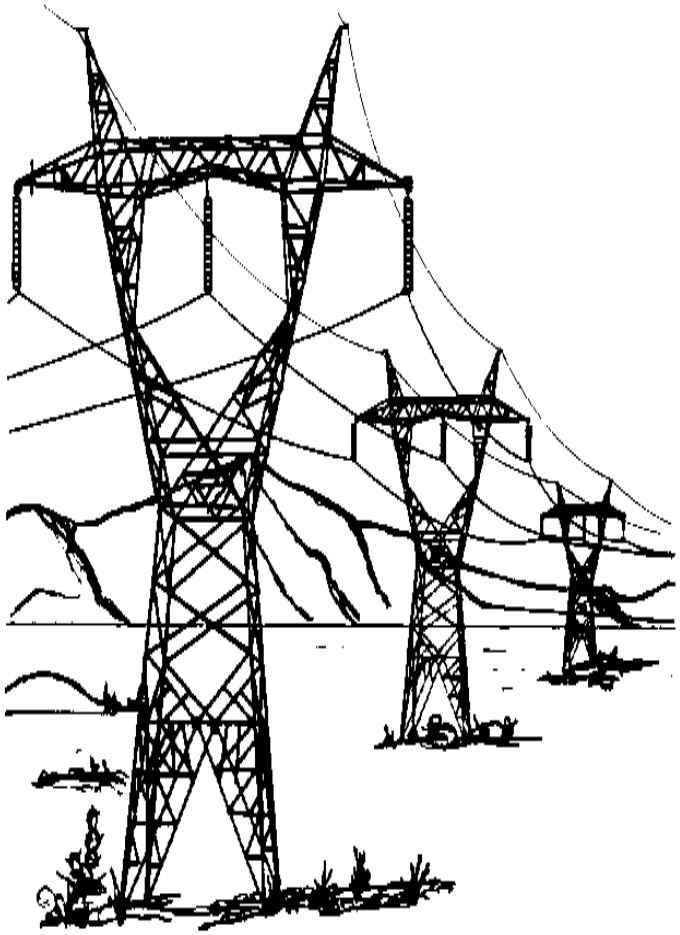


Overview of Western's Interconnected Bulk Electric System

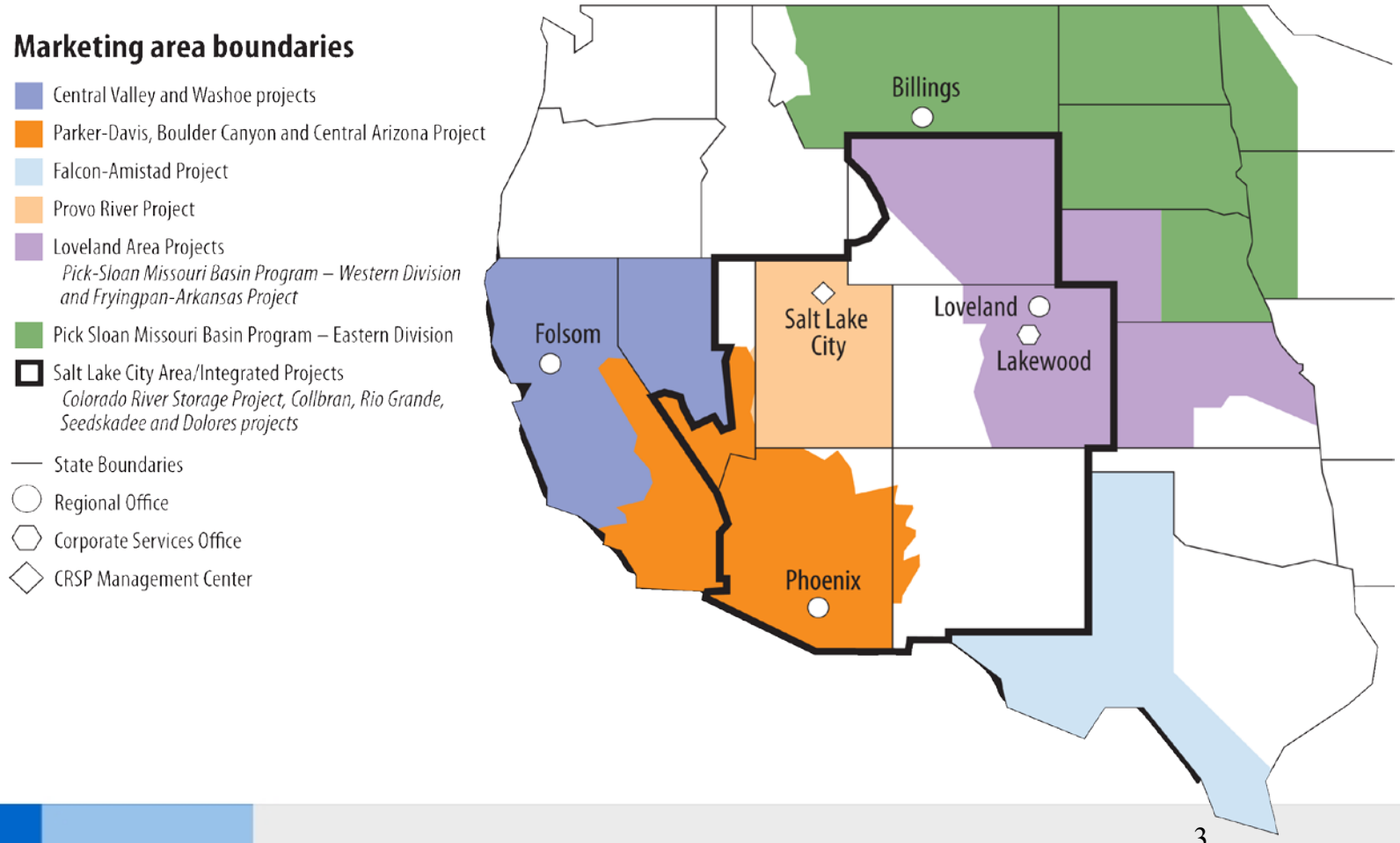
Western Area Power Admin.

Objectives

- Describe Western Area Power Administration Region and Facilities Overview
- Explain Fundamentals of Electricity, Power Transformers and Transmission Lines
- Discuss Overview of the Bulk Electric System (BES)
- Objectives Review

Western's Service Area

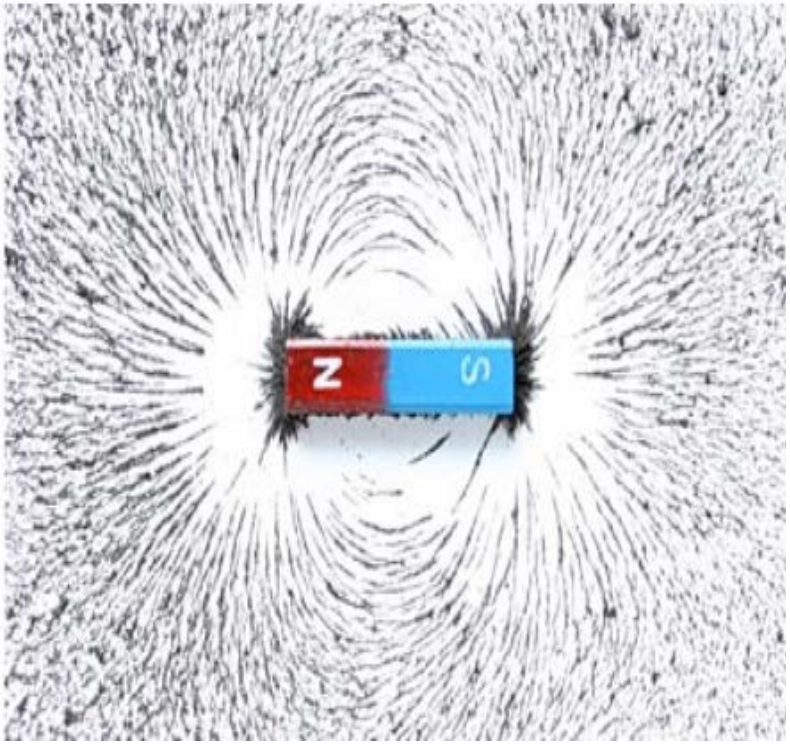
Western marketing areas and offices

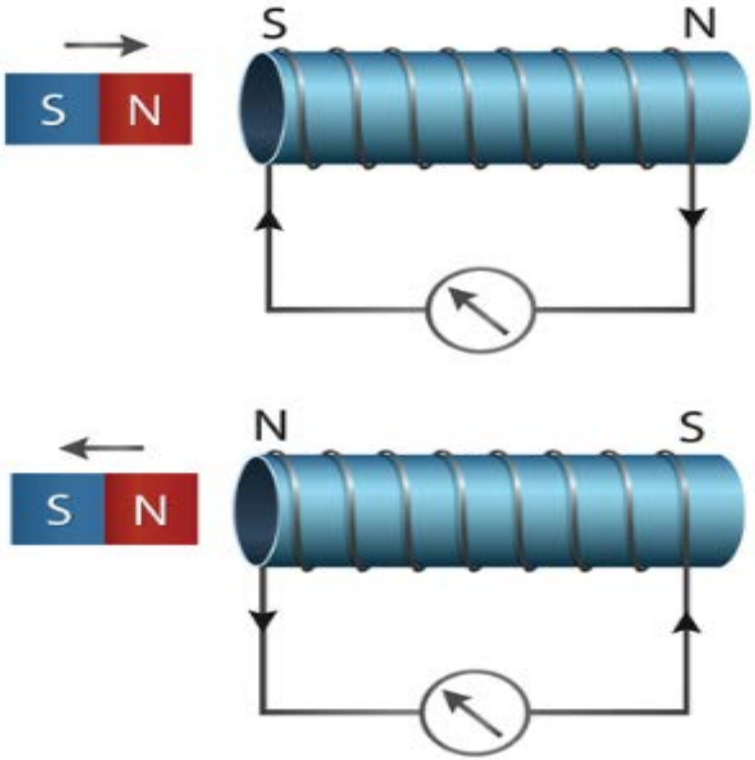


Wholesale Power Services

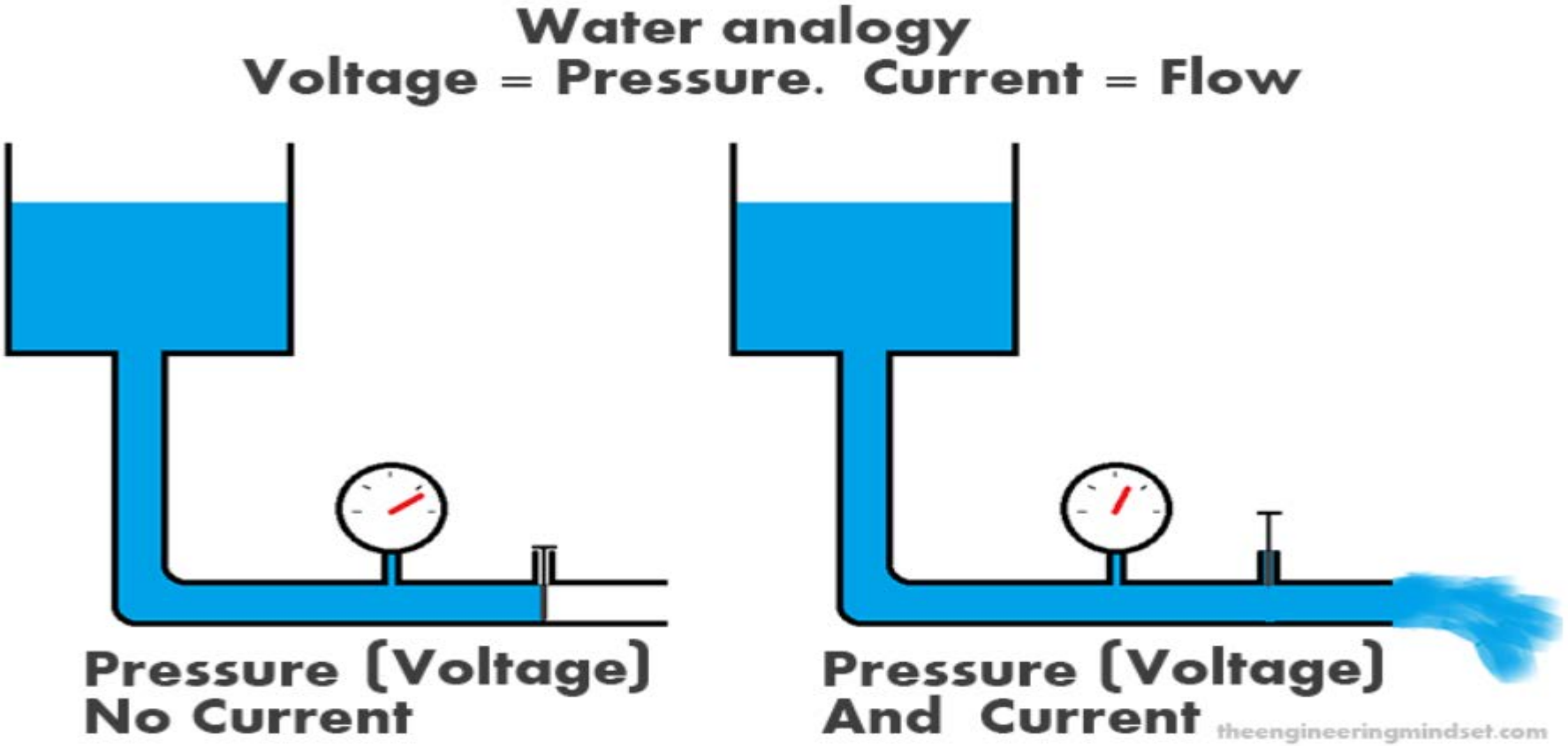
- Markets 10,479 MW from 56 Federal hydropower projects owned by Bureau of Reclamation (BOR) , Army Corps of Engineers and International Boundary and Water Commission (IB&WC)
- 16,800 miles of high-voltage transmission line across 15 states

How is Electricity Created

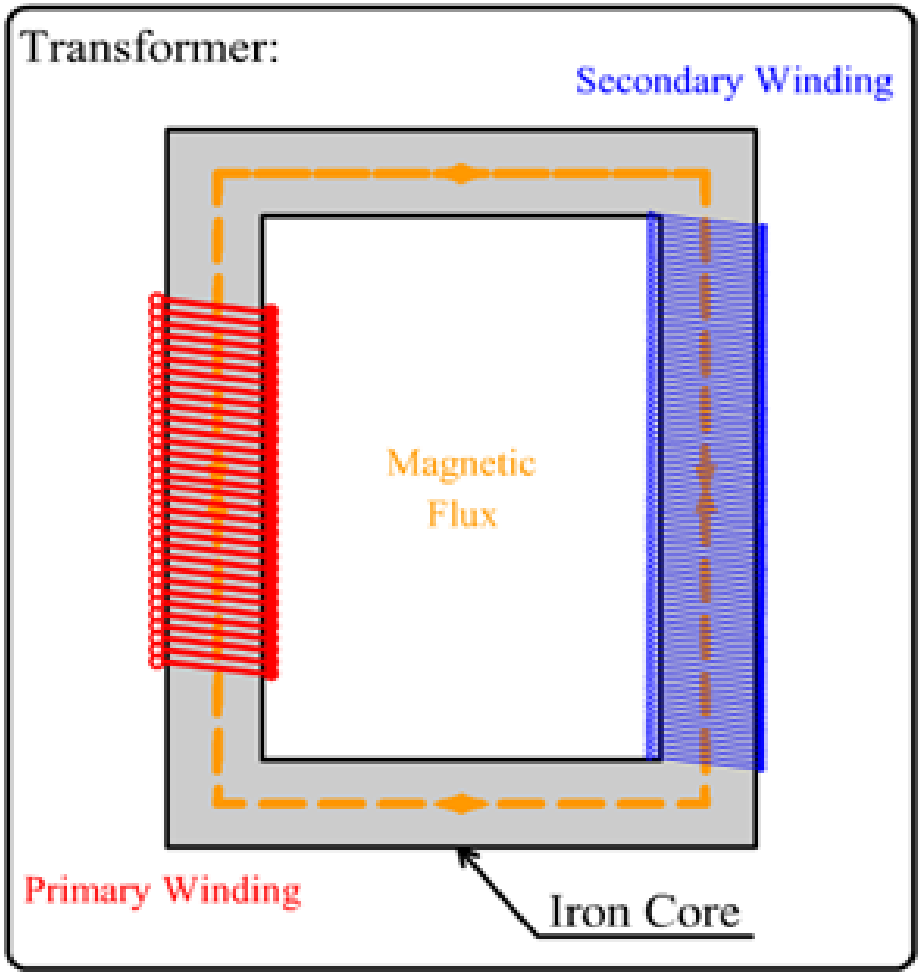




What is Current and Voltage



Transformers



Basic construction

- Two or more coils of wire wrapped around an iron core.
- A variation of an inductor, utilizes the magnetic field to transmit power to different voltage levels.

Transformer Operation

Primary Winding:

Ratings:

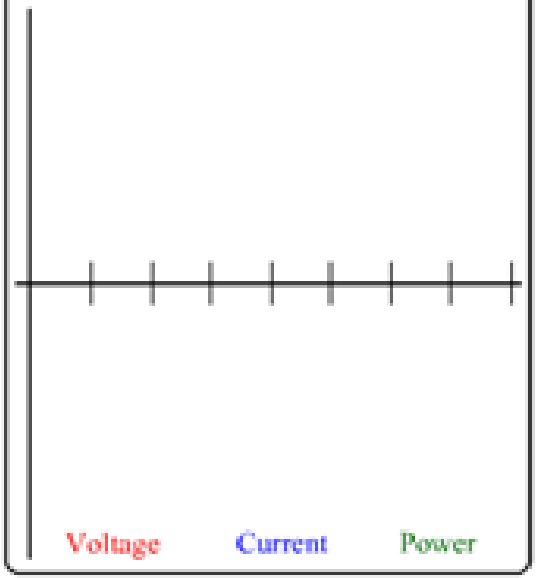
Power = 10 MVA

Voltage = 11.5 kv

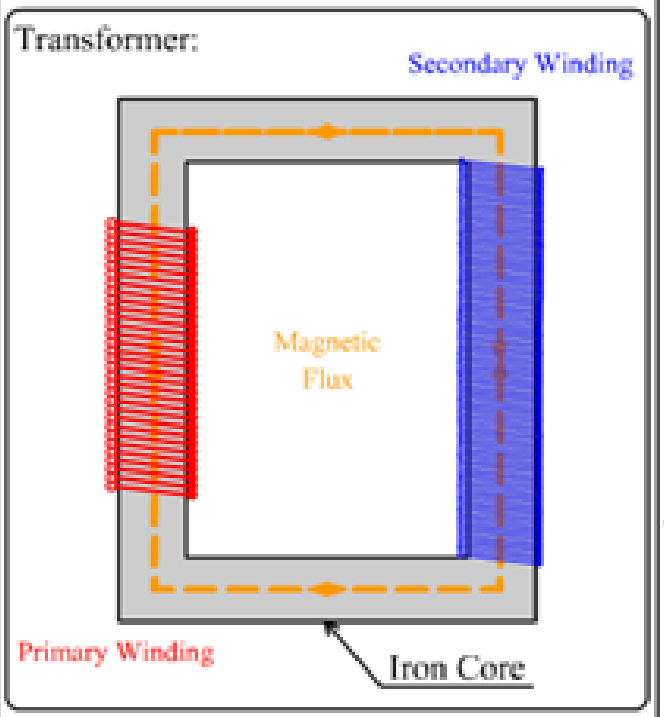
Current = 870 A

Number of Windings = 23,000

Waveform:



Transformer:



Secondary Winding:

Ratings:

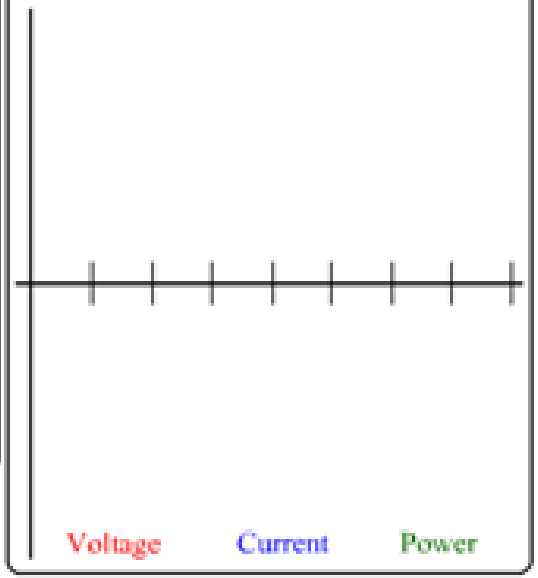
Power = 10 MVA

Voltage = 115 kv

Current = 87 A

Number of Windings = 230,000

Waveform:



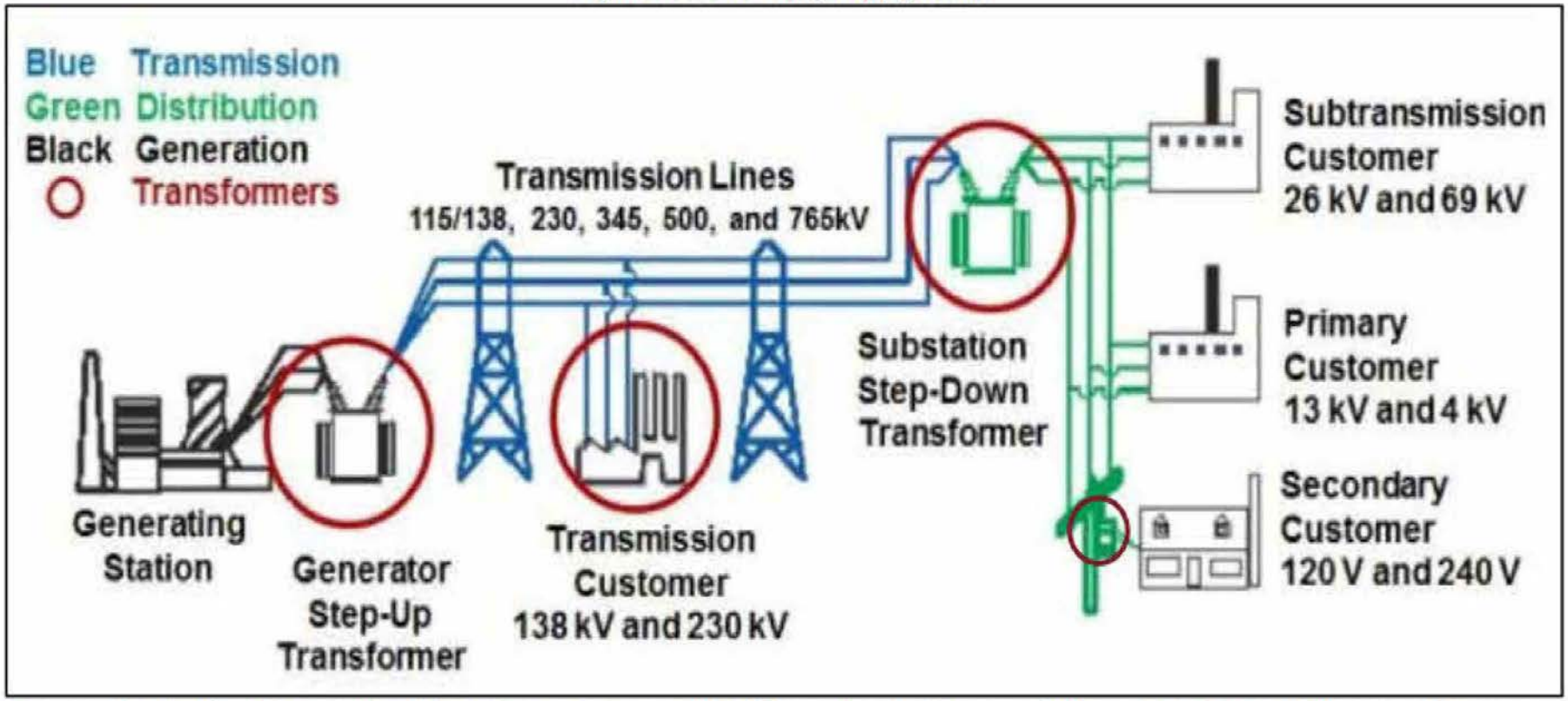
Substations and Transformers

- Major Equipment
  - Transformers: Transform voltage levels
  - Circuit Breakers: Isolate faults (disturbances) from the rest of the system
  - Disconnect Switches: Permit a circuit element to be safely disconnected and isolated from the system for maintenance or repair
  - Lightning Protection: Limit damaging transient voltage conditions
  - Instrumentation: Provide data needed to monitor the overall system and control the flow of power

Photo by Ravel F. Ammerman, NREL

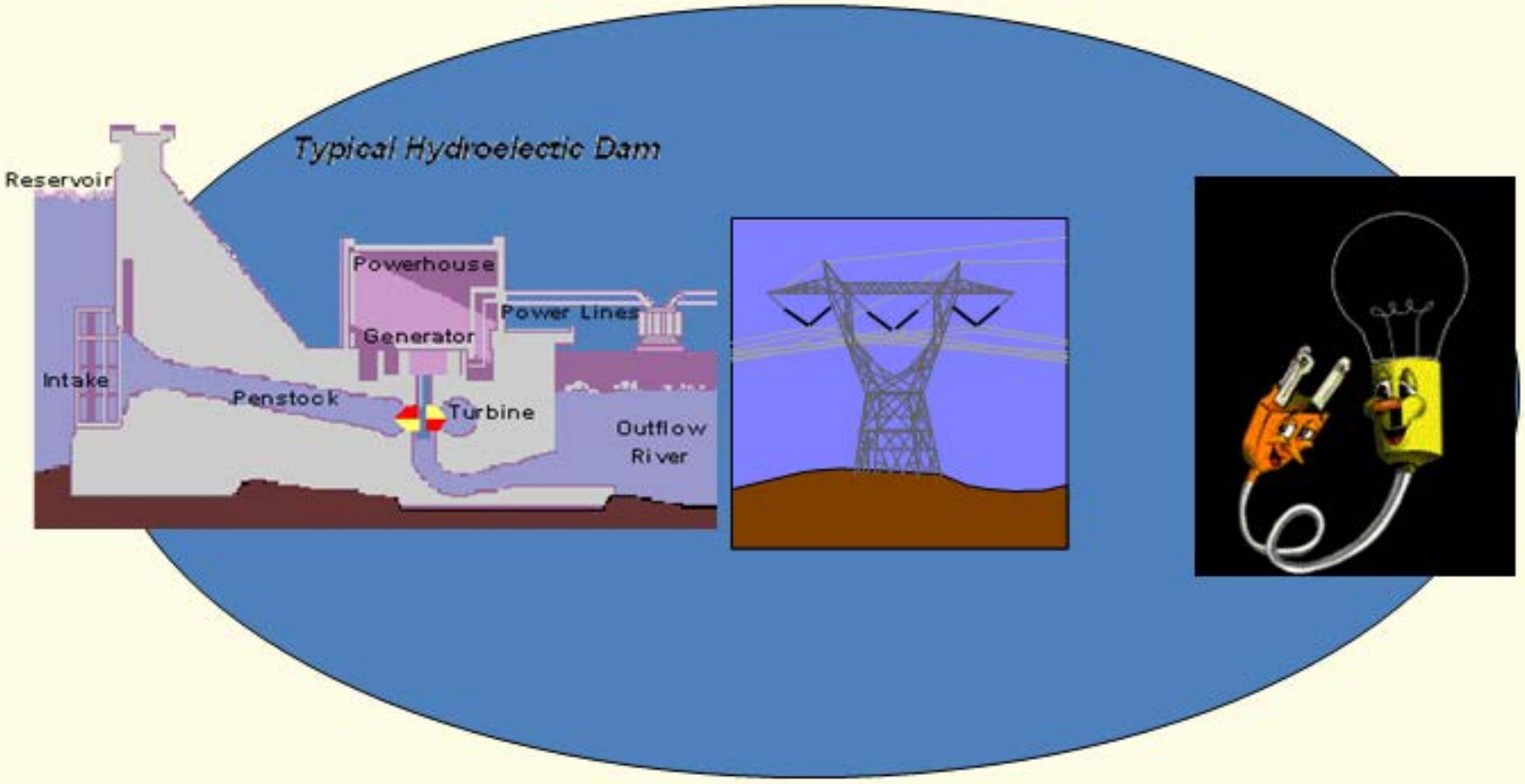
Power System Transformers

Figure 12: Electricity Supply Chain

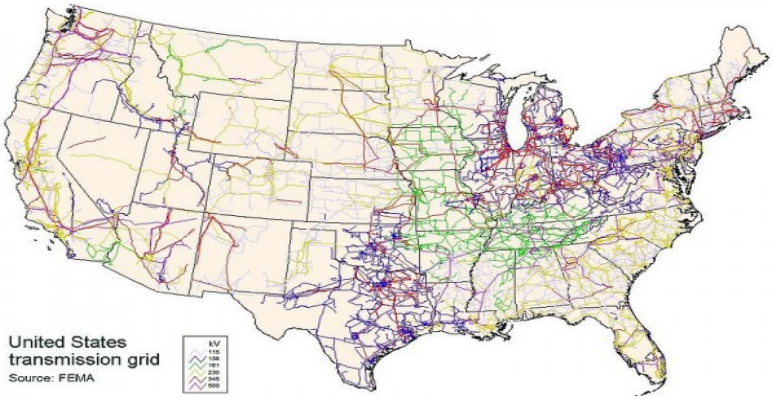


Source: U.S. Federal Energy Regulatory Commission and U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability

Hydro Generation System



Electrical Transmission System



69 kV

345 kV

230 kV

Source: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/transmission_lines.html

Transmission Voltage Levels

Transmission
- 230 kilovolt (kV)
- 345 kV
- 500 kV
- 765 kV
- 1,000 kV and above

Sub-transmission
- 69 kV
- 115 kV
- 138 kV

Differences: Transmission vs. Distribution Systems

- Size and scale
- Operation is fundamentally different
  - –Transmission system is operated actively
  - –Distribution system is operated passively

Distribution Voltage Levels

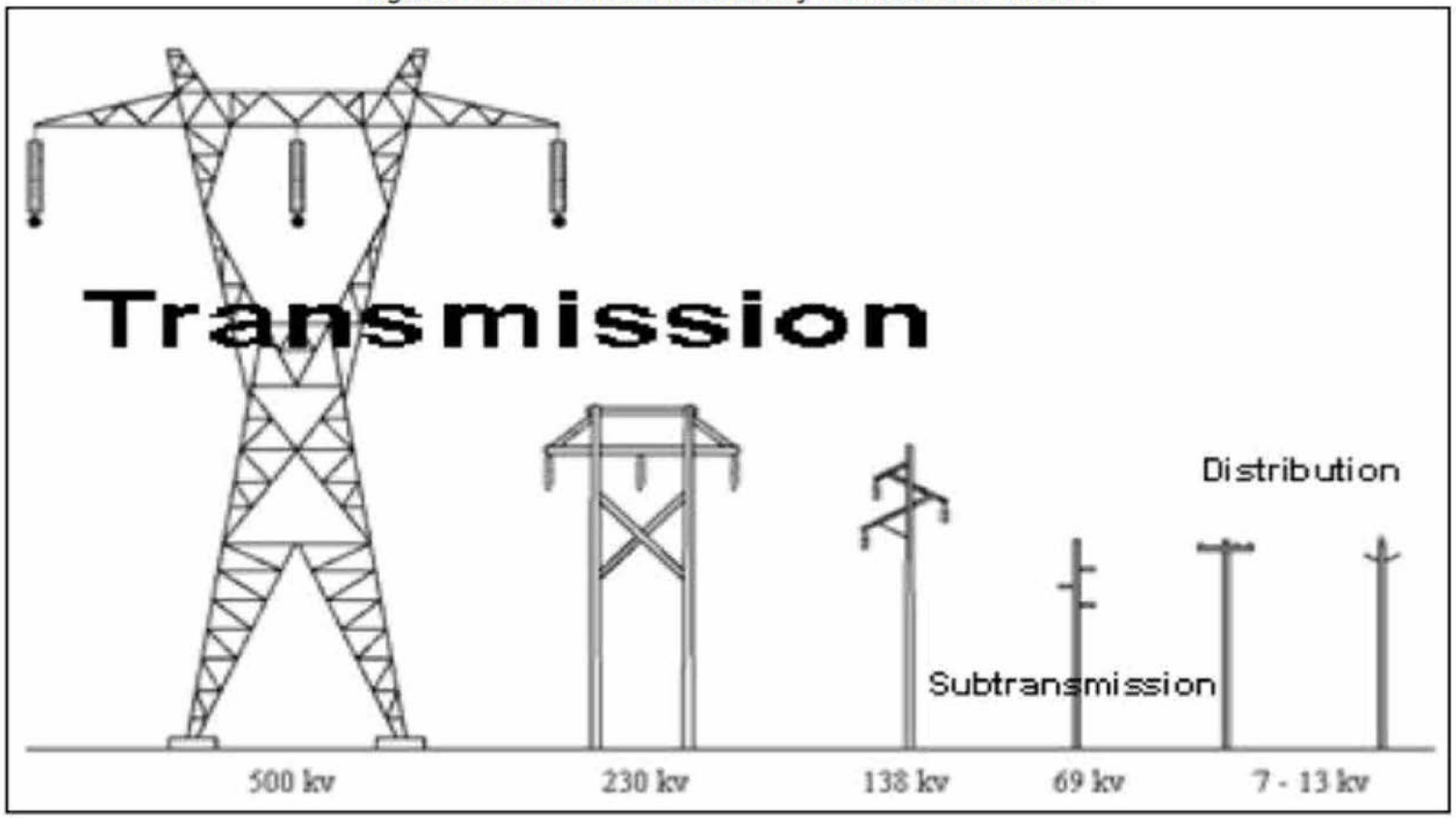
Medium Voltage
4.16 kV
6.9 kV
13.2 kV
25 kV
34.5 kV
46 kV

Low Voltage
480 volt (V)
120/240 V (single-phase)

Photo by Mike Coddington, NREL

Transmission & Distribution Lines

Figure 14: Structural Variations of Transmission Towers

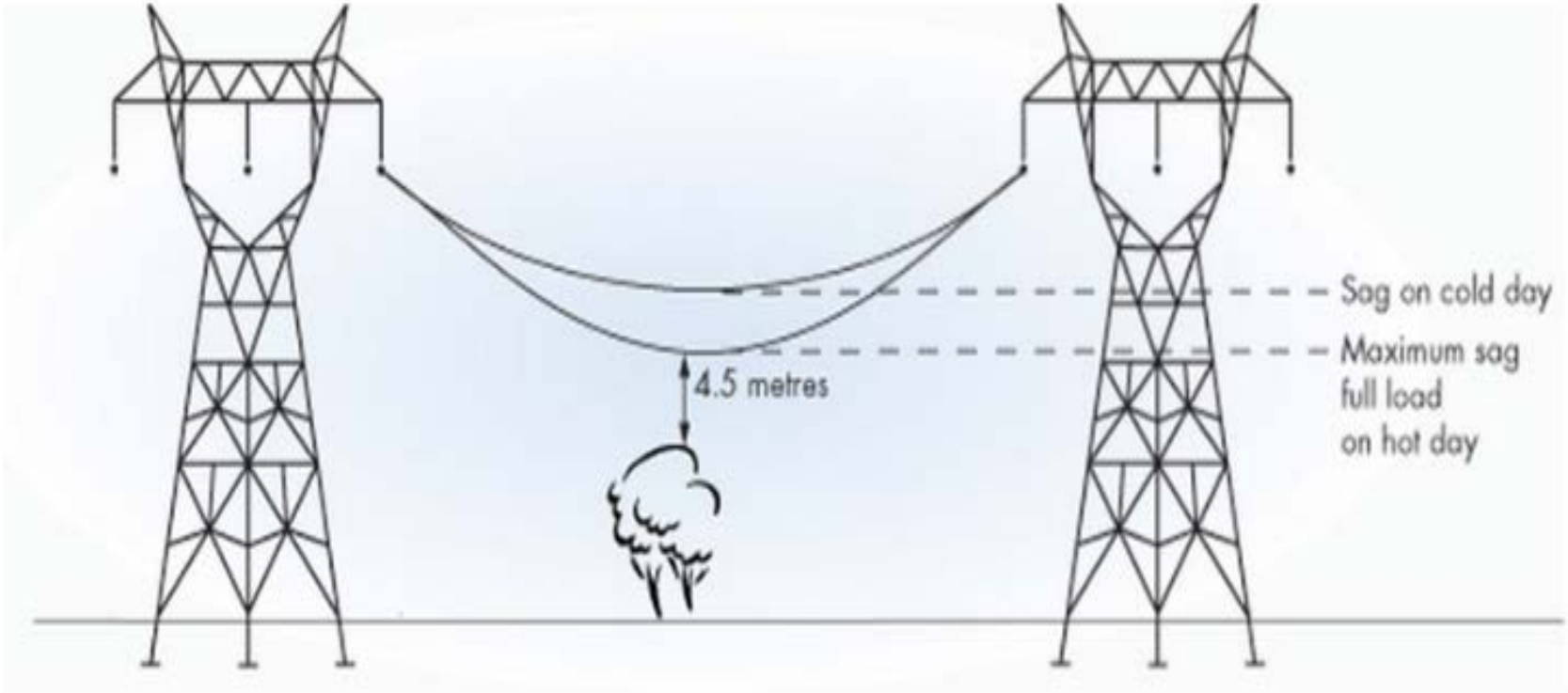


Source: U.S. Department of Labor, OSHA

Transmission Line Thermal Ratings

- Transmission lines may have more than one thermal rating.
- A Continuous rating would indicate the maximum flow that can be carried under normal conditions.
- Emergency ratings for a predetermined period of time may be supplied.
- Ratings will be affected by ambient temperatures and conditions.

Transmission Line Thermal Ratings



How is Electricity Measured?

- Electricity is measured in terms of watts, typically in kilowatts (1,000 watts) or megawatts (1,000 kilowatts). One MW is enough capacity to instantaneously light approximately 750 – 1000 homes.

- A kilowatt (or megawatt) is the amount of energy used, generated or transmitted at a point in time. The aggregation of megawatts possible at a point in time for a power plant, for example, is its capacity. The aggregation of kilowatts used at a point of time is the demand at that point.

How is Electricity Measured?

- One kilowatt of energy consumed over an hour is called a kilowatt-hour (or kWh). Meters measure the kWh usage over a month. Billing rates are established as ¢/kWh.

- One megawatt generated, delivered, or consumed over an hour at the wholesale level is called a megawatt-hour (or MWh). Wholesale transactions are priced at $/MWh.

Electricity is Unique

- Is generated and consumed at nearly the same time
- Storage has been impractical on a broad scale although that's beginning to change
- Requires an extensive delivery infrastructure (Bulk Electric System)

Balancing Generation and Load

Maintaining a reliable grid requires a constant balancing between generation (supply) and load (demand)

U.S. Power Generation Mix

Figure 3: U.S. Power Generation by Fuel Type in 2014

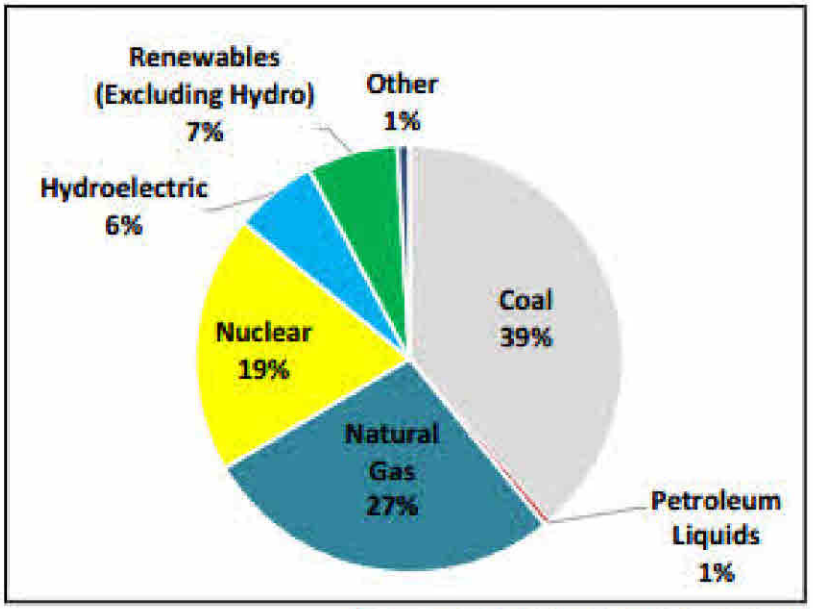
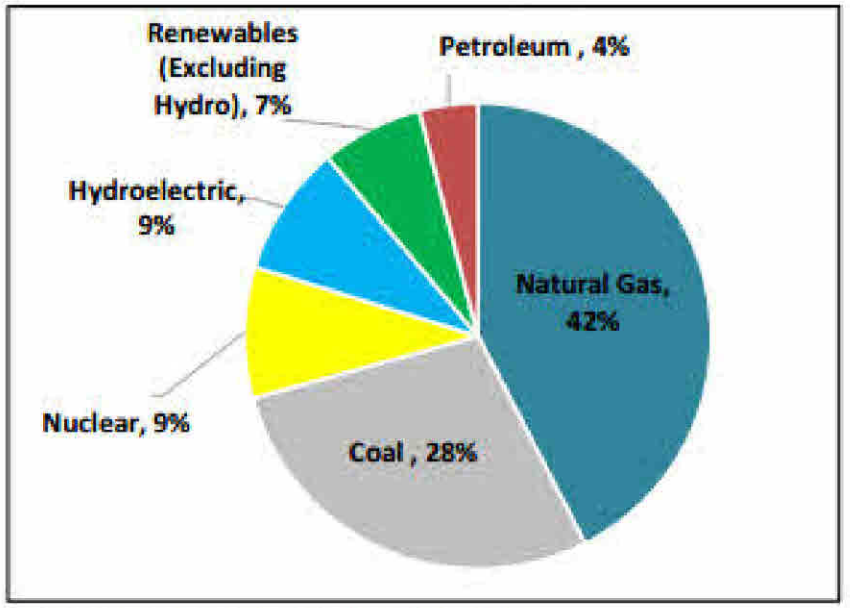


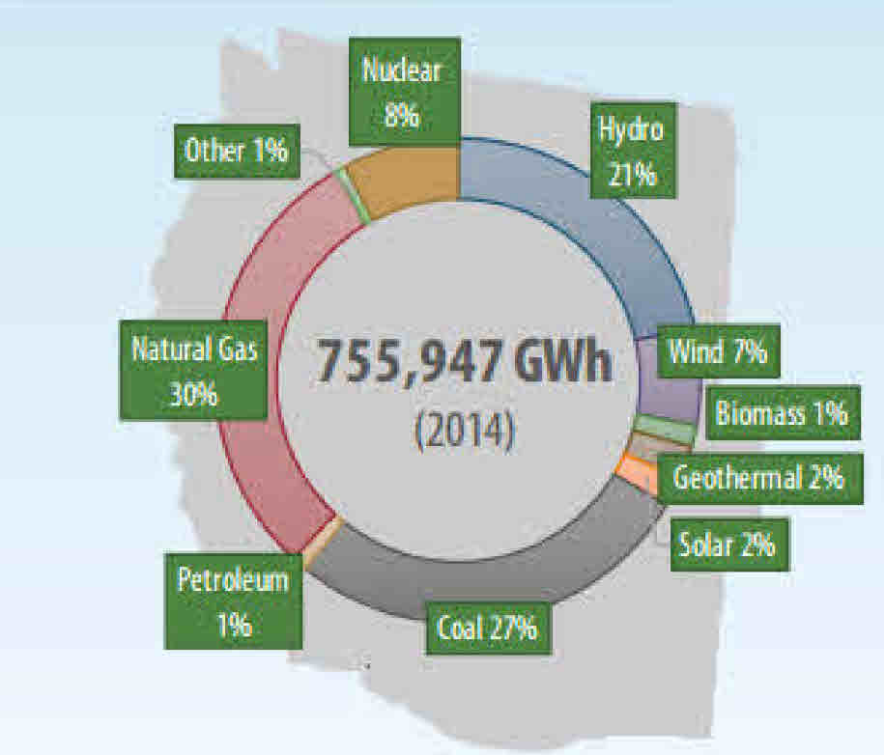
Figure 4: U.S. Generation Capacity in 2013



Sources: U.S. Department of Energy, Energy Information Administration (EIA)

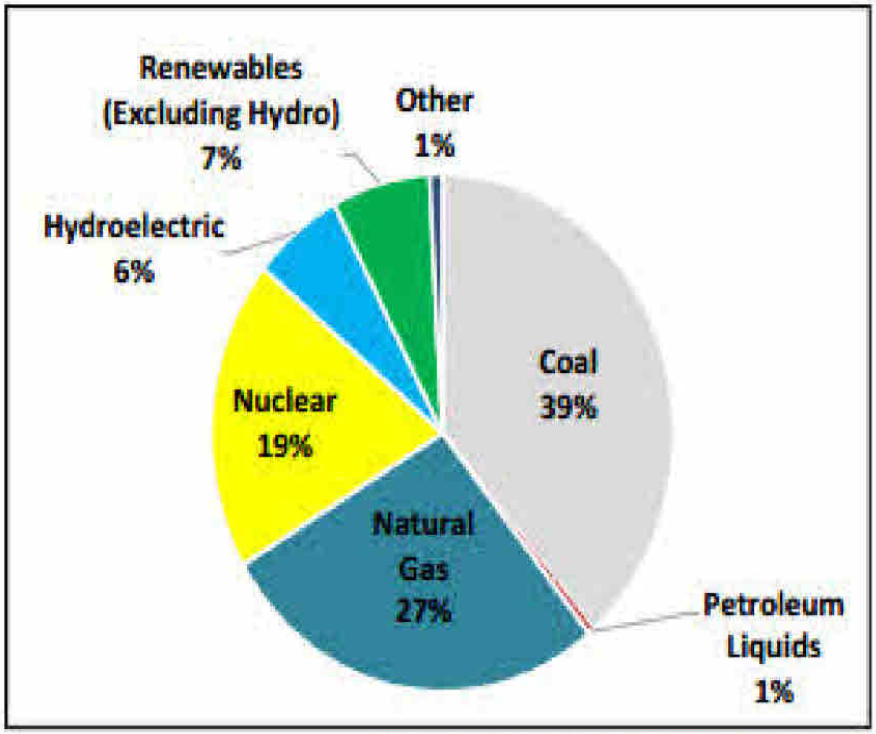
Figure 2: Conceptual Flow Chart of the Electricity Supply Chain

Power Generation in the West



Source: ACORE

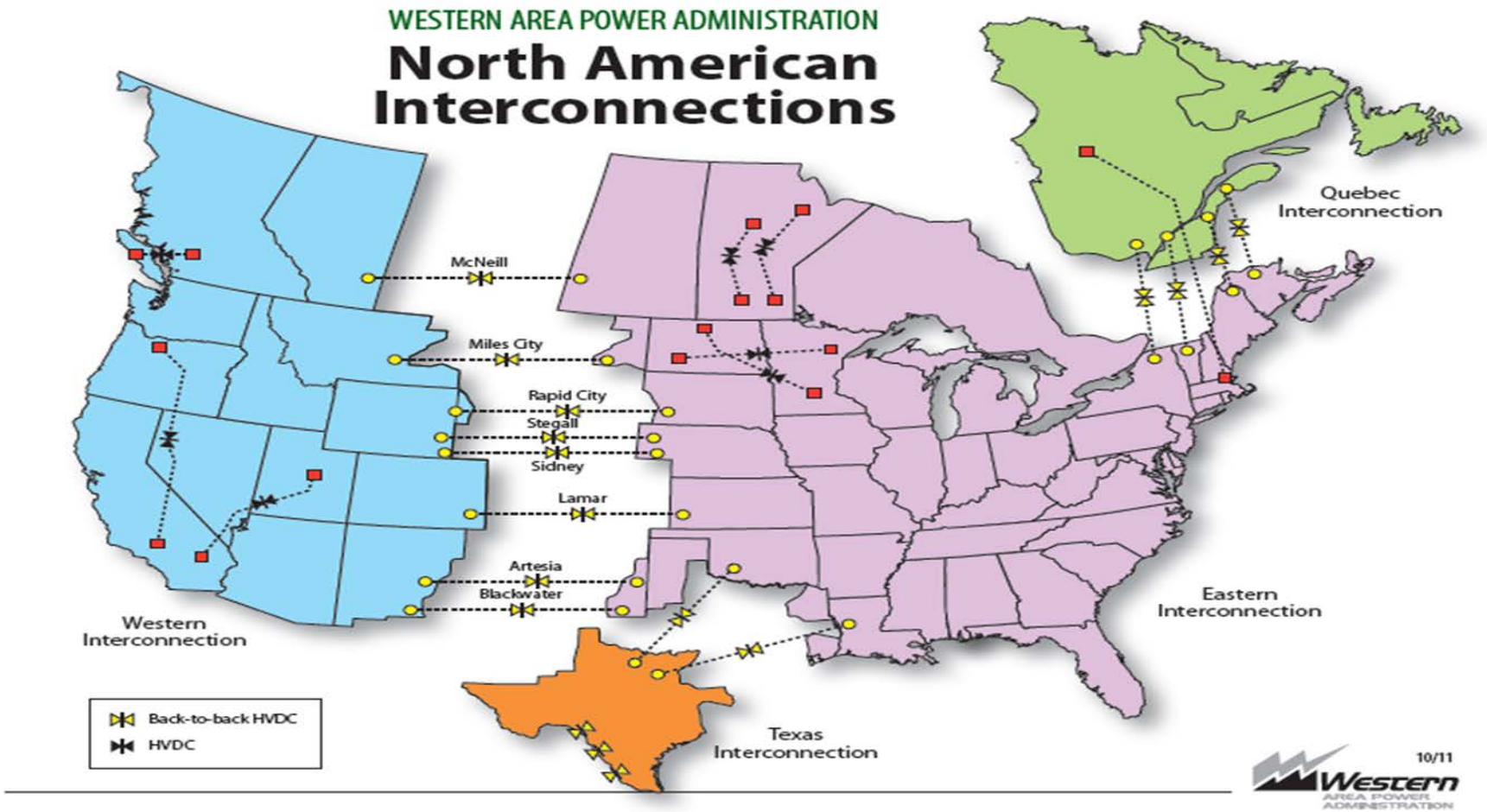
Generation in the Western U.S. AK, AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY



Source: U.S. Department of Energy

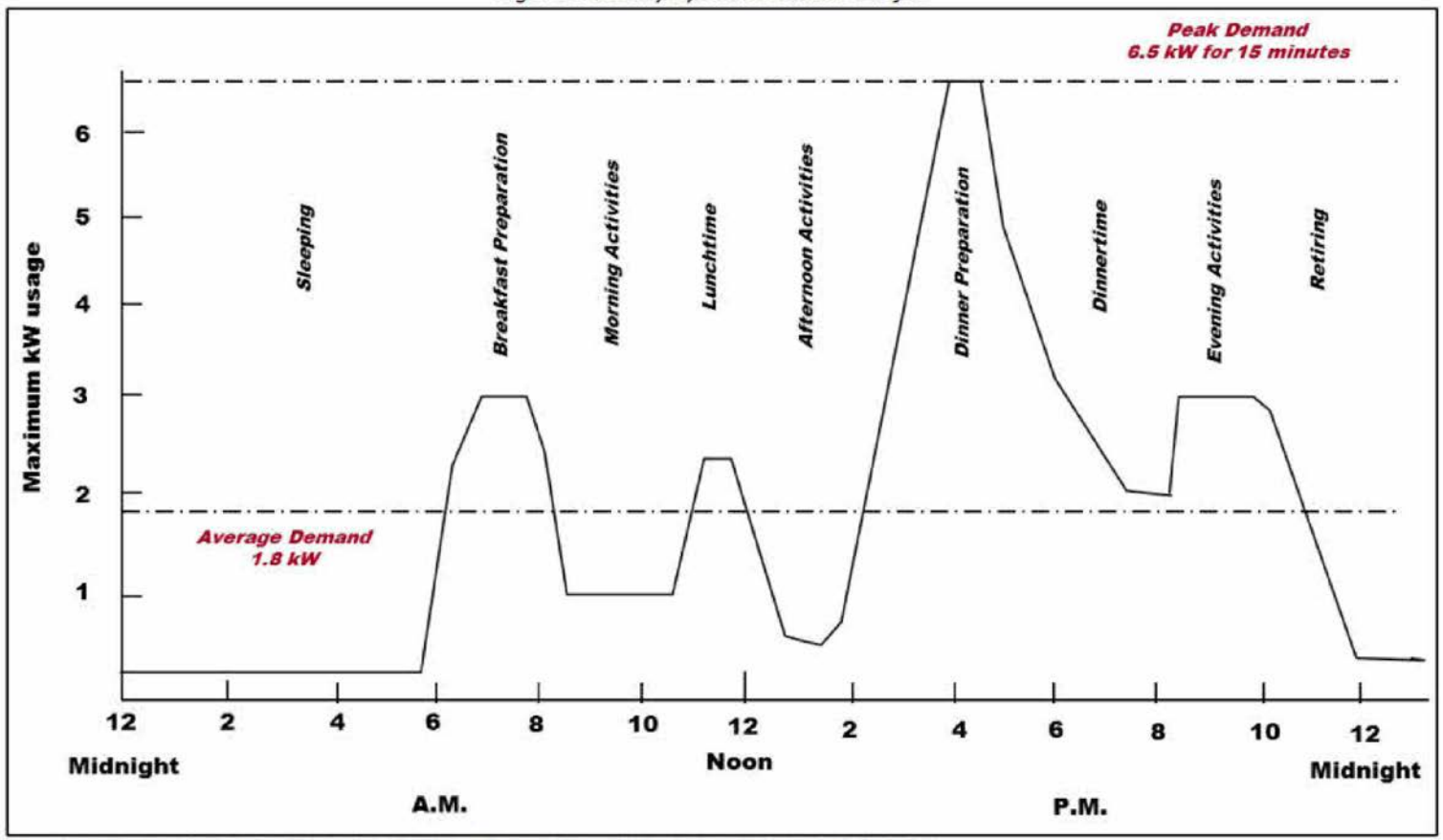
United States Generation Mix

Transmission and the Grid



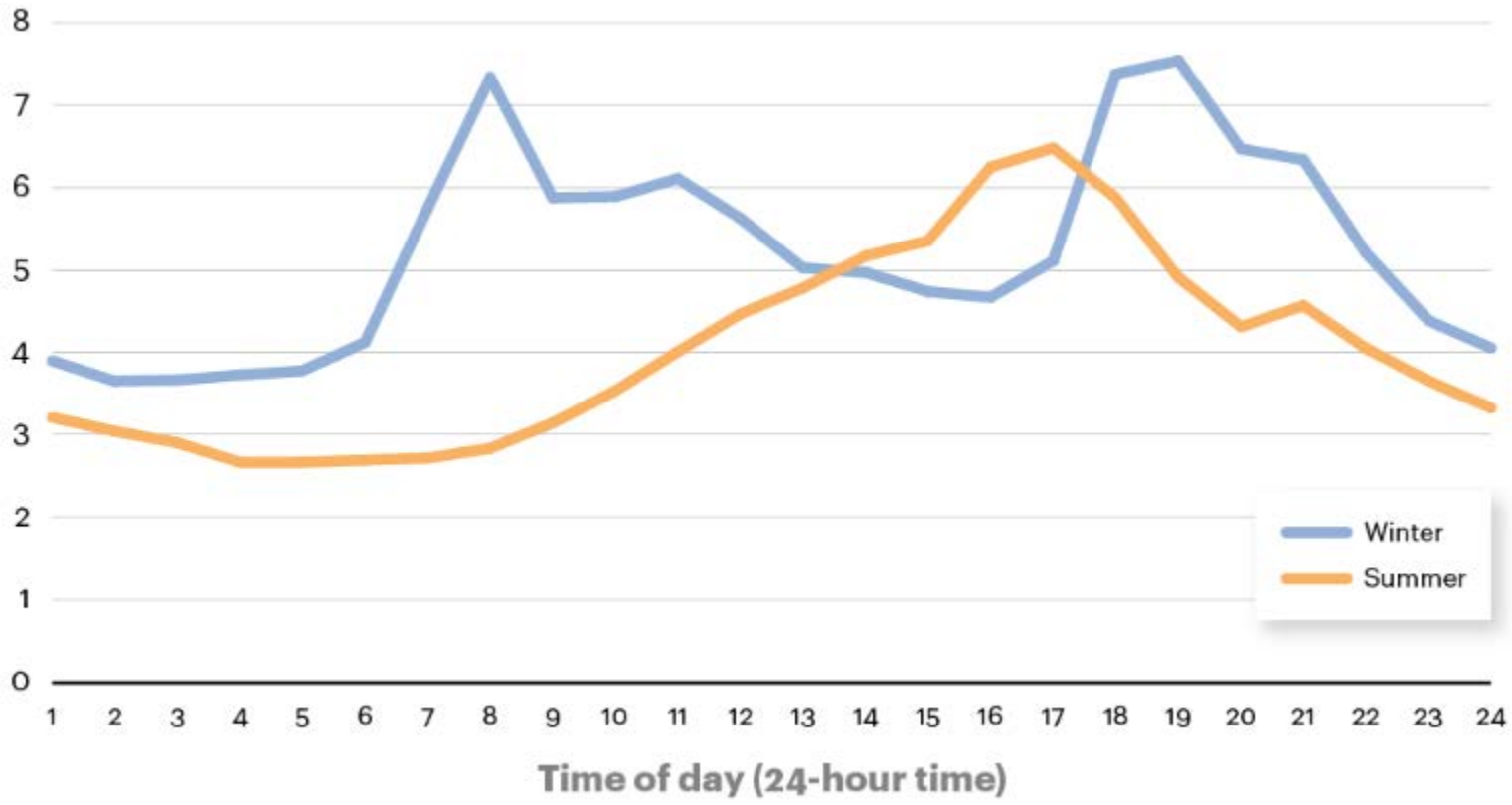
Power Flow on the BES

Figure 11: Daily System Demand Profile

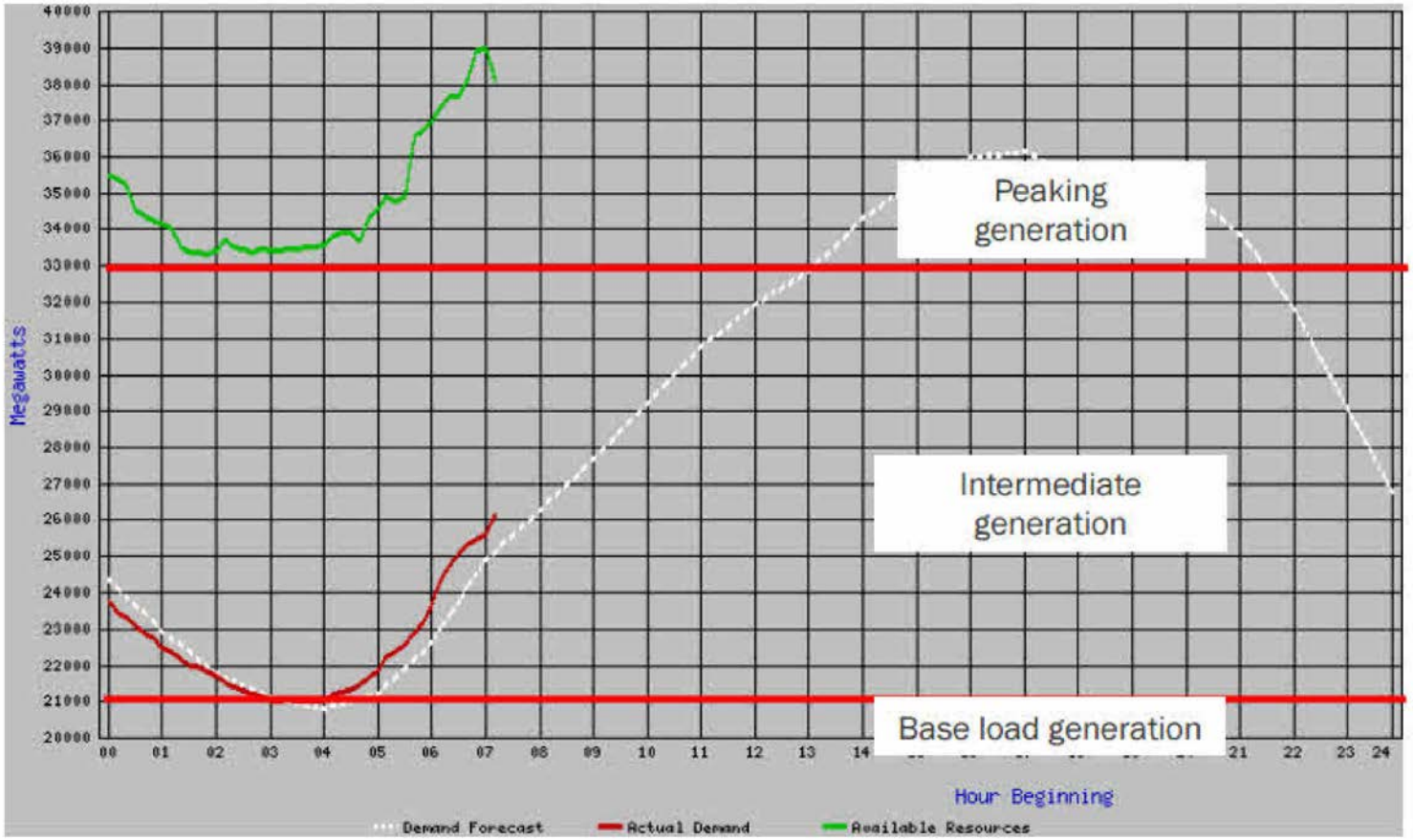


Source: U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability

Seasonal Power Flow on the BES



Daily Demand Curve and Generation Mix



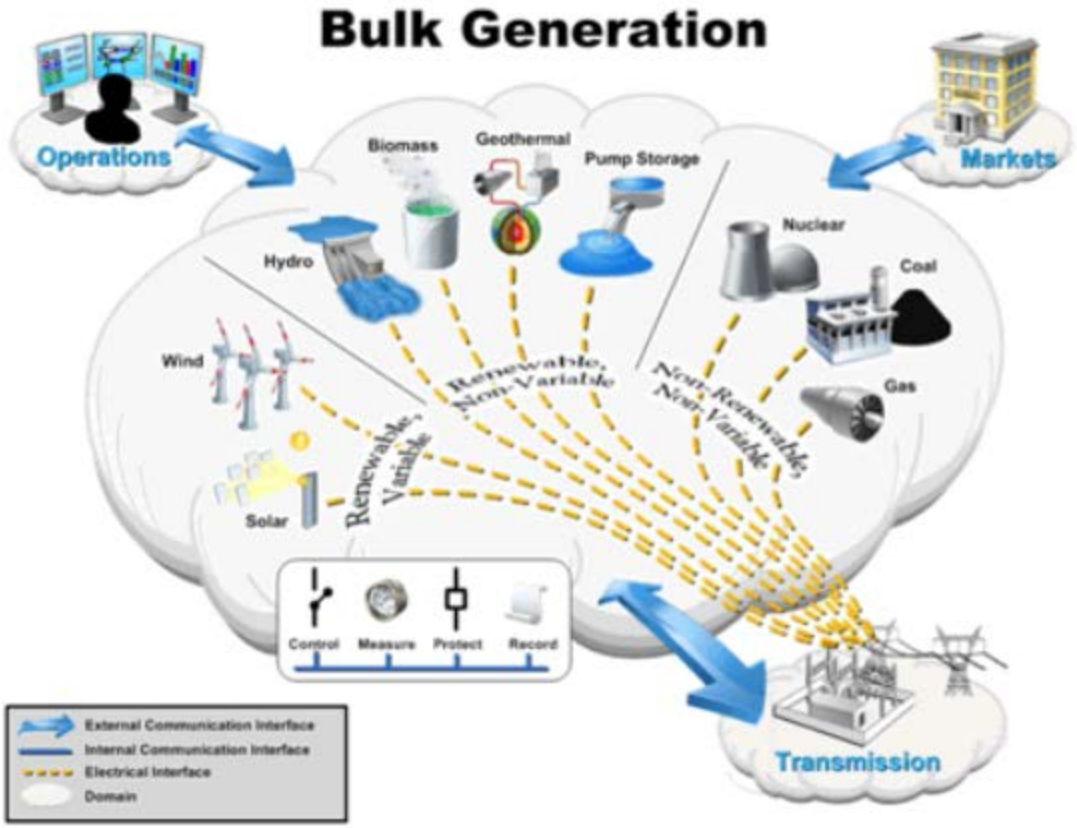
Source: California ISO (http://www.caiso.com/Pages/TodaysOutlook.aspx)

Generation Energy and Capacity

- Dispatchable
  - Conventional generation sources
  - Energy is inherently stored within source of fuel
  - Use when needed
- Non-Dispatchable
  - Renewable energy resources (wind and solar)
  - Characterized by variability and uncertainty
  - Energy source must be used when available

Source: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/index.html

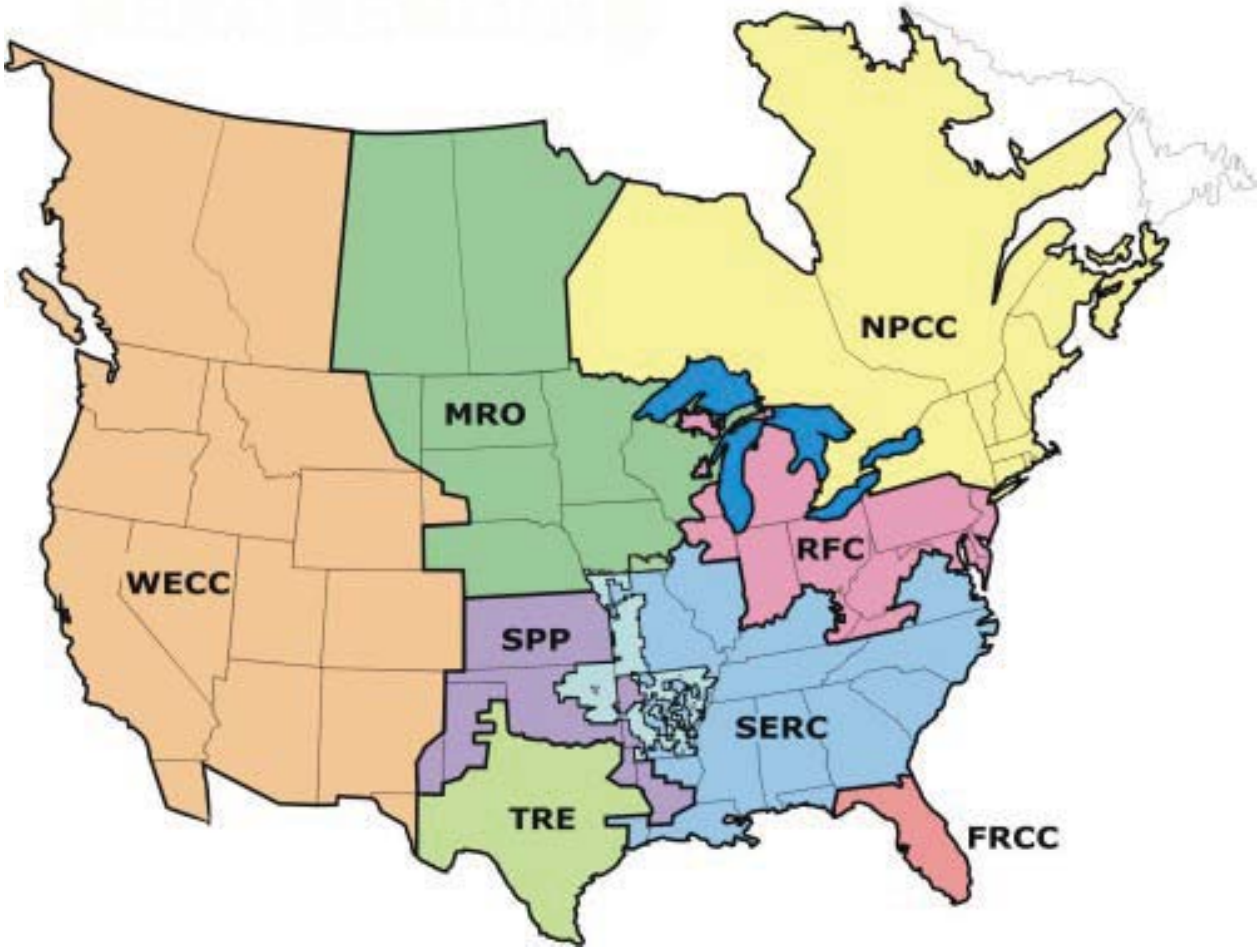
Generation Energy and Capacity



Regulation of the Interconnected Bulk Electric System (BES)

- Federal Energy Regulatory Commission (FERC) – Regulates the transmission and wholesale sale of electricity. Monitors energy markets.
- North American Electric Reliability Corporation (NERC) – Establishes reliability standards that grid operators must adhere to.
- Regional Reliability Organizations (RRO) - are the enforcement arm of NERC. They perform periodic audits of grid operators and can levy financial fines for non-compliance.

Regional Reliability Organizations

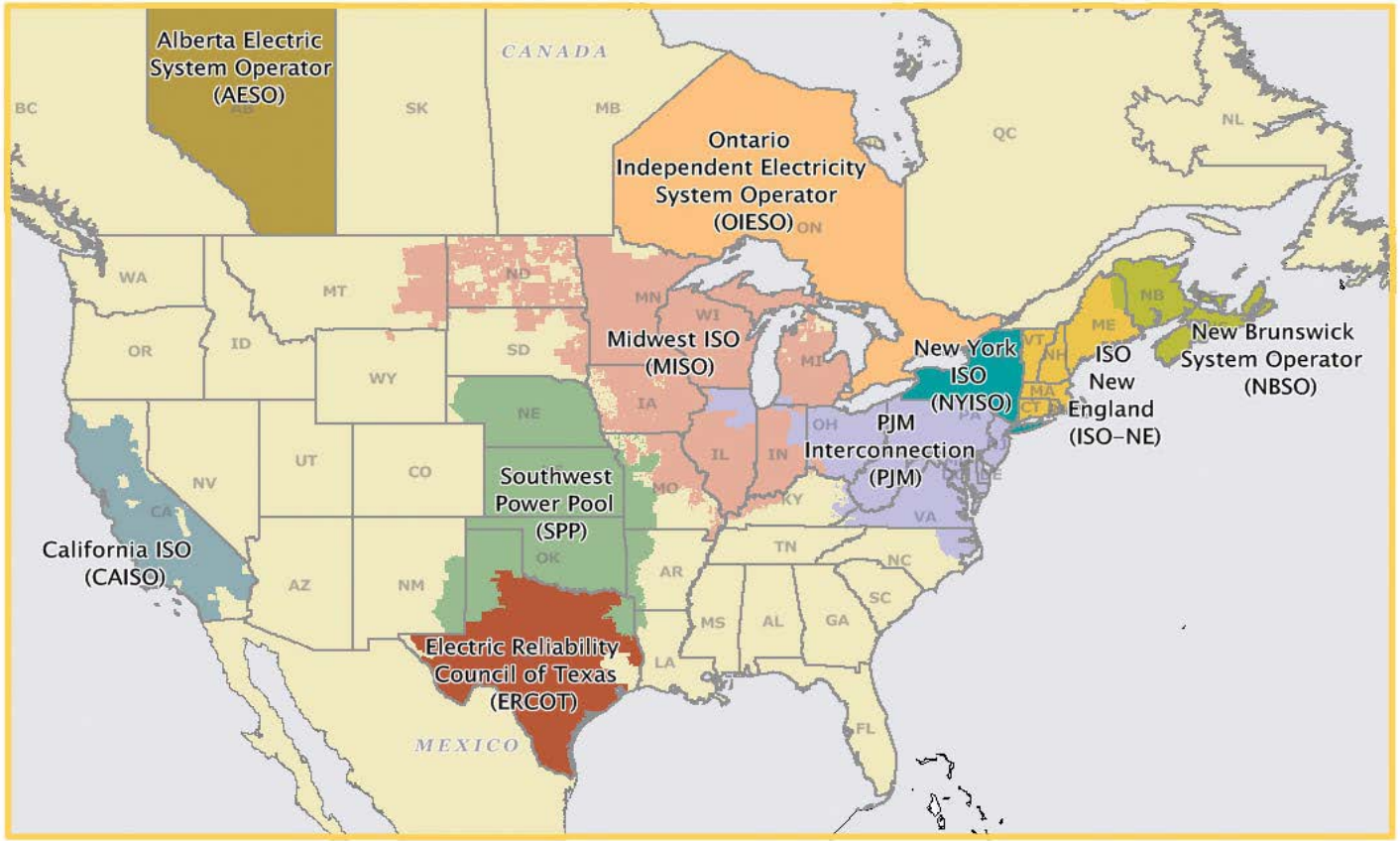


Electric Industry Regulation

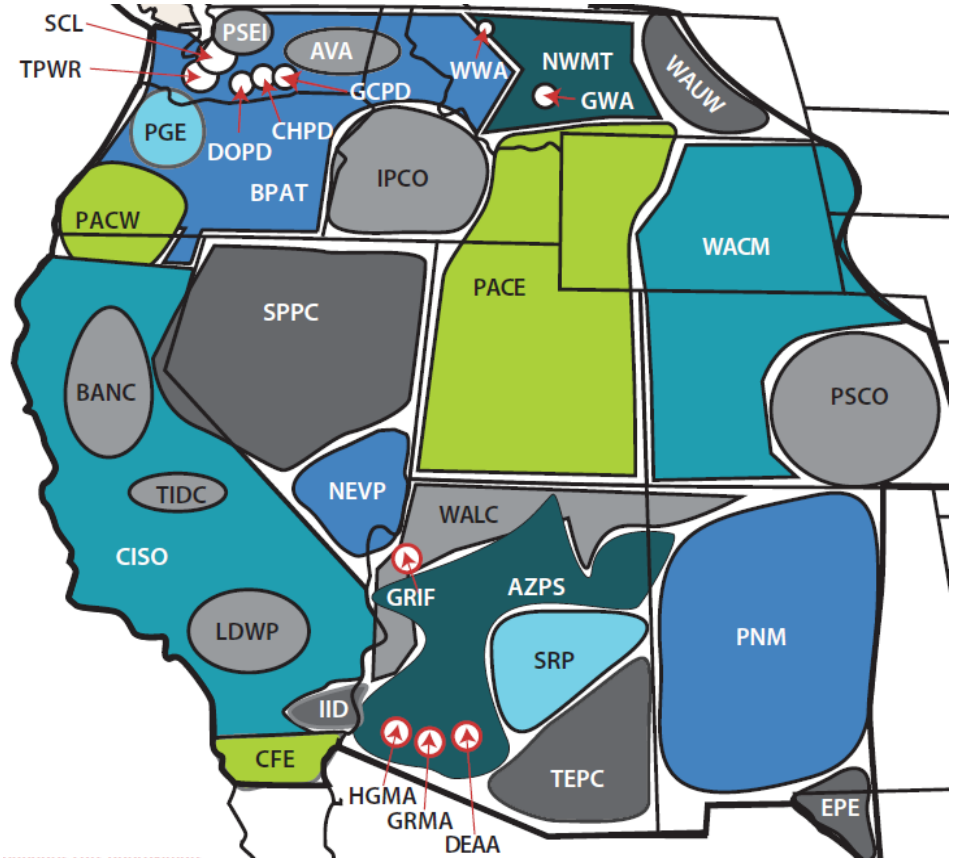
- Utility commissions and districts regulate privately and publicly owned electricity providers
  - Utilities Commission
  - Utility Regulatory Commission
  - Public Utilities Commission
  - Public Service Commission (may be civil service oversight body rather than utility regulator)
  - Public Utility District (***tribal***, state, or government owned utility, consumer owned and operated, small investor owned)
  - Publicly owned utilities include cooperative and municipal utilities
  - Cooperative utilities are owned by the customers they serve (farmers and rural communities)

RTO's in North America

North American Regional Transmission Organizations



Balancing Authority Areas in the West



Reserves

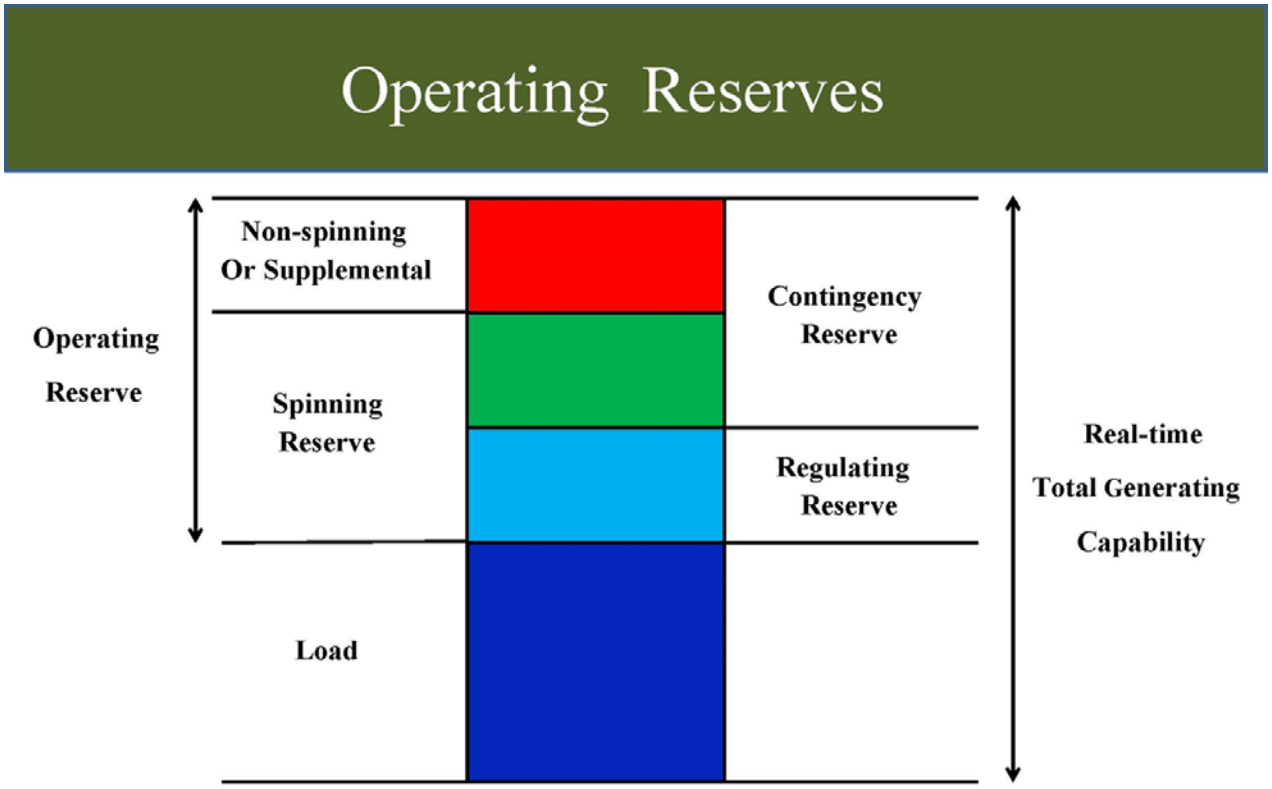


*Diagram of Reserve Generation, as Defined in NERC Glossary of Terms

Information Resources

- North American Electric Reliability Corporation Electricity Supply & Demand Database, http://www.nerc.com/pa/RAPA/ESD/Pages/default.aspx
- Office of Indian Energy, NTER Course on Electricity Grid Basics, https://nwtp.nterlearning.org/nwtp/data/nwtp/lm_data/lm_6001/338/objects/il_0_file_2189/DOE-IE_%20Foundational_Electricity_Grid_Basics.pdf
- NREL 2014 Renewable Energy Data Book, http://www.nrel.gov/docs/fy16osti/64720.pdf
- DOE Office of Electricity, Electricity Transmission, A Primer, http://energy.gov/oe/downloads/electricity-transmission-primer

Objectives Review

- Describe Western Area Power Administration Region and Facilities Overview
- Explain Fundamentals of Electricity
- Discuss Overview of the Grid

Questions?

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