# Electrical Production and Distribution on Campus

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## Course Description

Electrical production and distribution equipment and systems are characterized by highly sophisticated technologies that continue to develop rapidly. College and university electrical distribution systems generally consist of a switching station for receiving the electricity into the university system, switching substations (which include transformers), medium-voltage conductor circuits, electric power generation, and system protection. This class will explore electrical systems typical of university-owned facilities where electricity, whether generated on campus, purchased, or both is received and further distributed to points on campus.

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## Learning Objectives

In the next 100 minutes you will be introduced to terminology that you likely hear being used on your campus. I intend to give you enough information to make you dangerous…

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## Generation and Distribution

Forms of Production (How?)
- On-site Power Plant
- Renewable Energy Sources
- Hydroelectric Power
- Geothermal Energy
- Microgrids
- Energy Storage
- Nuclear

Distribution

The Case for Self-Generation (Why?)

Cost Considerations (How Much?)
- Understand Energy Use vs. Demand
- What's your Generation Strategy?

Purchase or Generate?

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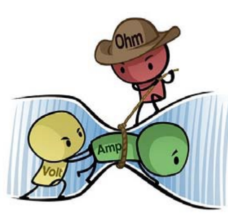
## Vocab




**Electricity**= flow of electrons

• Voltage (volts)= potential energy created by difference in charge between two points

• Current (amps) = rate at which the charge is flowing

• Resistance (ohms) = the material's tendency to resist the flow of charge.

Plumbing analogy: Voltage = water pressure. Current = flow rate. Resistance = pipe size.

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## Consumption

1. **Size and Population**: Larger campuses with a greater number of students, faculty, and staff typically consume more electricity.
2. **Climate**: Campuses in regions with extreme temperatures may have higher electricity consumption due to heating and cooling needs.
3. **Facility Types**: The presence of energy-intensive facilities like laboratories, data centers, and large athletic facilities can significantly increase electricity usage.
4. **Energy Efficiency**: Campuses that have implemented energy-efficient technologies and practices tend to use less electricity per square foot.
5. **Renewable Energy**: Some campuses invest in on-site renewable energy sources, such as solar panels or wind turbines, which can offset their electricity consumption.
6. **Local Energy Sources**: Campuses with on-site cogeneration (combined heat and power) systems can generate a portion of their electricity on-site, reducing dependence on the grid.
7. **Behavioral Factors**: Campus-wide energy conservation campaigns and student engagement can influence electricity consumption.
8. **Technological Advancements**: Advances in lighting, HVAC systems, and building automation can lead to energy savings.

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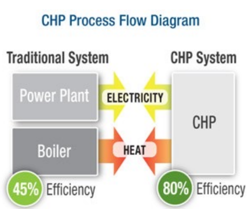
## Production

**On-Site Power Plants**: Some larger university campuses have their own on-site power plants. These power plants can use various energy sources, such as natural gas or biomass, to generate electricity. Combined heat and power (CHP) systems, also known as cogeneration, are efficient systems that simultaneously produce electricity and useful heat, which can be used for heating or cooling campus buildings

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## Production

**Renewable Energy Sources**: Many universities invest in renewable energy sources to generate electricity sustainably. This includes:

- **Solar Power**: Installing solar panels on rooftops, parking lots, or open spaces to capture sunlight and convert it into electricity.
- **Wind Power**: Utilizing wind turbines, either on tall towers or smaller installations, to harness wind energy for electricity production.
- **Biomass Energy**: Using organic materials like wood chips, agricultural residues, or even food waste to produce electricity through combustion or gasification.

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Colorado State rooftop installation

Rutgers parking canopy installation

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## Solar PV

- Direct conversion of solar irradiance into electricity. No generator needed.
- PV panels contain silicon layers which carry a negative and positive charge
- Silicon molecules, like copper, are prone to losing electrons
- Photons from the sun dislodge electrons in the atoms from the negative layer
- Conductors embedded in panel collect the flowing electrons
- Output from all panels is combined and sent to grid

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Castleton University

UC Davis

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## Production

**Hydroelectric Power**: If a campus is located near a river or water source, it may have a hydroelectric power facility that generates electricity by harnessing the flow of water through turbines.

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Fall Creek Gorge Cornell University

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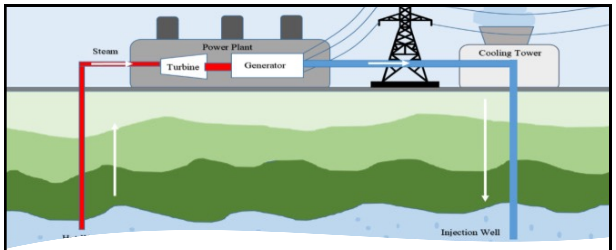


Production

**Geothermal Energy**: In regions with access to geothermal resources, universities can tap into the Earth's natural heat to generate electricity.

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## Production

**Microgrids**: Some campuses implement microgrids, which are smaller, localized grids that can operate independently from the main grid. These microgrids may incorporate renewable energy sources and energy storage systems to enhance resilience and sustainability.

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Production

**Energy Storage**: Installing energy storage systems, such as batteries, to store excess electricity generated during off-peak times for use during peak demand periods or when renewable energy sources are not available.

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## Production


**Nuclear**: Small Modular Reactors. SMRs are revolutionary in part because of their modular nature. They can be prefabricated off site, thereby saving money and time in construction.

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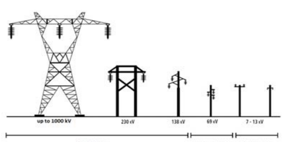
## Transmission vs. Distribution

High Voltage Transmission lines:
- 69,000 volts and up
- Installed overhead for cost and efficiency.
- Not insulated.
- Insulation = resistance = wasted energy in the form of heat
- Heavy load causes lines to sag




Distribution lines (Medium Voltage):
- Common voltages: 7,200-13,800 volts
- May be overhead or underground. U/G is much more reliable but up to 10X the cost of O/H. (Campus aesthetics another consideration!)
- If U/G, conduit may be direct buried, or encased in concrete "duct bank".
- Different utilities often share the same pole. Highest voltage electrical lines are always on top. Fiber optic, cable TV, telephone lines are installed below

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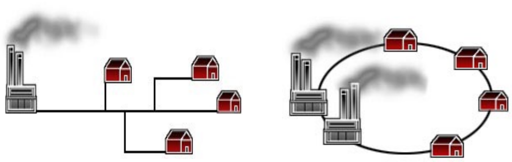
## Distribution: Radial vs. Loop Topology



**Radial**: One feeder line from generation to each load.
- Simple, lower cost, but inflexible in the event of a line fault
- No way to divert power through other feeders to keep power on

**Loop**: Multiple feeder lines, allowing power to flow to load from either direction
- Managed via switchgear (breakers, switches, etc) to allow or block the flow

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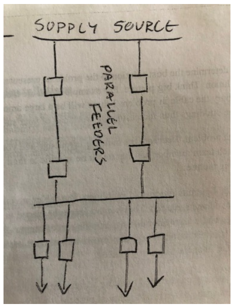
PARALLEL FEED

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SWITCH

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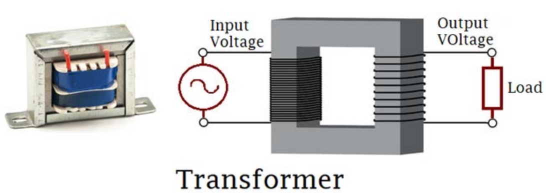
TRANSFORMER

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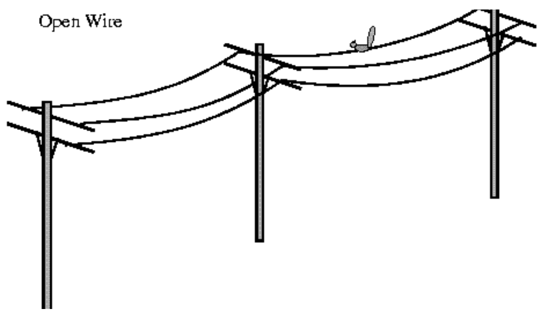
## OPEN WIRE CABLE

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## AERIAL CABLE


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## ABOVE GROUND CONDUIT

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## UNDERGROUND DUCT

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## DIRECT BURY CABLE

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## The Case for Self-Generation

- Continuity of service despite grid outages
- Agile response to market conditions
- Time of Day and Seasonal pricing factors
  - Rates vary by on-peak/off-peak periods, and summer/winter
- Demand Response/Curtailment Agreement
  - Lower rates/rebates utility for curtailment (load reduction)
  - Curtailment triggered by congestion, wholesale market price spikes, grid reliability concerns
- Base Load Generation vs. Peak Shaving
  - Base Load: Continuous operation serving all or most of campus demand
  - Peak Shaving: Rapid response generation to offset load during high demand hours
  - Energy Storage is another tool to achieve peak shaving—system costs rapidly coming down

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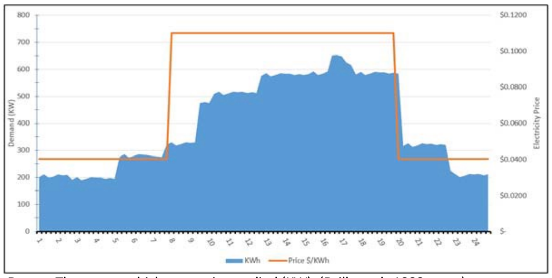
## Power (KW) vs. Energy (KWh)




**Power:** The rate at which energy is supplied (KW). (Drill needs 1000 watts)
Also called "Demand."
**Energy:** The amount of Power delivered over time (KWH) (Run the drill for 1 hr = 1 Kwh)
**Driving Analogy:** Power/Demand = miles per hour. Energy = total distance traveled.

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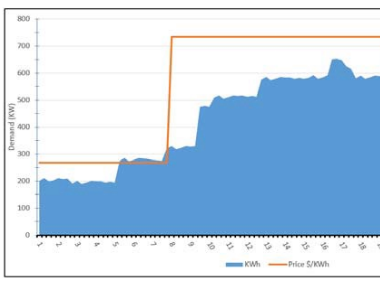
## Demand and Energy




Peak Demand: 652 KW
Demand Charge $6.77/ KW
Applied to ENTIRE month's usage

**Energy Charge**: $/KWh for total Energy Use (entire blue area)

**On-peak Demand Charge**: $/KW Charge based on your highest Demand (highest rate of energy consumption) during On-Peak hours. Demand is expensive because power plants, transmission, etc must be sized to meet peak demand.

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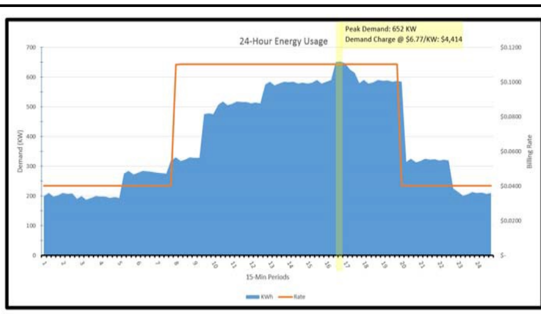


**What changes might this facility take to reduce its electricity bill?**
Scheduling options?
Generation options?
Load-following Generation?
Net metering?
Energy storage?

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## Purchase or Generate? And Which Technologies?

**Consider institutional priorities**
- Utilities Cost Reduction
- Budget Stability
  - Fixed Costs – Construction & Regulatory
  - Marginal Costs – Fuel and O&M
- Energy Security
- Continuity of Services/Emergency Power
- Environmental Impacts
- University branding
- Research and Learning opportunities

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## Purchase or Generate? And Which Technologies?

**Consider limitations**
- Available Capital
- Regional Energy Resources
- Physical Space / Existing Infrastructure
- Permitting Regime
- Community Support
- Timeline, Scalability
- Staffing & In-house Expertise
- Bring in third party operators?
- Sell utilities enterprise entirely?

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## How About Renewable Energy?

- Intrinsic environmental benefits
- Branding: students expect and demand it
- Dramatic CoE reductions
- Understand available incentives and market value of
- Renewable Energy Credits
- What's your clout with your utility? Get them to do the heavy lifting!

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## Your Turn

You have been hired to design an electrical production and distribution system for a new campus that is located in a very sunny (hot) and windy location. Aesthetics are very important. Long term budget stability is important. Your budget for construction is very flexible as long as you can justify with TCO calculations.

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