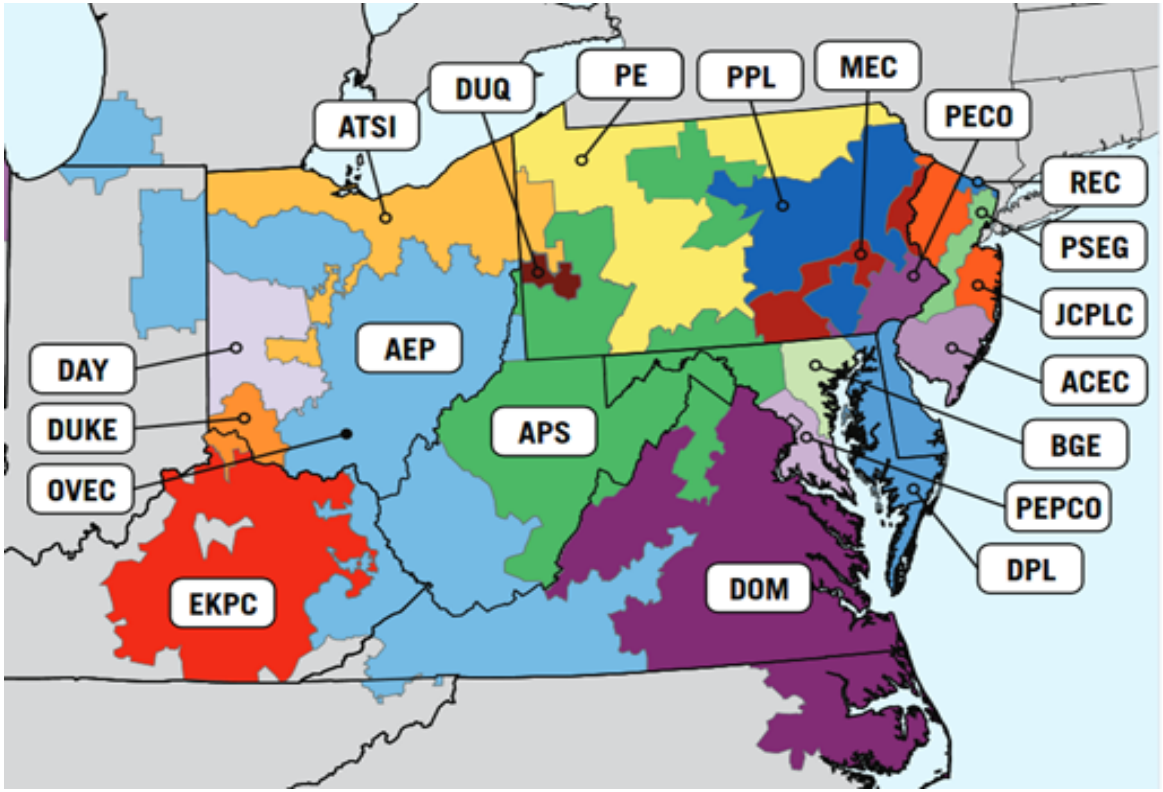
Electric Power Industry



- Utilities
  - Investor Owned utilities (IOUs)
  - Federally Owned Utilities: TVA, BPA, etc
  - Other Publicly Owned Utilities: State and Local Government agencies
  - Rural Electric Coop: Rural Electric Administration
- Non-Utility Generators (NUG)
  - Privately owned for own use and/or for sale to utilities

Electric Power Industry

- Electric Power Industry in US (Before 1980)
  - One of the most polluting industries
    - Emissions
      - Sulfur Oxides (SOx)
      - Carbon Dioxide (CO2)
      - Nitrogen Oxides (NOx)

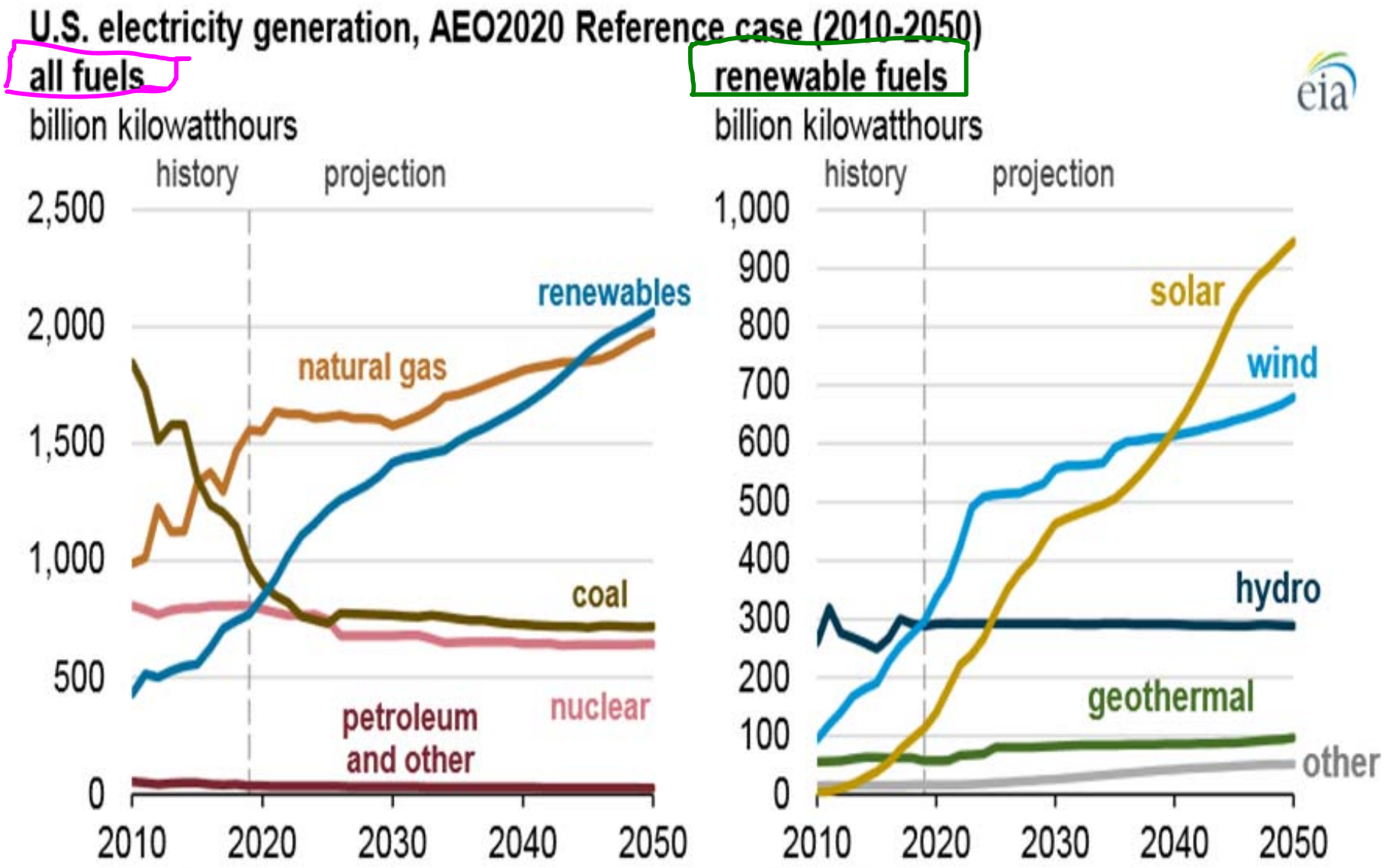
2018 Data
(www.eia.gov)
Energy Information Administration

Emission CO2 by the U.S Electric Power Sector
= 1,763 million metric tons (MMmt)
= 33% of total U. S. energy-related CO2 emission of 5,629 (MMmt)

Coal: 1,150 MMmt 65%
Natural Gas: 581 MMmt 33%

- Electric Power Industry in US (From 1980s)
  - Global warming
  - Emission reduction mandate
  - Renewable energy in to action

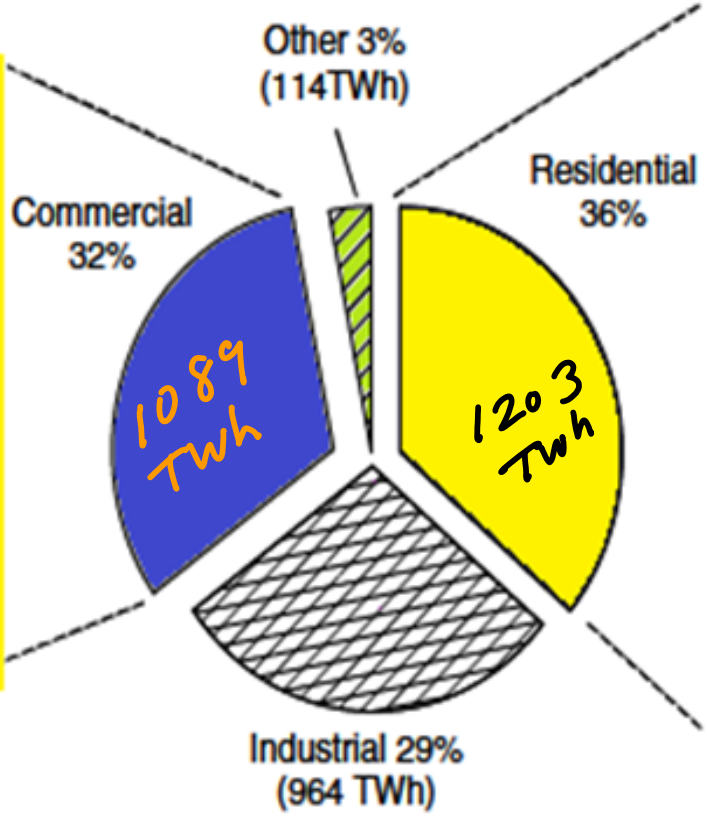
Electricity Generation



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Distribution of Electricity Sales

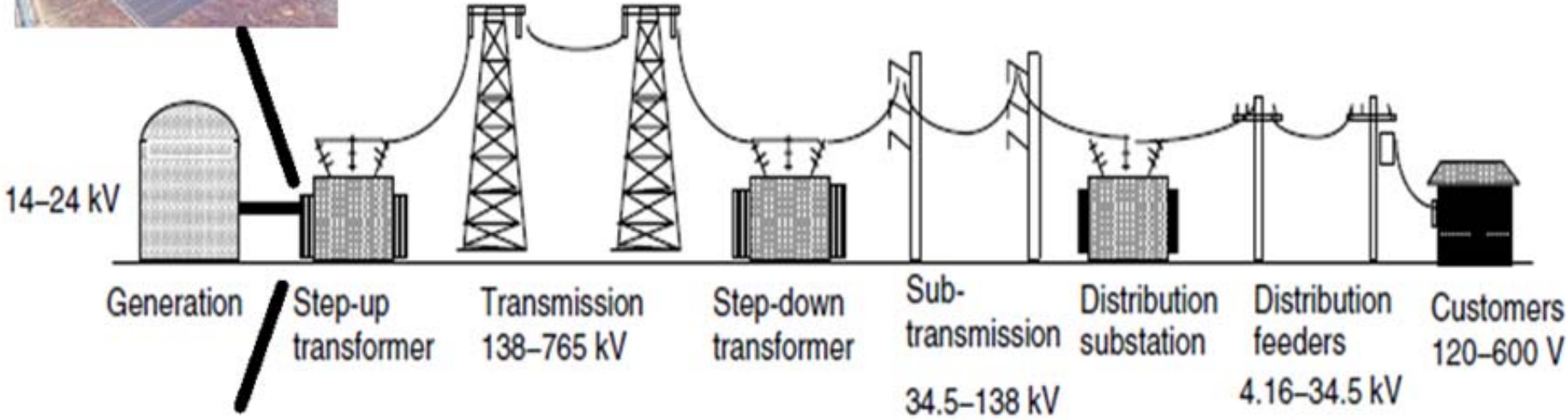
COMMERCIAL	PERCENTAGE
Lighting	32
Space Cooling	12
Office Equipment	7
Ventilation	5
Refrigeration	5
Space Heating	3
Water Heating	3
Computers	2
Cooking	1
Other Office	9
Non-Building Uses	21
TOTAL (TWh)	1089



RESIDENTIAL	PERCENTAGE
Space Cooling	13
Refrigerators	11
Motors	11
Heating	10
Water Heating	10
Electronics	9
Lighting	9
Heating Elements	9
Clothes Dryers	6
Cooking	3
Freezers	3
Televisions	3
Computers	2
Clothes Washers	1
TOTAL (TWh)	1203

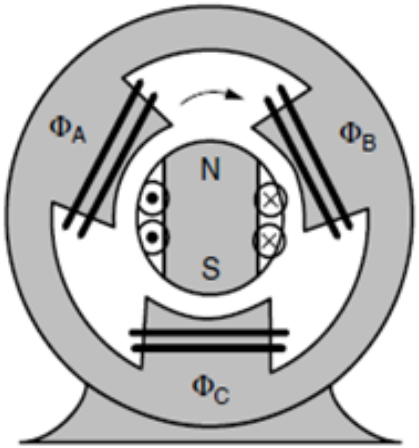
Distribution of retail sales of electricity by end use. Residential and commercial buildings account for over two-thirds of sales. Total amounts in billions of kWh (TWh) are 2001 data. From EIA (2003).

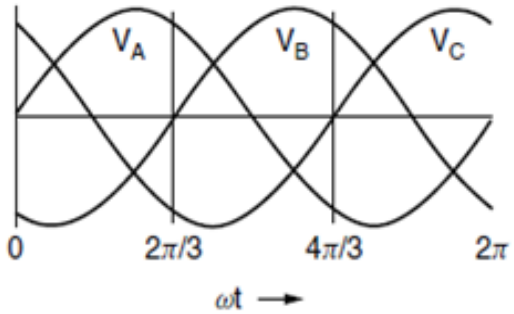
Power System Structure

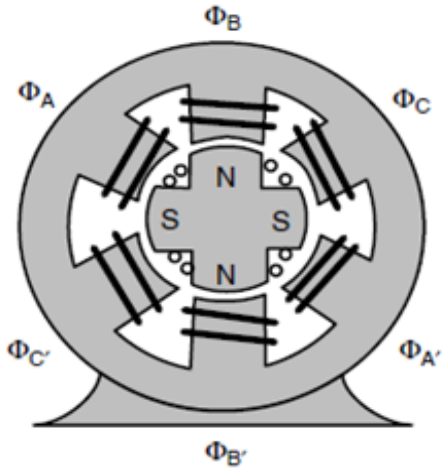


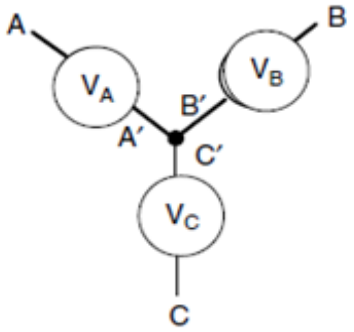
3-phase Synchronous Generators

- Theory: Electromagnetic Induction (1831) by Michael Faraday
- Rotating Magnetic Field (DC excited Rotor) + Armature (Stator)

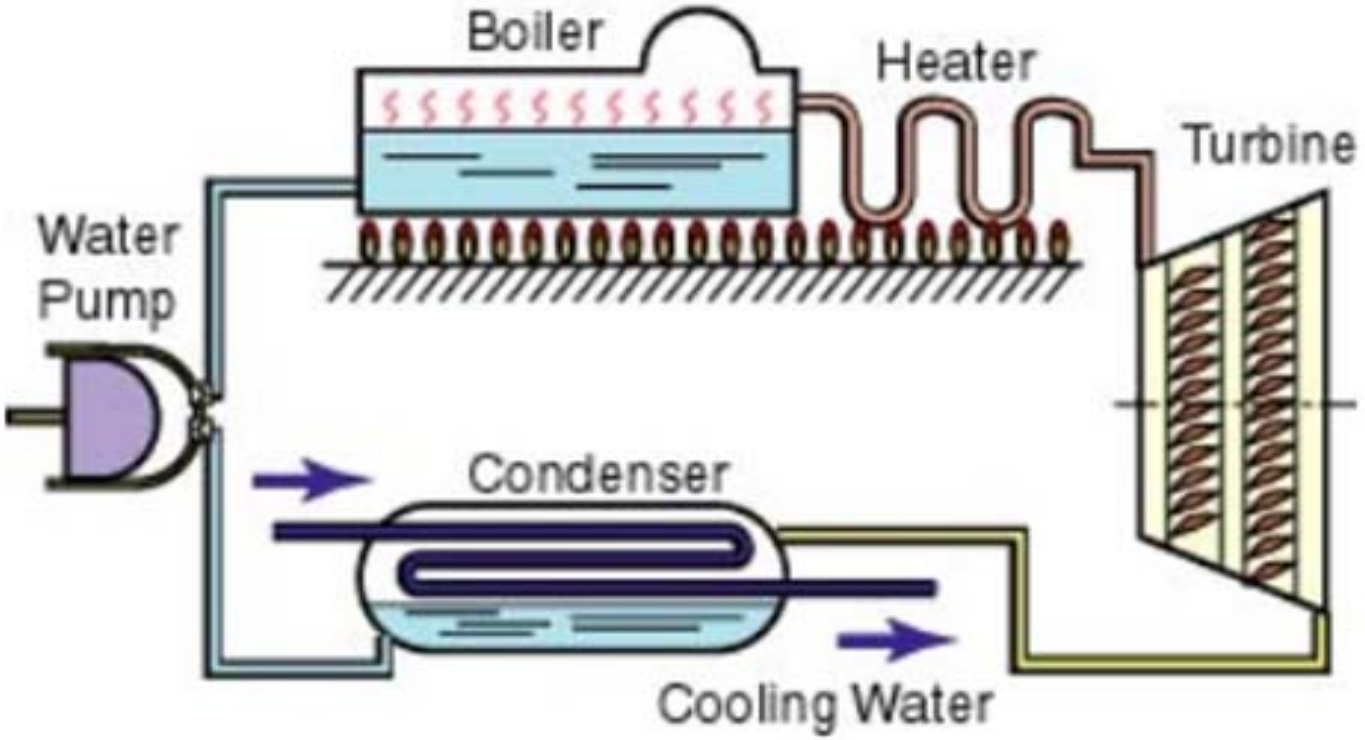




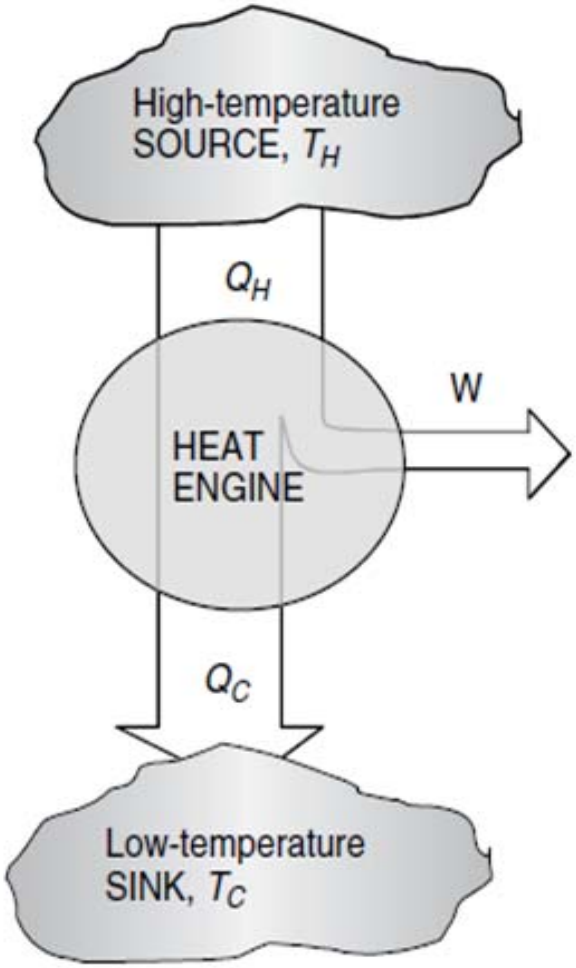




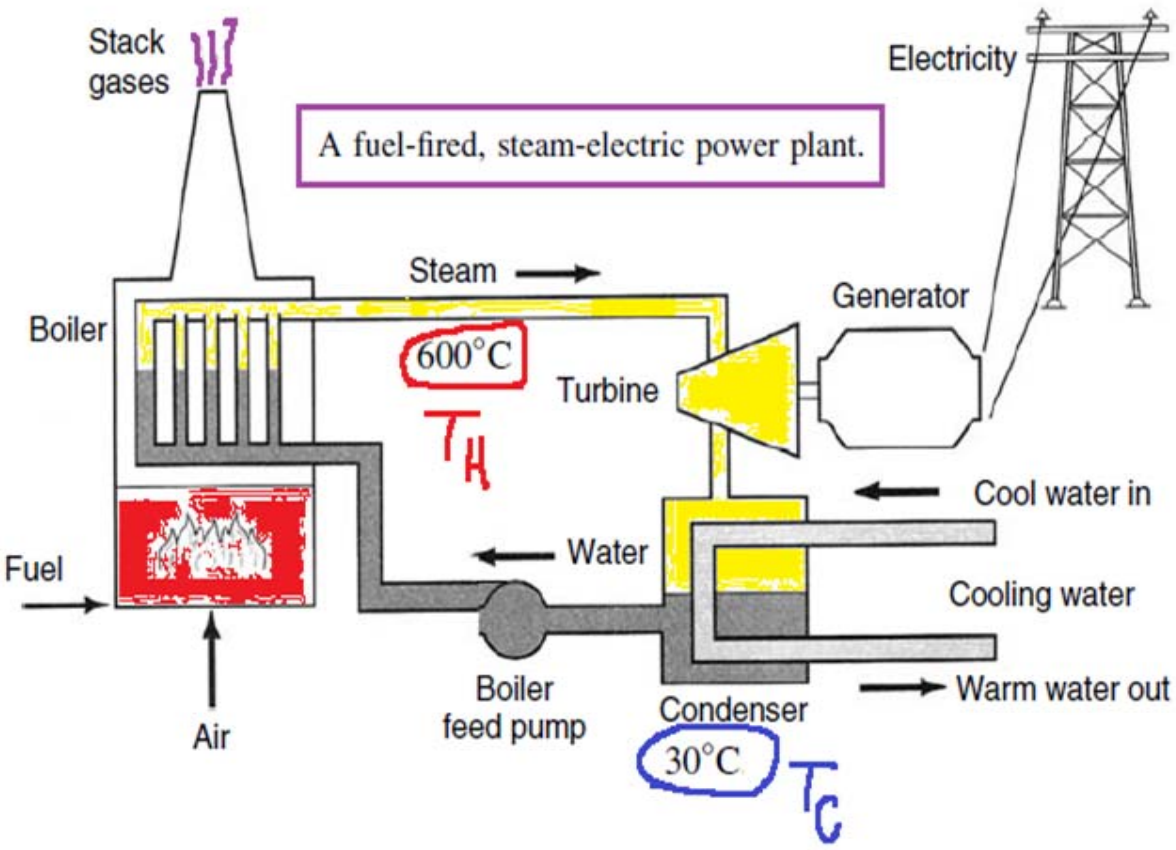
Heat Engines



Heat Engine


High-temperature
SOURCE, T_H
Q_H
W
HEAT
ENGINE
Q_C
Low-temperature
SINK, T_C

Basic Steam-Cycle for Electricity Generation



- "**Heat Rate**"
- Steam-Cycle Efficiency

- Steam Cycle Efficiency
  - Edison's First Plant
    - Heat Rate = 70,000 Btu/kWh
    - Efficiency = 3412/70000 = 0.0487 → 5 %
  - Average Steam Plant
    - Heat Rate = 10,000 Btu/kWh
    - Efficiency = 3412/10000= 0.3412 → 34 %