

NUCLEAR POWER!

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What is nuclear energy?

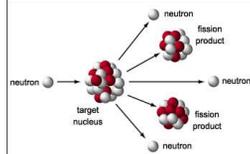
- One of the most controversial sources of energy
- Energy generated by steam-turbines just as in coal electric plants, but the source of the heat is different
- Major global power source:
 - 19% of the energy in the USA was nuclear in 2018
 - Highest percentage of total is France with more than 73% of all power generated in nuclear plants



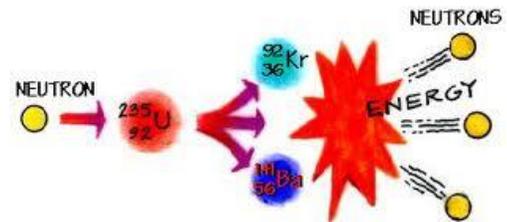
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Nuclear Fission

- A large atom is split into bits when it is hit by a neutron
- Atom hit is typically Uranium-235
- Lots of energy given off as heat as a result
- Heat boils water into steam and steam turns turbines



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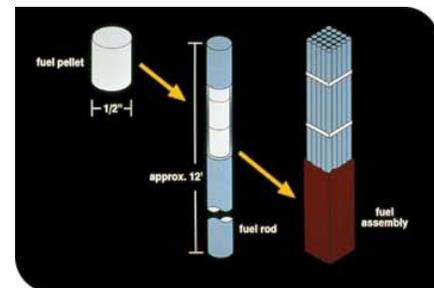
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How it works...

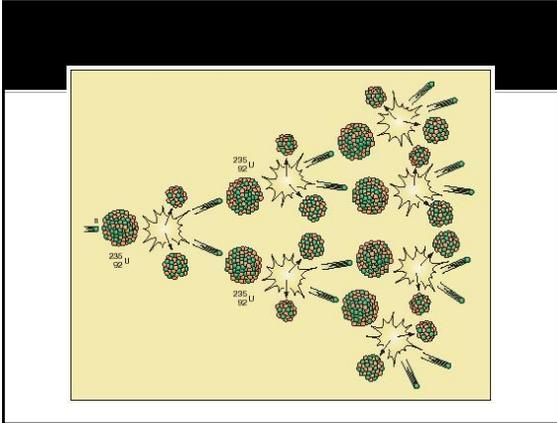
- Uranium pellets are contained in fuel rods in a containment structure
- Initial volley of neutrons starts the decay process, which works in a chain reaction fashion



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How it works...

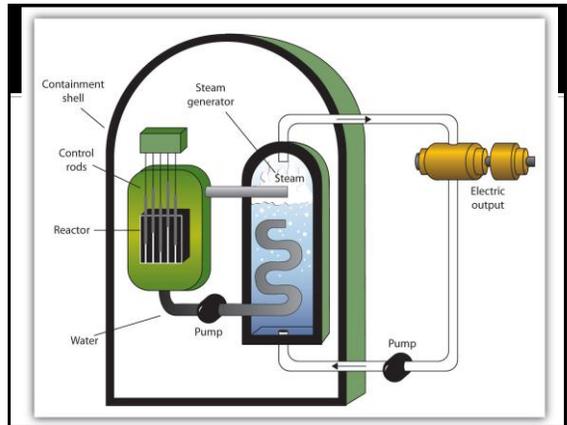
- Core of the reactor heats water, which heats other water
- Water in a nearby generator turns a turbine
- Turbine powers a generator

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How it works... Preventing a disaster

- To prevent chain reactions from getting out of hand, fuel rods are interspersed with control rods
- Control rods absorb excess heat along with water and prevent the chain reaction from continuing uncontrolled

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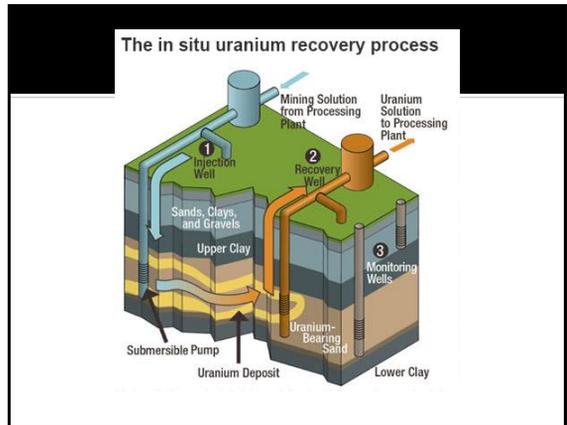


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Nuclear Fuel

- Up to 1000kg of ore might be needed to extract just 3kg of fuel
- Uranium ore ultimately is still a non-renewable resource and often pit mined
- Most ore has the wrong kind of uranium in it (U-238 when reactors use U-235), so fuel has to be enriched
 - Ore is mined, pulverized and milled into yellowcake
 - Yellowcake is converted into a gaseous form of Uranium, which is then separated by mass to create enriched Uranium
 - Gases are cooled and pressurized into a solid fuel

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Uranium milling
 After the uranium ore is extracted from an open pit or underground mine, it is refined into uranium concentrate at a uranium mill. The ore is crushed, pulverized, and ground into a fine powder. Chemicals are added to the fine powder, which causes a reaction that separates the uranium from the other minerals. Groundwater from solution mining operations is circulated through a resin bed to extract and concentrate the uranium.

Typical conventional uranium mill

Source: U.S. Energy Information Administration

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Advantages

- NO air pollution and virtually no CO₂ emissions
- Once a reactor is built, energy is cheap
 - 0.75 cents/kilowatt-hour vs. 2.53 cents/kilowatt-hour of FFs—3.5x cheaper
- Potential alternative to fossil fuels—easy to transition our existing grid onto
 - “Bridge” between renewable and non?

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Disadvantages—Safety

- Always the potential for nuclear meltdown, though these have been **INCREDIBLY RARE** in the history of nuclear reactors
- Uranium fuel can over heat and radioactive waste can be released

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3 Mile Island Disaster

- March, 1979 in Pennsylvania
- Workers didn't notice a closed water valve
- Overheated and causes a partial meltdown
- More than 200,000 people evacuated

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Chernobyl

- MUCH worse than 3 Mile Island
- April, 1986 in the Ukraine
- Workers were testing plant and removed control rods and disconnected cooling systems
- Explosion and fire that killed 31 people
- Radiation spread across Europe
- USSR very secretive about cleanup, but US National Academy of Sciences estimates an additional 4,000 cancer deaths over a 50 year period

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Radioactive Waste

- Spent Uranium is still radioactive and difficult to dispose of
- Half-life: the period of time for 1/2 of the radioactive atoms in a fuel source to decay
 - Uranium-235 has a half life of 704 million years

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Radioactive Waste

- Currently stored on site in water
- Some locations running out of room
- Proposals to bury the nuclear waste in Yucca Mountain in Nevada have been met with considerable controversy
 - Approved in 2002, but FED funding expired in 2002
 - Dept of Energy requested funding for additional drilling explorations in 2017 and 2018, but both were killed in committee
 - Desperate need for some type of centralized, safe containment




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Nuclear Fusion

- Opposite of fission: smashes atoms together
- Requires temperatures of 10x the core of the sun, 500...
 - Bit hard to contain.

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