

8.3.1 Question

A company that makes juice has many large refrigerators to store the produce and the juice. The company has 200 tons of refrigeration and pays 14¢ per kWh. They observe that the refrigeration systems are on 80% of the day, every day. If they treat the refrigeration systems with the SRA, what annual savings can they expect if the SRA improves the efficiency of the system by 15%?

8.3.2 Answer

We don't know the amount of power actually used by the system. We have to make an educated guess that the systems are reasonably efficient and use a COP of 2.7.[6]

The cooling power is 200 tons x 3.517 = 703.4 kW[7]

6. See Power Knot's application note here.
7. See Power Knot's application note here.

Assuming a COP of 2.7, the input power is:

$$\frac{703.4\ \text{kW}}{2.7} = 260.5\ \text{kW} \quad \text{(EQ 10)}$$

Because the systems are on for 80% of the time, the daily cost is:

$$260.5\ \text{kW} \times 24\ \text{h} \times \$0.14 = \$700.27 \quad \text{(EQ 11)}$$

And the annual cost is:

$$\$700.27 \times 365 = \$255{,}600 \quad \text{(EQ 12)}$$

With this system, because it turns on only 80% of the time, it is an appropriate size for the load. Therefore it is a good candidate for SRA and we can expect to see a reduction in energy used of 15% with the SRA. This will equate to an annual savings of:

$$15\% \times \$255{,}600 = \$38{,}340 \quad \text{(EQ 13)}$$