Nuclear Power Plants

Principle of operation and comparative analysis

Nuclear Power is Created!

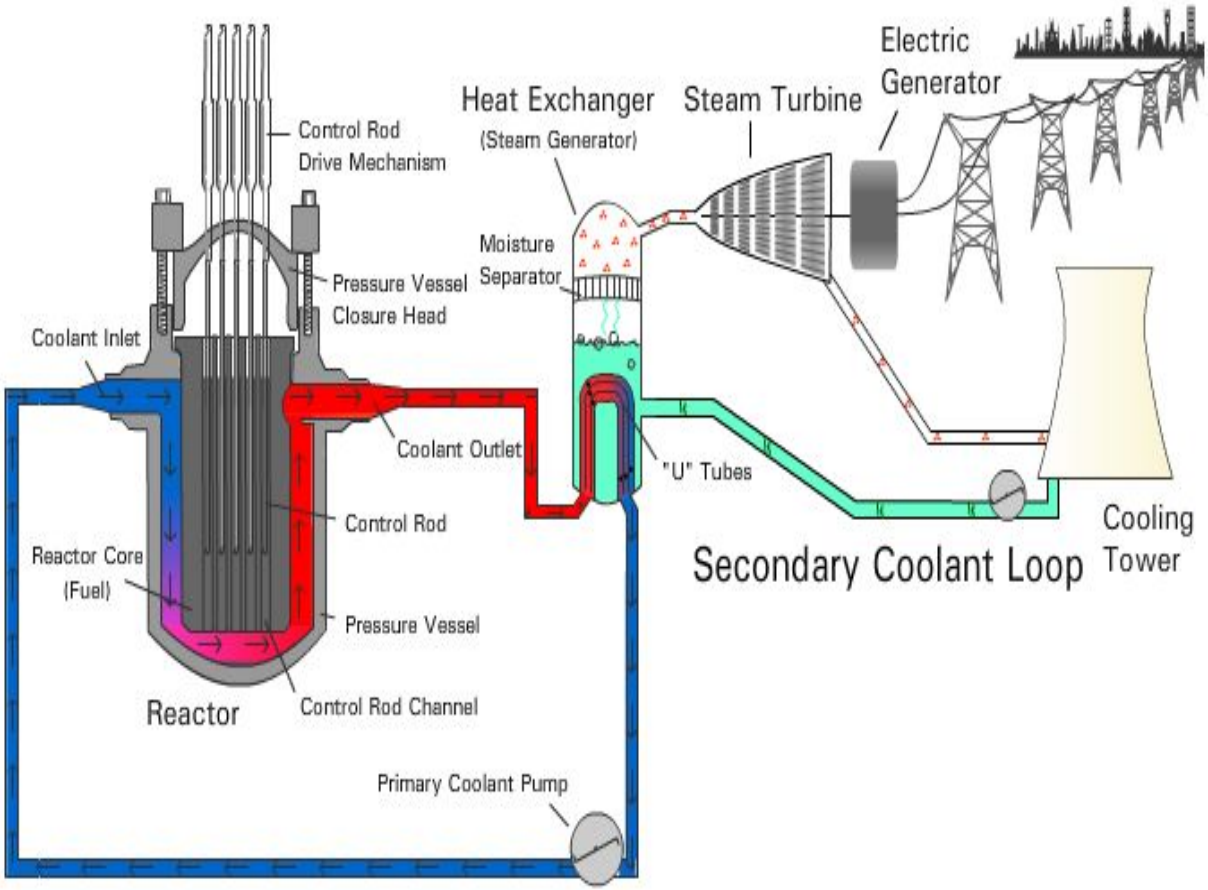
- On December 20, 1951, near the town of Arco, Idaho, engineers from Argonne National Laboratory started a reactor that was connected to a steam turbine generator. When the chain reaction reached criticality, the heat of the nuclear fuel turned water into steam, which drove the generator and produced 440 volts, only enough electricity to power four light bulbs. This was the first time a nuclear reaction had created usable power.

Public Fear

- Pennsylvania's Three Mile Island plant in 1979
- Ukraine's Chernobyl plant in 1986
- Three Mile Island only a small amount of radiation was released into the atmosphere
- But Chernobyl released a tragically large amount
- This has led to public fear of Nuclear energy in America, and no new nuclear plants have been ordered in the United States since 1977
- International growth of nuclear power continued almost completely unaffected, with an additional 350 nuclear plants built worldwide in the past 2 decades, almost doubling the previous total

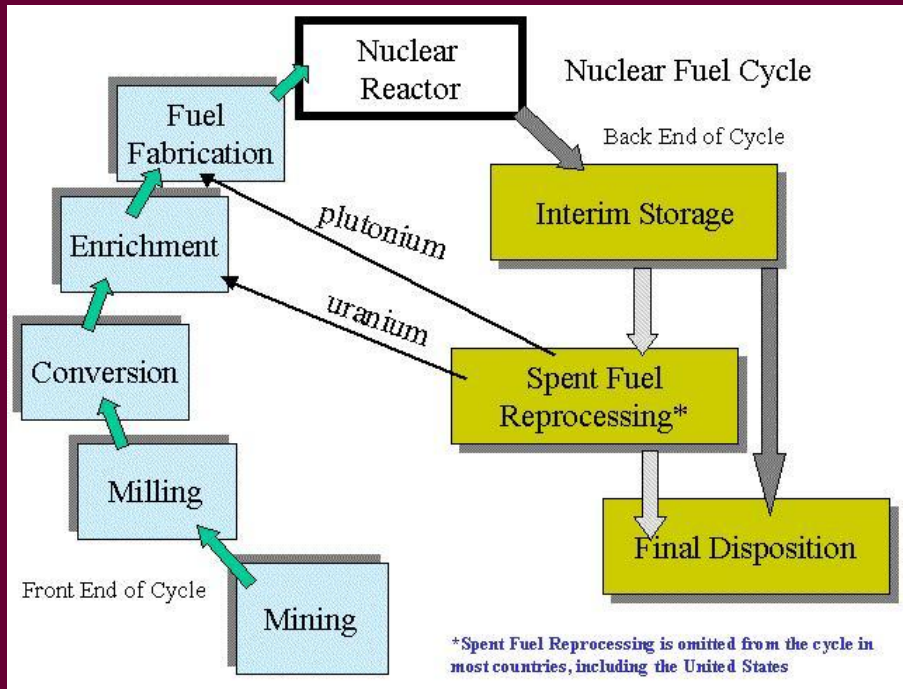
How it Works

- Coolant is pumped into the Reactor where it is heated and that coolant is fed to the Heat Exchanger where the heat is used to turn water into steam and run a steam turbine, which produces electricity. The steam is then led to a cooling tower for cooling and then pumped back to the heat exchanger.



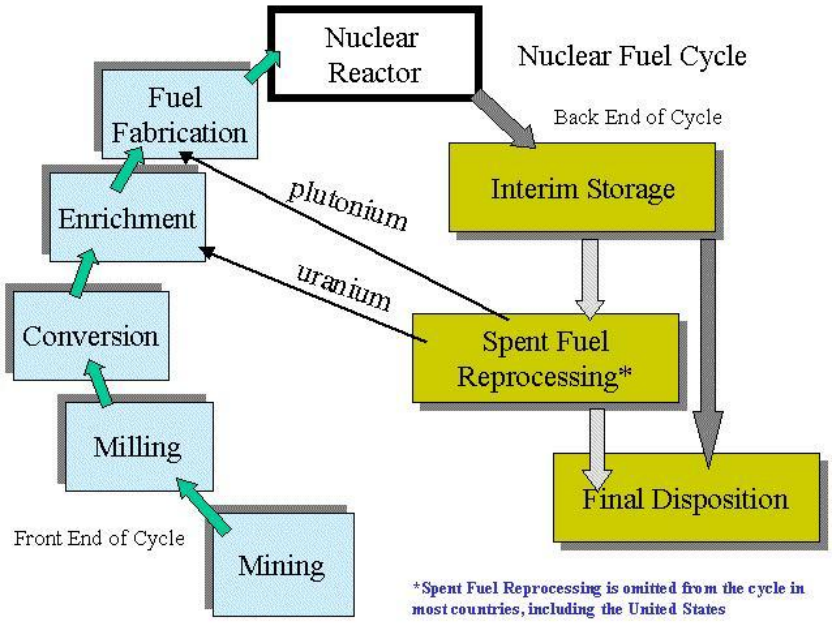
How it Works: The Fuel Cycle

- Mining: Uranium ore is extracted through conventional mining in open pit and underground methods similar to those used for mining other metals.
- Milling: grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching.
- Conversion: must be converted to uranium hexafluoride, UF6, which is the form required by most commercial uranium enrichment facilities currently in use.



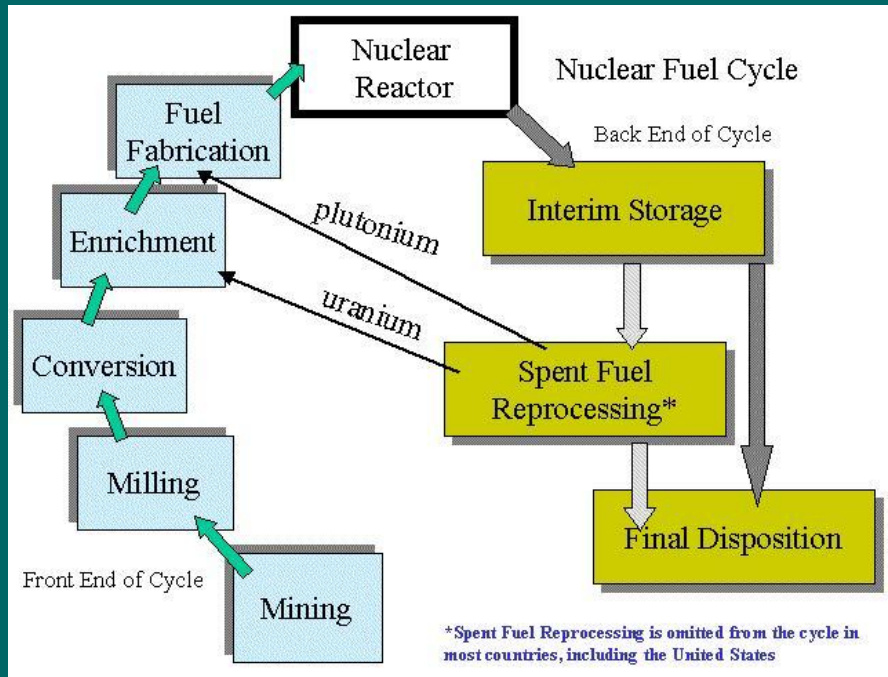
How it Works: The Fuel Cycle

- Enrichment: Natural UF6 thus must be "enriched" in the fissionable isotope for it to be used as nuclear fuel.
- Fuel Fabrication: The pellets are stacked, according to each nuclear core's design specifications, into tubes of corrosion-resistant metal alloy. The tubes are sealed to contain the fuel pellets: these tubes are called fuel rods.
- Nuclear Reactor: The finished fuel rods are grouped in special fuel assemblies that are then used to build up the nuclear fuel core of a power reactor. These are then used to drive the Reactor.



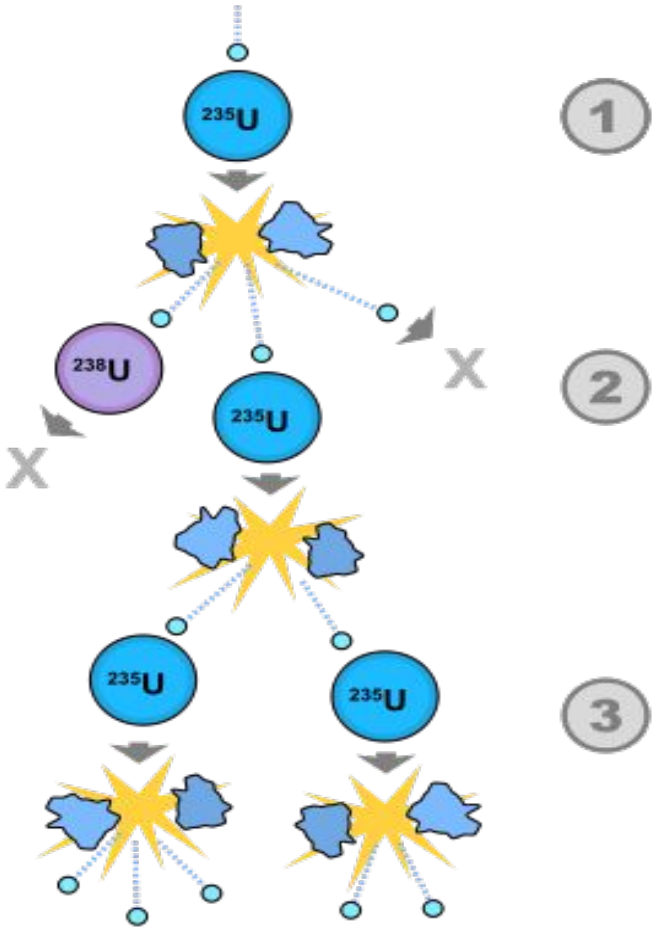
How it Works: The Fuel Cycle

- Interim Storage: The spent fuel rods are usually stored in water, which provides both cooling and shielding.
- Fuel Reprocessing: This step is skipped in here in the US but other countries like France reprocess the spent fuel and reuse it.
- Final Disposition: Plans for final storage are to store the spent fuel rods in Yucca Mountain, but these plans are on hold because of fear of radiation for the thousands of years these rods will last.



Fission

- The process of fission is when a uranium-235 atom absorbs a neutron and fissions into two new atoms (fission fragments), releasing three new neutrons and some binding energy. The new neutrons start the process all over again.



Criticality

- When a reactors neutron population remains steady from one generation to the next, the fission chain reaction is self-sustaining and the reactor's condition is referred to as "Critical", this is a good thing. When the reactors neutron production exceeds losses, characterized by an increasing power level, it's called "Supercritical", and when there are more losses than gains, its "Subcritical" and shows decreasing power.

$$k = L_f \; p \; L_{th} \; f \; n \; E$$

L_f - "fast non-leakage factor"

p - "resonance escape probability"

L_{th} - "thermal non-leakage factor"

f - "thermal fuel utilization factor"

n - "reproduction factor"

E - "fast-fission factor"

Compared to Other Sources of Energy

- 1 kilogram of coal generates 3 kilowatt-hours of electricity;
- 1 kilogram of oil generates 4 kilowatt-hours;
- 1 kilogram of uranium generates up to 7 million kilowatt-hours.
- Also, unlike coal- and oil-burning plants, nuclear plants release no air pollutants or the greenhouse gases that contribute to global warming.

Compared to Other Sources of Energy

- The two main sources of renewable energy are solar panels and wind turbines.
- Nuclear can produce large amount of power at one plant, and there is no down time.
- Renewable energy gives off no radiation and relatively cheap to start compared to Nuclear plant and cleaner.
- Nuclear may not be as clean as these sources but much cleaner than coal/oil.

Light Water Reactors

- Thermal nuclear reactor that uses ordinary water, also called light water
- Heats water to produce steam to drive a turbine
- This is the Reactor most commonly used in US

Pebble Bed Reactors

- Aims to achieve lower risks and higher thermal efficiencies than possible in traditional Nuclear Power Plants.
- Instead of water, it uses pyrolytic graphite as the neutron moderator, and an inert or semi-inert gas such as helium, nitrogen or carbon dioxide as the coolant, at very high temperature, to drive a turbine directly.
- This eliminates the complex steam management system from the design and increases the thermal efficiency.

Fast Breeder Reactors

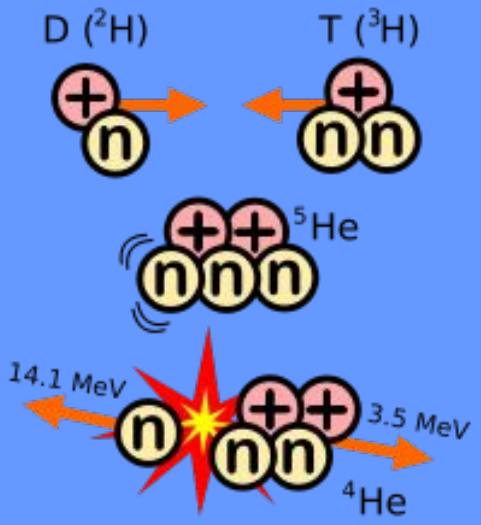
- A fast neutron reactor designed to breed fuel by producing more fissile material than it consumes
- Several prototype FBRs have been built, ranging in electrical output from a few light bulbs equivalent to over 1000MW
- Technology is not economically competitive to thermal reactor technology, but research is still being committed anticipating that rising uranium prices will change this in the long term.

Floating Nuclear Power Stations

- Self-contained, low-capacity, floating nuclear power plants, each powered by two modified KLT-40 naval propulsion reactors.
- Each vessel would then provide up to 70MW of electrical or 300MW of heat energy that are enough for a city with population of 200,000 people.
- Could be modified as a desalination plant producing 240,000 cubic meters of fresh water a day.
- First one is set to launch in 2010.

Fusion

- Process by which multiple atomic particles join together to form a heavier nucleus
- The fusion of two nuclei lighter than iron or nickel releases energy
- Hydrogen isotopes are most commonly used
- This is what naturally happens in stars



Summary

- America currently gets about 16% of its energy use from Nuclear Power, while France produces about half of its energy needs solely from Nuclear
- Needs to be looked at to solve our global warming problem as well as the rise in oil prices
- Most people are afraid of what they don’t know, so if people better understood Nuclear power and the efforts that are being made to improve safety and minimize Nuclear waste, they might not be afraid