EE 303 Energy Systems and Power Electronics

Energy Overview

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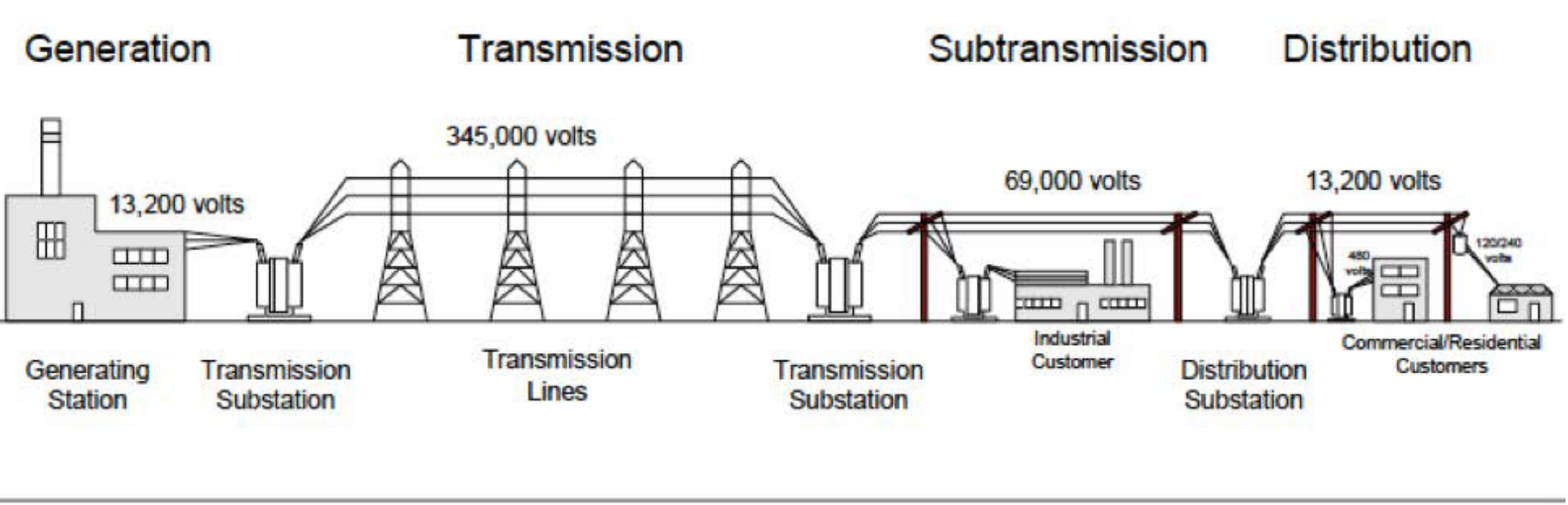
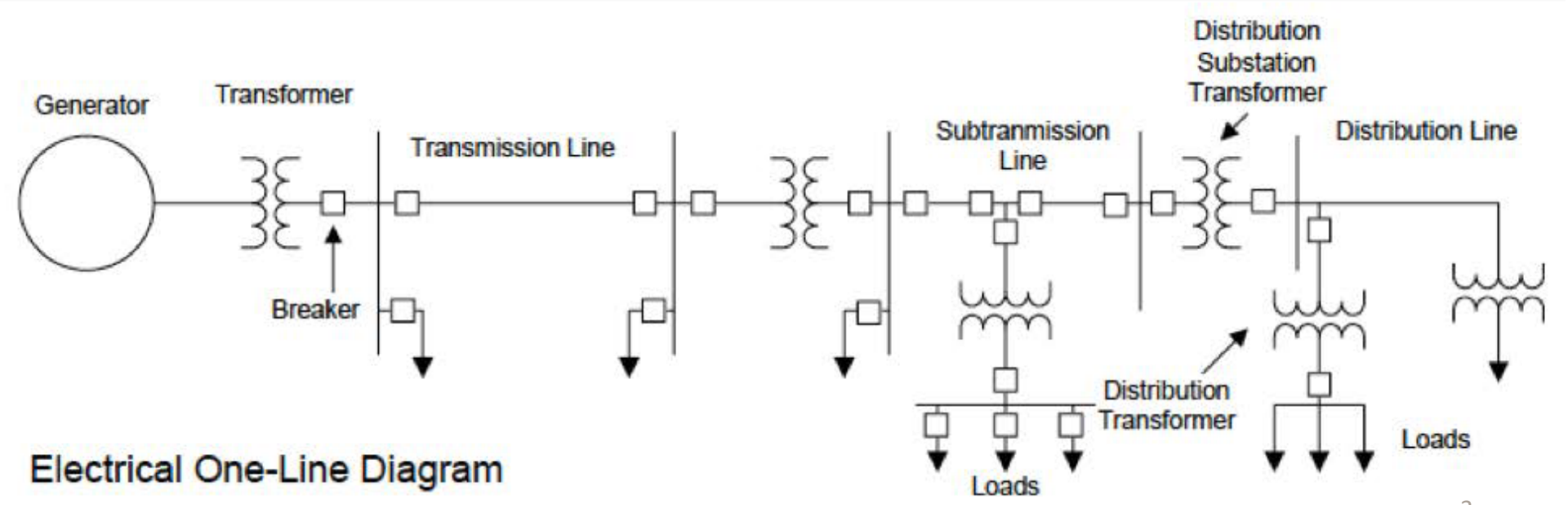
Energy Related Statistics





Electrical One-Line Diagram

Electricity Generation by Fuel – 1990-2040

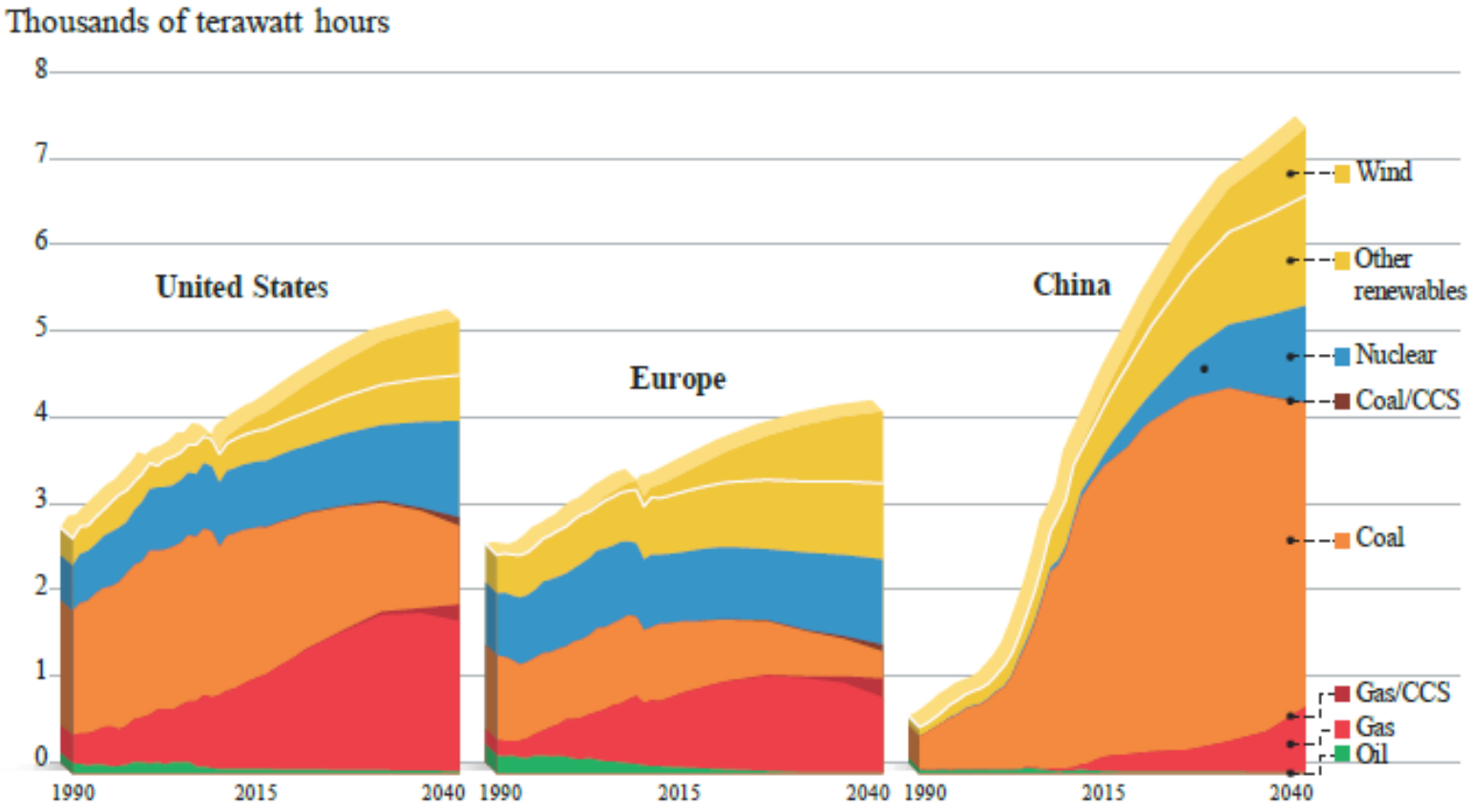
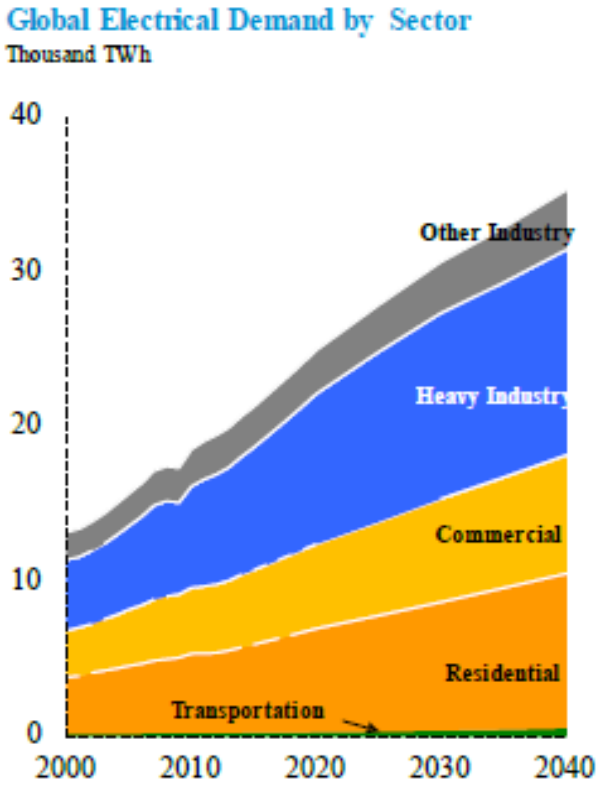
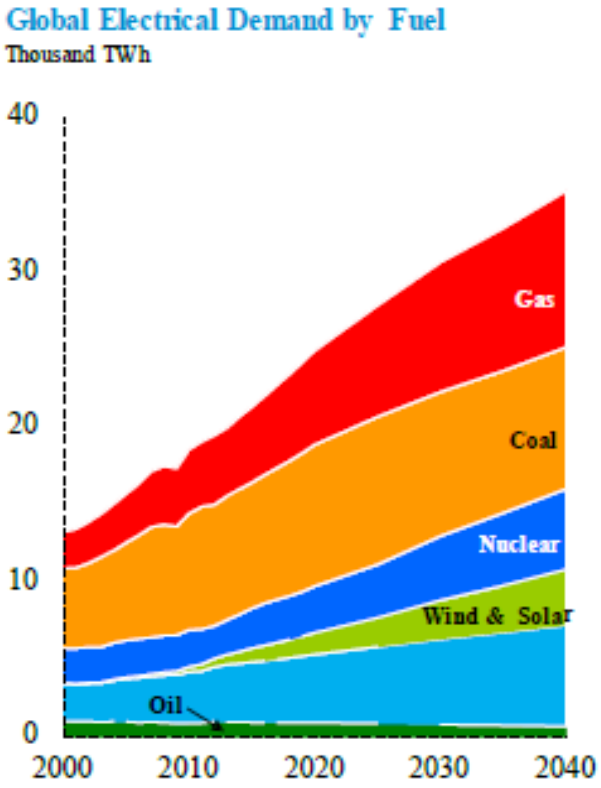


Image Source: www.exxonmobil.com

Electricity Demand by Fuel and By Sector – 2000-2040





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Electricity Use by Region

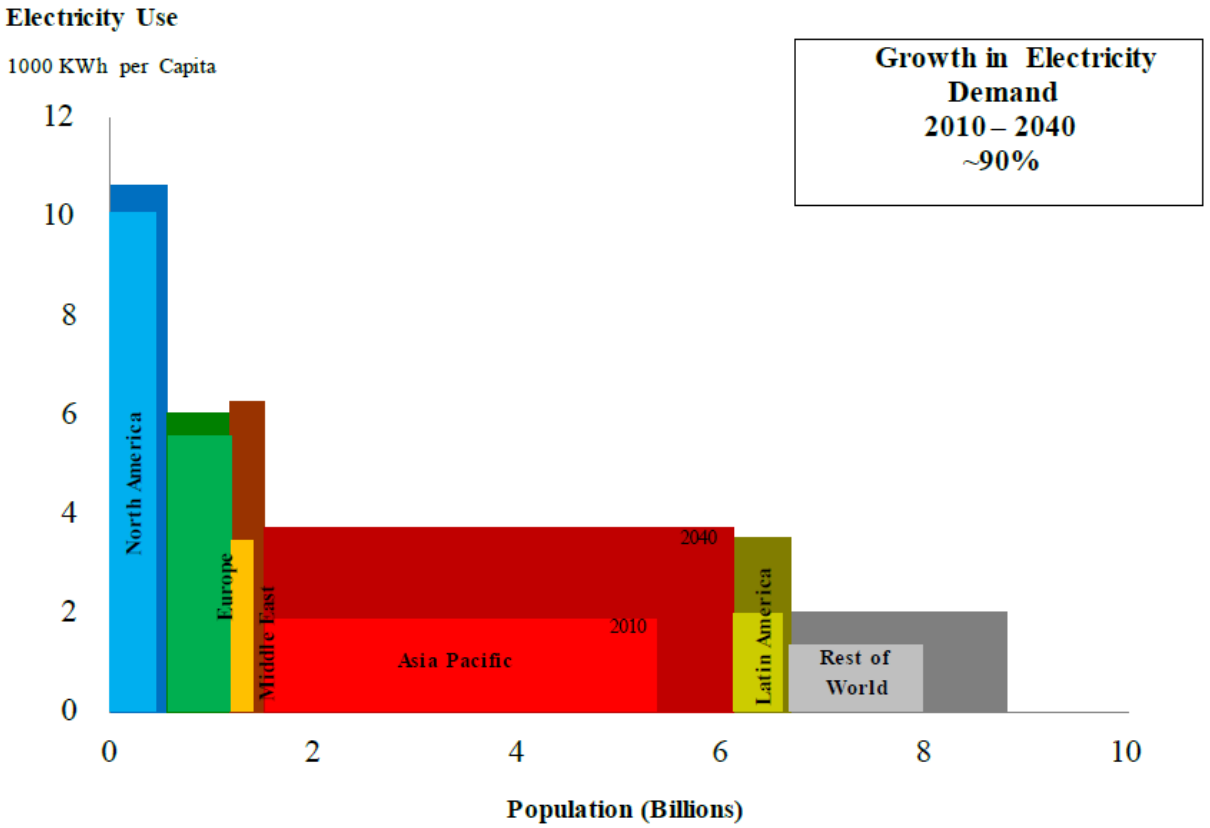

Image Source: www.exxonmobil.com

CO_2 Emission Plateau

Energy-Related CO_2 Emissions by Region

Billion Tonnes

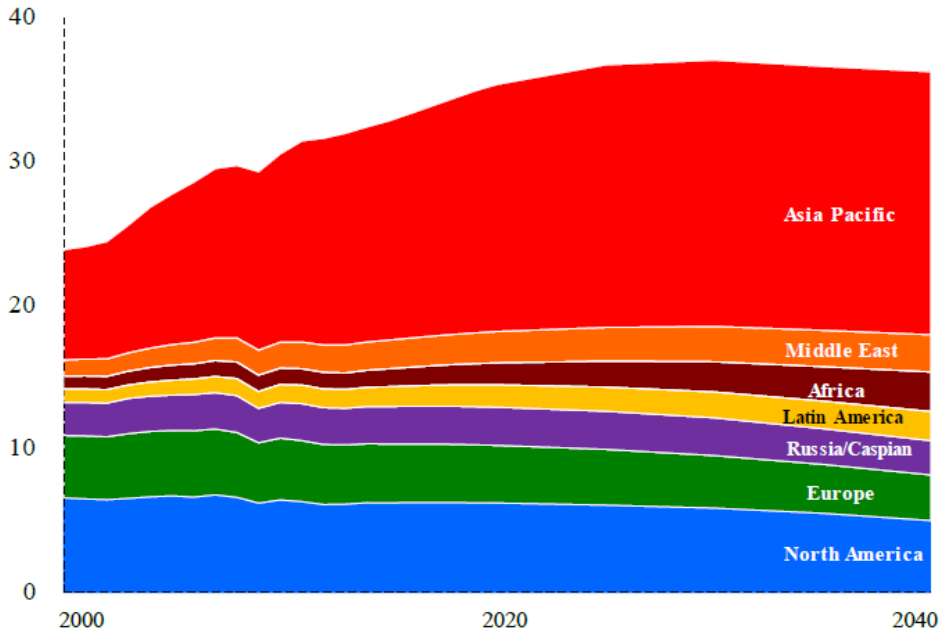

Image Source: www.exxonmobil.com

Earth Average Temperature Increase – 2011-2099

Three Scenarios:

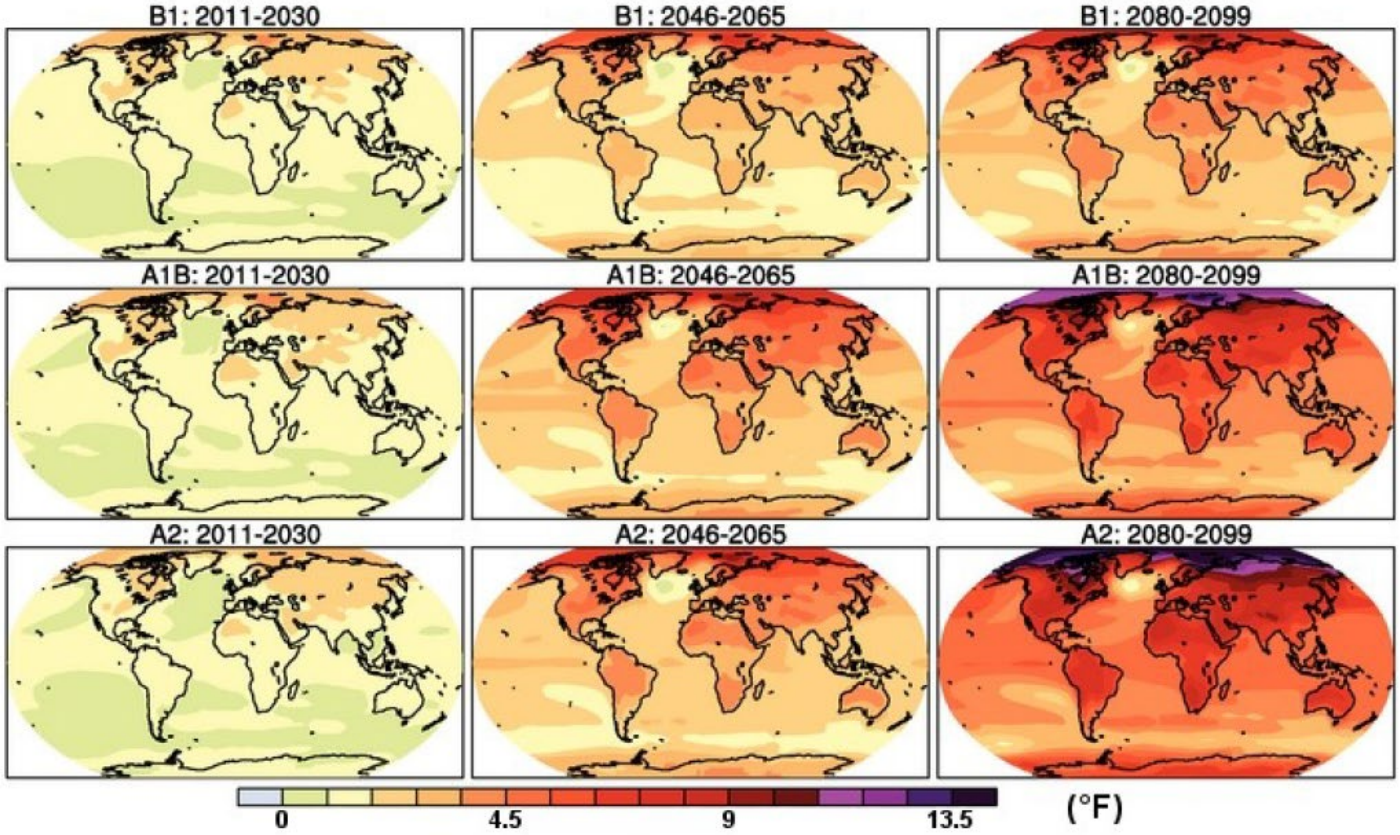

Image Source: www.epa.gov

Renewable Energies – Wind and Solar

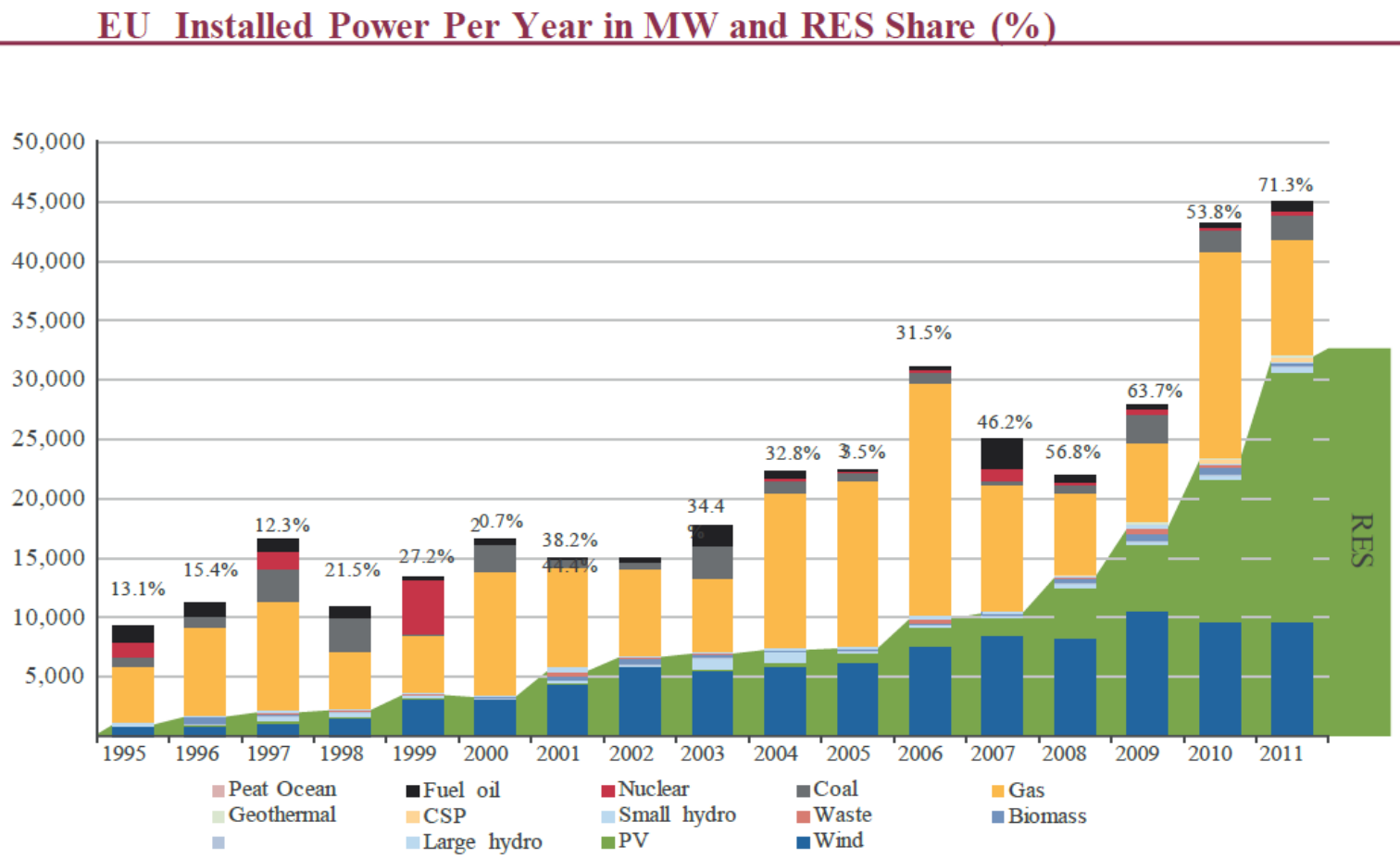

Image Source: www.ewea.org

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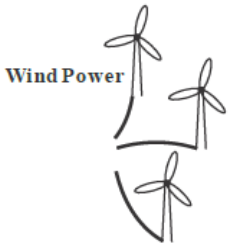
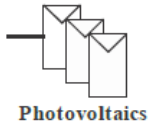
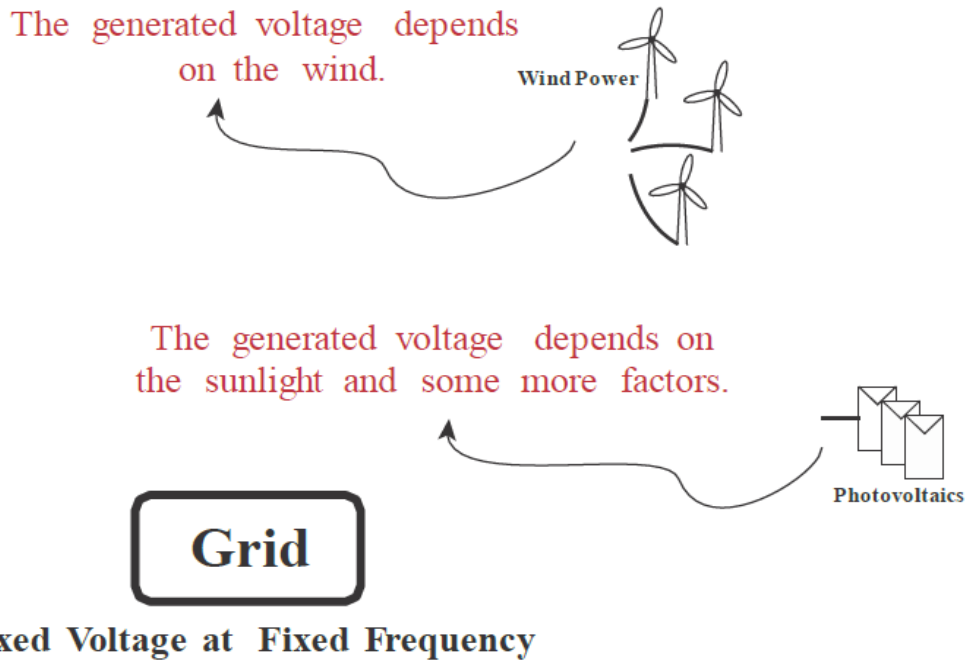




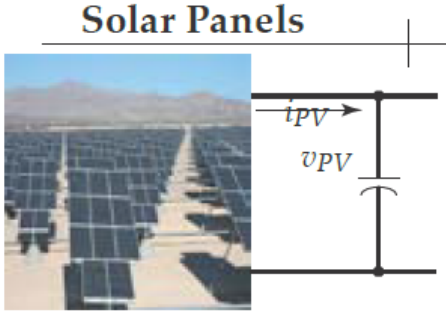
Grid

Fixed Voltage at Fixed Frequency

Renewable Energies – Wind and Solar



Solar Energy Grid Integration



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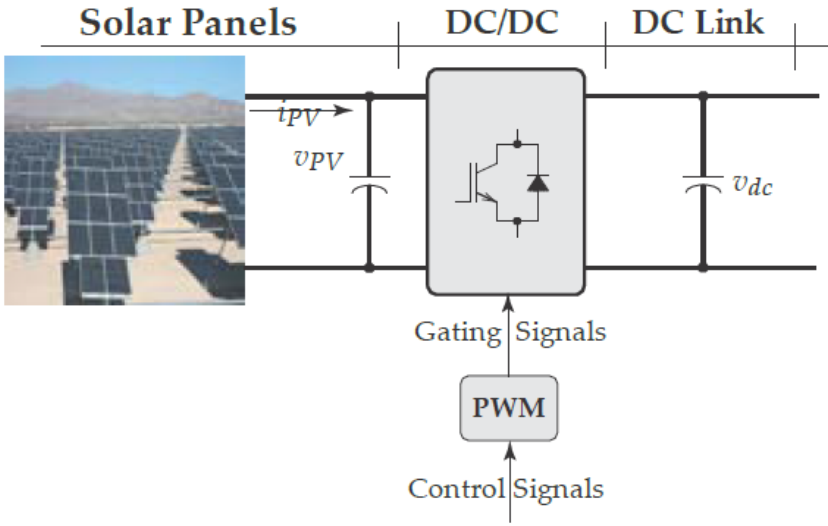

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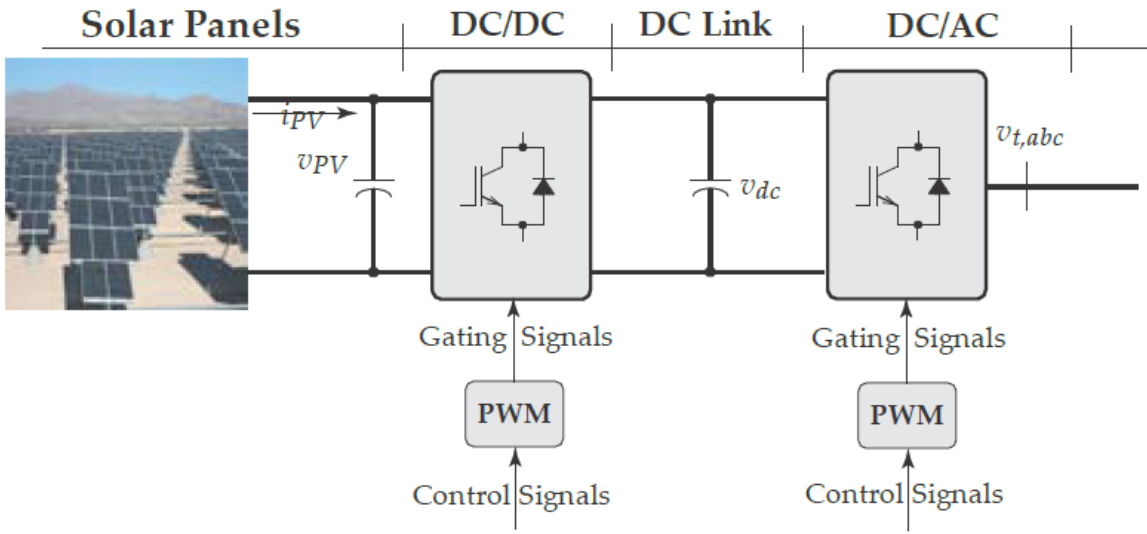

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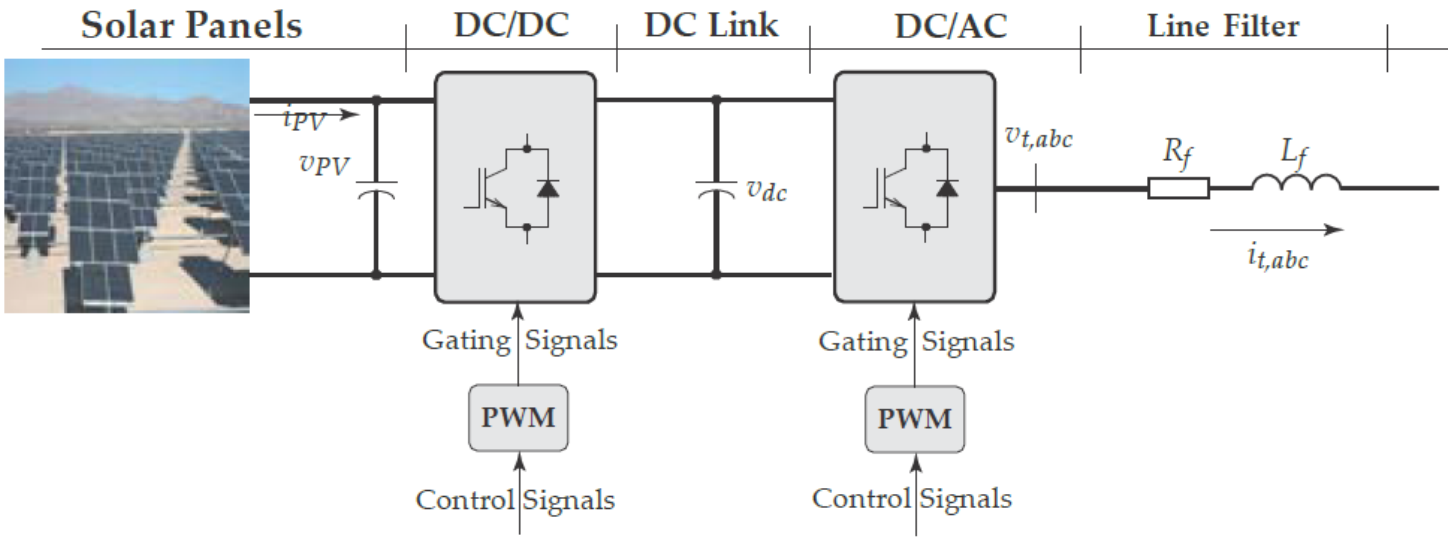

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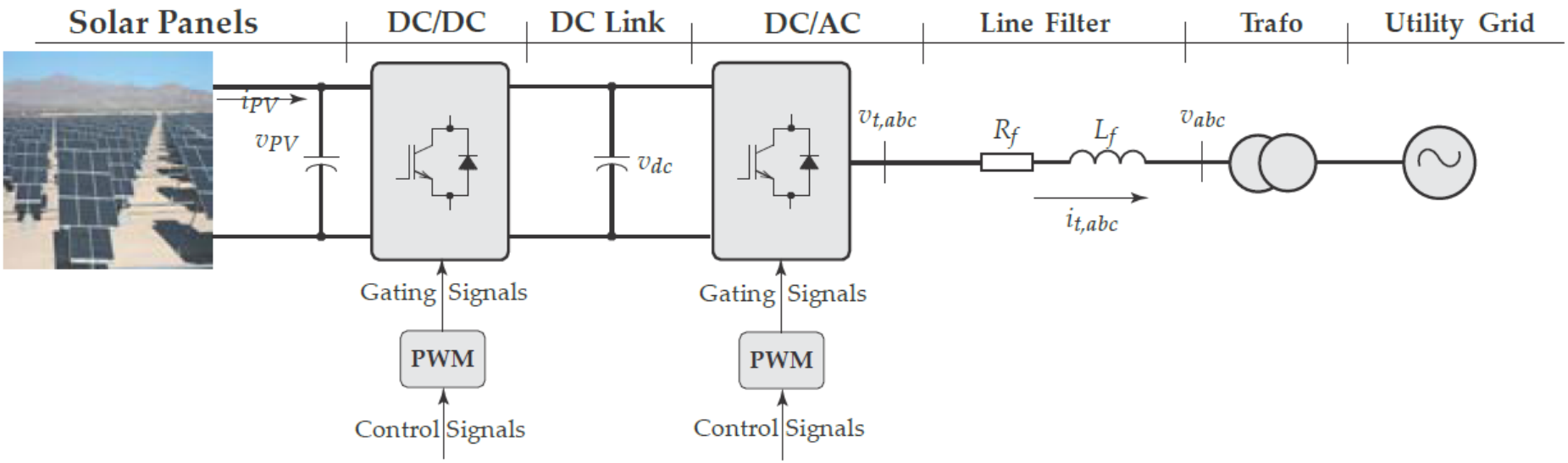

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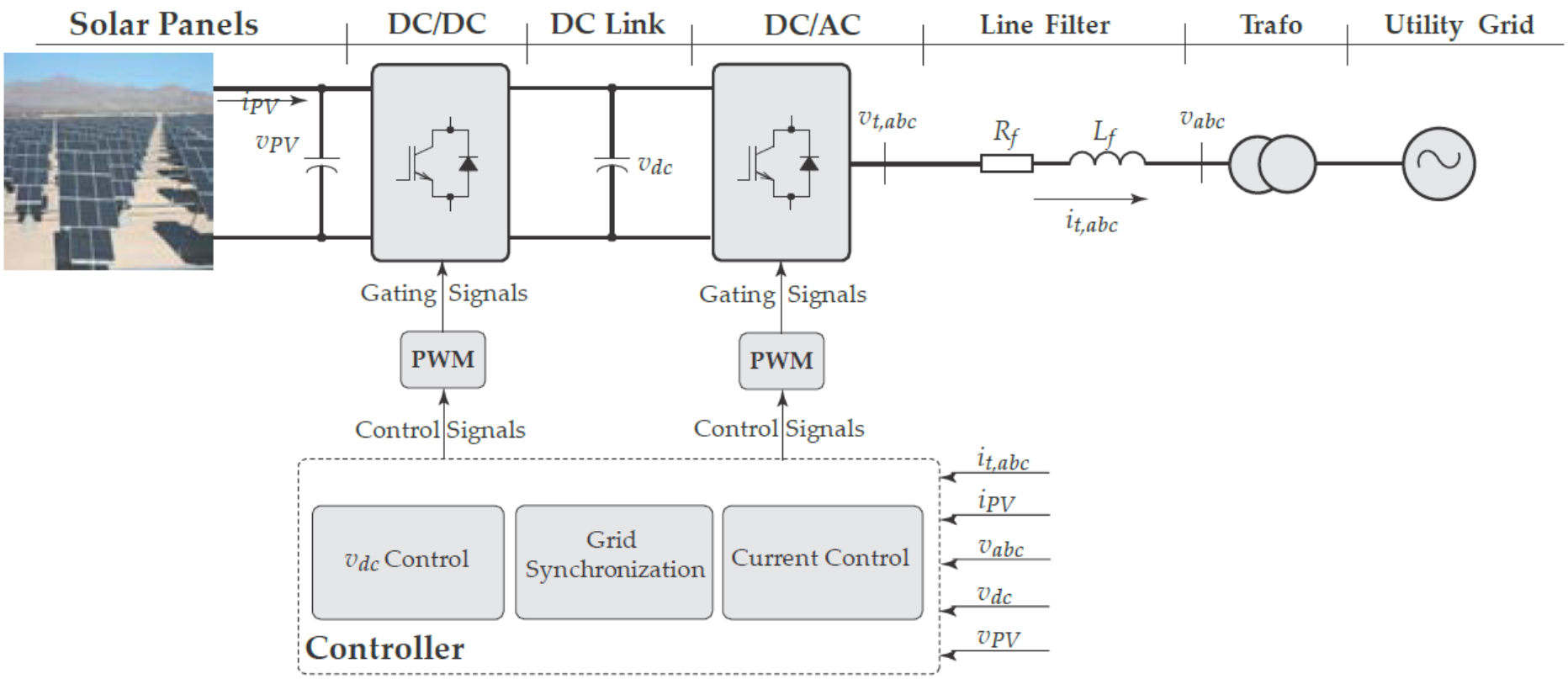
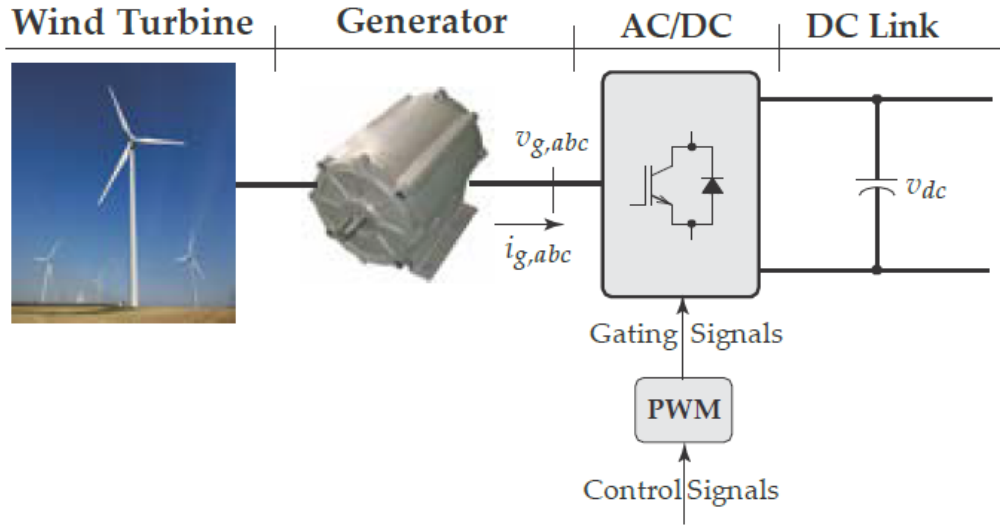


Wind Energy Grid Integration

Wind Turbine

Wind Energy Grid Integration

Wind Energy Grid Integration



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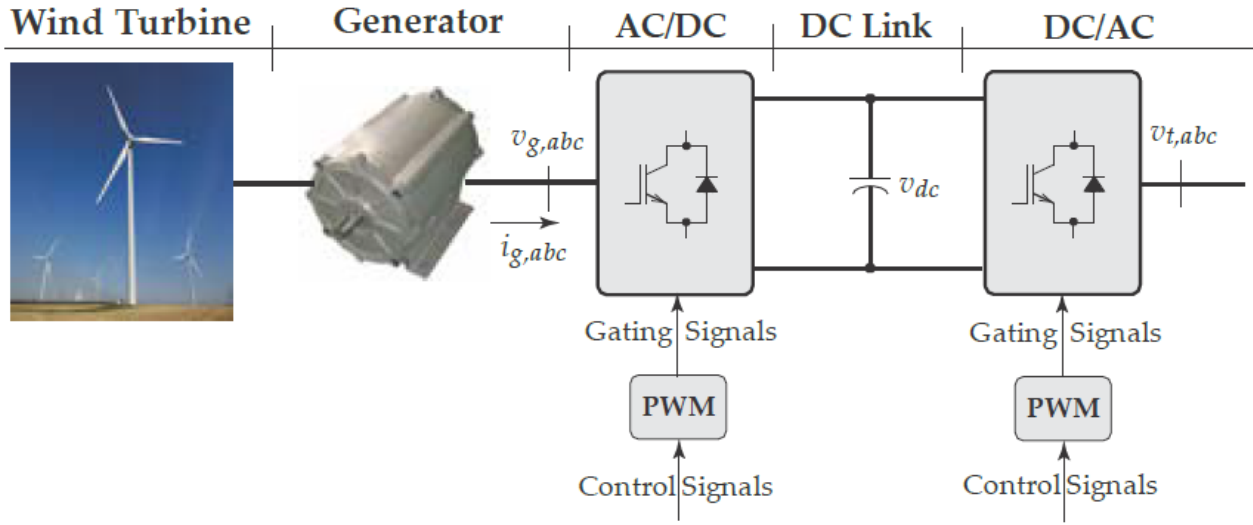

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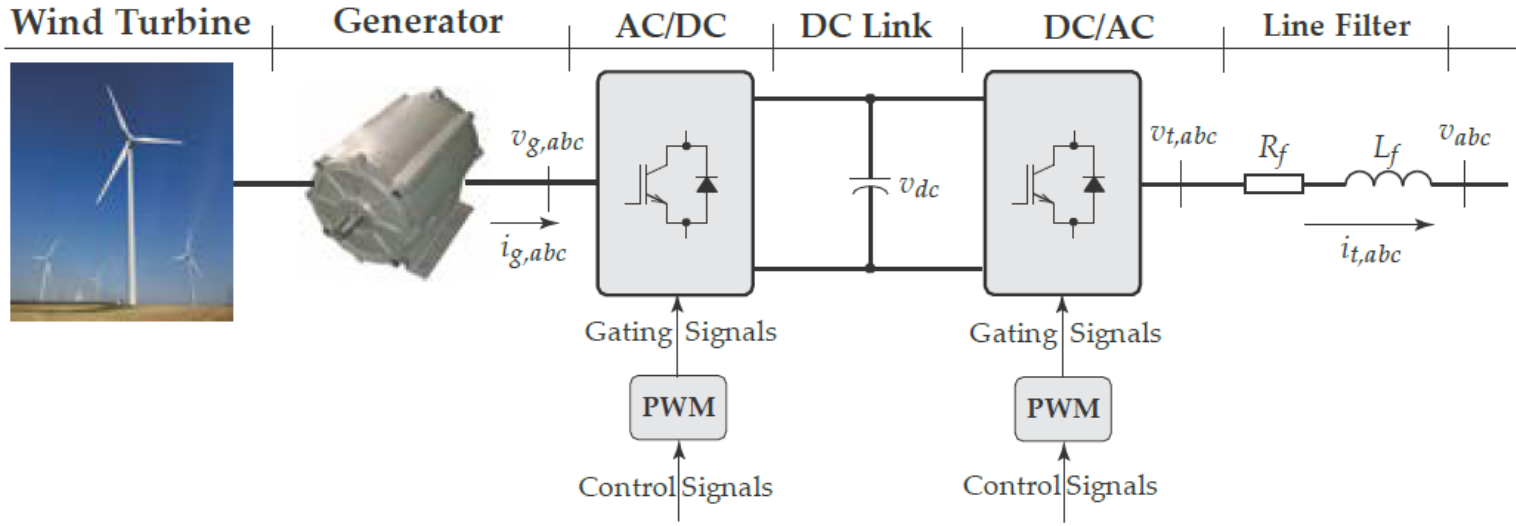

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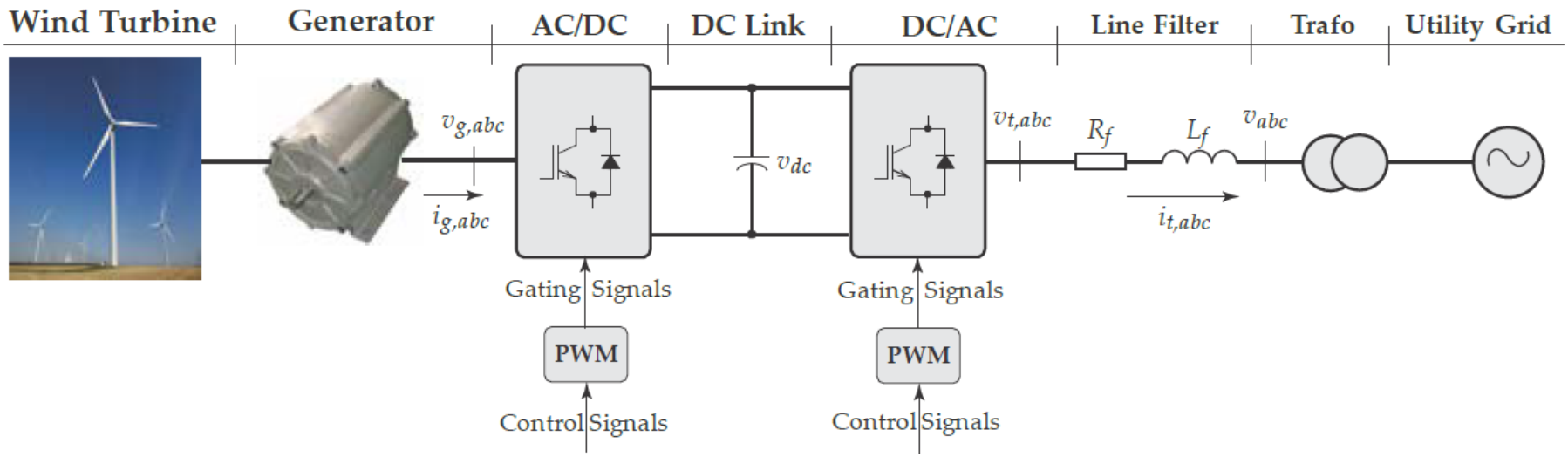

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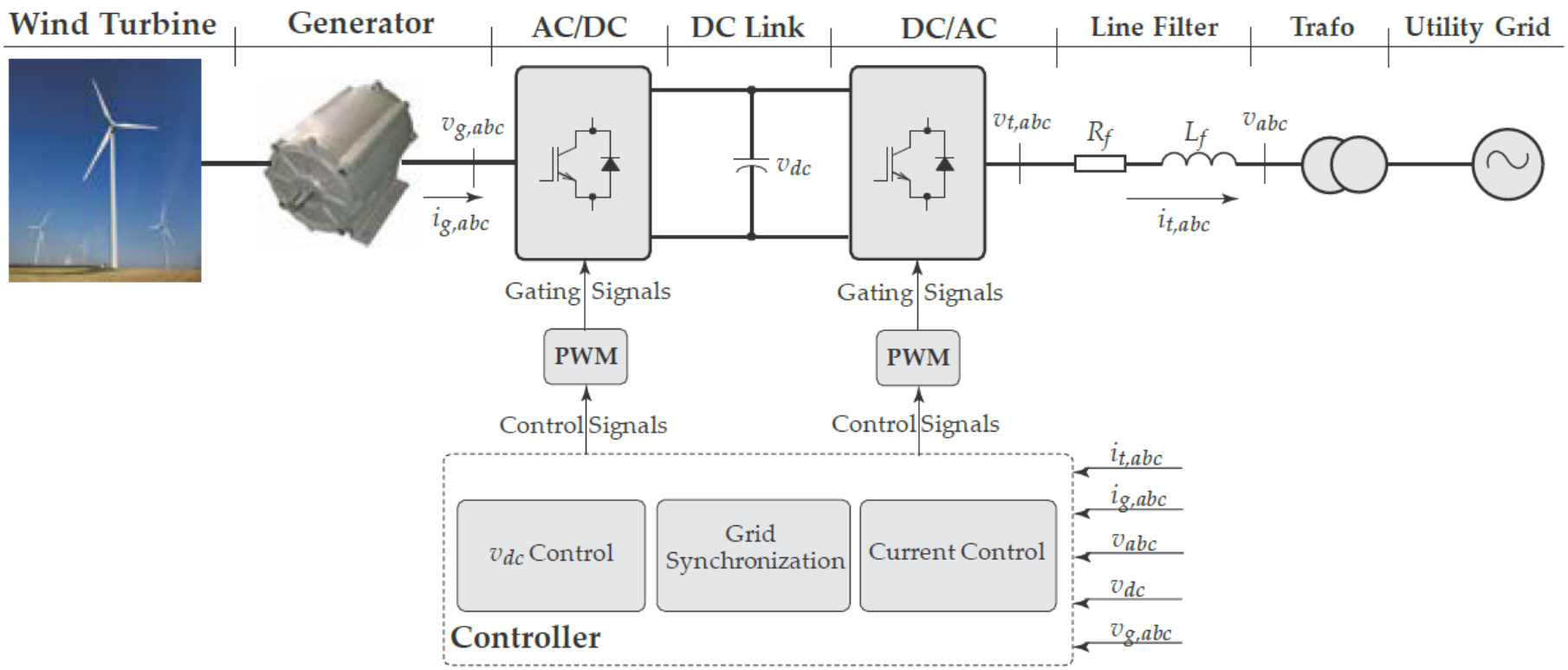
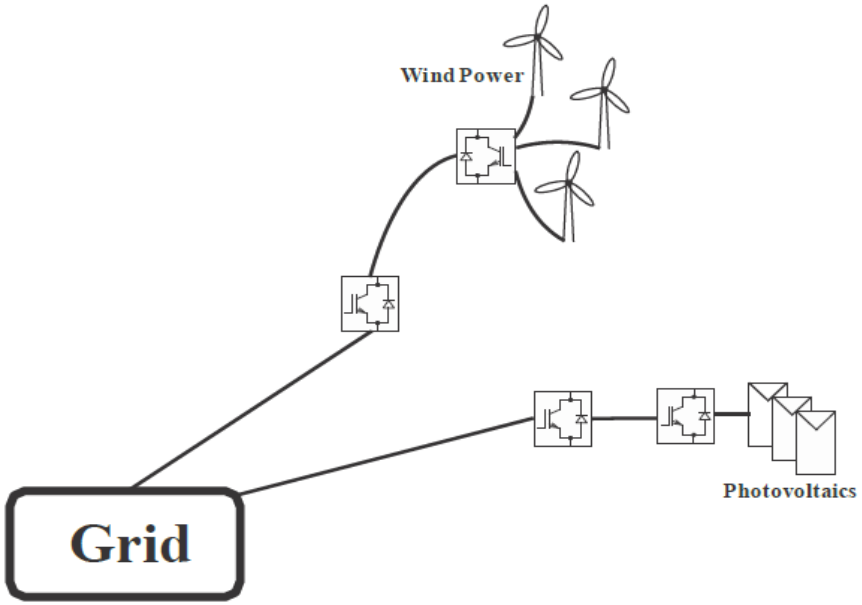


What is a Microgrid?



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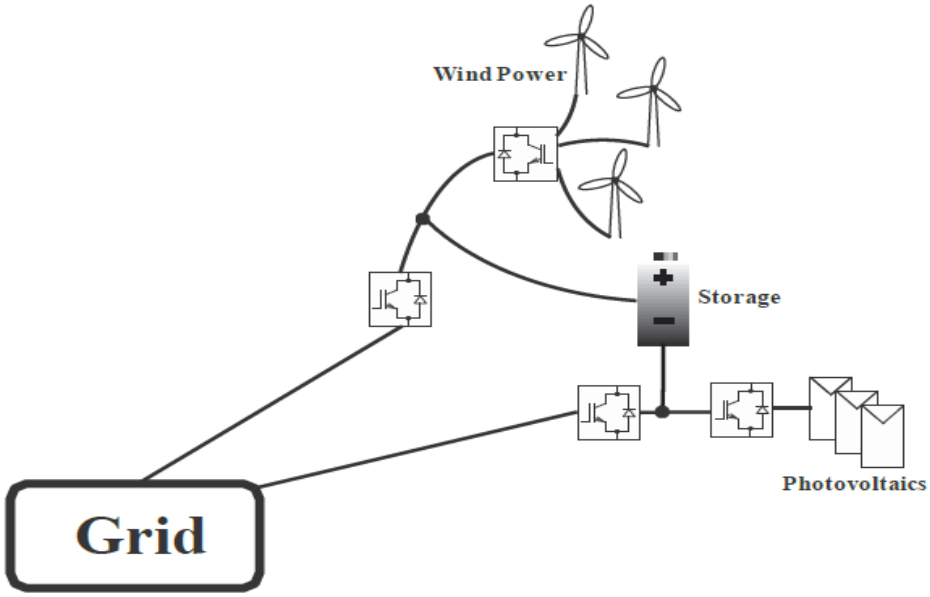

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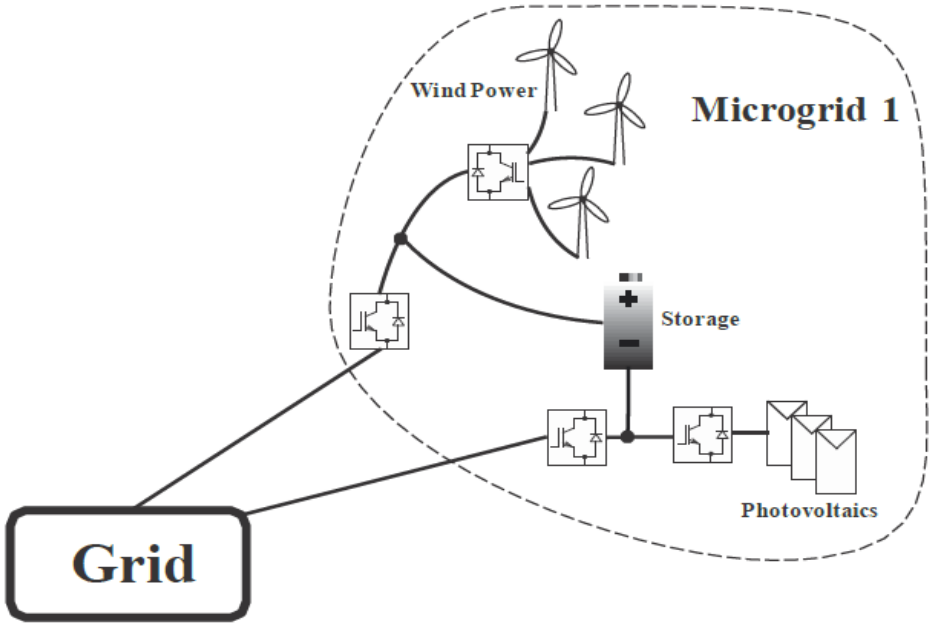

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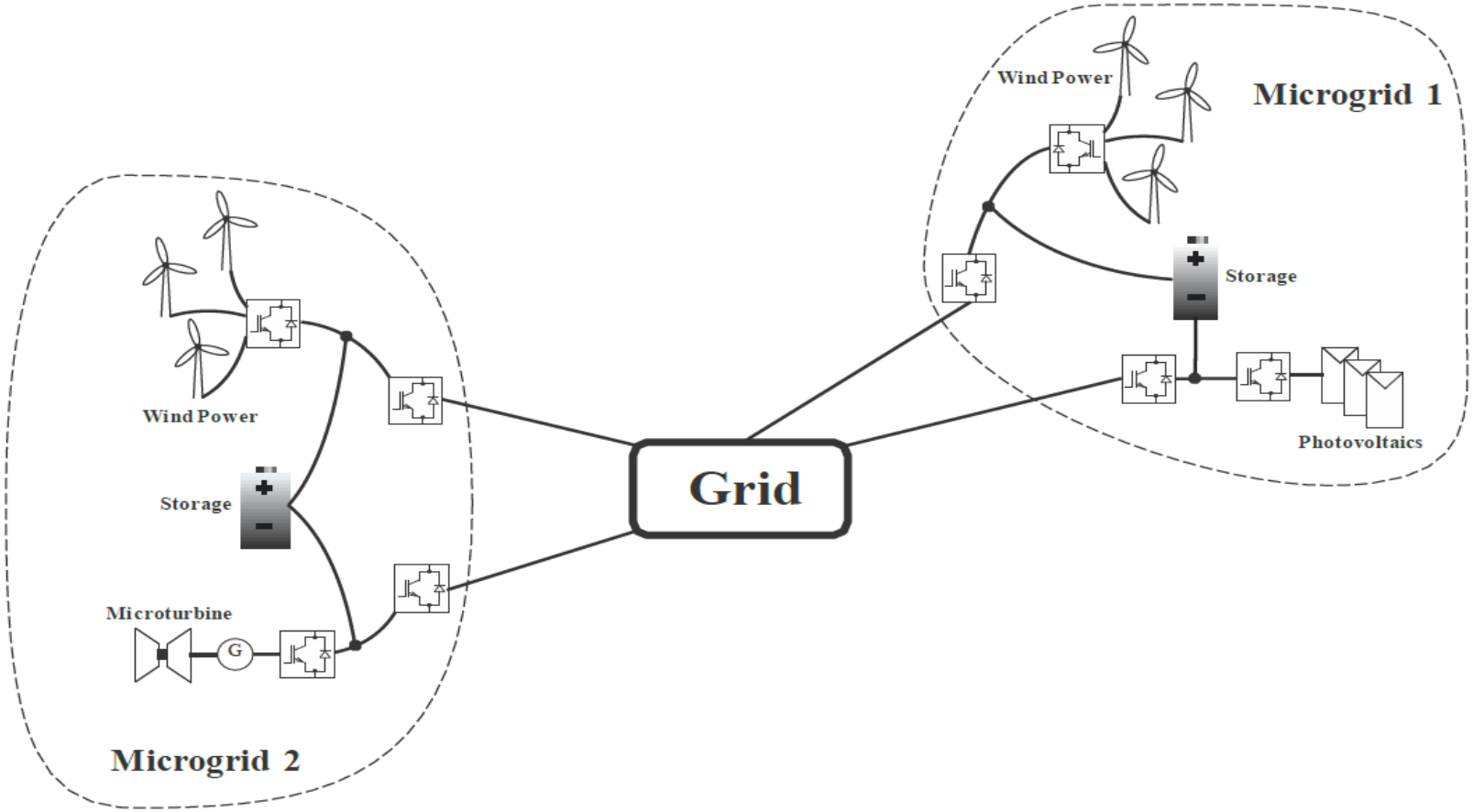

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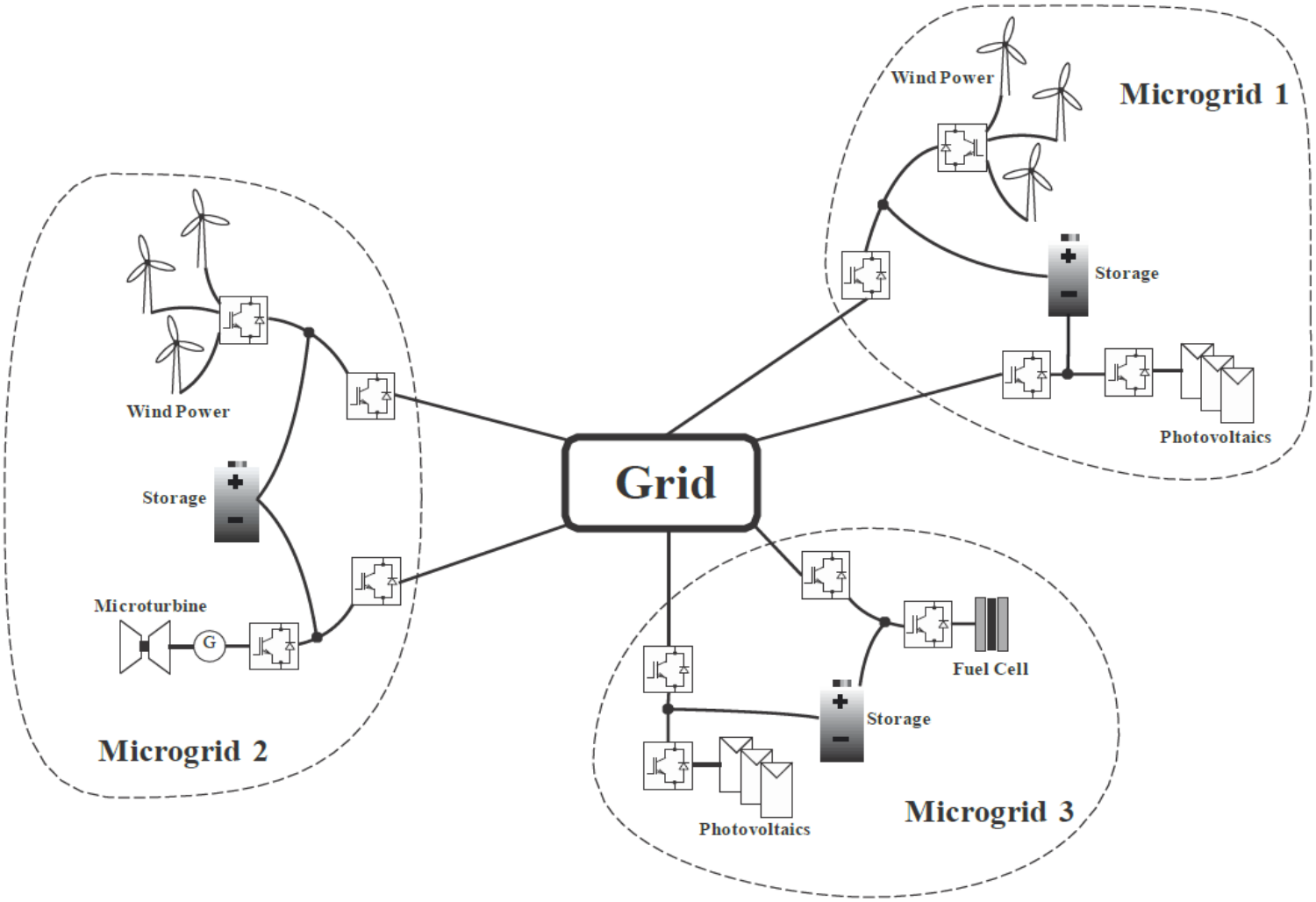
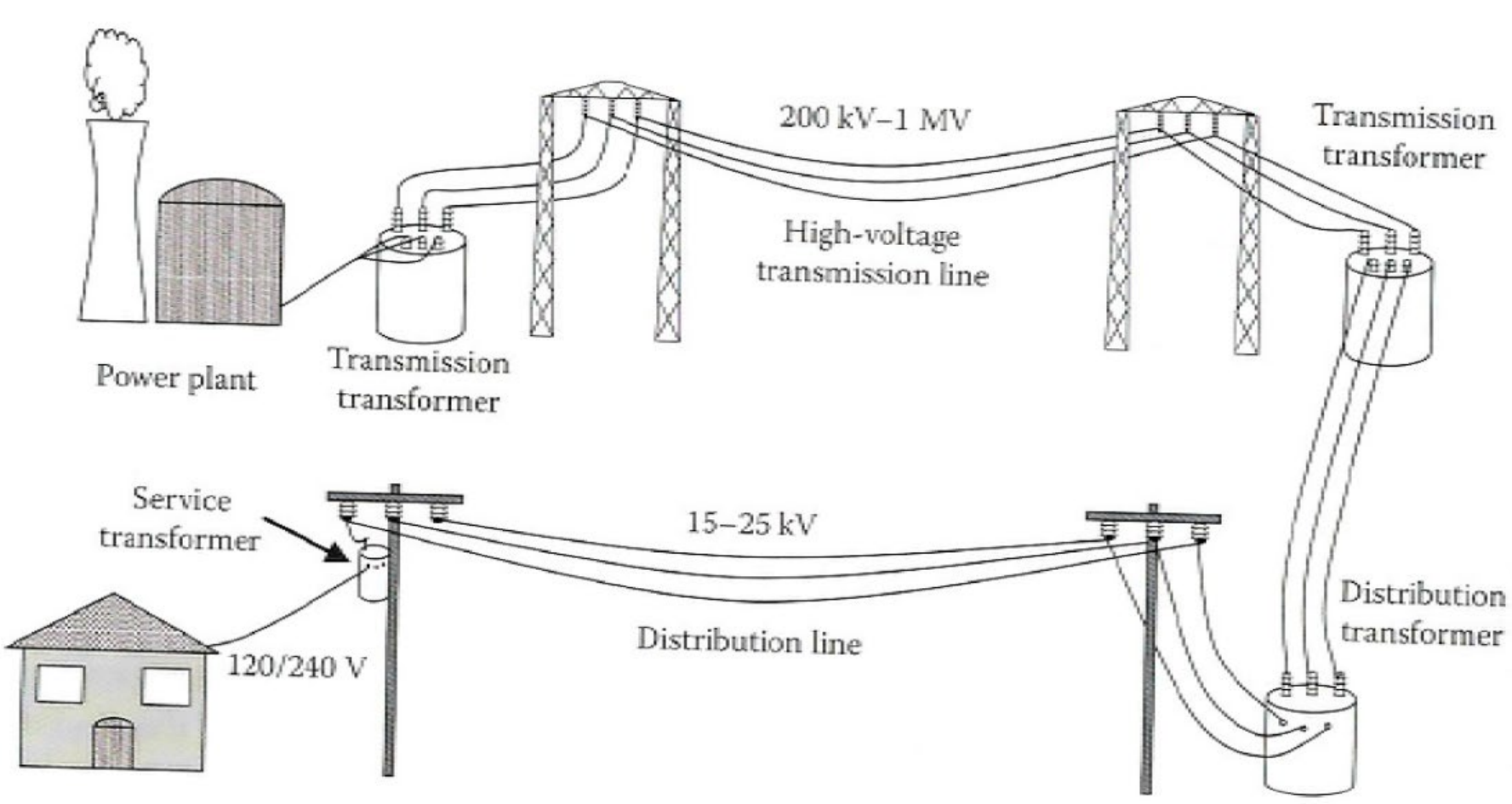


Energy Quiz

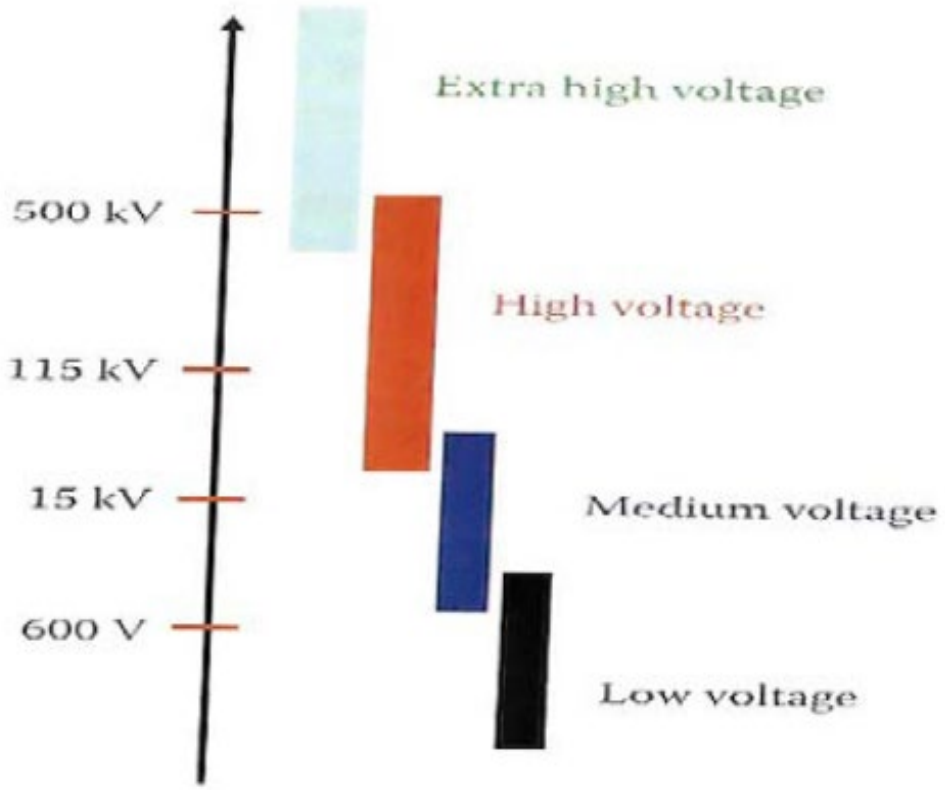
Here is a quick quiz on several energy-related issues:

http://corporate.exxonmobil.com/en/company/multimedia/energy-lives-here/quiz

Main components of Power system



Categorization of transmission lines



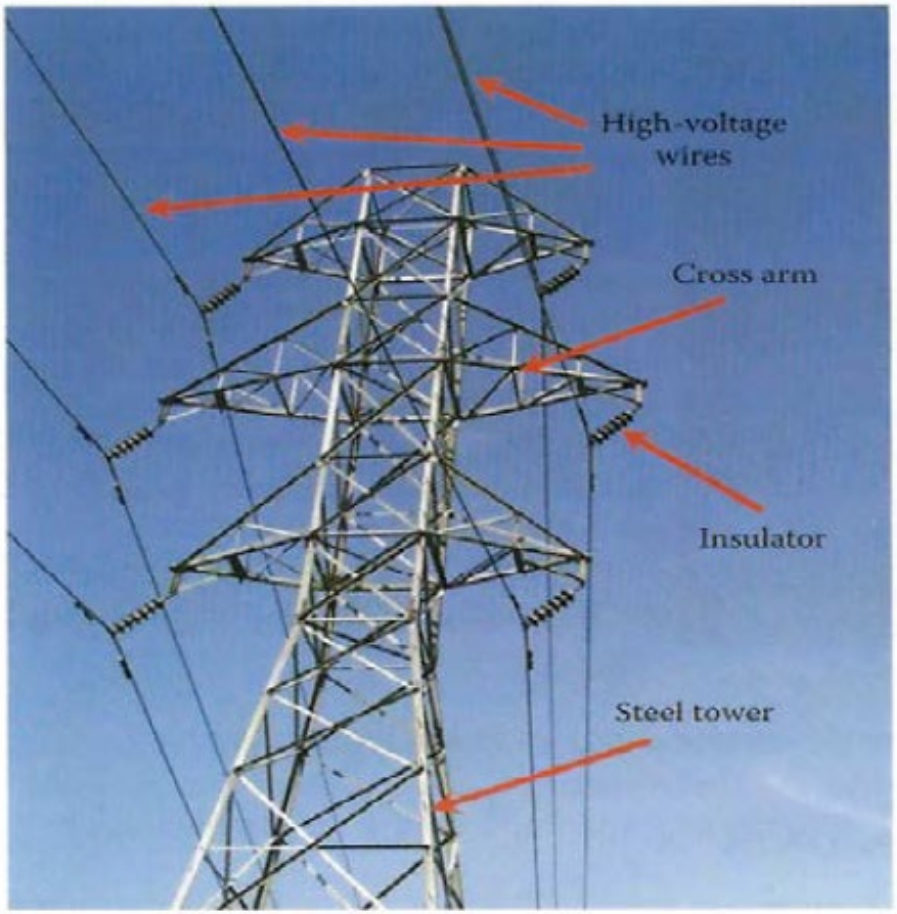
Power plants: Nuclear, Hydro and Thermal

(a)

(b)

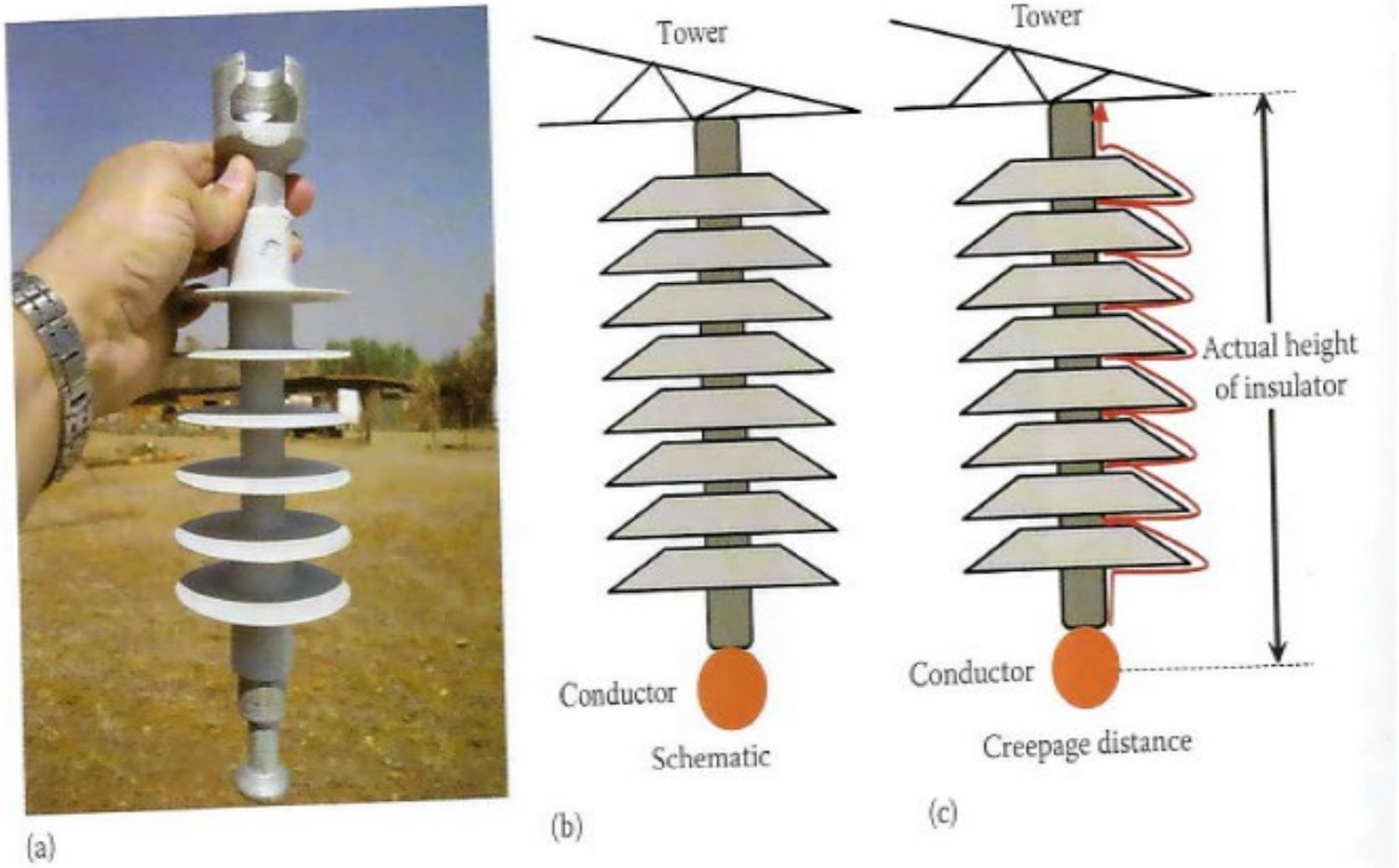
(c)

Main components of Power System

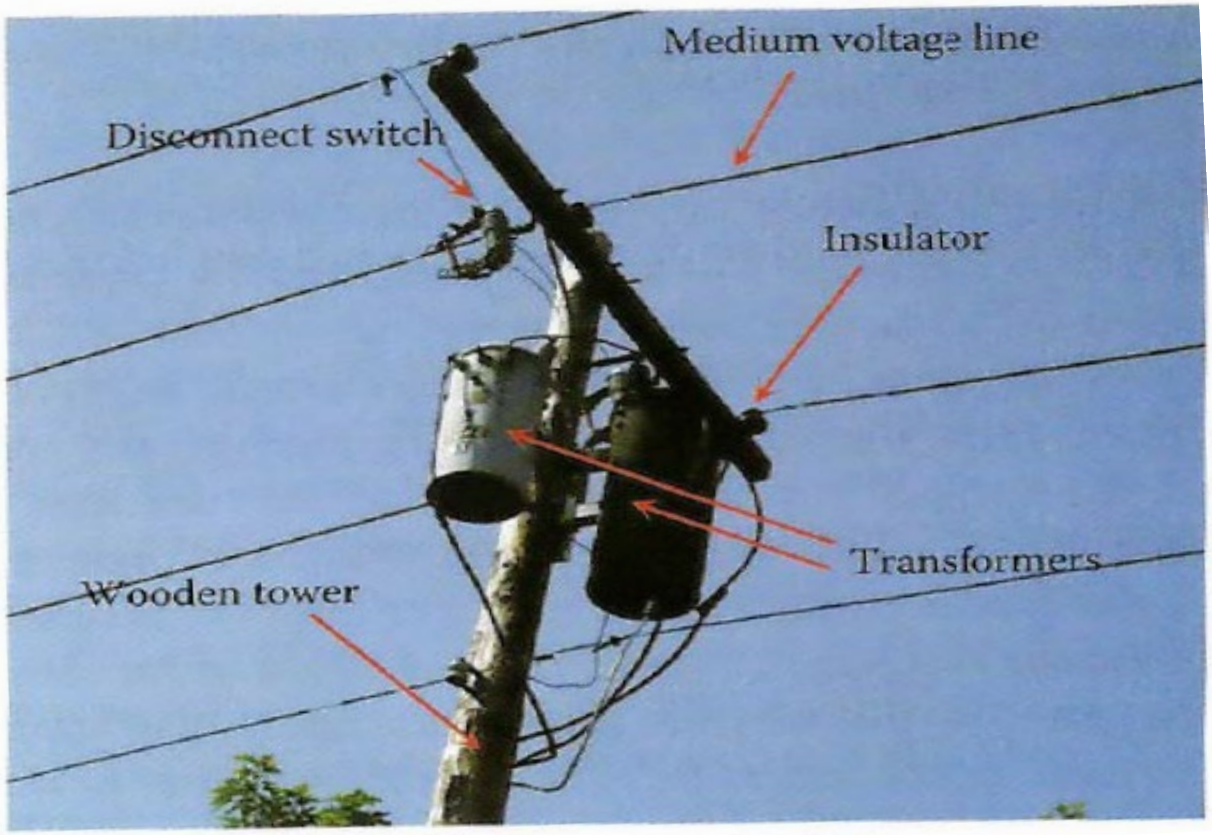


Transmission line tower.

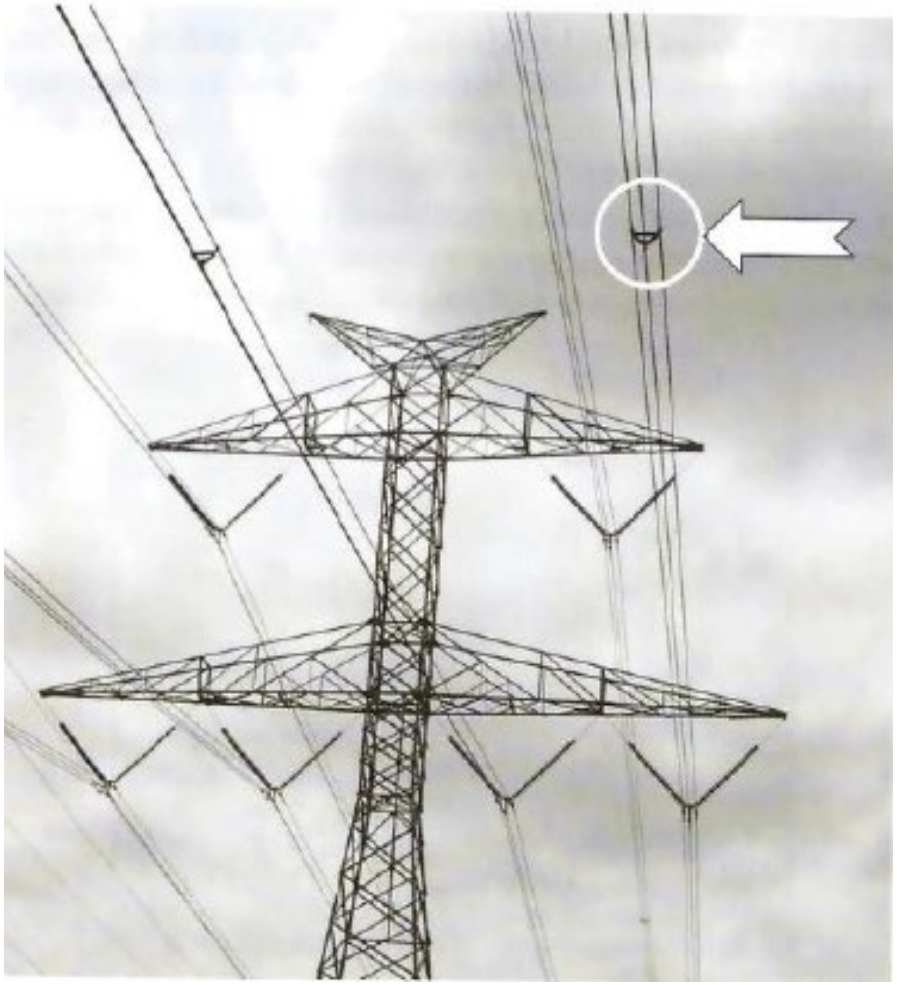
Insulators


Tower
Conductor
Schematic
(b)
Tower
Actual height of insulator
Conductor
Creepage distance
(c)
(a)

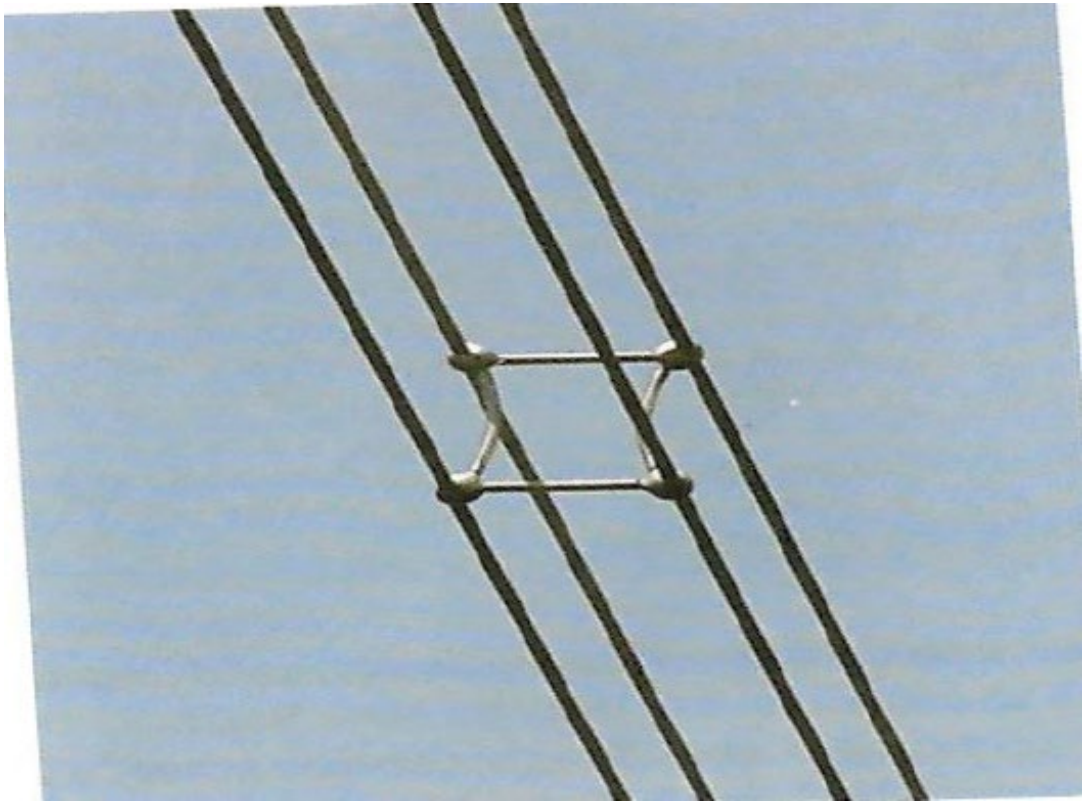
Distribution line tower



Bundled Conductor



Bundled Conductor with four sub-conductors



Power System Basics

Notation: Power

- Power: Instantaneous consumption of energy
- Power Units

  Watts = voltage x current for dc (W)

  kW – 1 x 103 Watt

  MW – 1 x 106 Watt

  GW – 1 x 109 Watt

- Installed U.S. generation capacity is about 1,100 GW (about 3.5 kW per person)

Notation - Energy

- **Energy:** Integration of power over time; energy is what people really want from a power system

- **Energy Units**

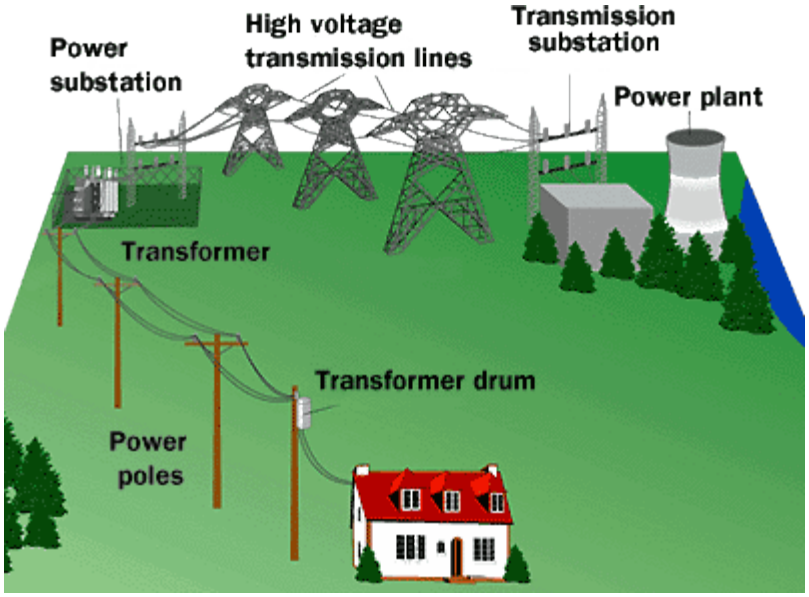
  Joule = 1 Watt-second (J)
  kWh = kilowatt hour (3.6 x 106 J)
  1 Watt-hour = 3.4121 BTU

- U.S. annual electric energy consumption is about 4,000 billion kWh (about 13,000 kWh per person, which means on average we each use 1.5 kW of power continuously)

Electric Power System

Usually Divided into:

- **Generation:** Source of power, ideally with a specified voltage and frequency.
- **Transmission:** Transmits power; ideally as a perfect conductor.
- **Loads:** Consumes power; ideally with a constant resistive value.

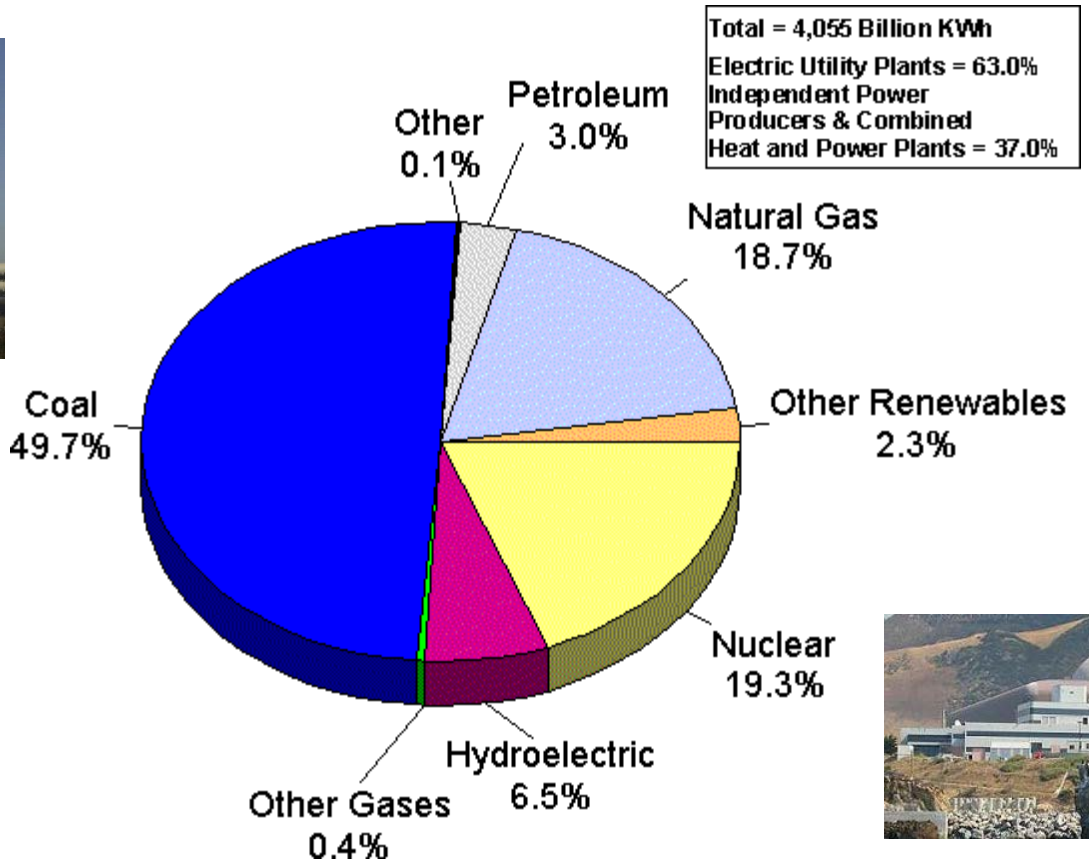


Electric Power System

Complications:

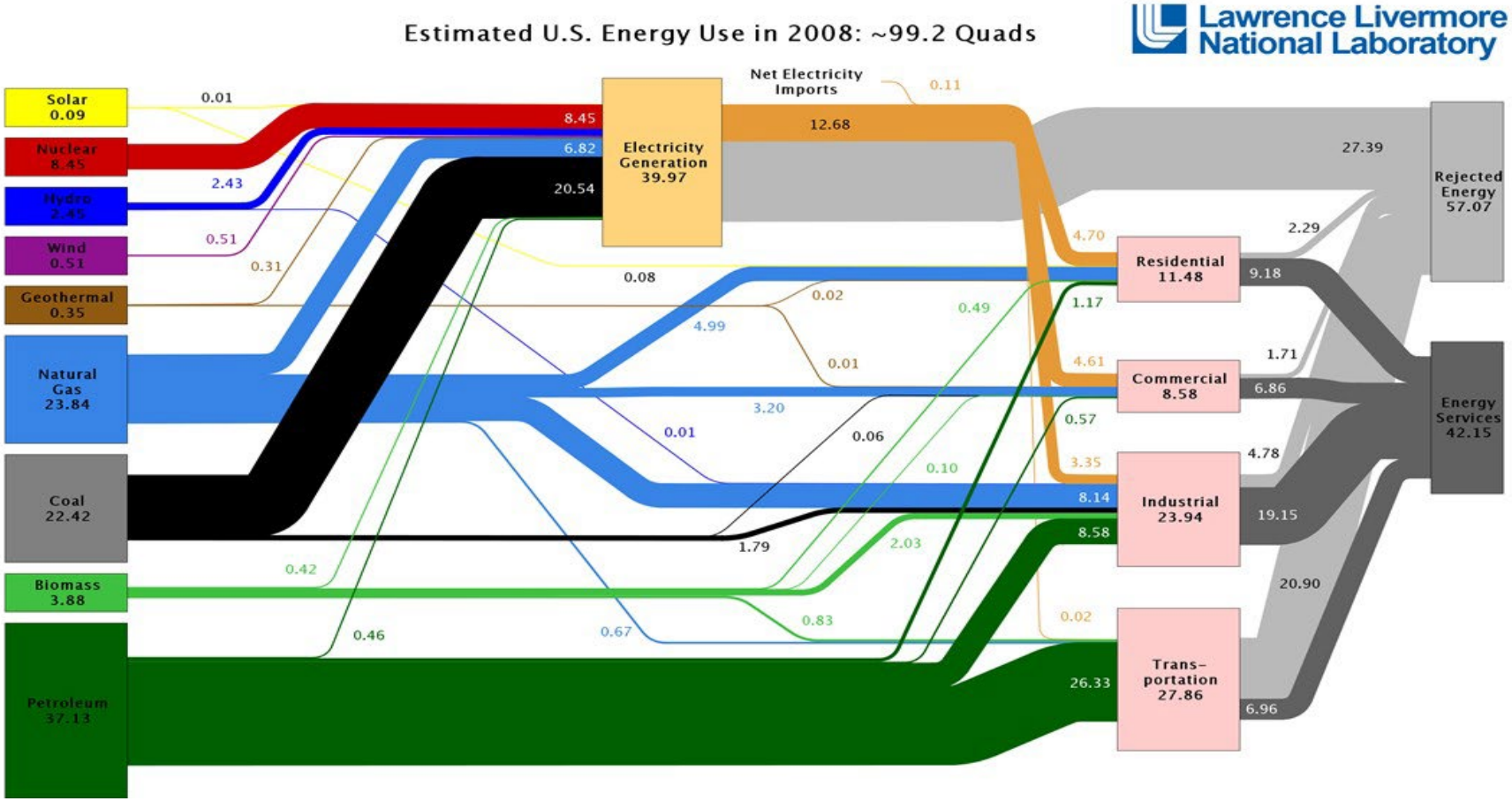
- No ideal voltage sources exist,
- Loads are seldom constant,
- Transmission system has resistance, inductance, capacitance and flow limitations,
- Simple system has no redundancy so power system will not work if any component fails.

US Electric Power Generation

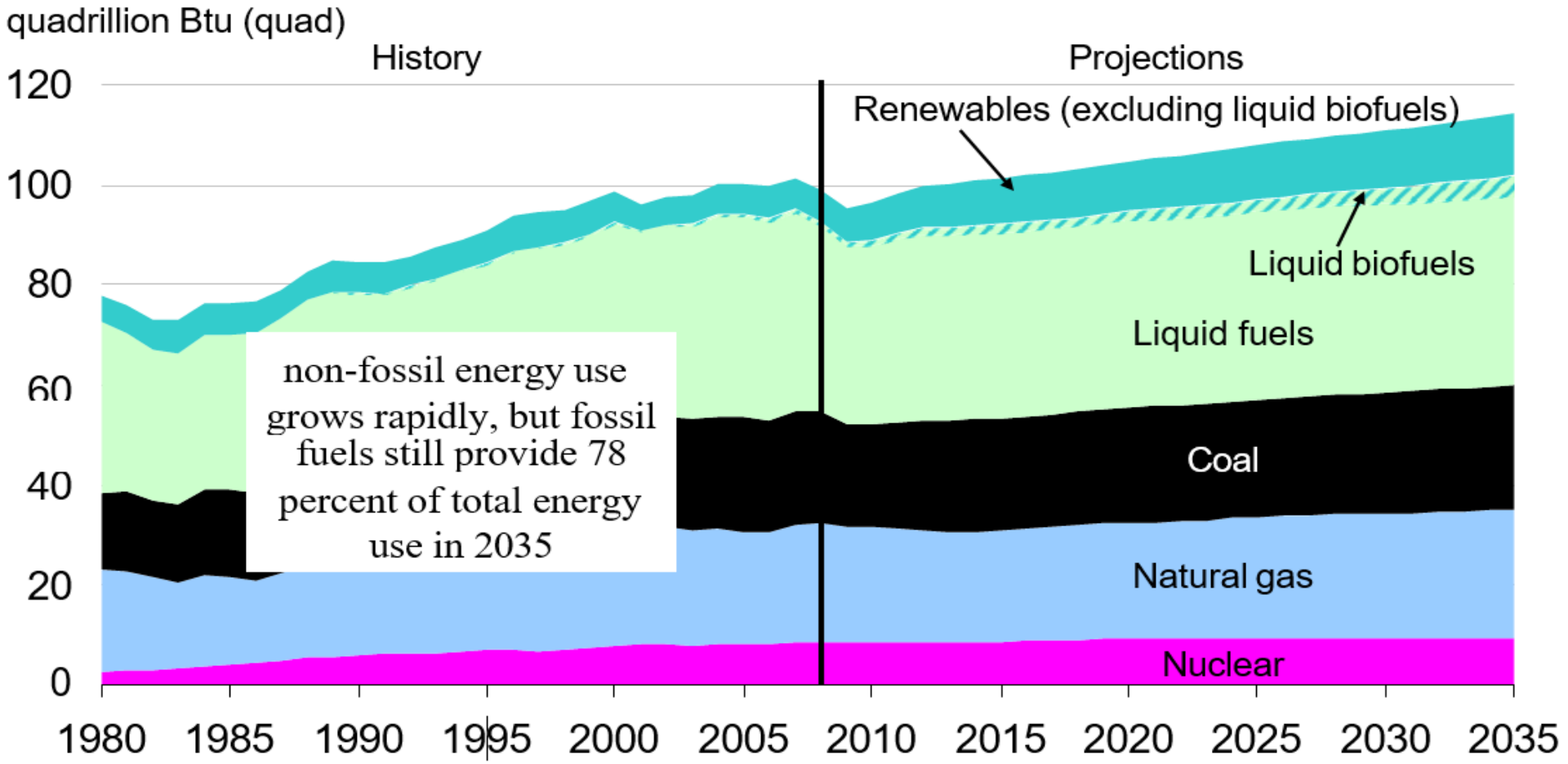


Energy Flow

1 QUAD = 10^{15} BTU

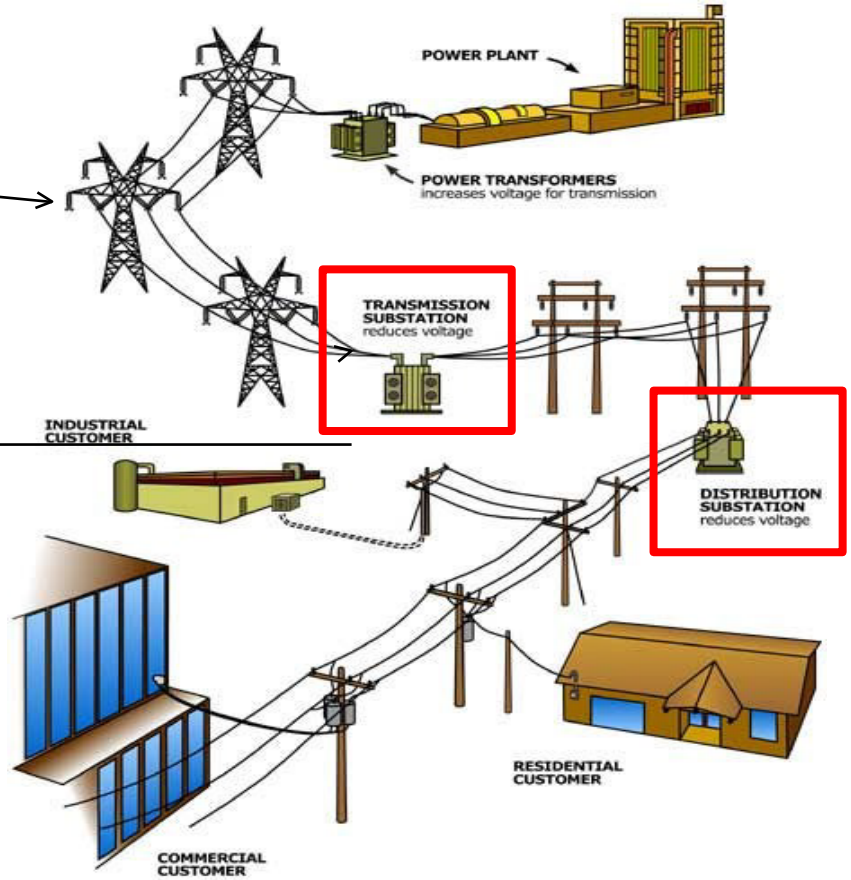


Electric Power Generation

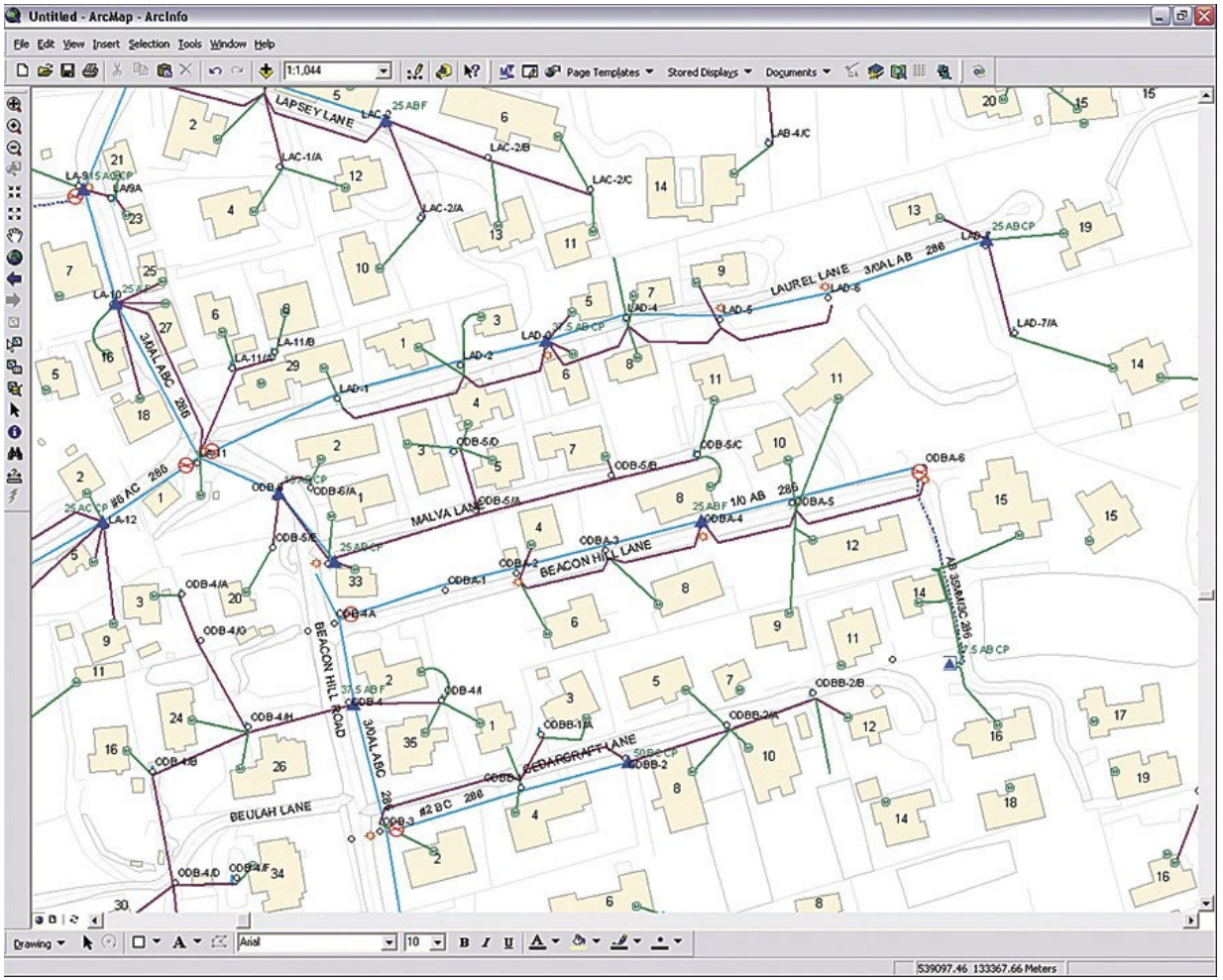


Source: DOE EIA *Annual Energy Outlook 2010*

Electric Power Transmission



Electric Power Distribution

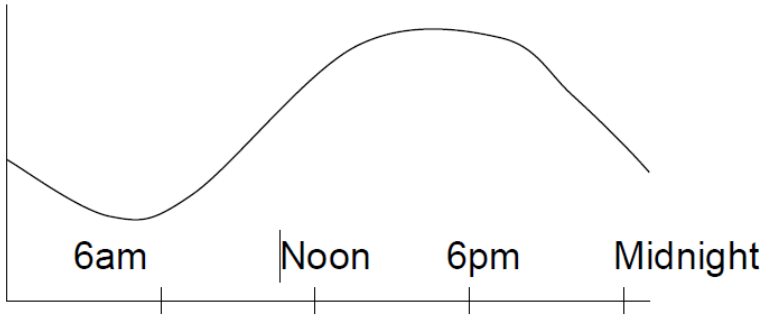


Goals of Power System Operation

- Supply load (users) with electricity at:
  - ✓ Specified voltage (120 ac volts common for residential),
  - ✓ Specified frequency,
  - ✓ With minimum cost (usually).

Major Impediments

- Load is constantly changing.



- Power system is subject to disturbances, such as lightning strikes.
- Engineering tradeoffs between reliability and cost.

Brief History of Electric Power

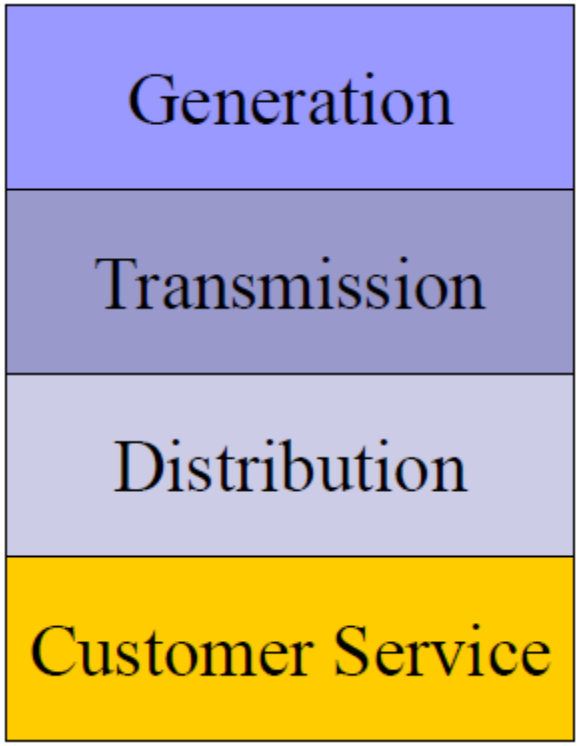
- Early 1880's –Edison introduced Pearl Street dc system in Manhattan supplying 59 customers
- 1884 –Sprague produces practical dc motor
- 1885 –Invention of transformer
- Mid 1880's –Westinghouse/Tesla introduce rival ac system
- Late 1880's –Tesla invents ac induction motor
- 1893 –First 3 phase transmission line operating at 2.3 kV
- 1896 –ac lines deliver electricity from hydro generation at Niagara Falls to Buffalo, 20 miles away
- Early 1900's –Private utilities supply all customers in area (city); recognized as a natural monopoly; states step in to begin regulation.

Contd…

- By 1920's –Large interstate holding companies control most electricity systems.
- 1935 –Congress passes Public Utility Holding Company Act (PUHCA) to establish national regulation, breaking up large interstate utilities
- 1935/6 –Rural Electrification Act brought electricity to rural areas
- 1930's –Electric utilities established as **vertical monopolies**

1930's: Vertical Monopolies

- Within a particular geographic market, the electric utility had an exclusive franchise.
- In return for this exclusive franchise, the utility had the obligation to serve all existing and future customers at rates determined jointly by utility and regulators.
- It was a "cost plus" business.



Contd, 1930's: Vertical Monopolies…

- Within its service territory each utility is the only game in town.
- Neighboring utilities functioned more as colleagues than competitors.
- Utilities gradually interconnected their systems so by 1970 transmission lines crisscrossed North America, with voltages up to 765 kV.
- Economies of scale keep resulting in decreasing rates, so everyone was happy.

Contd, History – 1970's…

- 1970's brought inflation, increased fossil-fuel prices, calls for conservation and growing environmental concerns.
- Increasing rates replaced decreasing ones.
- As a result, U.S. Congress passed Public Utilities Regulator Policies Act (PURPA) in 1978, which mandated utilities must purchase power from independent generators located in their service territory.
- PURPA introduced some competition.

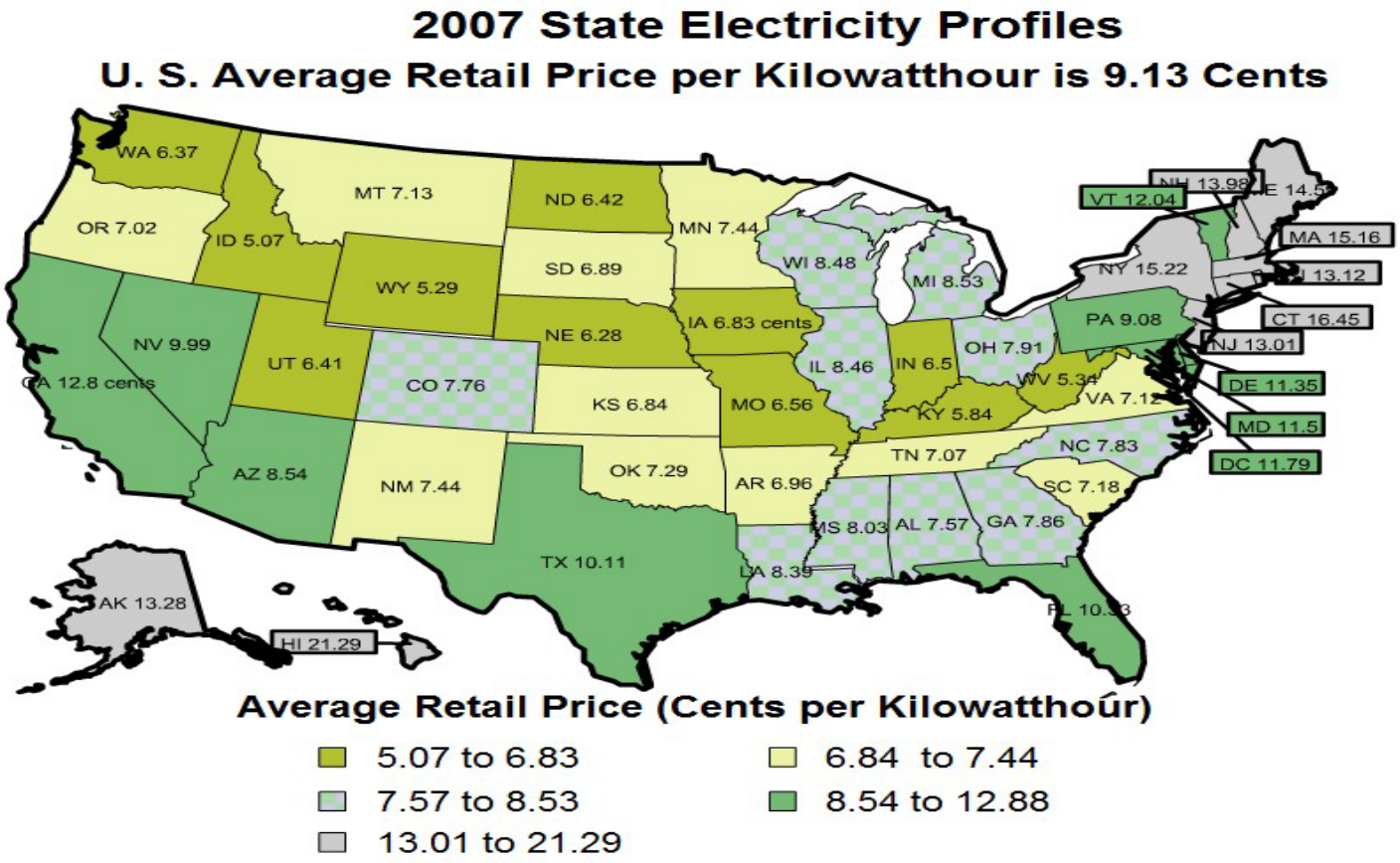
Contd, History – 1990's…

- Major opening of industry to competition occurred as a result of Federal Power Act of 1992
- This act mandated that utilities provide "nondiscriminatory" access to the high voltage transmission
- Goal was to set up true competition in generation markets
- Result over the last few years has been dramatic restructuring of electric utility industry

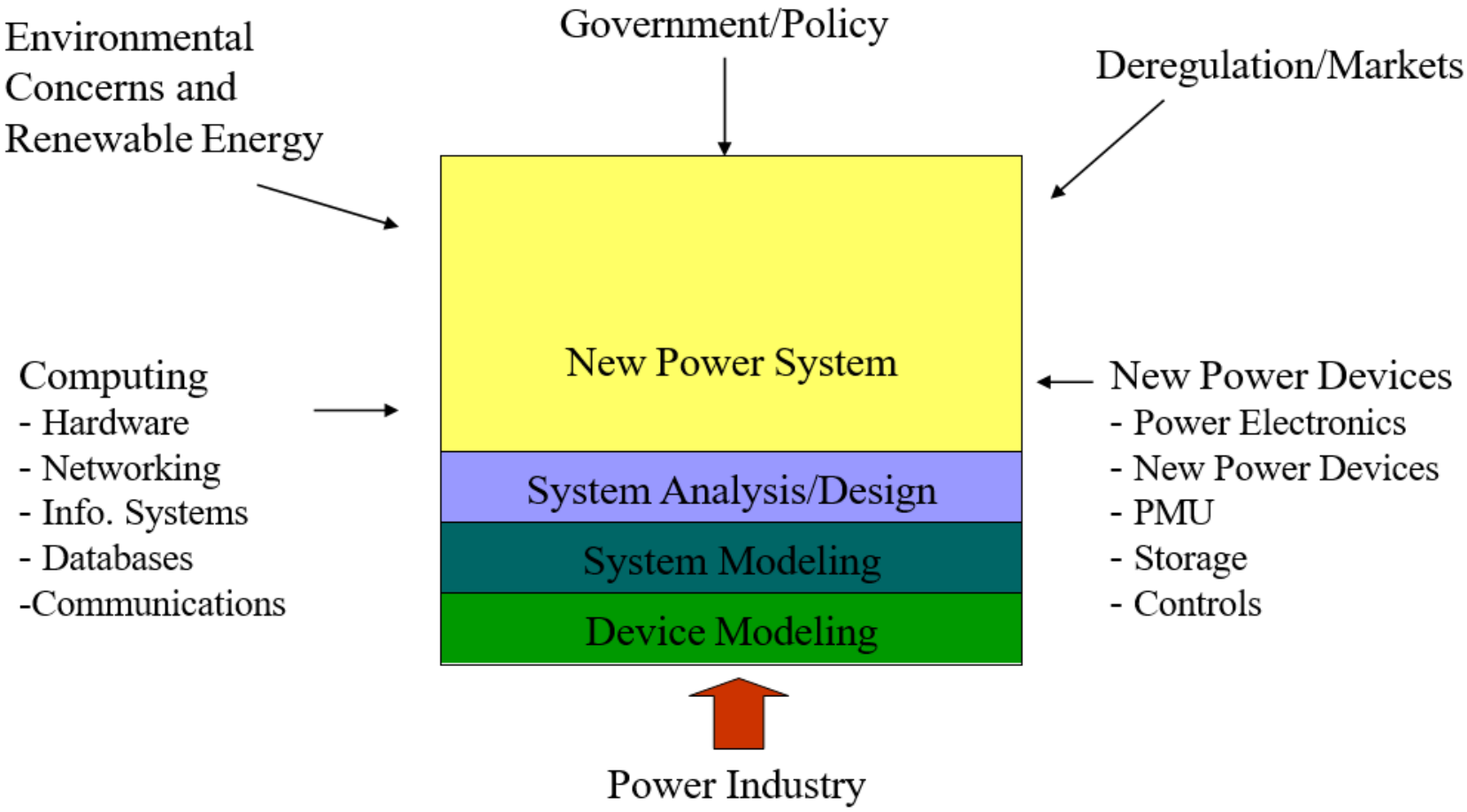
Utility Restructuring

- Driven by significant regional variations in electric rates.
- Goal of competition is to reduce rates through the introduction of competition.
- Eventual goal is to allow consumers to choose their electricity supplier.

State Variation in Electric Rates



Industry Forces Today



Thank You!