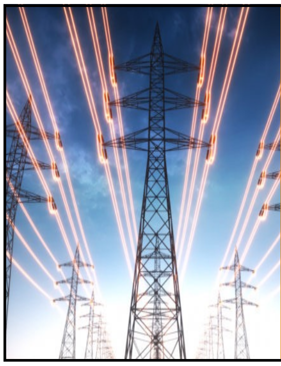

APPA Utilities

# ELECTRIC PRODUCTION & DISTRIBUTION

June 2024

1

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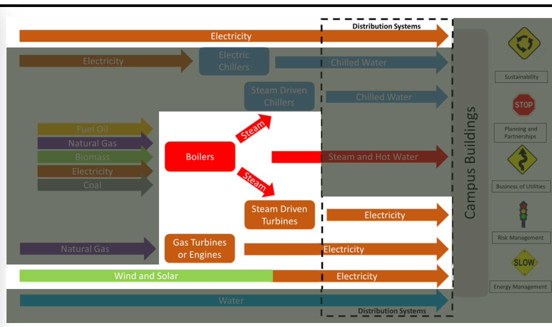
2

## ELECTRICTY

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## COURSE DESCRIPTION

**Overview of electric production and distribution terms and concepts**

- **Electricity production**
  - Turning the generator
  - U.S. electricity generation mix
- **Power purchase vs. self-generation**
- **Electricity transmission**
- **Electricity distribution**
- **Electric reliability**
- **Common campus electricity distribution systems**





4

## LEARNING OBJECTIVES

**Basic understanding of:**

- How electricity is produced, transmitted, and distributed
- Electricity production and distribution options
- Common approaches in higher education
- Class exercise – APPA University





5

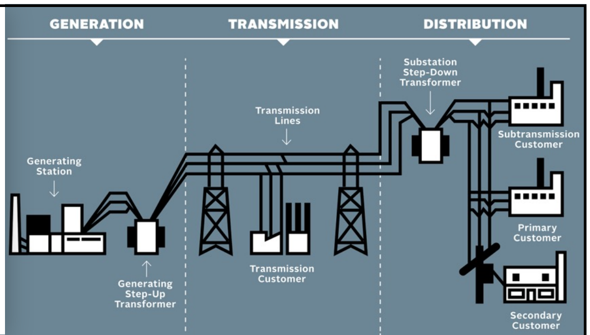
PHYSICAL PLANT

**"Everything" Needs Electricity**

- Drinking water
- Chilled water
- Heating hot water
- Steam
- Building lighting and power
- Geothermal
- Sanitary sewer
- Storm sewer

6

## ELECTRICTY




7

## ELECTRIC PRODUCTION

It's "simple"

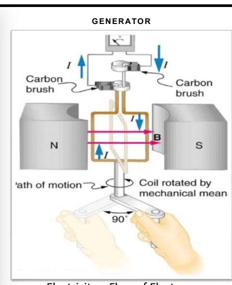
**Turn copper inside a magnet***

- Copper turning speed determines frequency

**How it is turned is up to you…**

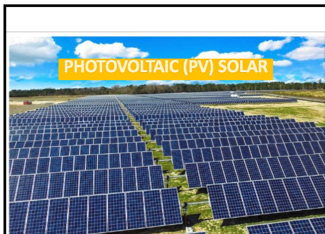
- Resource availability
- Economics
- Sustainability goals

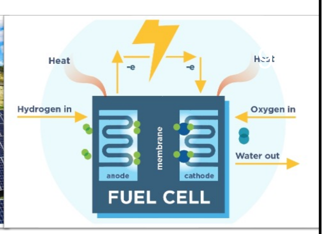
* Exceptions (fuel cell & PV solar)




Electricity = Flow of Electrons

8



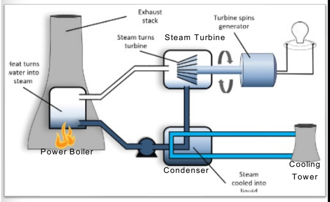




## ELECTRIC PRODUCTION EXCEPTIONS

9

## TURNING THE GENERATOR

- **Steam (~80% of power production)**
  - Coal, natural gas, fuel oil, bio-fuel
  - Nuclear
- **Combustion Turbine**
  - Natural gas
  - Fuel oil
  - Heat can be recovered to generate steam for use in a steam turbine
- **Engine**
  - Natural Gas
  - Fuel oil (diesel)
- **Water**
  - River/dam
  - Waves
  - Pumped hydro
- **Wind**

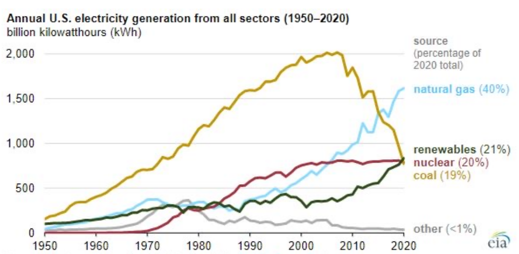



CONVENTIONAL THERMAL POWER PLANT

10

10

## ANNUAL GENERATION




Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*
Note: This graph shows electricity net generation in all sectors (electric power, industrial, commercial, and residential) and includes both utility-scale and small-scale (customer-sited, less than 1 megawatt) solar.

11

11

## POWER PURCHASE OPTION

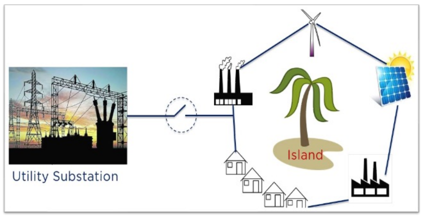
### Power Purchase Agreement (PPA)

- Developer investment (DBOOM) on university property
- University purchases net power produced a fixed rate ($/kWh) and receives Renewable Energy Credits (REC)
- Agreement durations 20 – 35 years (typ)
- Additional things to consider:
  - Climate
  - Parking lot usage cases
  - Production & microgrid stability risk
  - Interconnection cost and risk
  - FERC registration and "sale for resale" prohibition
  - Buy-out clauses
  - End of agreement clauses

12

12

## SELF-GENERATION – INCREASED RELIABILITY & RESILIENCY




- Generation capacity vs. campus demand
- N+1 redundancy
- Black-start capability
- Ability to "island" from local utility grid

13

13

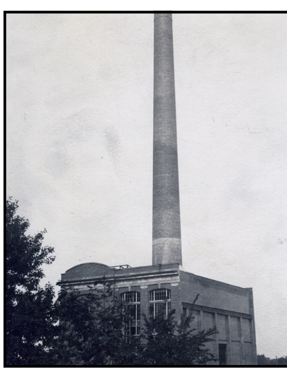
## CAMPUS UTILITY RATES

**Not just one way…**

- Cost based accounting
- Enterprise model or not…
- Fees or not…
- Capital depreciation or not…
- Debt interest or not…
- Where does the distribution system stop?
- Special rates…grants may dictate…
- Rates for energy conservation projects…


14

14



## APPA University Plant

### Things to Consider

- **University Values & Expectations**
  - Sustainability
  - Academic vs. Research
  - Reliability vs. Resiliency
- **Location**
  - Heating and cooling needs
  - Energy resource availability
- **Generation**
  - Technology
  - Fuel/energy resource availability & cost
- **Return On Investment (ROI)**

15

15

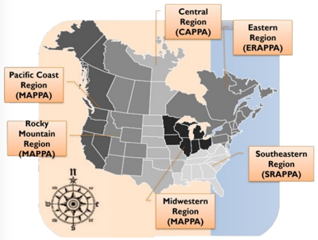
## CLASS EXERCISE

**Assumptions:**

- New university/site
- Self- generate
- In/adjacent to major city
- Positive ROI

**10-minute discussion → report out:**

- Fuel / energy resource to be used
- Generation type and capacity
- Why

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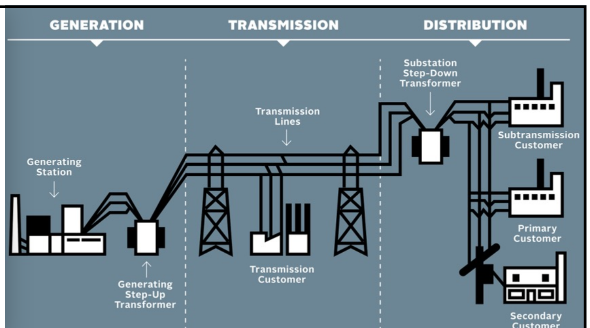
16

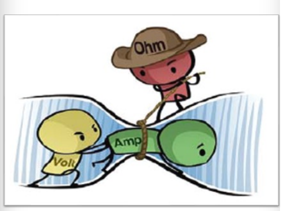
## ELECTRICTY




17

17

## ELECTRICITY EXPLAINED




**Voltage (Volts)**
Difference in charge between two points (pressure in the circuit)

**Current (Amps)**
Rate at which the charge is flowing (like flow rate)

**Resistance (Ohms)**
The material's tendance to resist the flow of charge (like pipe size or friction)

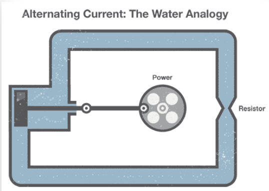
Power (Watts) = Voltage (V) x Current (Amps)

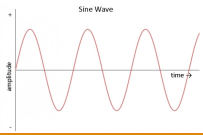
Voltage (V) = Current (Amps) x Resistance (Ohm)

18

18

## AC CURRENT EXPLAINED




### AC = Alternating Current

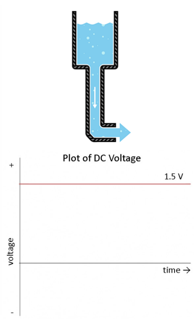
- Current reaches a peak and changes direction (sine wave)
- Transmits electric efficiently over long distances
- AC voltage can be easily stepped up for longer distance transmission, then stepped down for building use
- Examples: turbine generators, inverters, transmission & distribution, buildings, industrial

Alternating Current (AC) vs. Direct Current (DC) - SparkFun Learn

19

19

## DC CURRENT EXPLAINED




### DC = Direct Current

- DC is constant and flows in one direction, from negative to positive
- Transmits electric over short distances
- DC is more stable and reliable for sensitive devices and power storage
- Examples: batteries, DC generators. Solar PV cells, telecom, electronics

Alternating Current (AC) vs. Direct Current (DC) - SparkFun Learn

20

20

## AC / DC CONVERSION

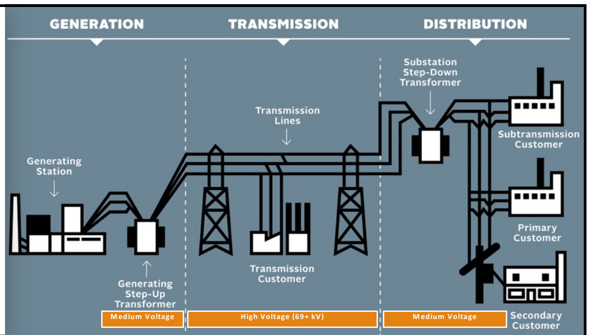
**Inverter** – converts DC to AC

**Rectifier** – converts AC to DC

21

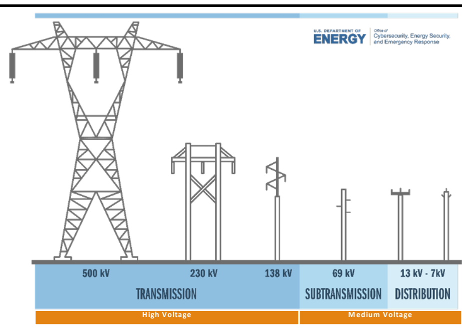
21

## SYSTEM VOLTAGES




22

## TRANSMISSION & DISTRIBTUTION



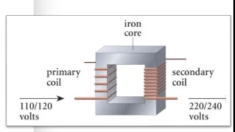

23

## TRANSFORMERS

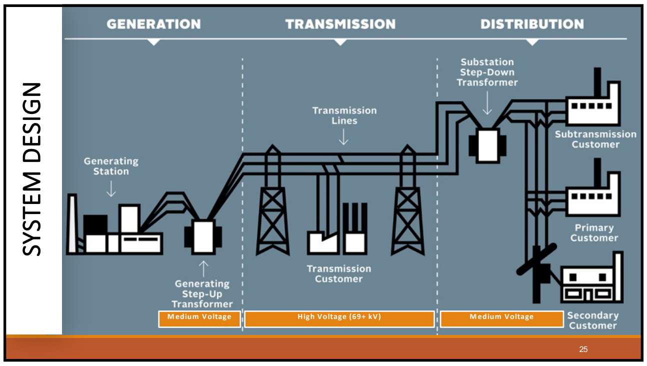
- Changes voltage and current
- Step-up Transformer increases voltage, but lowers current
- Step-down Transformer decreases voltage, but raises current
- ***Why is this necessary?***
  Current produces heat (losses)

  Stepping up voltage (138kV+) for long distance transmission greatly improves efficiency by minimizing heat losses and therefore cost

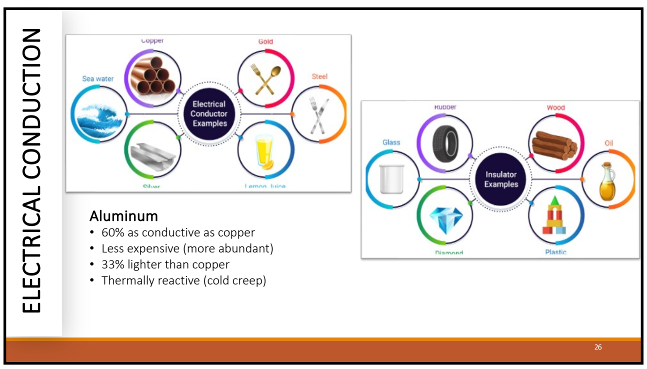
  Voltage can then be stepped down to safe usage levels (120/240V) close to the point of use



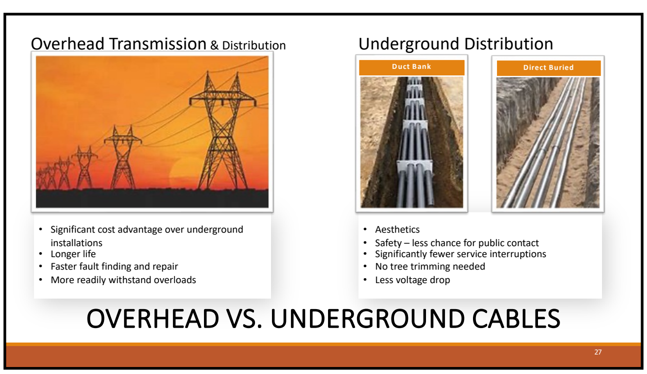

24


SYSTEM DESIGN
GENERATION
TRANSMISSION
DISTRIBUTION
Generating Station
Generating Step-Up Transformer
Transmission Lines
Transmission Customer
Substation Step-Down Transformer
Subtransmission Customer
Primary Customer
Secondary Customer
Medium Voltage
High Voltage (69+ kV)
Medium Voltage
25

25


ELECTRICAL CONDUCTION
Electrical Conductor Examples
Copper
Gold
Sea water
Steel
Insulator Examples
Rubber
Wood
Glass
Oil
Plastic
Aluminum
• 60% as conductive as copper
• Less expensive (more abundant)
• 33% lighter than copper
• Thermally reactive (cold creep)
26

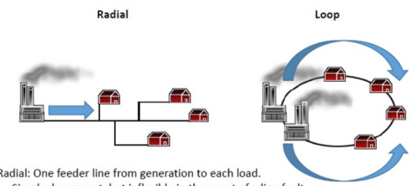
26


Overhead Transmission & Distribution
Underground Distribution
Duct Bank
Direct Buried
• Significant cost advantage over underground installations
• Longer life
• Faster fault finding and repair
• More readily withstand overloads
• Aesthetics
• Safety – less chance for public contact
• Significantly fewer service interruptions
• No tree trimming needed
• Less voltage drop
OVERHEAD VS. UNDERGROUND CABLES
27

27

CAMPUS DISTRIBUTION

## 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

28

28

ELECTRIC RELIABILITY

**Service Interruption** –
- An event that results in zero voltage at the customer load
- Also known as power outage

**Power Quality** –
- Power delivered to the customer within a specified voltage range above required minimum current

*Power Quality events are not considered to be Service Interruptions as defined by IEEE*

How do you know if you have experienced a power quality event?

What are the potential impacts of a power quality event?

29

29

BUILDING ELECTRICITY

Emergency generators supply power for Building Code life safety systems such as:
- Egress lighting
- Fire alarm systems
- Smoke evacuation
- Elevators
- Broadband Utility and Telephone Utility Rooms
- Communication and Fiber rooms
- Central Control system cabinets

Standby generators supply power for user defined needs beyond building code life safety. For example:
- Critical lab equipment such as ultra-lows/freezers
- Critical lab exhaust fans

30

30

## BUILDING ELECTRIC OUTAGES

- Outage identified
- Isolate circuits (using loop or redundancy to maintain power)
- Communicate if power lost
- Diagnose issue
- Repair and test
- Restore power
- After-action review
- Communicate / notify


31

31

## APPA University Electric Distribution

### Things to Consider

- University Values & Expectations
  - Reliability vs. Resiliency
  - Aesthetics
- Return On Investment (ROI)

32


## APPA University Electric Distribution

### Things to Consider

- University Values & Expectations
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33

33

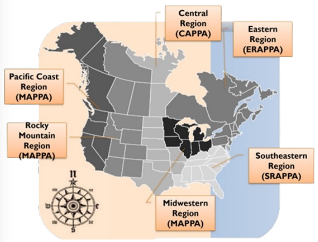
CLASS EXERCISE

**Assumptions:**

- New university/site
- Academic and research
- Self- generate
- In/adjacent to major city
- Positive ROI

**10-minute discussion → report out:**

- Major features of electrical distribution system design
- Reliability and resiliency design features
- Why




34

34

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35

35

QR CODE GOES HERE

- Sign-in sheet
- Evaluation form

36