Advanced technology in electrical power generation

Presentation plan

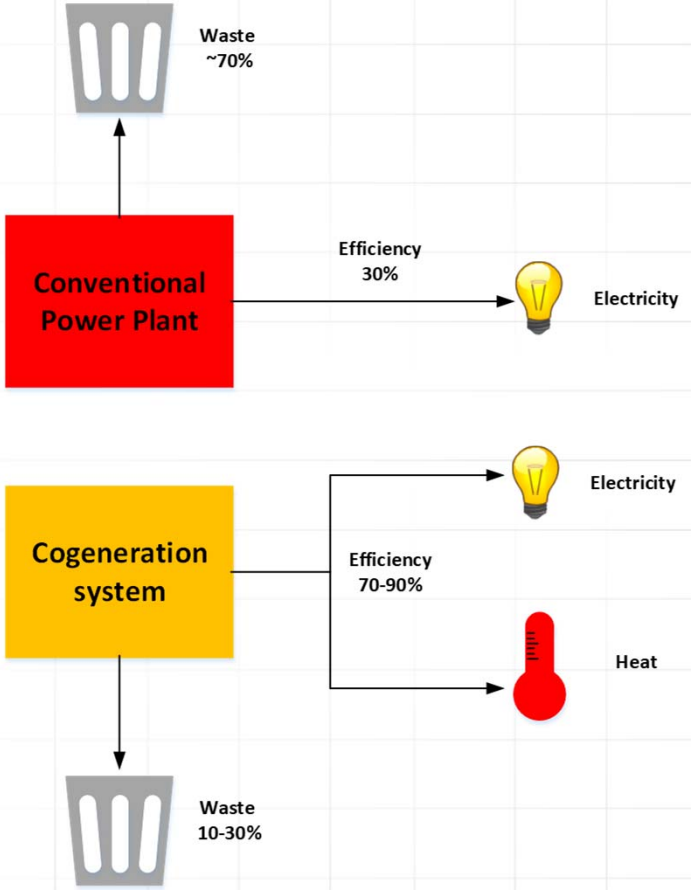
- Cogeneration Systems in Energy Production
- Clean Energy Production System from Fossil Fuels – Oxyfuel, Capture of Carbon Dioxide
- Environmental Impact of Energy Production System
- Nuclear Fuel Cycle, Nuclear Fission Principles, Types of Reactors

Cogeneration Systems in Energy Production

- Energy in most powerplants is transferred by hot steam.
- Steam is obtained by heating water through burning of coal, gas, oil or through nuclear reaction.
- Conventional power plant efficiency is around **35%**, therefore **65%** of energy is lost.
- Cogeneration = production of heat and electricity at the same time using one primary energy source.
- Mechanical energy → drives rotor of generator → electricity production
- Thermal energy → e.g., hot air, hot water production.
- Cogeneration power plants efficiency is around **50%** up to **70%.**

Cogeneration Systems in Energy Production

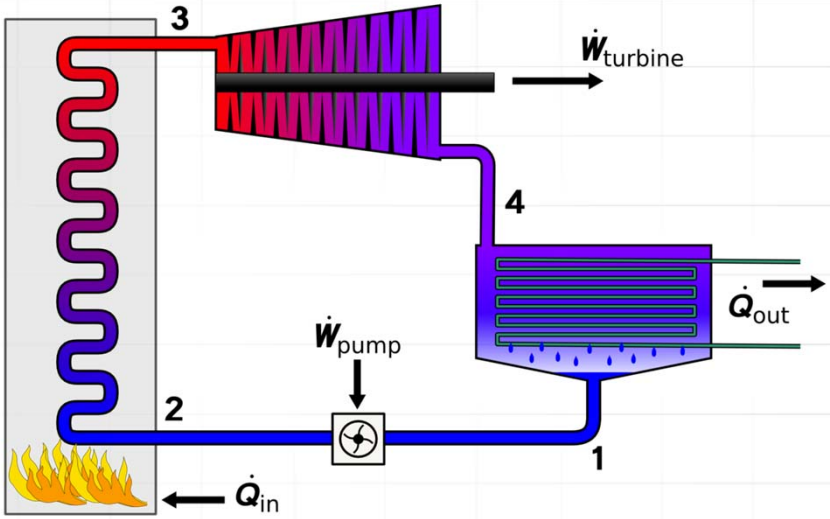
- Cogeneration can:
  - reduce gas emission,
  - increase efficiency of electricity production process,
  - decrease energy costs,
  - Use RES (Renewable Energy Sources) as a fuel e.g., biomass
- Local generation reduces load on utility networks and eliminates transmission losses
- Most of cogeneration power plants is based on steam turbines (Rankin-cycle)



Cogeneration Systems in Energy Production

➢ Rankin cycle:

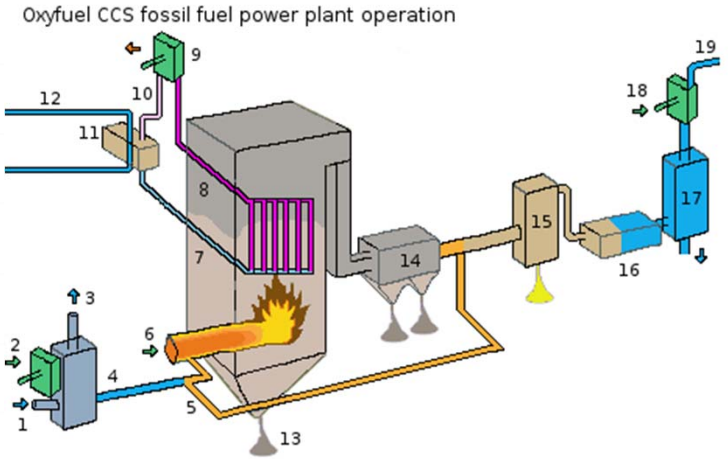
- **Isentropic compression (1-2)** - Water is pumped form low to high pressure, pump doesn't require high input of energy.
- **Constant pressure heat (2-3) –** water on high pressure enters boiler and then it is heated without change of pressure (P=const.) with utilization of heat source (e.g., coal boiler). Liquid water becomes dry saturated steam.
- **Isentropic expansion (3-4) –** dry saturated steam expands through turbine producing power. Energy is taken from steam, therefore pressure and temperature of its decreases.
- **Constant pressure heat rejection (4-1) –** wet steam is flowing through system to condenser, where it is condensed with stable pressure (P=const.) to the form of saturated liquid water.



1 – Pump, 2 – Boiler, 3 – Turbine, 4 – Condenser
Source: https://en.wikipedia.org/wiki/Rankine_cycle

Clean Energy Production System for Fossil Fuels - Oxyfuel

- Oxyfuel combustion process is based on burning a fuel with utilization of oxygen and recirculated flue gas, instead of air.
- Oxyfuel provides higher flame temperature – nitrogen element of air is not heated.
- Firing with pure oxygen = too high temperature of flames → utilization of mixture of recycled flue gas and oxygen.
- Oxyfuel combustion → approximately 75% less flue gas than air fueled combustion.
- Exhaust consisting of CO_2 and H_2O.
- Reduction of harmful substances into the atmosphere.
- Prevention of high temperature nitrogen oxides (No_x)
- Oxyfuel combustion method costs more than traditional conventional air-fired plant.
- Separating oxygen form the air – requires much energy

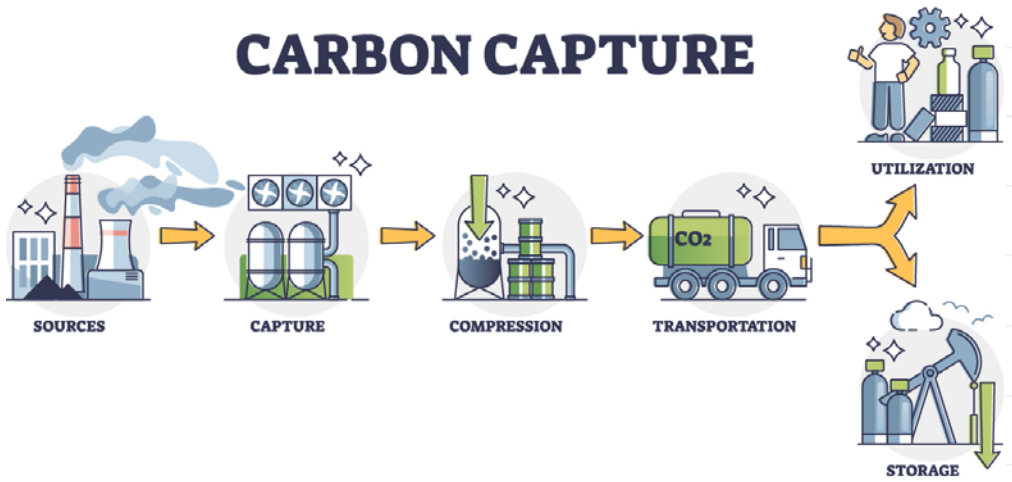


Source: https://en.wikipedia.org/wiki/Oxy-fuel_combustion_process

Clean Energy Production System for Fossil Fuels – Capture of Carbon Dioxide

- Carbon capture and storage (CCS) – process during which pure stream of CO_2 from sources such as factories, power plants is separated, treated and transported to storage for long term.
- CO_2 usually is captured from large sources – e.g., biomass power plants, conventional power plants.
- CO_2 is mainly stored underground, in geological formations.
- CCS is employed to contribute climate change mitigation.
- There are 3 ways that this capturing can be carried out:

- Post combustion capture – CO_2 is captured after combustion of the fossil fuel
- Pre-combustion capture – fossil fuel is oxidized partially.
- Oxy-combustion – based on oxy-fuel combustion (slide before)



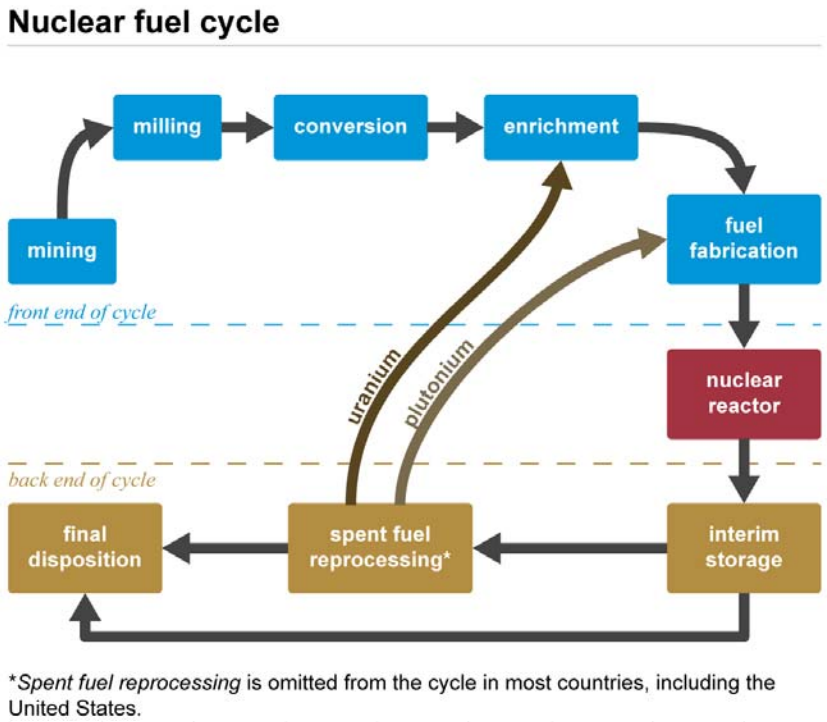
Source: https://blog.labtag.com/carbon-capture-technology-converting-co2-into-something-useful/

Environmental Impact of Energy Production System

- Global warming – green house gases (such as CO_2) as a product of fossil fuels combustion keeps heat inside the atmosphere.
- Air pollution – especially in urban areas, what causes health problems.
- Water pollution – changes of groundwater flow because of coal mining.
- Solid waste disposal – removal of large quantities of material during mining.
- Devastation of the area – by mines or dredging.
- In 2013 burning of fossil fuels produced around 32 billion tones of carbon dioxide.

Nuclear Fuel Cycle

- Nuclear fuel cycle consists of:
- *front-end steps* – preparation of uranium for use in reactors
- *back-end steps* – safe managing, preparing and dispose of used or spent but still radioactive nuclear fuel
- Nuclear fuel cycle is an industrial process which involves activities to produce power from nuclear fuel in reactors.
- After use in reactor fuel become highly radioactive and must be removed.
- Used fuel must be stored under water in spent fuel pool for years.
- After few years in pool, fuel is cooled and can be moved.



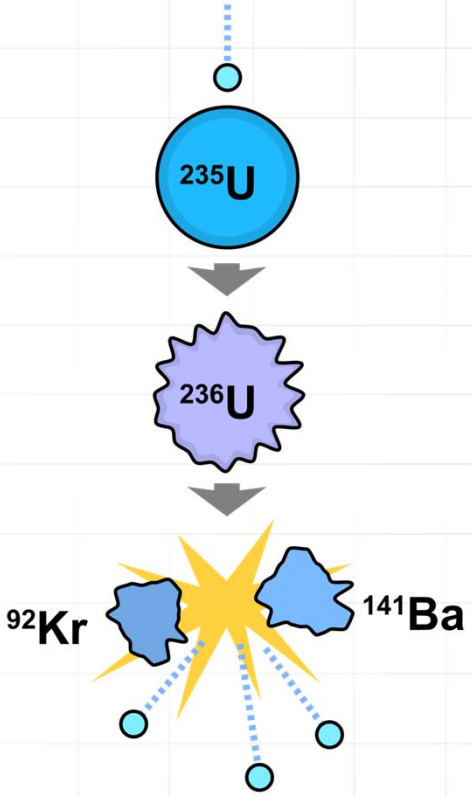
Source: https://www.eia.gov/energyexplained/nuclear/the-nuclear-fuel-cycle.php

Nuclear Fission Principles

Nuclear fission is the process when the nucleus of an atom splits into two or more nuclei which are smaller. During this process large amount of energy is released.

- Every nuclear power plants uses nuclear fission.
- For uranium power plant:

1. Neutrons collide with fuel atoms (Uranium-235) and lead to split of it.
2. Large amount of energy is released → heat + radiation
3. Additional free neutrons are released
4. New neutrons continue collie with another uranium atoms
5. Process is repeats and becomes self-sustaining.



Source:
https://en.wikipedia.org/wiki/Nuclear_fission

Types of Reactors

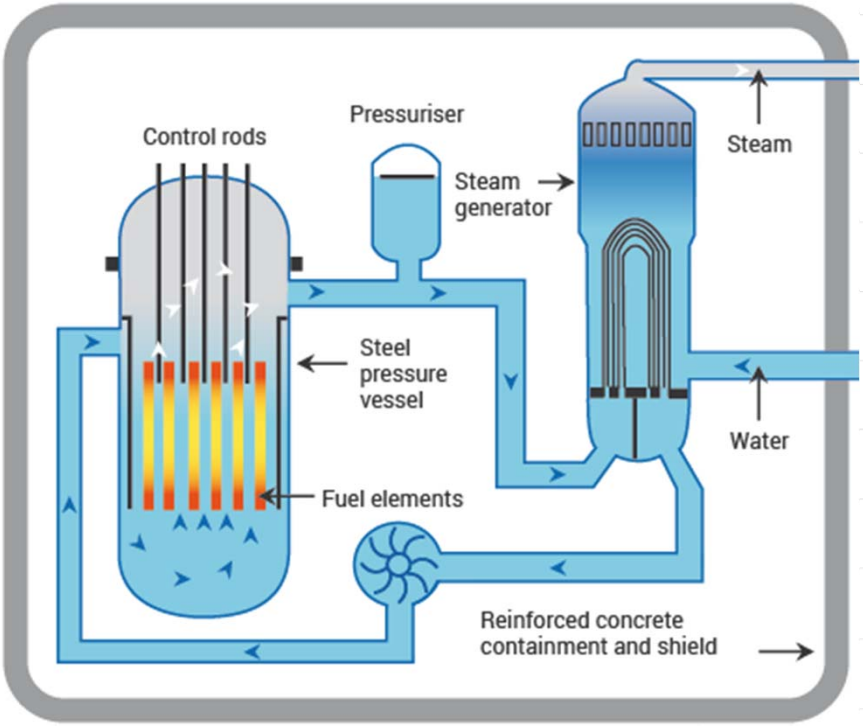
➢ Pressurised water reactor (PWR)

Nowadays this type of reactor is most common. PWRs are using water as coolant and moderator of nuclear reaction. This type of reactor has two cooling circuits:

- Primary cooling circuit – coolant under vey high pressure flows through core of reactor.
- Secondary cooling circuit – generated steam drives turbine.

Water in core has temperature around 325°C, thus is kept in pressure around 150 bars.

- Holds between 80 and 100 tones of Uranium.



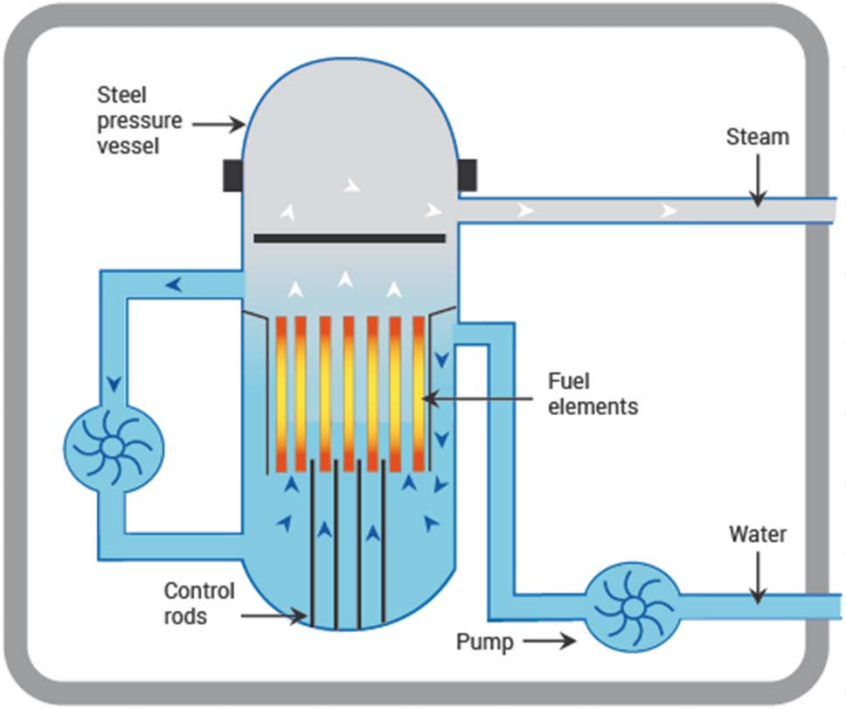
Source: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

Types of Reactors

➢ Boiling water reactor (BWR)

This type of reactor has a lot of similarities to PWR. Difference is that it has only one circuit.

- Water in circuit is at lower pressure in comparison to PWR, it is around 75 bars.
- Water boils in the core around 285°C.
- 12-15% of water in the upper part of core is in form of steam.
- Holding up to 140 tones of Uranium.



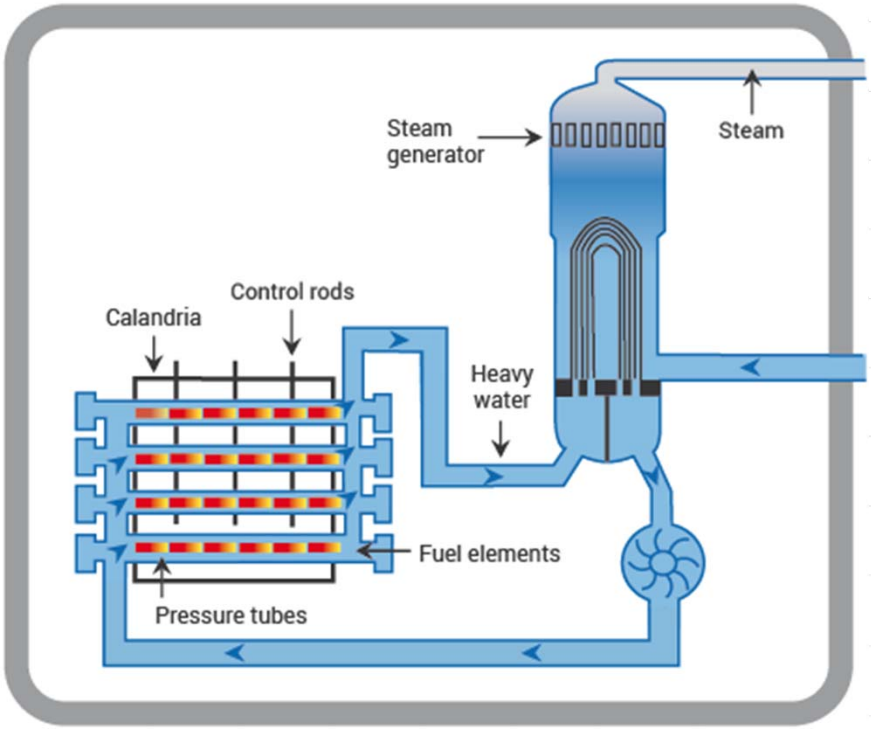
Source: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

Types of Reactors

➢ Pressurised heavy water reactor (PHWR)

This generator uses natural Uranium oxide as fuel, therefore needs more efficient moderator.

- Moderator – heavy water (D_2O).
- Produces more energy per kg of used uranium than other reactors.
- Heavy water under high pressure (100 bars) as a coolant.
- Temperature in the primary cooling circuit – around 290 °C.



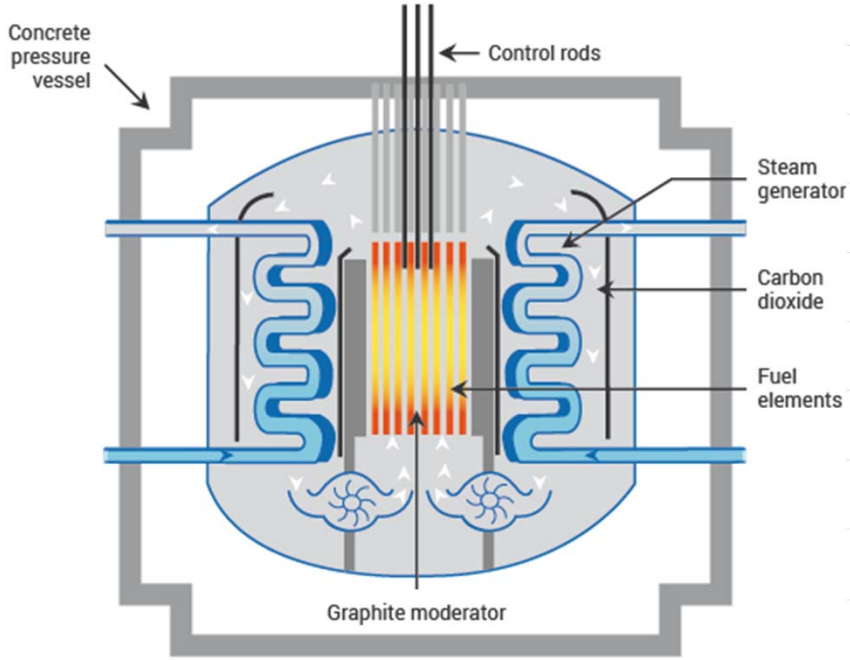
Source: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

Types of Reactors

➢ Advanced gas-cooled reactor (AGR)

This type of generator uses uranium oxide pellet enriched to 2.5 - 3.5%

- Moderator – graphite.
- Primary coolant – carbon dioxide, which circulates in core with temperature of 650 °C.
- Thermal efficiency is around 41%.
- Refueling can be done during on load conditions.



Source: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

Types of Reactors

➢ Light water graphite-moderated reactor (LWGR)

In this type of reactor low-enriched uranium oxide is used as fuel.

- Moderator – graphite
- Coolant – water, which boils in core at 290 °C and with pressure of 6.9 MPa

➢ Fast neutron reactor (FNR)

In this type of reactor plutonium is used as fuel.

- Moderator – doesn't have, uses fast neutrons
- Coolant – liquid sodium
- Get more than 60 times as much energy from the original uranium compared to normal reactors
- Expensive to build

Thank you for your attention!