Track: The Power Connection: Electric Generation for Gas Utilities

Unit #2: Terminology and Concepts

Presentation Outline

- Electricity Terms
- Electric to Gas Conversions
- Grid Loads & Characteristics
- AC vs DC Voltage & Frequency
- Phase & Transport
- Power Use Characteristics

Electricity Terms

- Power & Energy
- Load & Usage
- Watts & watthours
- Volts & amps
- Grid
- Primary & Secondary Energy

Power vs. Energy

Work – *"The transference of energy that is produced by the motion of the point of application of a force and is measured by multiplying the force and the displacement of its point of application in the line of action."*

Energy – *"A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work."*

Power – *"The time rate at which work is done or energy emitted or transferred."*

– Merriam-Webster

Work – Energy transfer

Energy – Capacity to do work

Power – Rate at which energy is transferred

Sources: https://www.merriam-webster.com/dictionary/energy
https://www.merriam-webster.com/dictionary/power

4

Load

Load – The power consumed by a circuit. Or: A device that consumes power on a circuit.

Grid Load | Electrical Demand – The demand for electricity on a grid at a given time.

Anything that consumes electricity is a load or demand on the grid. Loads can be categorized in several ways, based on the service they provide, market they serve, and characteristics of the load itself. Predicting and responding to these loads is a critical aspect of electrical grid management.

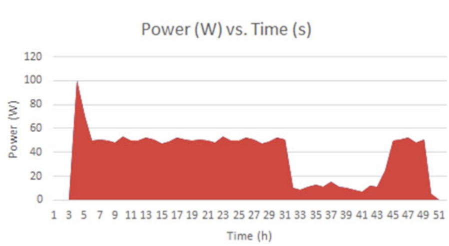
Market Categorization:

- **Residential** – Loads include things like appliances, lighting, HVAC, small electronics, etc. These loads tend to peak in evenings, weekends, and during hot days.
- **Commercial** – Loads include things like lighting, large HVAC, office equipment, elevators, etc. These loads tend to peak during mid-day on weekdays and during hot days.
- **Industrial** – Loads include lighting, motors, machinery, large furnaces, etc. These loads peak during business hours or the operation of specific equipment, which may be unique to each location.
  - These loads are sometimes large enough for utilities to engage in agreements with users on when load will be needed or strategies to move loads to different times.

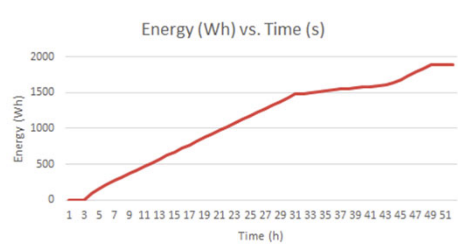
Usage

While "load" describes how much energy is being used at a particular moment (described as power and measured in watts), **usage** refers to how much is used over time (described as energy and measured in watthours).

Any equipment that places a load on the grid for any amount of time has usage that can be measured. Some equipment may use small amounts over a long period of time, or large amounts over a short period.



Energy (usage) is the sum of the area under the power chart.



Watts vs. Watthours

Watts (W) – A measure of POWER describing how much is produced, transferred, or consumed instantaneously. This is our **load**.

Watthours (Wh) – A measure of ENERGY describing how much is produced, transferred, or consumed over a given amount of time: watts over the course of an hour. This is our **usage**.

Kilo- – One thousand (kW or kWh)

Mega- – One million (MW or MWh)

Giga- – One billion (GW or GWh)

Tera- – One trillion (TW or TWh)

Examples:

A 1,000-watt microwave running for 6 minutes uses 0.1 kWh.

1 kW x 0.1 hr = 0.1 kWh

A 100-watt incandescent lightbulb running for 1 hour uses 0.1 kWh.

0.1 kW x 1 hr = 0.1 kWh

A 10-watt LED lightbulb running for 10 hours uses 0.1 kWh.

0.01 kW x 10 hr = 0.1 kWh

ESC FRONTIER energy 7

Metric Units

- **Joule (J):** The fundamental unit of energy in the SI system. This is equal to the amount of energy transferred when one newton of force is applied to an object over a one-meter distance.
  - Approximately equivalent to the energy required to lift an apple one meter.
- **Newton-meter (N·m):** Equivalent unit of energy to a joule but unit used to describe energy in torque.

1 J = 1 N·m

1 Wh = 3,600 J

1 kWh = 3,600,000 J = 3.6 MJ

1 MWh = 3.6 GJ

ESC FRONTIER energy 8

Watts at Scale

Watts (W) – Most consumer electronics are rated in watts they consume.
- *Consumption:* Lights, computers, refrigerators, fans, etc.

Kilowatts (kW) – High-consuming residential, commercial, and industrial equipment, and whole buildings are rated in kilowatts they consume. Small power-production sources produce on this scale.
- *Consumption:* Space heaters, electric clothes dryers, HVAC, ovens and commercial kitchen equipment, large pumps & motors, welders, whole buildings.
- *Generation:* Residential and small commercial scale solar, small gas and back-up generators.

Megawatts (MW) – Industrial HVAC, manufacturing processes, and large complexes are rated in Megawatts they consume. Many power plants produce on this scale.
- *Consumption:* Large data centers, chemical plants, oil refineries, district heating and cooling, arc furnaces.
- *Generation:* Small to mid-sized power plants.

Gigawatts (GW) – Whole states consume on this scale. Very large power plants produce on this scale.

Terawatts (TW) – Nations produce and consume on this scale.

Watts at Scale

Consumption	Production
1W - Nightlight	**1W** – Consumer portable solar panel
10W – LED light bulb	
100W – Incandescent light bulb	
1kW – Microwave	**1kW** – About two rooftop solar panels
10kW – Commercial electric oven	
100kW – Industrial HVAC system	
1MW – Office high-rise	**1MW** – Large warehouse solar installation
10MW – Large data center	
100MW – Industrial manufacturing plant	
1GW – Medium-sized city	**1GW** – The largest US solar installations

Volts & Amps

Voltage (V) – *"The difference in electric potential between two points."* Also known as "electrical pressure."

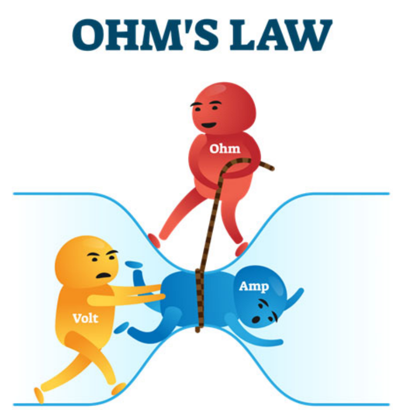
Units: **Volts, V**

Current (I) – *"Flow of charged particles, such as electrons or ions, moving through an electrical conductor."*

Units: **Amperes, Amps, A**

Resistance (R) – *"An object's opposition to the flow of electric current."*

Units: **Ohms, Ω**



Sources: https://en.wikipedia.org/wiki/Electric_current
https://en.wikipedia.org/wiki/Voltage
https://en.wikipedia.org/wiki/Electrical_resistance_and_conductance

Power

Power (P) – *"The time rate at which work is done or energy emitted or transferred."*

Units: **Watts, W**

Energy – *"The capacity for doing work." Power produced or consumed over a period of time.*

Units: **Watthours, Wh**

V = I x R	**P = I x V**	**Energy = Power x Time**
I = V / R	**I = P / V**	**Power = Energy / Time**
R = V / I	**V = P / I**	

Source: https://www.merriam-webster.com/dictionary/energy
https://www.merriam-webster.com/dictionary/power

Grid

Grid – *"An electrical grid is an interconnected network for electricity delivery from producers to consumers. Electrical grids consist of power stations, electrical substations to step voltage up or down, electric power transmission to carry power over long distances, and finally electric power distribution to customers."*

– Wikipedia

Components

Power Plant/Station – A facility or location that generates electricity.

Electrical Substations – Stations that perform electrical grid-supporting functions in support of electrical transmission, distribution, collection, conversion, and switching.

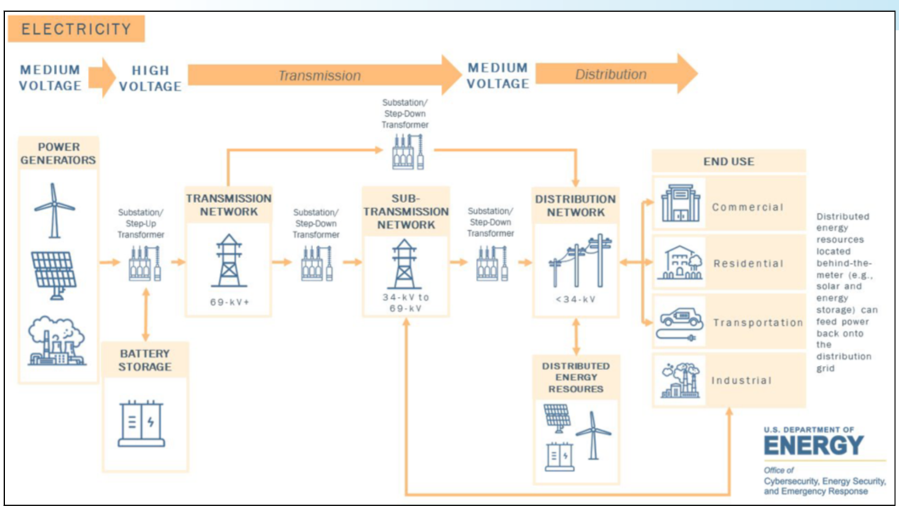
Transmission Lines – High-voltage power lines that carry electricity over long distances.

Distribution Lines – Lower-voltage power lines that carry electricity over short distances to customers.

Meter – Devices that connect end-user to distribution lines and report on electrical usage for the purposes of monitoring and billing.

Source: https://en.wikipedia.org/wiki/Electrical_grid
https://en.wikipedia.org/wiki/Substation

Grid



Source: https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

Primary & Secondary Energy

All energy comes from nature. Natural gas, coal, oil, solar, wind, nuclear…all these sources are already existent in the world around us. Some of this energy is not useful in its original form, however.

Primary Energy is energy that comes directly from a natural source that has not been converted into another form of energy. This is natural energy in its raw form.

- Natural gas, coal, crude oil, nuclear, solar, wind, hydro, geothermal…

Secondary Energy is energy that has been converted from its primary form to a new form for use.

- Petroleum products, refined fuels, electricity, heat…

Example: Light from the sun (solar energy) is useful in its primary form to light a warehouse through skylights or solar tubes. A warehouse without skylights wanting to use solar energy must install solar panels to convert this sunlight into electricity, a secondary energy.

Source: https://energyexcursions.com/courses/energize-the-future/lessons/what-is-energy/topic/primary-versus-secondary-energy/
https://ourworldindata.org/energy-definitions

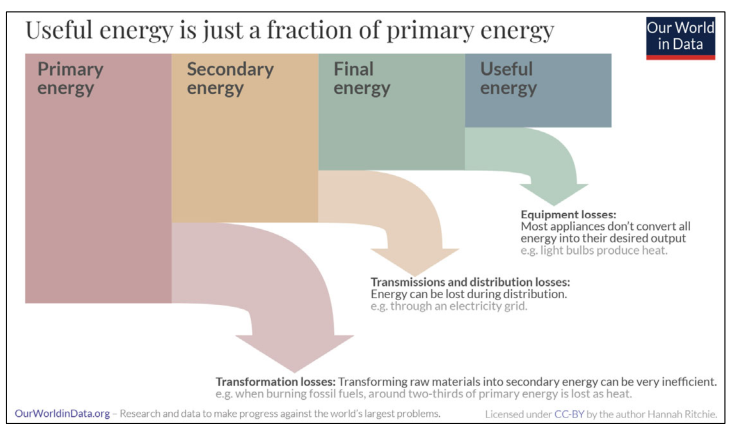
15

Final & Useful Energy

Final Energy is energy that a user receives or buys.

Useful Energy is energy that is actually put into the desired output the user wants.

Example: A homeowner buys 1kWh of electricity to run a 100W incandescent lightbulb for 10 hours. The incandescent lightbulb is only 5% efficient at converting this electricity into light. 1kWh of final energy is purchased for 0.05kWh of useful energy.

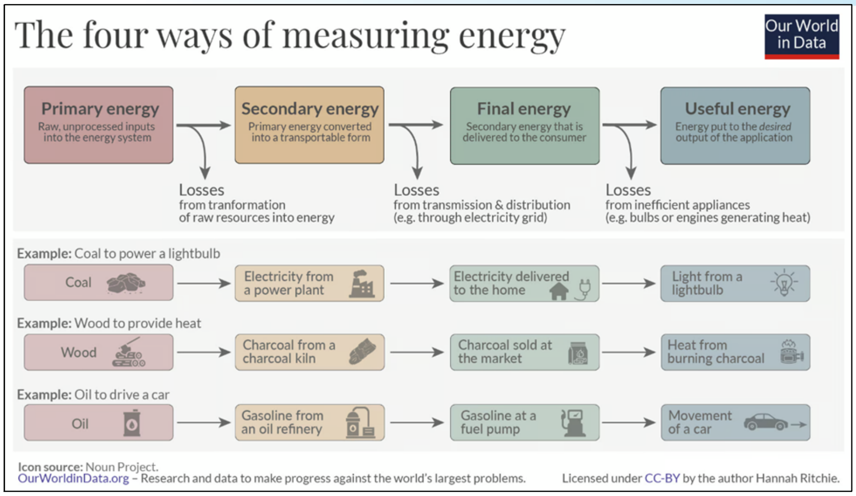


https://ourworldindata.org/energy-definitions

Source: https://energyexcursions.com/courses/energize-the-future/lessons/what-is-energy/topic/primary-versus-secondary-energy/

16

Final & Useful Energy



https://ourworldindata.org/energy-definitions

17

Electric to Gas Conversions

- Converting kW to BTU
- Energy Comparisons Electric to Gas

kW to BTU Conversion

3,412 Btu = 1 kWh
3,412 Btu/hr = 1kW

1 cubic foot natural gas (cf) ≈ 1,036 Btu
3.29 cf ≈ 1kW

Energy

Gas		Electricity
0.00329 cf	3.412 Btu	1Wh
3.29 cf	3,412 Btu	1kWh
32.9 Ccf	3.412 MMBtu	1MWh
3.29 MMcf	3,412 MMBtu	1GWh

Power

Gas		Electricity
0.197 cf/min	3.412 Btu/hr	1W
3.29 cf/hr	3,412 Btu/hr	1kW
32.9 Ccf/hr	3.412 MMBtu/hr	1MW
3.29 MMcf/hr	3,412 MMBtu/hr	1GW

ESC FRONTIER energy 19

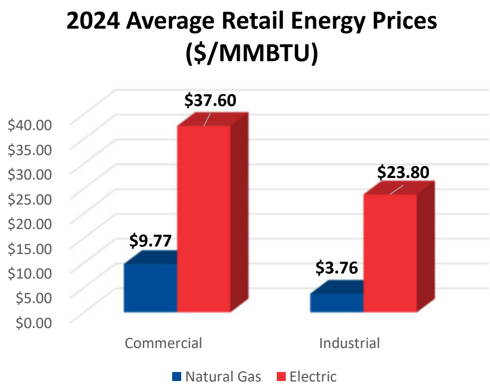
kW to BTU Conversion Examples

If running at full power for 1 hour…

Example	Electric Power	Gas Power	Electric Usage	Gas Usage	
Incandescent Lightbulb	100 W	341.2 Btu/hr	0.1 kWh	341.2 Btu	0.329 cf
LED Lightbulb	10 W	34.12 Btu/hr	0.01 kWh	34.12 Btu	0.0329 cf
Space Heater	1.5 kW	5,120 Btu/hr	1.5 kWh	5,120 Btu	4.94 cf
Electric Furnace	10 kW	34,120 Btu/hr	10 kWh	34,120 Btu	32.9 cf
Electric Water Heater	4.5 kW	15,350 Btu/hr	4.5 kWh	15,350 Btu/hr	14.8 cf

ESC FRONTIER energy 20

Energy Efficiency & Costs



Converting Gas & Electric Prices to $/MMBTU

- Average Retail Natural Gas Prices
  - Commercial = $10.12/MCF
    - $10.12/MCF / 1.036 BTU/MCF = $9.77/ MMBTU
  - Industrial $3.90/MCF
    - $3.90/MCF / 1.036 BTU/MCF = $3.76/ MMBTU
- Average Retail Electric Prices
  - Commercial = 12.85 cents/kWh
    - $.1285/kWh / 3412 BTU/kWh * 1,000,000 = $37.60/MMBTU
  - Industrial 8.15 cents/kWh
    - $.0815/kWh / 3412 BTU/kWh * 1,000,000 = $23.80/MMBTU

Source: https://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_pcs_dmcf_a.htm , https://www.eia.gov/electricity/data/browser/#/topic/7?agg=1,0&geo=vvvvvvvvvvvvo&endsec=2&freq=A&start=2001&end=2024&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0
2023 https://www.eia.gov/outlooks/aeo/

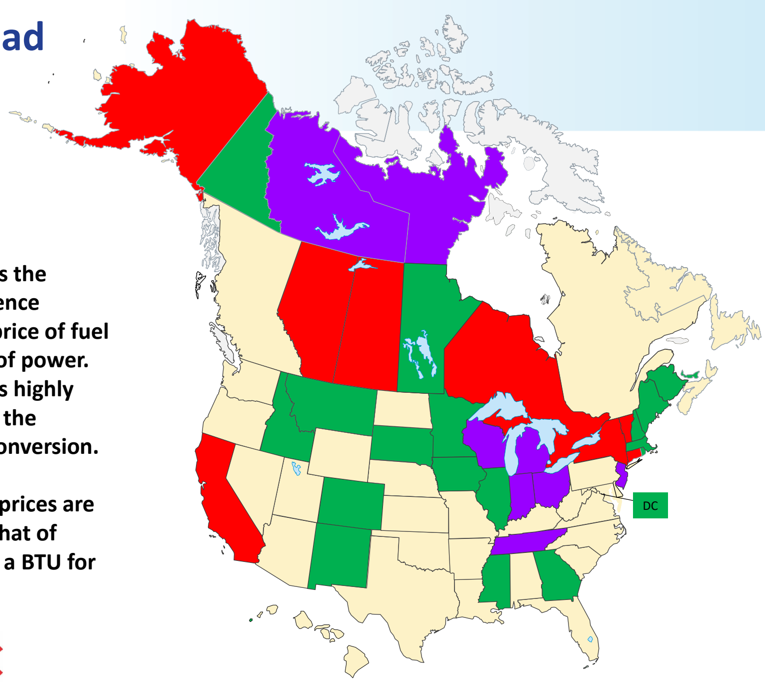
21

https://www.eia.gov/outlooks/aeo/

Spark Spread

Spark spread is the relative difference between the price of fuel and the price of power. Spark spread is highly dependent on the efficiency of conversion.

Retail electric prices are typically 3X+ that of natural gas on a BTU for BTU basis.



Spark Spread > 5
Spark Spread 4-5
Spark Spread 3-4
Spark Spread 2-3

Based on 2023 retail commercial energy rates from EIA.

Grid Loads & Characteristics

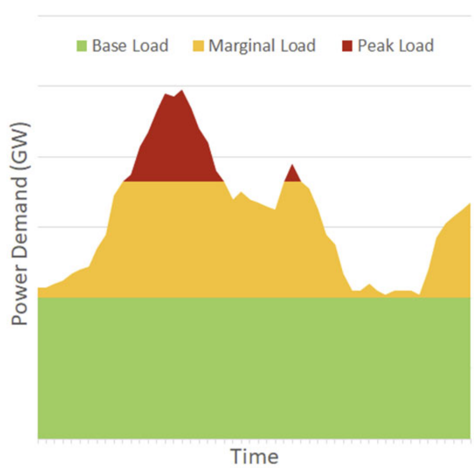
- Baseload, Marginal Load, Peak Load
- Power Quality
- Grid Surges
- Power Resiliency
- Renewable Integration

Base, Marginal, and Peak Load

Base Load – The electrical grid has a minimum load from customers that is always present.

Marginal Load (Intermediate Load) – Load on the electrical grid from customers that is not base load, varying over time, is satisfied with marginal power.

Peak Load – Spikes or periods of highest load on the electrical grid which power sources must be ready to immediately supply to prevent brownouts or blackouts.



ESC
FRONTIER energy
24

Base, Marginal, and Peak Load

Base load can be serviced by base load power plants which have power that is always available to satisfy this "base" level of constant demand.

Marginal load power sources must be able to ramp up and down more quickly than base load sources in preparation or response to varying demand from the grid.

Peak loads put pressure on electrical grids. These loads can be intermittent spikes, sometimes lasting less than a second, or periods of prolonged high usage.

- A short spike might come from a large industrial customer's equipment.
- A long spike may come from many customer ACs operating during a hot, sunny day.

ESC FRONTIER energy 25

Peak Loads

Grid operators must have supply ready to respond for peak loads, or a way to manage grid loads. Without this grid instability can occur and have unintended consequences:

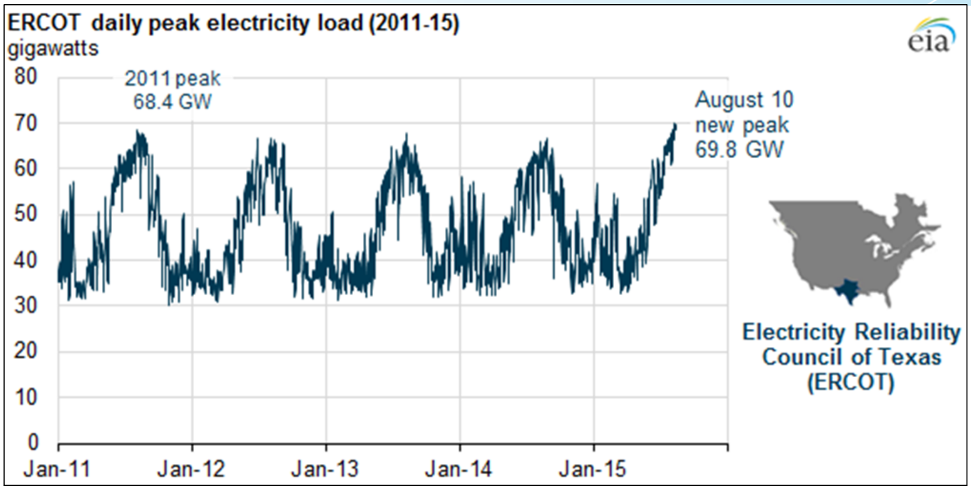
- **Power fluctuations** can damage grid and customer equipment.
- **Brownouts** may occur. This is when part of the grid loses the capacity or power to operate properly, usually for minutes or hours.
- **Blackouts** may occur. This is when part of the grid loses power entirely for a prolonged period.

Grid operators can manage peak loads in three ways:

- **Peaking power plants** – These are power plants that sit in reserve to be operated only as needed.
- **Energy storage** – Grid-scale batteries or other energy storage solutions may be used to store energy for rapid response or use during peak loads.
- **Demand-side management** – Grid operators may enter into agreements with customers to control load.

ESC FRONTIER energy 26

Peak Loads



Source: https://www.eia.gov/todayinenergy/detail.php?id=22532

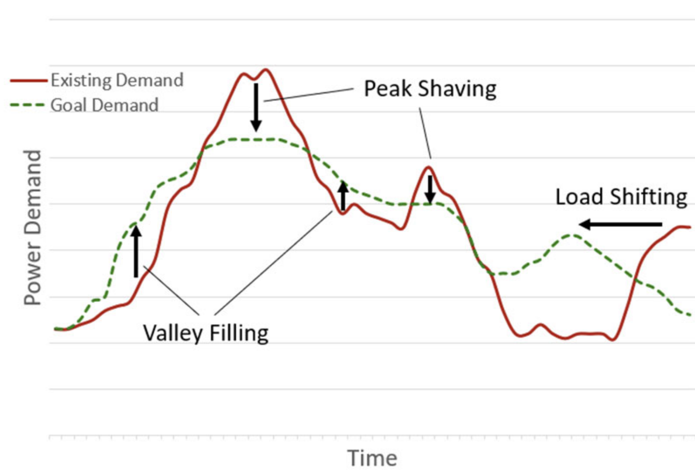
27

Demand-Side Management

It is in a utility's best interest to make their grid more stable and predictable from both the supply side and customer side.

Demand-side management consists of a series of strategies that can help utilities control customer demand:

- **Load shifting** – Helping customers move their loads to off-peak periods.
- **Peak shaving** – Helping customers reduce loads during peak periods.
- **Valley filling** – Helping customers more effectively utilize energy during periods of low demand.



28

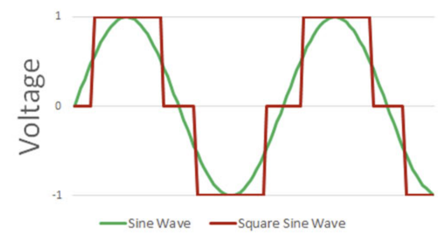
Power Quality

Power must meet specific specifications to be used safely and effectively. This is referred to as **power quality**.

- Service must not be interrupted.
- Voltage must be in range and not experiencing temporary sags or swells.
- Waveform must be a smooth sine wave.
- Frequency must be stable at the specified Hz.
- Phase voltages must be balanced with each other.

Poor power quality can have unintended consequences:

- Interference with sensitive devices
- Loss of data
- Overheating
- Energy loss
- Damage to equipment
- Hazards to people



Example: Poor quality inverters on small scale, off-grid solar setups can cause speakers to buzz.

Source: https://www.smart-energy.com/industry-sectors/smart-grid/what-is-power-quality-and-why-is-it-important/

ESC FRONTIER energy 29

Grid Surges

Voltage dips & spikes – As different loads draw from the grid and power sources add to the grid, voltage dips and spikes can happen. These must be managed to ensure power quality.

Surge current – Some devices or loads can create surges in current draw on the grid, often as they turn on or cycle.

- An everyday example of this can be seen when lights momentarily dim in a house when the AC or other high-draw appliance turns on.

Grid surges – Large, sudden increases in current and/or voltage in the grid. These can be caused by electrical switching, faults, or lightning strikes. These can damage equipment, create safety hazards, and cause outages.

Various devices and strategies may be used to manage voltage variances and protect the grid from surges.

ESC FRONTIER energy

Power Resiliency

Power resiliency is how well the grid can manage disruptions from:

- Forces of nature like earthquakes, hurricanes, floods, and solar storms.
- Human interference like equipment damage or failures, cyberattacks, and physical attacks.

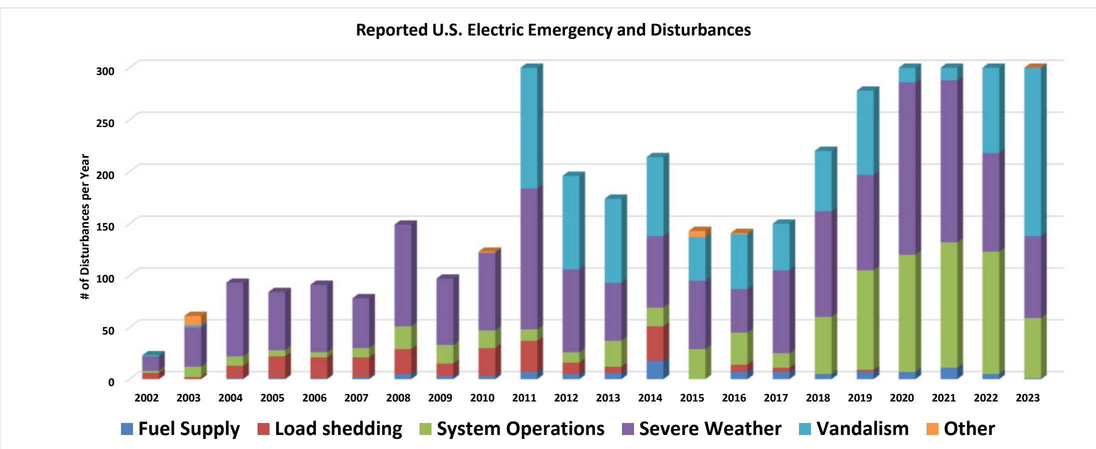
Power resiliency is ensured through:

- Monitoring – Quickly identifying issues.
- Response strategies – Maintaining resources to quicky respond to issues.
- Redundancy – Ensuring backups are in place.
- Robust Infrastructure – Building with materials and strategies that can withstand natural and human interference, both intentional and unintentional.
- Security – Adopting both physical and cyber security measures.
- Engagement – Connecting with customers and other stakeholders to understand their needs and how the grid is used.

Source: https://www.cisa.gov/sites/default/files/publications/Factsheet%20Resilient%20Power%20Best%20Practices.pdf
nrel.gov/docs/fy19osti/73489.pdf

Electric Outages

The number of large outages, number of people impacted by power outages and duration of outages continues to grow.



Renewable Integration

Renewable energies offer utilities ways to:
- Reduce or eliminate fuel costs.
- Stabilize energy prices and move toward energy independence.
- Improve grid reliability and resiliency through distributed systems.
- Improve social impacts of energy generation such as public health, safety, image, and workforce development.
- Reduce environmental impacts of energy generation.

There are, however, challenges to seamless grid integration, including:
- Intermittent power availability
- Capital cost
- Public reception
- Environmental impacts in new areas

Source: https://www.ucsusa.org/resources/benefits-renewable-energy-use

Renewable Integration

Various mechanisms are working to resolve renewable energy challenges. Among these are:
- Energy storage technologies and integration with the grid.
- Market forces and economies of scale improving equipment manufacturing, costs, and workforce experience.
- Research and public education to build public knowledge.
- Improved equipment and system designs in response to environmental challenges.

Source: https://www.ucsusa.org/resources/benefits-renewable-energy-use

Net Metering

Net Metering is a policy where customers that generate electricity for the grid are compensated for that generation against their grid usage.

This is usually the total energy produced by the system minus the energy the customer consumes on site. By doing this, customers sell their excess energy at a retail price instead of wholesale.

Net metering can be implemented differently in different states or by different utilities, and some states may not implement a policy at all. Customers may,

- Be offered credit for the extra energy at full utility rates.
  - Effectively negating any usage with generation.
- Be offered credit at a lower rate.
- Be credited up to a specific cap.

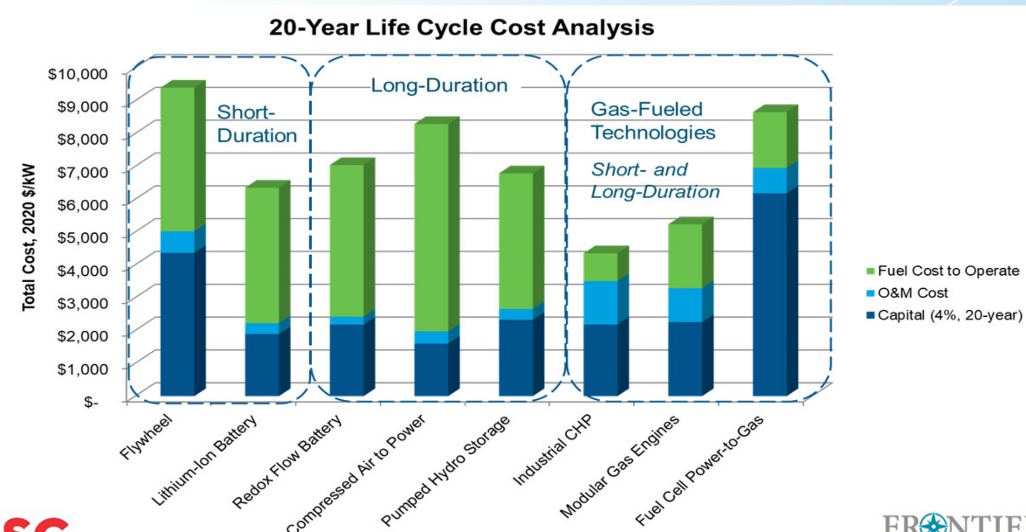
In effect, customers can run their meters backwards and "store" excess energy they generate and do not use in the grid.

ESC

FRONTIER energy

35

Electric Storage Options



Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF,

ESC

FRONTIER energy

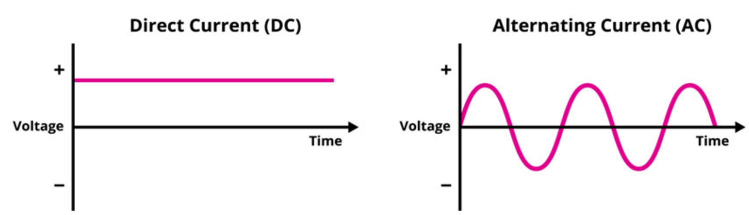
AC vs DC Voltage & Frequency

AC & DC

Current is the flow of electrons, but there are different ways for electrons to move through a circuit.

Direct Current (DC) – A static voltage is applied to a circuit and electrons move in one direction.

Alternating Current (AC) – An alternating voltage is applied to a circuit, causing electrons to move and switch direction of motion each time the voltage alternates.



Since it's the ***movement*** of electrons that delivers power, both methods are effective.

Source: https://en.wikipedia.org/wiki/Electric_current
https://en.wikipedia.org/wiki/Voltage
https://en.wikipedia.org/wiki/Electrical_resistance_and_conductance

AC & DC

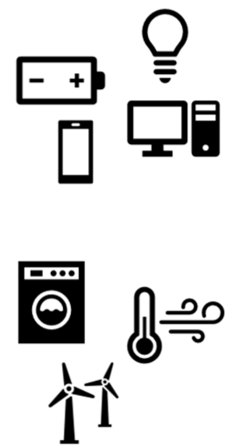
AC and DC power have unique characteristics that make them ideal for specific applications.

DC power is the power batteries both use and produce, and provides a constant voltage and reduced electromagnetic interference that many digital devices rely on. Many electronics without moving parts rely on DC power.

- Batteries, solar panels, LED lights, cell phones, computers…

AC power is easier to generate with mechanical energy. Many electronics with moving parts rely on AC power.

- Generators, motors, HVAC systems, refrigerators, washing machines…



AC Power in Transmission

Using DC power for long distance transmission has not historically been practical. Voltage conversion with DC was difficult and expensive.

AC power transmission is the backbone of our energy grid.

High Voltage Direct Current (HVDC) transmission has become more practical with technological advancements in recent years and is used for some newer infrastructure.

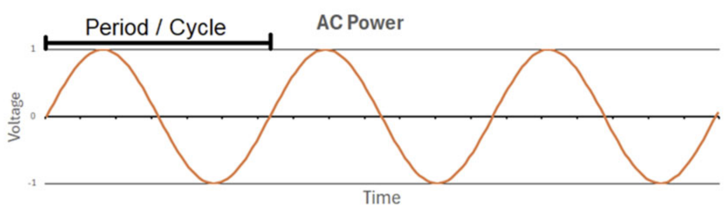
AC Power Frequency

AC Power is defined by the **frequency** at which it modulates. This period of time between complete cycles is measured in **Hertz** or cycles per second.

The US uses 60Hz AC power, though 50Hz is also common throughout the world.

The frequency of AC power directly impacts how equipment operates.

- Many cheap plug-in clocks use AC frequency to keep time.
- Variable frequency drives (VFDs) change the frequency of AC power delivered to motors to control their speed.



41

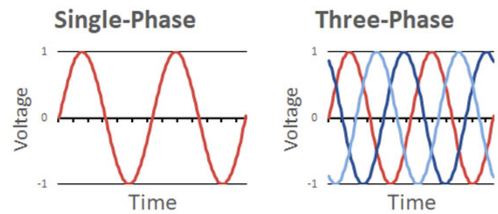
Phase & Transport

- Phase
- Volts, Amps, & Phase Relationship
- Transformers
- Switchgear
- Customer Side of Meter

Phase

AC power delivery, by definition, modulates and this means power delivery is not uniform over time. Power "pulses" through the wires. This can be resolved with multiple phase AC power delivery.

Single-phase AC power is power sent over one wire that follows a single oscillating pattern, switching voltage back and forth and creating peaks and valleys of power.
Three-phase AC power is power sent over three wires that each follow a single oscillating pattern, but offset their peaks and valleys to reduce time between power peaks and valleys.



Three-phase AC power delivers more power, more consistently, and more efficiently through less material, with fewer losses over long distances. Three-phase is used directly by some larger equipment but converted to single-phase for most everyday needs. Power converted to additional phases is used in some specialty cases.

ESC

Source: https://powerelectrics.com/blog/what-is-3-phase-power

FRONTIER energy

43

Volts, Amps, and Phase Relationship

Single-Phase	**Three-Phase**
P = V x I	**P = V x √3 x I**

Example:

Single-Phase	Three-Phase
120W = 120V x 1A	207W = 120V x √3 x 1A

ESC

FRONTIER energy

44

Transformers

Transformers convert power from one voltage to another, “stepping” it up or down. They can also convert three phase power to one phase for delivery.

Long-distance transmission lines usually operate between 69kV and 735 kV.

Local distribution lines operate at voltages below 34kV.

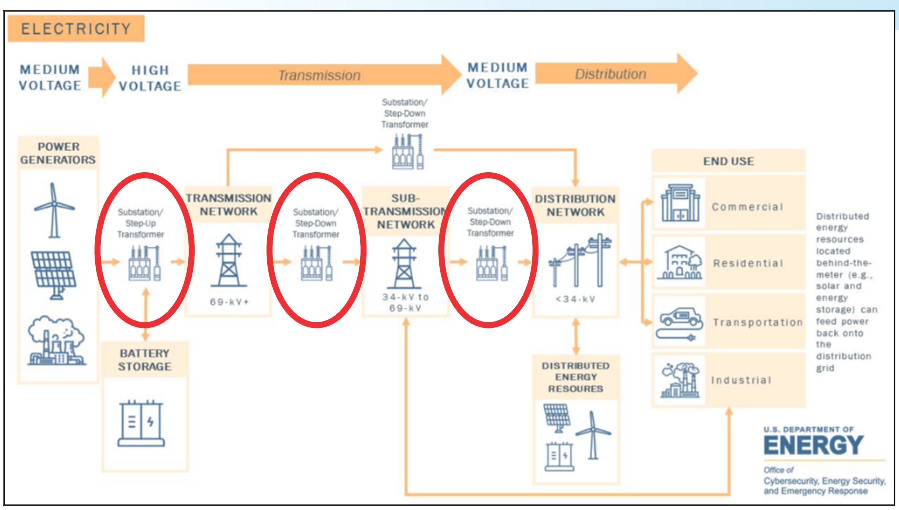
Lines connecting to end-customers from the grid usually operate at voltages below 1kV.

Larger industries or commercial sites may use higher voltage connections.

Source:https://www.arcgis.com/apps/mapviewer/index.html?panel=gallery&layers=d4090758322c4d32a4cd002ffaa0aa12
https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

45

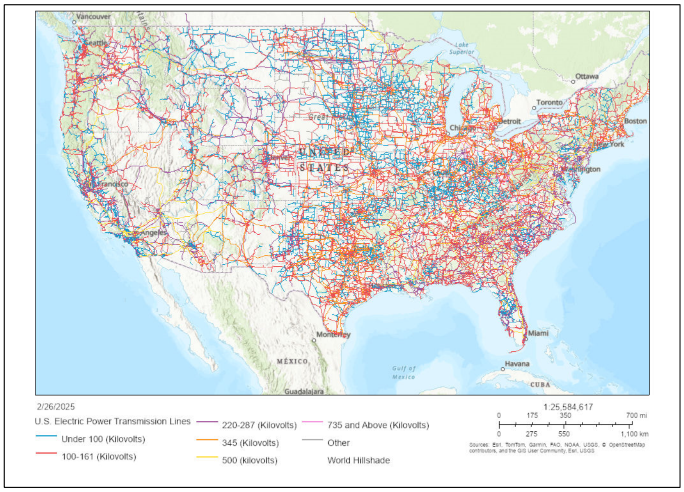
Transformers

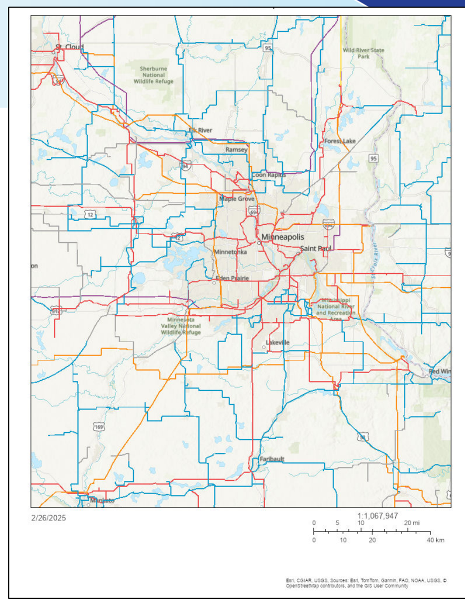


Source: https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

46

Transmission Voltages





Source: https://www.arcgis.com/apps/mapviewer/index.html?panel=gallery&layers=d4090758322c4d32a4cd002ffaa0aa12

47

Switchgear

Electrical **switchgear** helps control, protect, and isolate equipment and portions of the grid. This general term includes components such as:

- Switches
- Circuit breakers
- Fuses
- Lightning arrestors
- Control panels
- Transformers
- And more.

Switchgear allows workers to disconnect portions of the grid for maintenance, protects the grid by isolating faults

Image: https://en.wikipedia.org/wiki/Switchgear

Source: https://en.wikipedia.org/wiki/Switchgear

48

Customer Side of Meter

Customers are connected to the grid by a **meter** that measures their usage.

Customers have **electrical panels** that contain fuses, switches, and/or breakers to manage individual circuits.

Electricity is delivered to end-use devices by a network of **wires, switches**, and **outlets**.

Larger customers may have multiple, more advanced versions of these components.

ESC

FRONTIER energy

49

Power Use Characteristics

- Power Factor
- Apparent Power
- Real Power
- Reactive Power
- Load Factor
- Capacity Factor

Power Factor

Power factor is defined as the useful power in watts (real power) divided by the product of the input voltage and input current (apparent power). Effectively, when current and voltage are not in phase, power factor suffers.

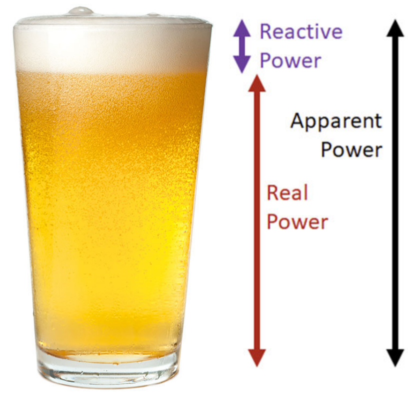
PF = Real Power / Apparent Power

Power factor is a number between 1 and 0, representing high and low power factors, respectively.

Apparent Power – The demand or load being placed on the grid.

Real Power – The power doing the work desired.

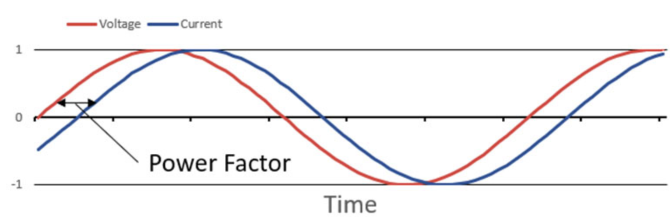
Reactive Power – Wasted or lost power generating unnecessary heat or vibrations.



Power Factor

Poor power factor means energy is being used inefficiently and can:

- Cause heat damage.
- Result in lost power.
- Push investment into larger equipment and infrastructure than necessary.
- Require more investment in energy generation.



Resistive loads have a power factor of 1. These resist the flow of current without creating magnetic fields.

- Electric heaters, incandescent lights, toasters, etc.

Inductive loads have power factors lower than 1. These use and create magnetic fields which can induce current in a circuit.

- Motors, transformers, inductors, etc.

An industrial site with a low power factor may improve power factor by putting variable frequency drives on their motors to modulate their speed and optimize their load, or install capacitor banks to help offset loads.

Load Factor

Load factor is the amount of energy a load uses over a given time divided by its maximum load potential to use energy. This is a number between 1 and 0, expressed as a decimal or percentage, where lower corresponds to less usage.

High Load Factor: 0.8 to 0.9

Medium Load Factor: 0.4 to 0.6

Examples:

A 10W LED light bulb running constantly for an hour:

Average usage of 10W / Max usage of 10W = Load Factor of 1 for that hour

A 10W LED light bulb running at a dimmed brightness for an hour:

Average usage of 5W / Max usage of 10W = Load Factor of 0.5 for that hour

A 10W LED light bulb being switched on for an hour, and off for an hour on repeat for an hour:

Average usage of 5W / Max usage of 10W = Load Factor of 0.5 for that hour

A three-lamp streetlight may have the potential to use all three bulbs but only uses one at a time. Load factor of 0.333.

Sources: https://www.electricalengineering.xyz/load-factor-formula-definition-and-applications/
https://www.energycap.com/resource/what-is-load-factor/

Load Factor

Load factor can apply to a single device, a building, or even a city or grid. It is often calculated for a year, using **Effective Full Load Hours (EFLH)**, which describe how many hours that equipment "effectively" runs at full power over the year.

Effective Full Load Hours (EFLH) =Total Annual Usage (kWh) / Registered Demand (kW)

Load Factor = EFLH / Hours in a Year

Examples:

A space heater can use 1500W when on, but is set to a 1000W setting on average, and is used for 8 hours a day.

(1 kW x (8 hrs per day x 365 days per year)) / 1.5kW = **1,947 EFLH**

1,947 EFLH / (24 hrs per day x 365 days per year) = **0.22 Load Factor**

A microwave uses 1000W when on and is used for a total of about 30 minutes a day in a Monday – Friday office.

(1 kW x (52 weeks per year x 5 workdays per week x .5 hrs per day)) / 1kW = **130 EFLH**

130 EFLH / (24 hrs per day x 365 days per year) = **0.015 Load Factor**

Load Factor

Load factor is important for understanding how much energy equipment uses when compared to what it is capable of using.

The electrical infrastructure for a residence, for example, is built with a specific load factor in mind. Should all equipment be turned on and outlets utilized, a fuse will blow or breaker will trip to prevent overloading the home's infrastructure.

A utility, for example, will want to know what the potential draw is for a new industrial site, to size electrical infrastructure appropriately should high demand be needed, but will want to know the site's expected load factor through the year to know how much energy will actually be consumed.

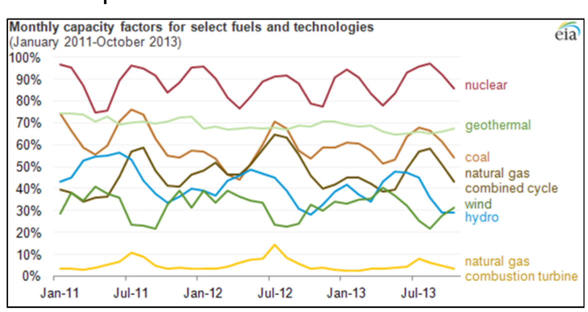
Capacity Factor

Grid capacity factor *is a measure (expressed as a percentage) of how often an electricity generator operates during a specific period of time using a ratio of the actual output to the maximum possible output during that time period.* This is a number between 1 and 0, where 1 corresponds to full utilization and zero corresponds to none.

Base load power plants will have high capacity factors, as there is always demand on the grid for the energy they generate.

Peaking power plants will have low capacity factors as they are only utilized during peak periods.

Wind and solar power plants generally have lower capacity factors due to their variable power generation which may not always match demand.



Source: U.S. Energy Information Administration, Electric Power Monthly, Tables 6.7a and 6.7b

Source: https://en.wikipedia.org/wiki/Capacity_factor
https://www.solisrenewables.com/blog/what-is-capacity-factor


Thank You
Consider taking the on-line test while
course material is fresh in your mind
ENERGY SOLUTIONS CENTER
FRONTIER energy
400 North Capitol Street, 4th Floor
Washington, DC 20001
escenter.org