Nuclear Energy 101

7

Argonne National Laboratory Nuclear Engineering Division



Let's start with a truly important energy engineering question:

How does your coffee pot work?

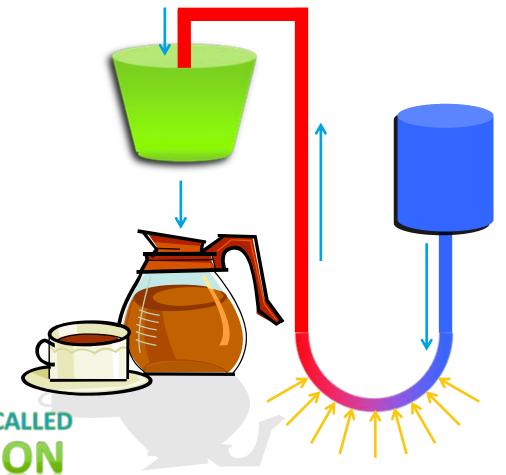


- Why does the water pour out of your coffee pot's filter basket into the pot below?
- How does the water you put into your coffeepot go from the tank to the filter basket?

Coffee Pots: The Naked Truth

- Water absorbs energy and heats up
- Water's density decreases with temperature
 - Steam's density is MUCH lower than liquid water
- Hot, low density water rises to filter basket
 - Added energy enables water to do some useful work

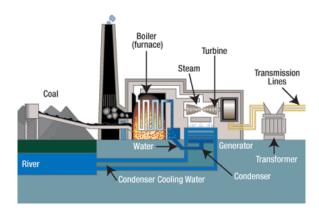
THE WORK DONE BY THE WATER IS CALLED NATURAL CONVECTION



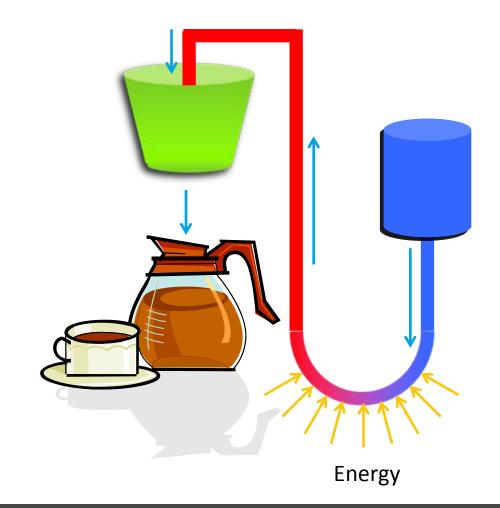
Energy

What does this have to do with NUCLEAR ENERGY?

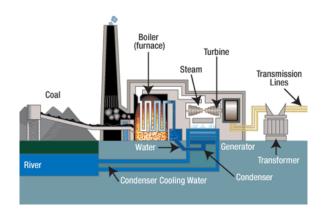
What does this have to do with ELECTRIC GENERATION?



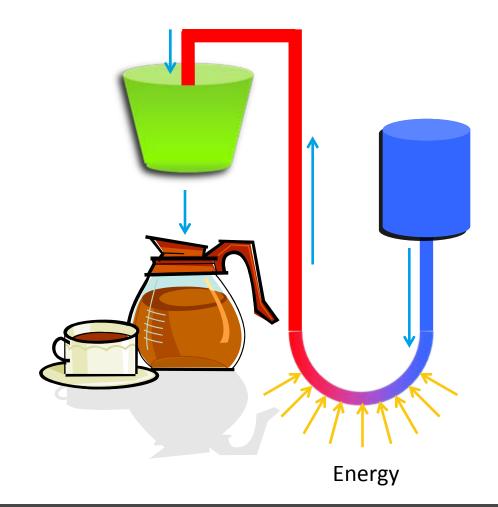




This is worth a closer look.

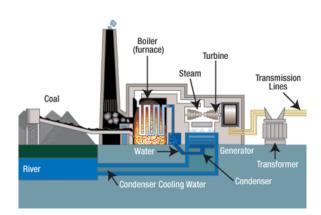




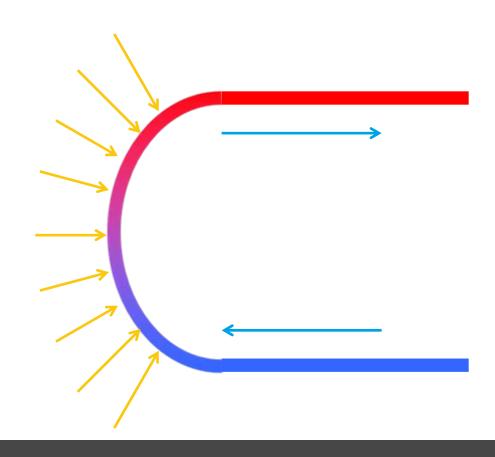


First, we won't need a coffee pot in a power plant.

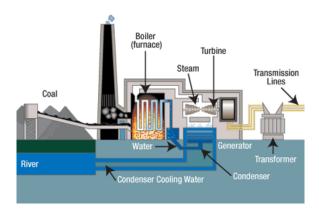
Next we should probably look at things from a different angle.



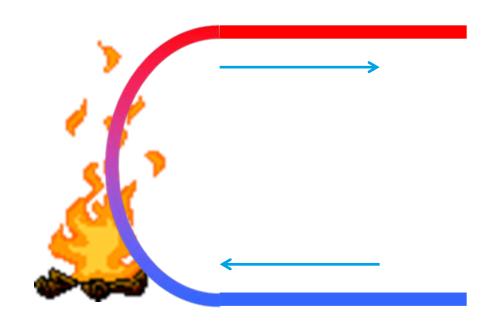




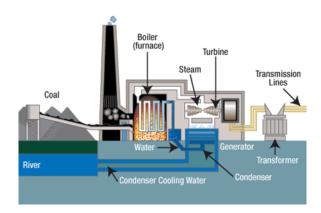
We need a bigger heat source than a coffee pot's hot plate.



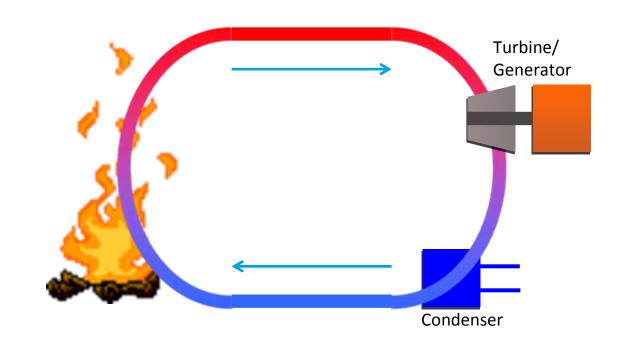




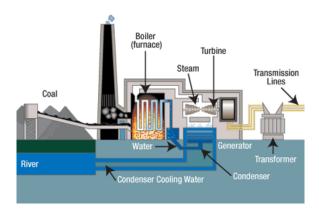
We'll burn something (wood, coal, natural gas, oil) in a boiler. Now let's make some electricity!



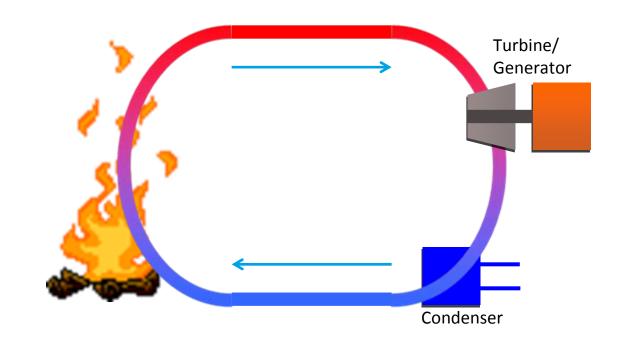




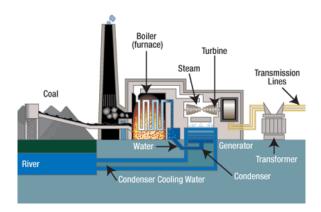
A turbine and generator makes electricity using the energy of the steam. A condenser turns the used steam back to water.



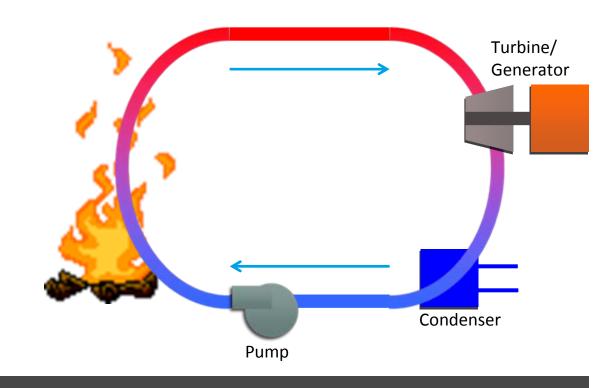




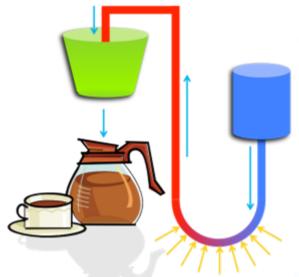
How do we control how much electricity we make?





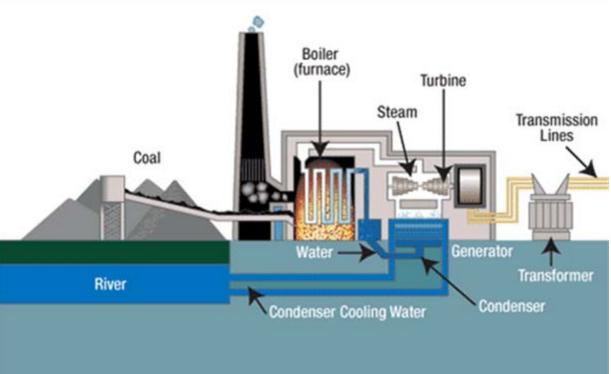


A pump allows us to control how much water is available to the heat source to make steam.



Energy





How is a Power Plant like a Coffee Pot?

Take a closer look at a coal fired power plant.

Can you find:

1) the Boiler 2) the Turbine 3) the Generator 4) the Condenser

How is a nuclear power plant different?

It's the Fuel!

Nuclear power plants use the energy stored in the nucleus of large atoms rather than the energy stored in weaker chemical bonds.



It's the Fuel!

TO POWER 1000 HOMES

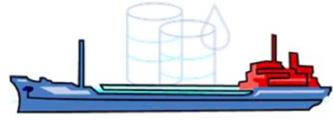




150 Tons of Uranium



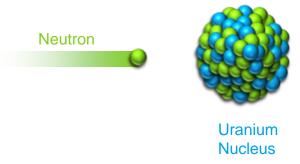
2,100,000 Tons of Coal



10,000,000 Barrels of Oil

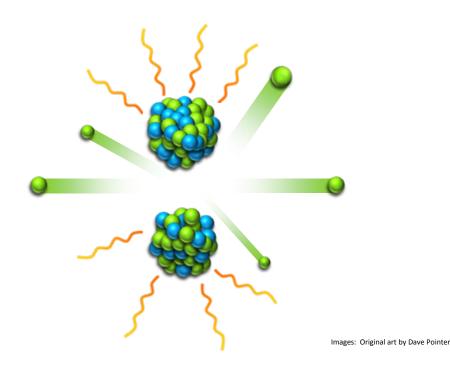
What is Nuclear Fission?

- If the nucleus of a heavy atom (such as Uranium) absorbs a neutron, the nucleus can become unstable and split.
- This is called NUCLEAR FISSION.

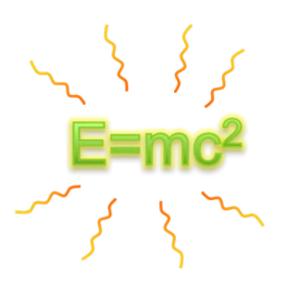


What is Nuclear Fission?

The nucleus splits in two halves and releases some neutrons, and radiation



What is Nuclear Fission?



During fission, a small amount of mass is lost. This mass is transformed into ENERGY, which is also released.



Let's Build a Nuclear Power Plant

Questions? Send them to neoutreach@anl.gov

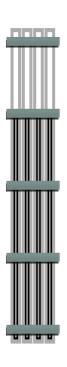


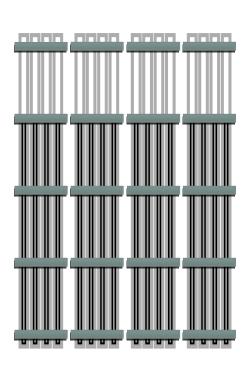


First, ceramic **fuel pellets** are manufactured from **uranium** ore

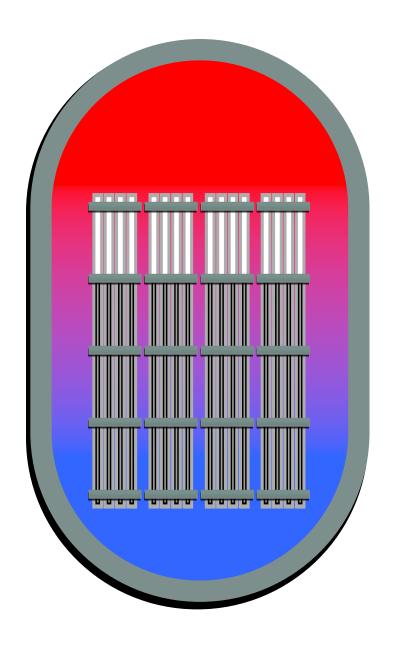
The ceramic **fuel pellets** are stacked in a column

And sealed inside a metallic alloy case, called the **cladding**, to form a **fuel rod**





The **fuel assemblies** are arranged in a larger regular array or reactor **core**

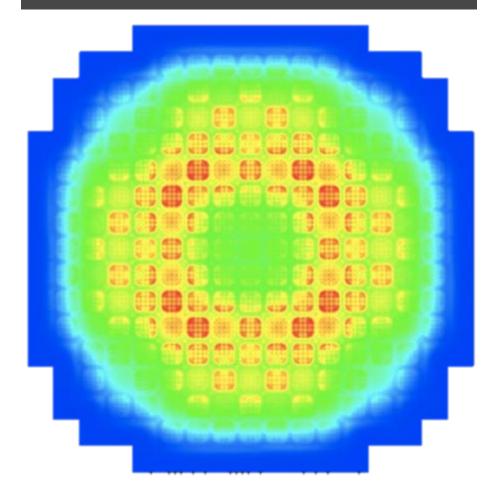


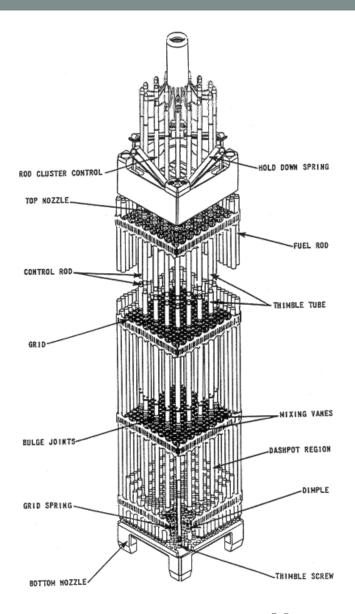
The **fuel assemblies** are arranged in a larger regular array or reactor **core**

The reactor core is contained inside a heavy steel reactor pressure vessel (RPV)

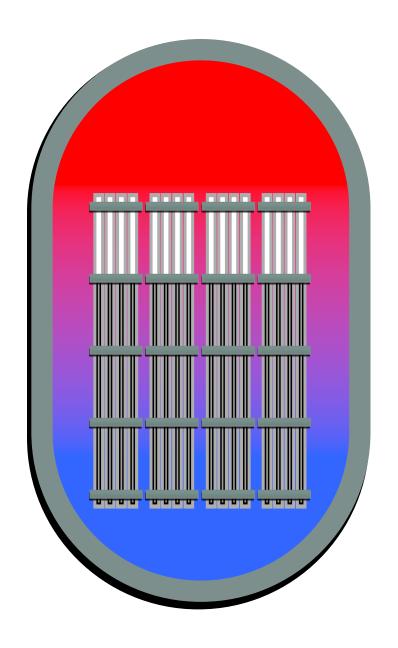
A Reality Check

Fuel assembly and reactor core design are complex engineering challenges. We've simplified things a bit in our cartoon.



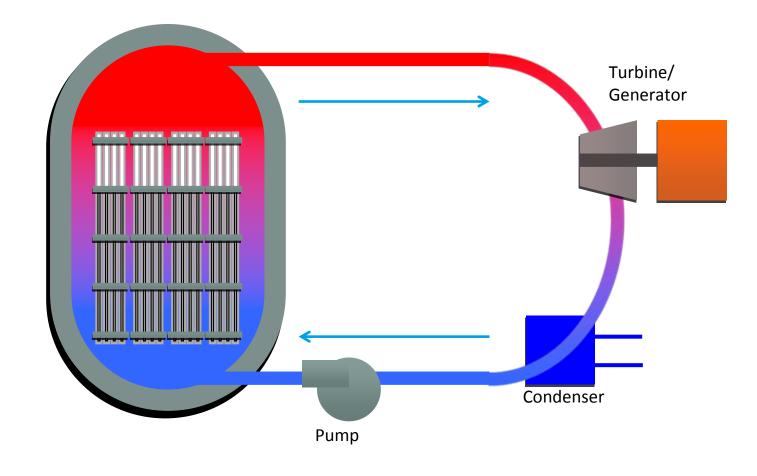


Reactor Fuel Assembly

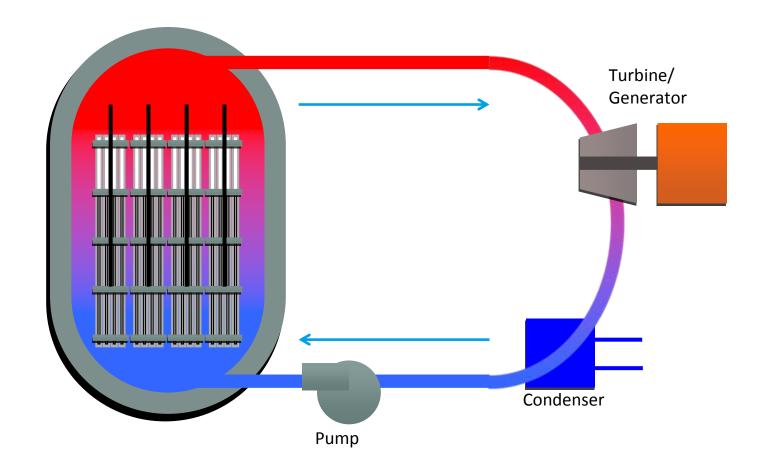


The fuel assemblies are arranged in a larger regular array or reactor core

The reactor core is contained inside a heavy steel reactor pressure vessel (RPV)



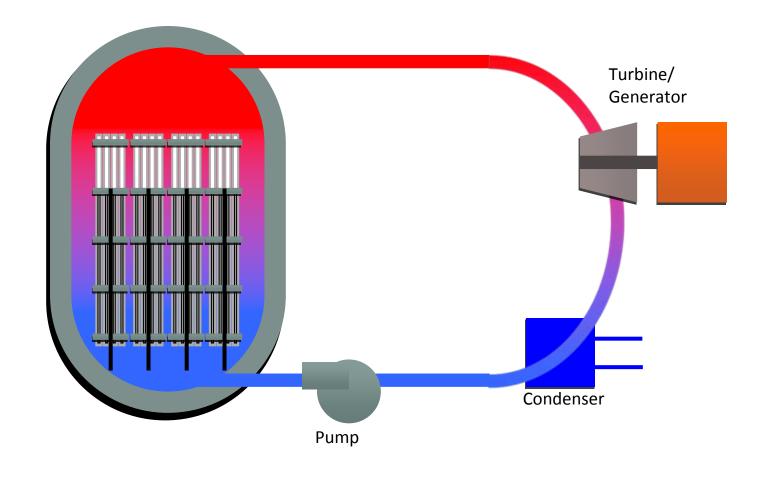
In a nuclear power plant, the **reactor core** replaces the burning fossil fuel as the energy source



Control rods absorb neutrons and are used to stop/start the reaction.

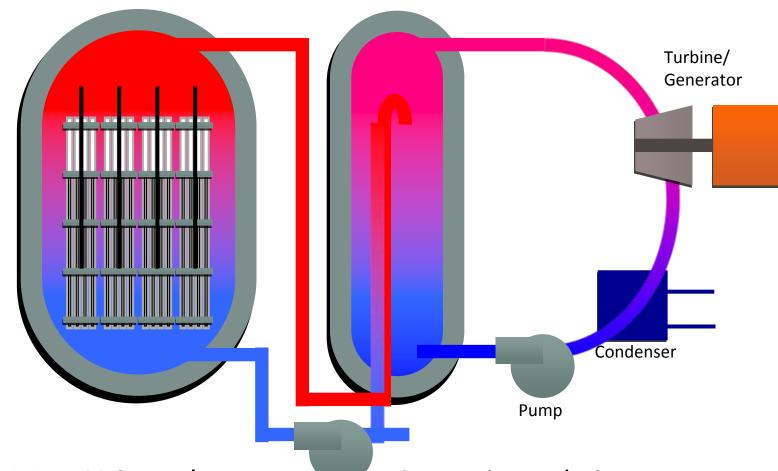
What's so CRITICAL?

- CRITICAL
 - # of Neutrons Produced **EQUALS** # of Neutrons Absorbed
- SUB-Critical
 - # of Neutrons Produced is LESS THAN # of Neutrons Absorbed
- SUPER-Critical
 - # of Neutrons Produced is GREATER THAN # of Neutrons Absorbed



39 of the 104 nuclear power plants in the U.S. look like this

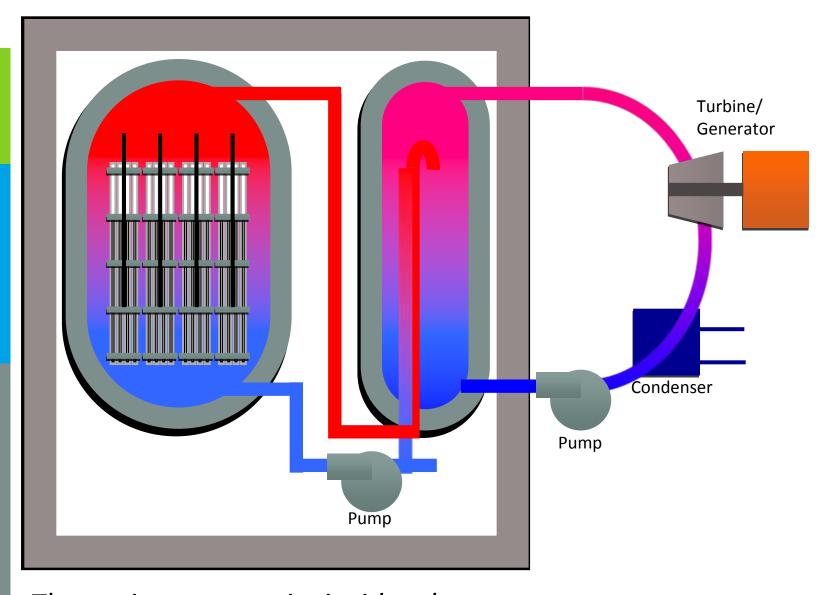
They're called **BWR**s or **Boiling Water Reactors**



Pump

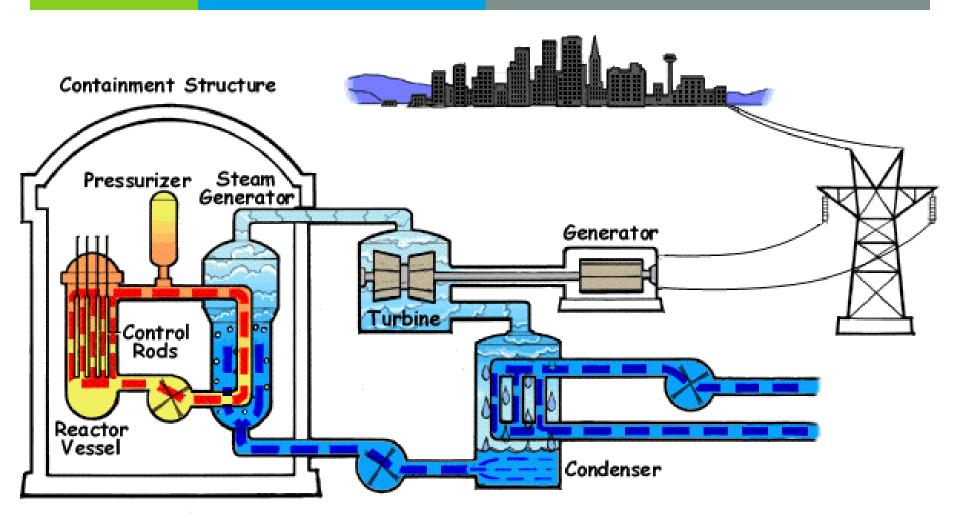
Most U.S. nuclear power plants are **PWR**s or **Pressurized Water Reactors**

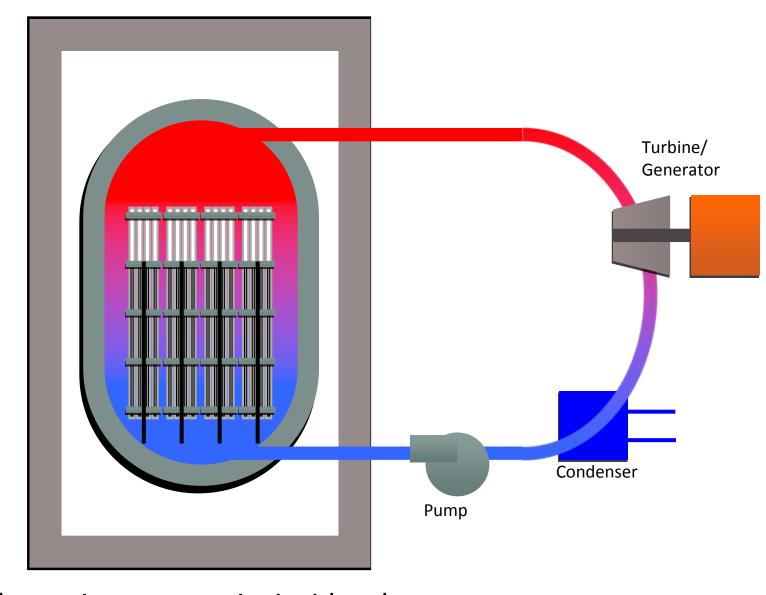
Steam is made in a steam generator rather than directly in the reactor core



The entire reactor sits inside a large concrete and steel **containment building**

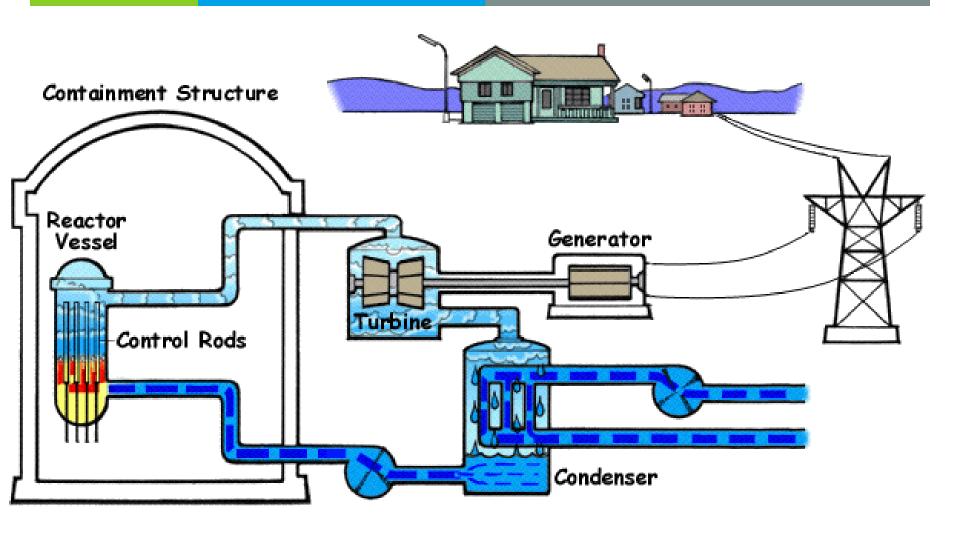
Pressurized Water Reactor



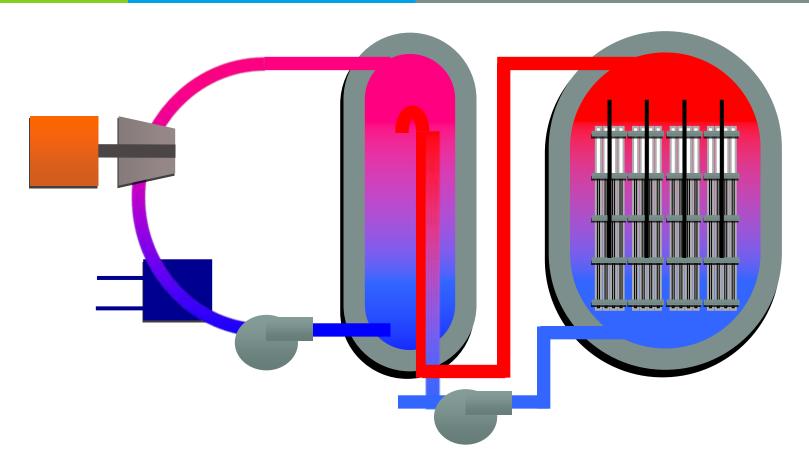


The entire reactor sits inside a large concrete and steel **containment building**

Boiling Water Reactor

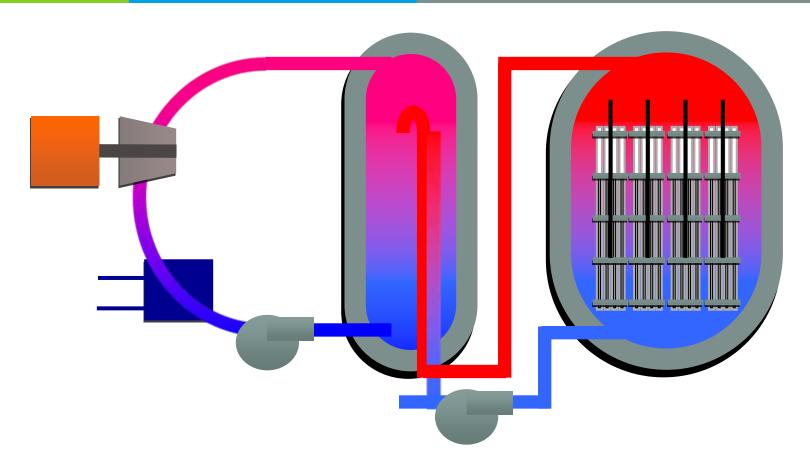


POP QUIZ!!!



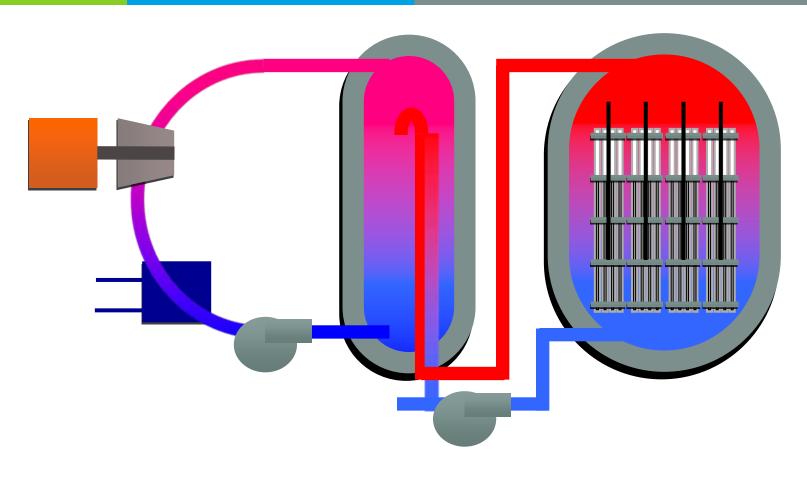
Which type of reactor is this? PWR or BWR?

POP QUIZ!!!

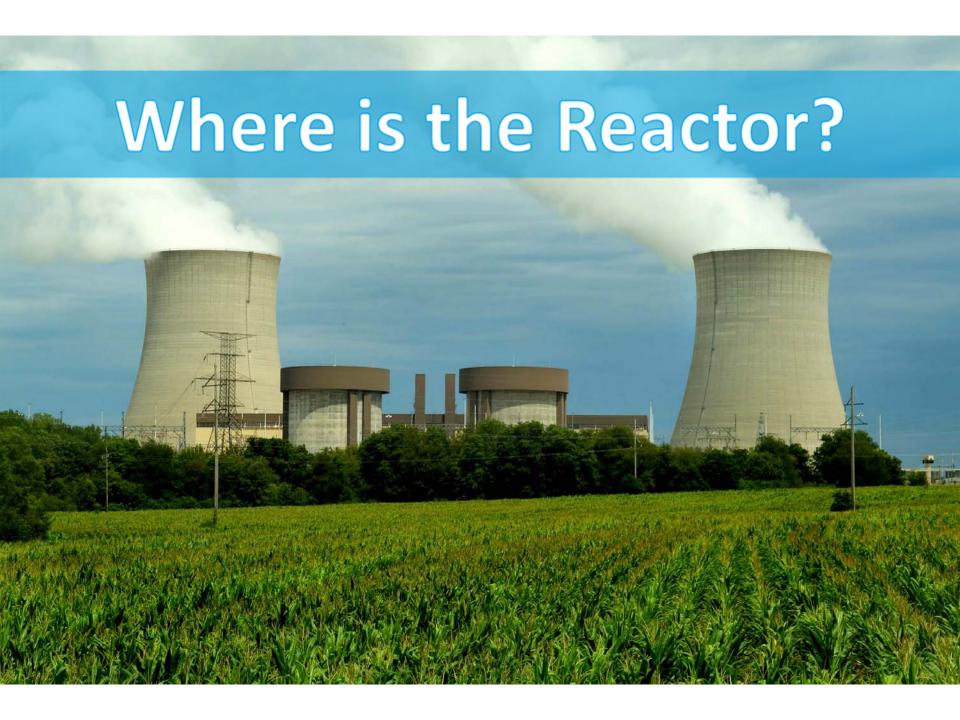


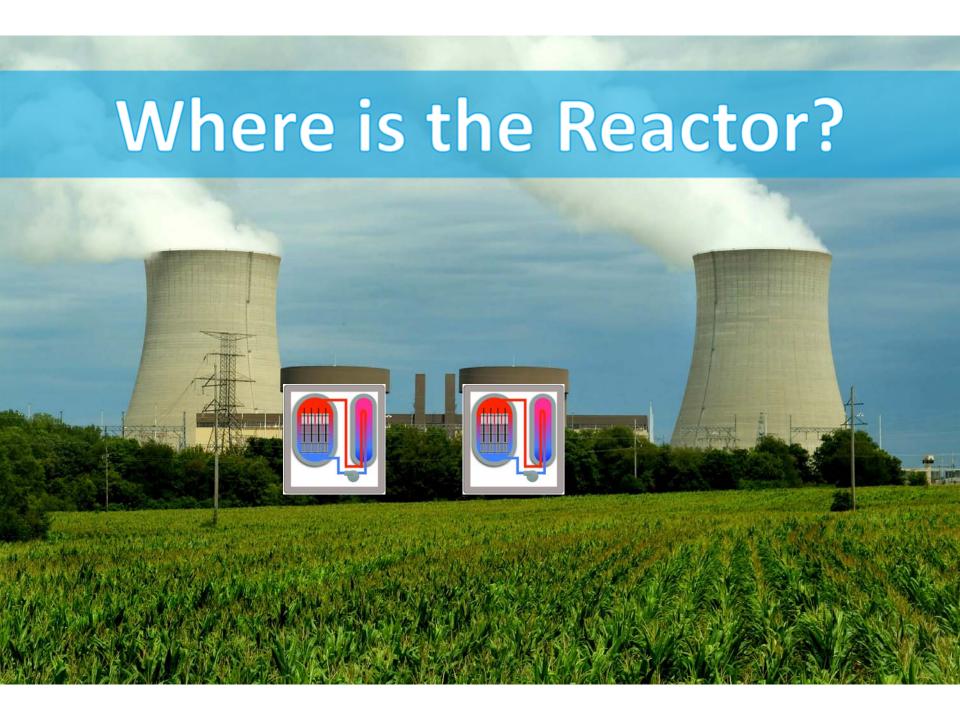
Hint: It has a steam generator.

POP QUIZ!!!

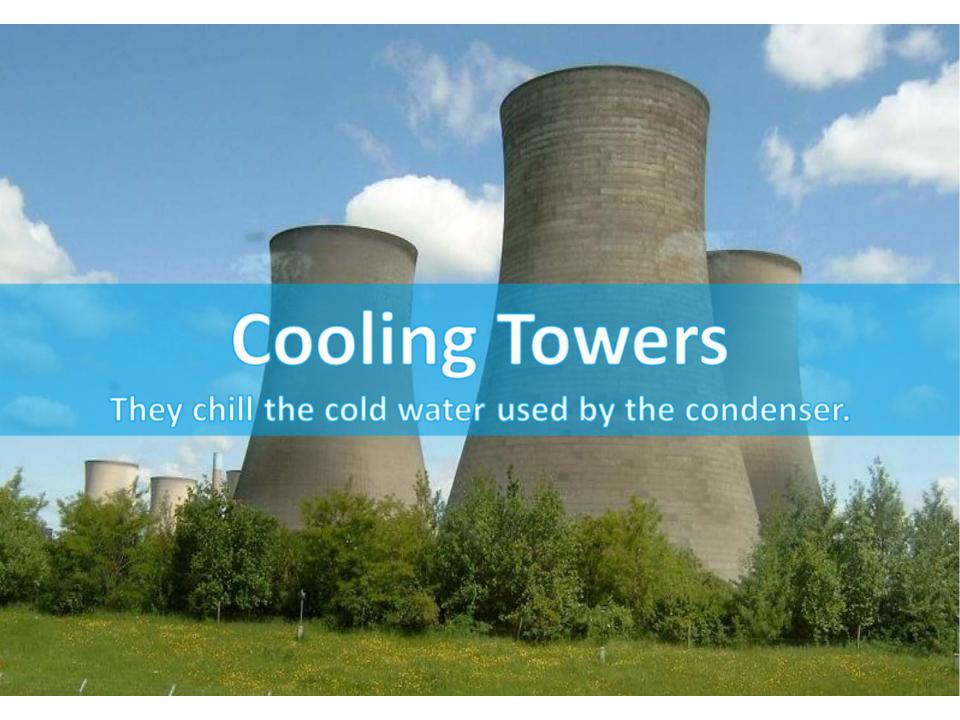


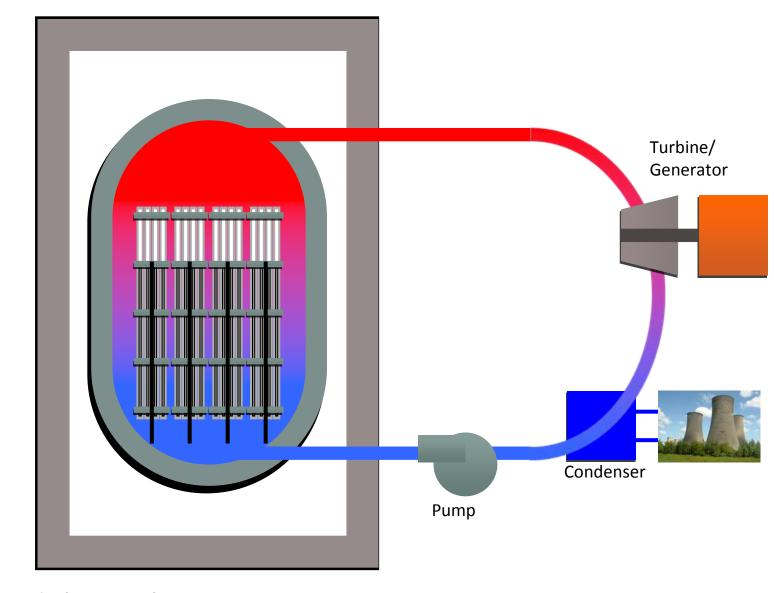
It is a PWR!





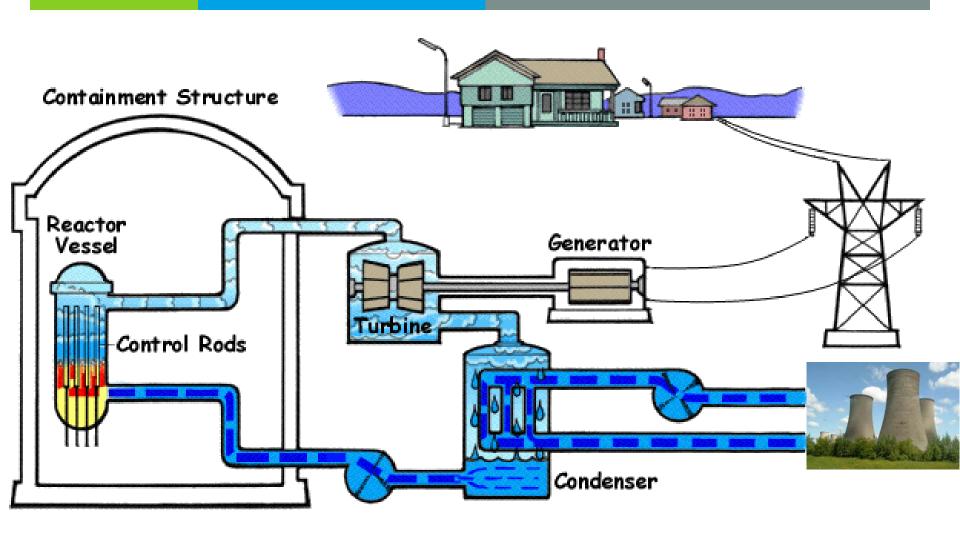




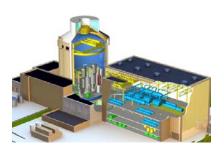


Find the cooling towers!

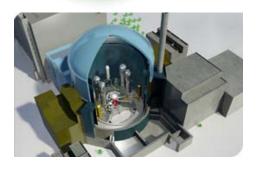
Boiling Water Reactor



What have we left out of this presentation?

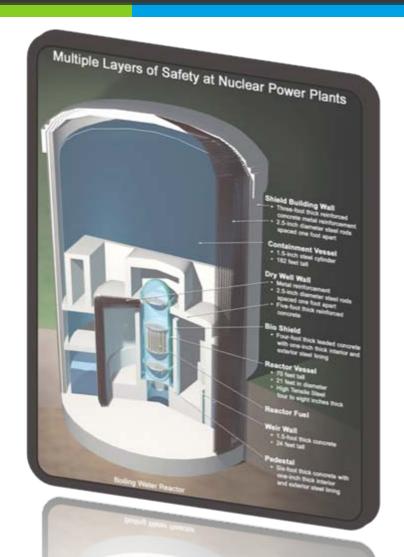






- Instrumentation
- Systems for optimizing efficiency
 - Control system components used by operators
 - Steam system components for thermodynamic efficiency
- Equipment to support outages and refueling
- Safety Systems

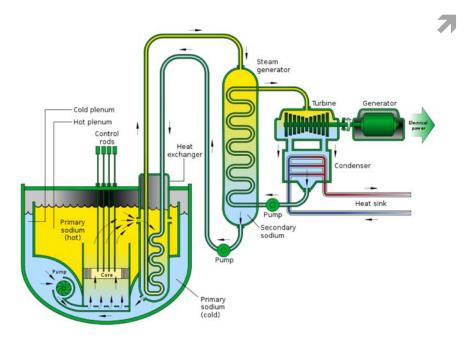
A few words about SAFETY



- Reactor designs provide two primary safety functions
- Contain radioactive material to protect the public
 - Many layers of containment
- Maintain ability to cool the fuel
 - Systems to move additional cooling water through the core during accident scenarios
 - Pumps driven by offsite power
 - Backup battery power
 - Backup diesel generators

Advanced Reactors

- Generation III+ reactors have more safety systems that are driven by natural forces like gravity and natural convection.
 - Less susceptible to interruptions in offsite power and less reliant on backup diesel generators
 - Small Modular Reactors



- Generation IV reactors use alternative coolants such as helium, liquid metals, or molten salts.
- Operate at higher temperatures and offer improved efficiency
- More safety features which rely on natural forces
- May offer opportunities to better utilize fuel resources



Nuclear Energy 101

Questions? Send them to neoutreach@anl.gov

