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Energy Primer

Energy primer

Energy and power units:

- kW means kiloWatt, kilo = 1000 Watt named after a person, so capitalized
- 1000 Watts = 1 kW (note spelling)
- kW is a rate, like miles per hour or gallons per minute, so saying "kilowatts per hour" makes no sense, just like "miles per hour per hour"

To get total energy (or miles or gallons) we multiply by time:

- 1000 Watts for one hour = 1 kWh (“one kiloWatt hour”)
- Example: a 1000 Watt hot water maker is on for one hour
- 1000 W = 1 kW times 1 hour = 1 kWh
- KVA is another unit similar to kW, but it includes what is called the power factor.
- Note on units: Watts, Volts, Amps (Amperes) are all capitalized. Don’t capitalize meters, hours or gallons.

Check-in:
Your tea maker uses 1250 Watts, and takes 10 minutes to boil 500 grams of water. If electricity costs $0.40/kWh:

- How many kW is the heater?
- How many kWh did the tea require to heat?
- How much did this cost you?

Power Factor

- For simple things like hot water makers or toasters, PF (power factor) = 1.00, meaning 100% of the electrical energy goes to work.
- Motors, compressors, refrigerators, computers and pumps can have power factors as low as 50%, meaning if you think the device is using 1000W, you are really paying for 2000W.
- HELCO charges us a premium if our campus total PF is less than 90%
- HELCO charges us about $0.40 (40 cents) for every KVA, so if you have an energy

number, you can round to about half of this number to convert to dollars (neat tip).

Check-in:

Your refrigerator uses 1250 Watts and is on 10 minutes every hour to keep your food chilled. If the Power factor is 0.50:

- How many kW is the refrigerator power rating?
- How many kWh does the fridge use each hour?
- How much each day (assuming the same rate)?
- How much does this cost each day, using the power factor?
- How much would this cost each month?
- Why is it important not to leave the door open while you look around?
- If you looked at an energy graph of your house, how could you spot the refrigerator?

Lighting:

We are in the 4th generation of lights in this country.

~1850 incandescent lights (Edison and his gang). These look like hot wires in a glass envelope

Most energy goes to heat, so not efficient, simple to operate, PF 1.00 (just a hot wire, like a coffee heater)

~1950 Fluorescent lights (note spelling: flUOrescent, like FlUOrine)

More efficient, contain mercury (toxic), need a transformer (hot, noisy)

Related: mercury vapor (white) and sodium vapor (yellow) lamps, also known as metal halide lamps, often found in streetlights, gyms, tennis centers. PF is about 80%. Many of these are being replaced with LEDs (see below).

All of these create an electrical arc through a vapor of metal (even fluorescent bulbs, which contain mercury and a phosphorus inner coating to transform the harsh mercury light into visible light)

~2000 Compact Fluorescent bulbs (CFL)

Similar to traditional long or circular bulbs, but able to screw into 1850 era light sockets (yes, they are that old).

Contain mercury and phosphorus, 3-5 year lifespan, PF ~80%, often a harsh white/blue light, as opposed to the warmer hot incandescent light bulbs. This color is referred to as a temperature, so 2000°K is a warm looking source, while 3500°K would look harsh and blue-tinted.

~2010 Light Emitting Diodes (LED)

Very efficient, can be many colors, little heat, long lifespan, PF close to 95%, uses about 65% less energy than traditional bulbs, relatively expensive, but long lifespan makes for excellent ROI and TCO (return on investment, total cost of ownership). These vary in temperature (see above), with newer LED units in the warmer 2000°K range, where older ones tended to look blue and harsh, often around 3500°K. Newer ones are also dimmable.

~2018 Smart LED bulbs

Same as above, but linked through wireless or power lines to controllers, so you can say "Hey Siri, turn on the lights" and magic will happen. These are key to the smart home, where sensors for lighting and occupancy can control lighting, saving energy, and therefore money.

Conservation:

- Every dollar spent on conservation is worth about $8 in new energy sources.
- Monitoring is key, to determine energy flows, leaks, identity (energy profile) and more.
- This can be electrical metering, infrared cameras, flow meters, propane meters, water meters, temperature sensors and other linked data gathering devices.
- Key targets are refrigeration (e.g. cafeteria), water pumps (e.g. pool), lighting, water heating and timing–when these resources are used relative to energy harvesting.
- Especially important at night, when PV and solar thermal systems are dependent on storage (the sun is not shining much at night).

Solar energy sources: Solar thermal and PV

Solar thermal:

Goal: Turn solar radiation into hot water

Active systems: Sun—>solar panel—>pump—>tank—> users

Passive systems: Sun —>solar panel/tank —> users (no pump needed, uses convection)

HPA systems are of two types:

Carter dorm has the active system, while Perry-Fiske and cafeteria have passive Solahart systems

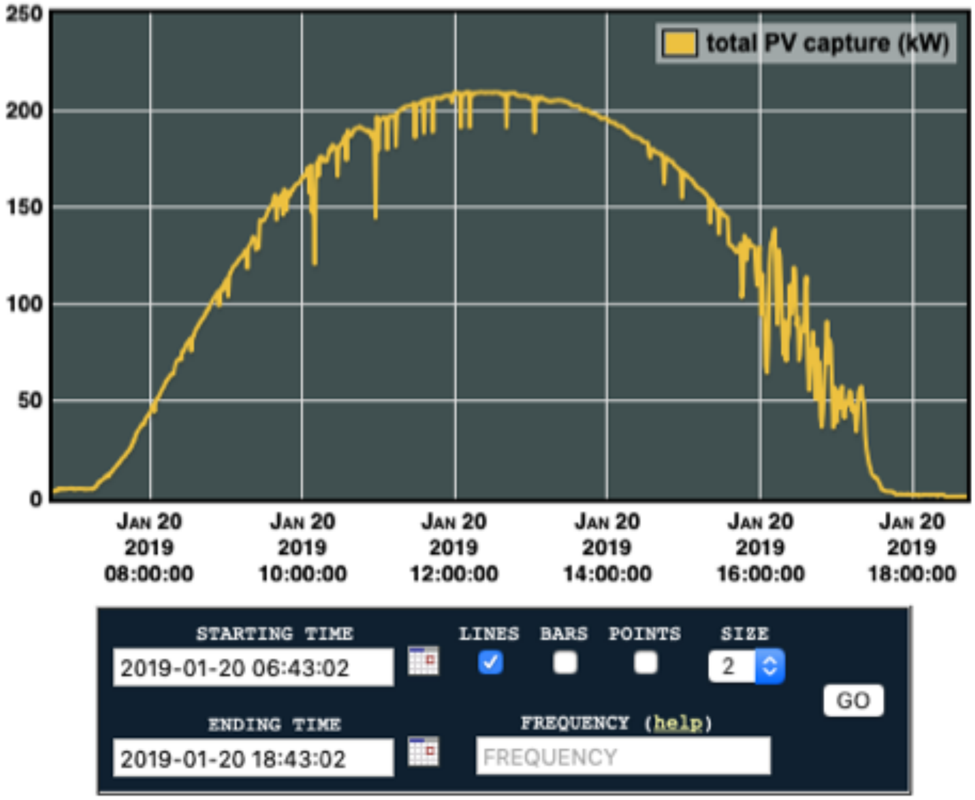
- Propane is used to "finish" these systems, making sure that users always have hot water at about 120°F. These are propane "flash" heaters, making sure that any water going to the showers/sinks/washers is always at 130°F. You can see these behind each bathroom if you are curious.
- Hot water is stored in tanks, with about 10-15 kWh energy in each Solahart tank. Each Solahart system costs about $6K installed (panel and tank). To store 10 kWh using batteries would cost $13,000.
- Solar thermal panels are about 90% efficient at converting solar radiation into hot water. PV panels are about 15% efficient in converting solar radiation into electrical energy.
- Propane is competitive with electrical energy at about $0.25-$0.35 per kWh equivalent in our hot water heaters.

PV (photovoltaic): sunlight to DC electrical energy

- If solar thermal captures solar radiation as heat, PV systems convert this radiation into electrical flow in one direction (direct current, or DC, like batteries). This is convenient for battery storage, but to be used in most homes and businesses, AC (alternating current, 60 Hz) is needed. Inverters are electronic devices that turn DC from PV and/or batteries into AC for use.
- Since HPA is on one meter with HELCO, we are essentially a “micro-grid” meaning any electrical energy harvested from PV (or released from batteries) goes to slow down or reverse the HELCO meter. Since we do not presently get any credit for energy out, we want to make certain we can store any excess energy on campus for our night time use.
- Since the sun is brightest at noon, PV engineers use an estimation of a PV array output called “solar hours”, meaning the equivalent amount of energy harvested if noon lasted that many hours. This is like making a camel hump curve into a rectangle, adding the edges to the top.

For example, our PPA (purchase power agreement) array behind the elab produces about 100 kW maximum. This is true at noon, but less so either side of noon, so we use “solar hours” to estimate energy harvest each day. For us, this is about 5.5 solar hours, depending on season:

100 kW x 5.5 solar hours = 550 kWh or about $200 saved each day.



STARTING TIME: 2019-01-20 06:43:02

LINES ☑ BARS ☐ POINTS ☐ SIZE 2

ENDING TIME: 2019-01-20 18:43:02

FREQUENCY (help): FREQUENCY

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PPA arrangements usually charge us a fraction (about $0.20 per kWh) of the HELCO cost, but we have to pay for what it produces, not what it uses. If we are pushing energy off campus to HELCO using the PPA array, we are in effect paying to give this energy away, which happens during vacations (summer, winter, spring).

Wind energy:

- Based on the flow of air over very thin wings ("blades") that rotate around a center, which turns an electric turbine, usually AC.
- Two types: HAWT-horizontal axis wind turbine and VAWT-Vertical axis wind turbine ("salad spinners")

- HAWT turbines are either following blade or leading blade. Our large turbine is a following blade, smaller ones have a tail fin and are leading blade. Commercial turbines are leading blade, with gears that force the blades into the wind
- Wind turbines suffer from water and dirt damage, and need frequent maintenance
- Wind turbines are noisy, and interfere with the view shed
- Cats kill far more birds than wind turbines, but there are environmental impacts (see Altamont Pass)

Net zero energy is when we have effectively stopped the HELCO meter, meaning we are producing exactly how much we are using.

We hope to harvest enough to reach net zero around 10AM each day until about 2 PM each afternoon. The extra energy during that time we hope to capture using battery and other storage systems (pumped storage hydro, hot water activation, etc.)

Energy Storage:

Batteries for large scale systems are usually either lead acid batteries dating back to around 1800, or lithium batteries from this century:

~1800 lead acid batteries

- lead and sulfuric acid
- environmentally nasty
- 3 year lifespan
- shorter if used more
- only 40% of capacity is usable
- slow discharge and recharge
- about $300 for each kWh stored

Example: our overnight campus use is about 100 kW for 20 hours or 2000 kWh (or 2 mWh). At $300/kWh this would cost us $600,000 and would last 3-5 years at max capacity, but in actuality it would be 2.5 times this because these batteries cannot be discharged all the way, so $1.5M.

~2010 lithium batteries (LiPO, Lithium iron phosphate, etc.)

- Used in Prius, Leaf and other cars
- lightweight

- fast discharge and recharge (good for regenerative braking in cars)
- 20 year lifespan at 80% capacity
- greener
- expensive ($500 per kWh)
- Tesla's Power Wall is one example, so is the blue box in the student union and IT office. Kauai island is using these to move that island to complete energy neutrality in the next few years.

The same example above costs more, last longer, and requires fewer batteries. It also discharges faster to maintain our microgrid, and recharges faster when used as backup power for the IT building, protecting our computers from multiple outages we face with HELCO. You may also see these in the student union (left inside the main doors, blue lights)

Pumped storage hydro:

This is just like a typical hydroelectric plant with a dam above a river below. Water tanks low on campus have a pump and a generator. When we have extra energy, we pump this water uphill to a similar tank where it is stored for use later on. When needed, the system activates the generator, which provides power for the campus. This is green, cheap, renewable, lasts 50 years or more and can be safely integrated into other water systems (e.g. fire suppression) as needed.

Net neutrality:

We have three ways we can claim neutrality:

1. Net **energy** neutral: We export the same amount of energy around noon that we use overnight, so as far as the HELCO grid is concerned, we have a net zero energy profile. We still pay for what we use at night, though)
2. Net **money** neutral: We capture any excess energy during the noon hours when the HELCO meter would be spinning backwards, and use this at night from our batteries or other storage). If we were allowed to sell power to the grid, this would also work.
3. Net **carbon** neutral: We measure all carbon used on campus, including transportation, heating and other carbon impacts and offset with energy produced via solar thermal, PV, wind or other means (not nuclear, don’t worry). This is the most current global metric used, and relates well to our sustainability misssion.

Each has certain PR and moral aspects, depending on the goals of the organization. Since our business is creating change agents to solve sustainability issues in the future, each of these is important.