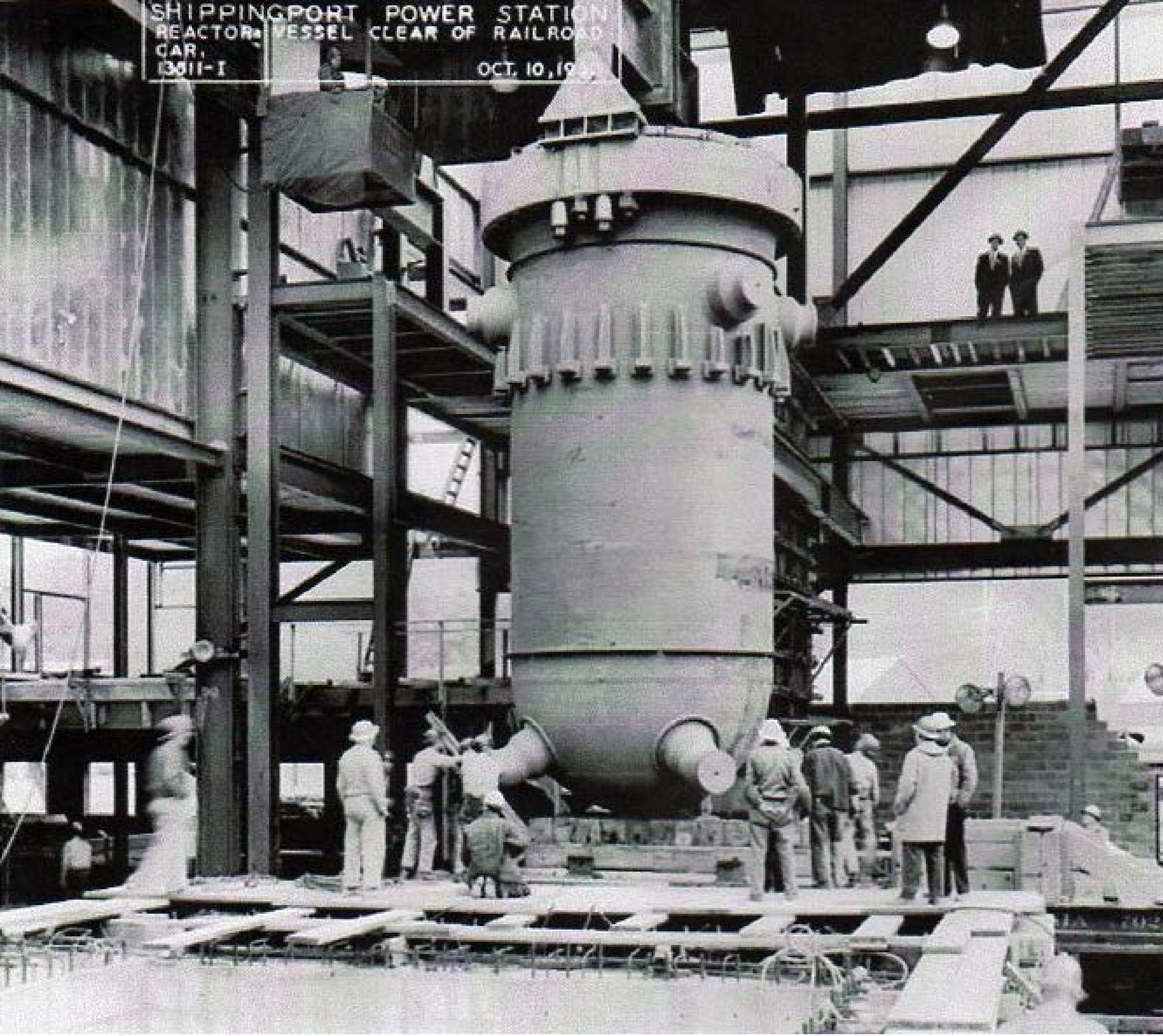
Nuclear Energy 101

The American Nuclear Society

Credit: W. D. Pointer, Ph. D

Shippingport Reactor Vessel



We’re going to wrestle with some big questions

HOW?

We’re going to wrestle with some big questions

We’re going to wrestle with some big questions

What if?

We're going to wrestle with some big questions

When?

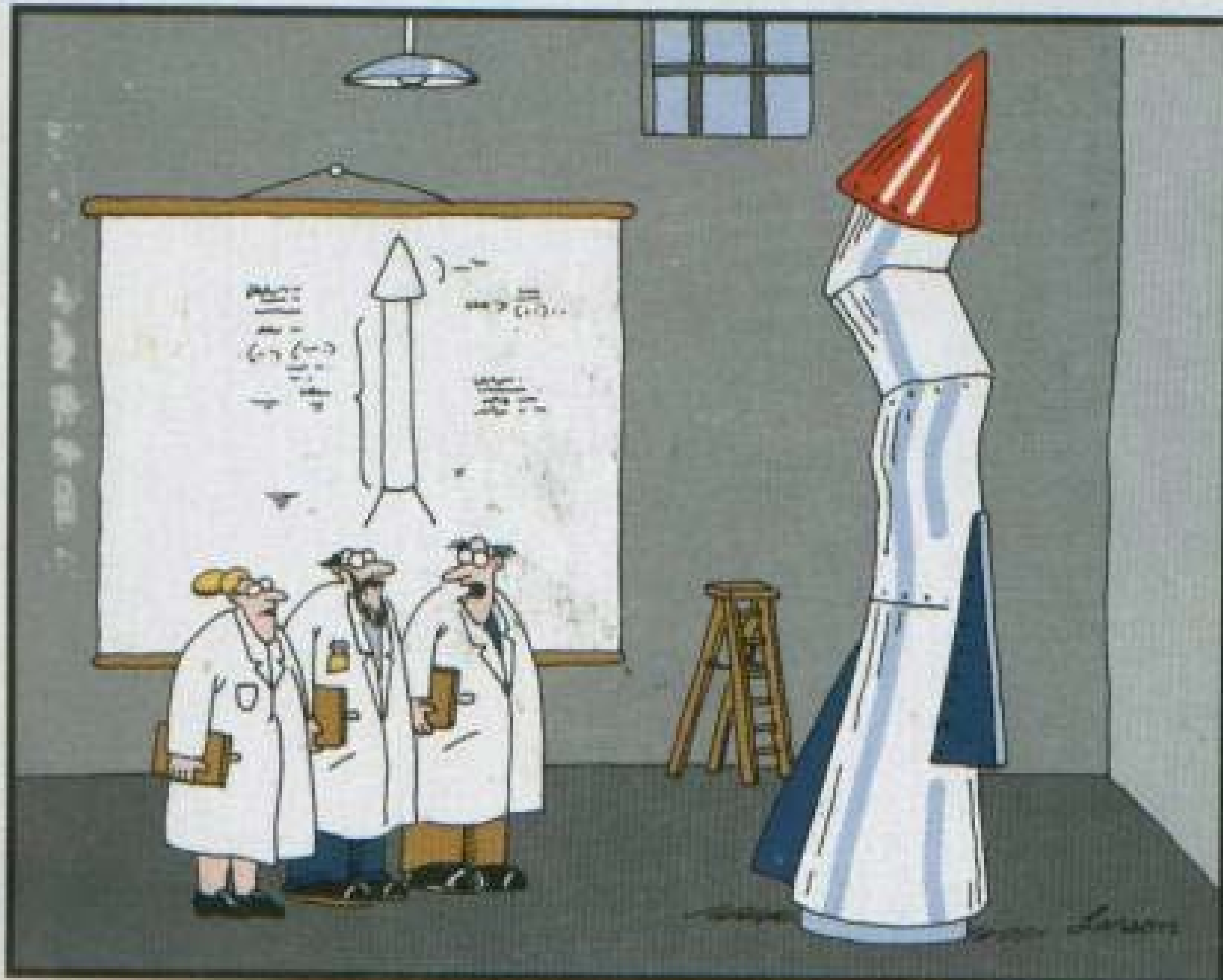
WHY?

We're going to wrestle with some big questions

WHY?

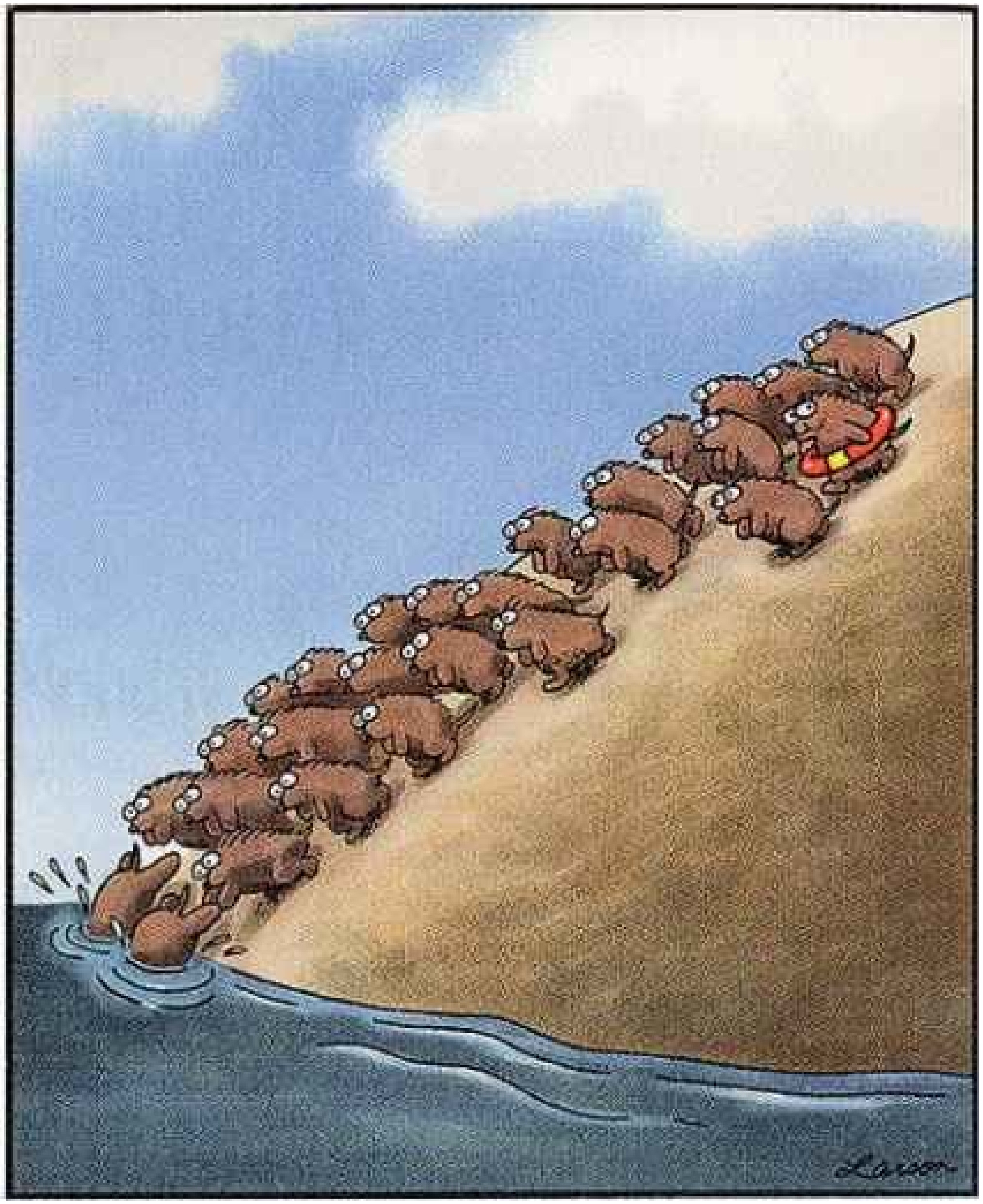

I WONDER WHY MAN WAS PUT ON EARTH. WHAT'S OUR PURPOSE? WHY ARE WE HERE?
TIGER FOOD.

It’s OK if we don’t have the answers.
We’ll engage the scientific method to figure things out.



"It's time we face reality, my friends. ...
We're not exactly rocket scientists."

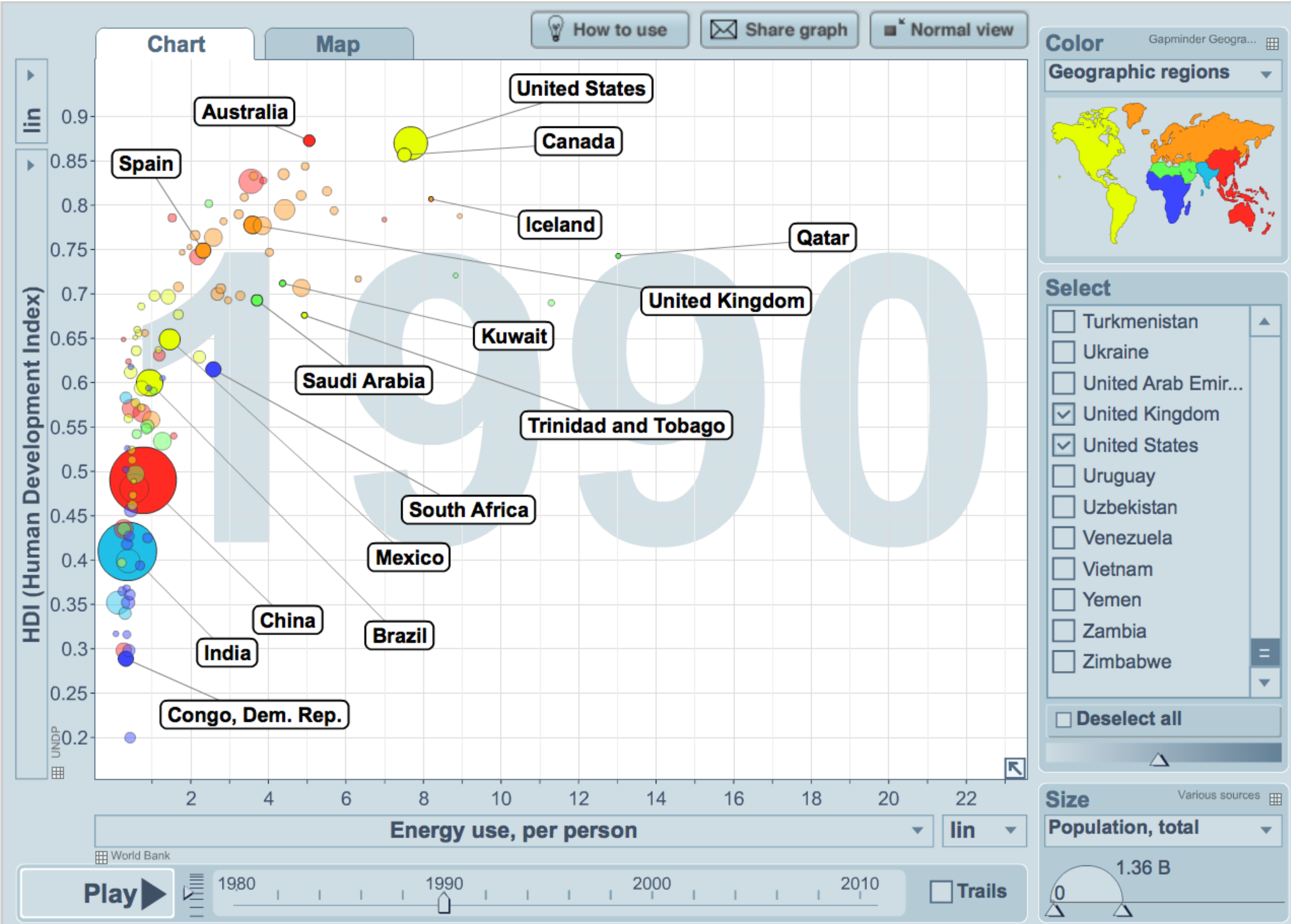
A little creativity can make a big difference.


Larson

Let’s get started

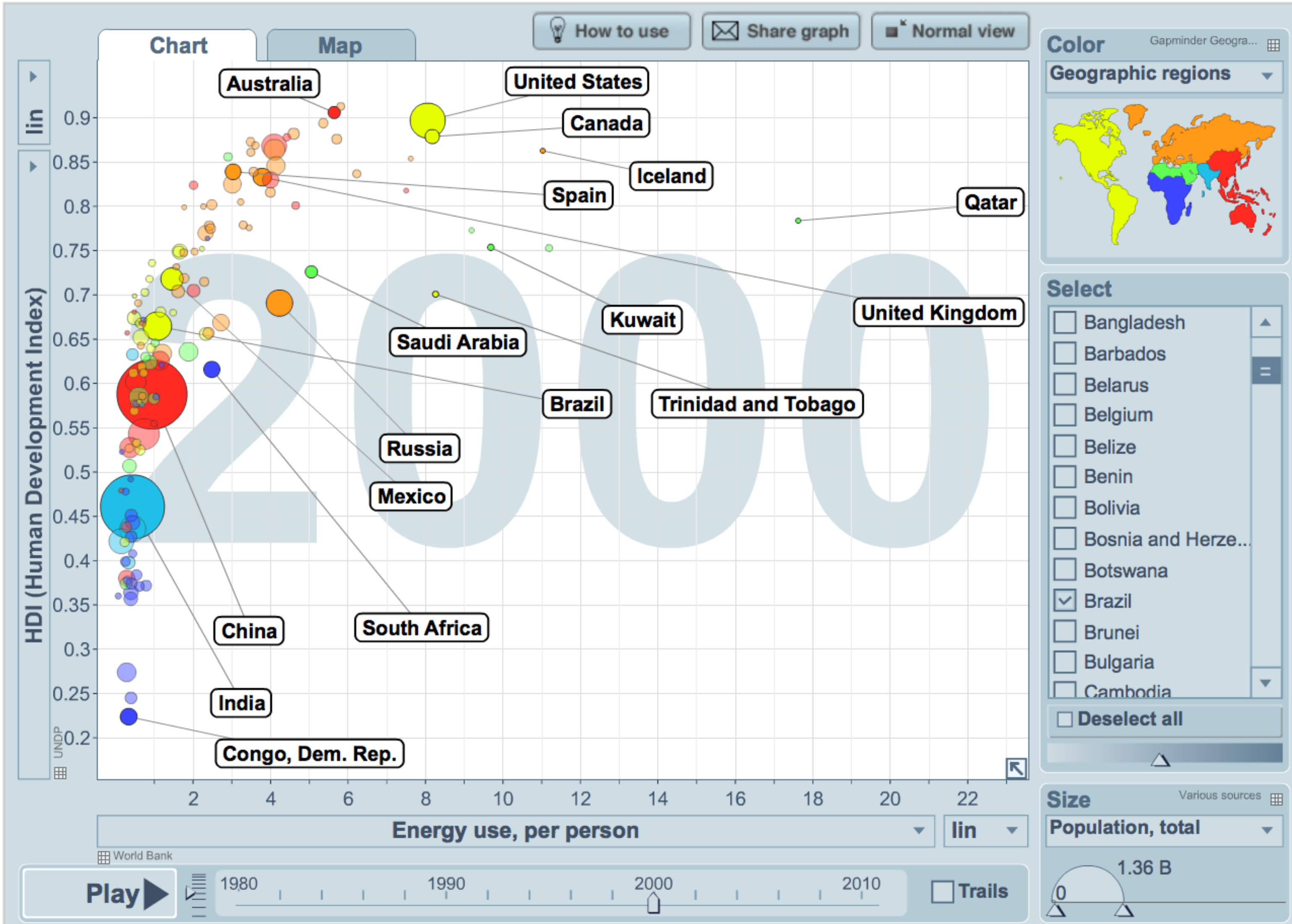
Why do we need more energy?

Electricity Enables Human Development



Energy use is shown in Tonnes of Oil Equivalent (or TOE)
Visualization from **Gapminder World**, powered by Trendalyzer from www.gapminder.org

Electricity Enables Human Development



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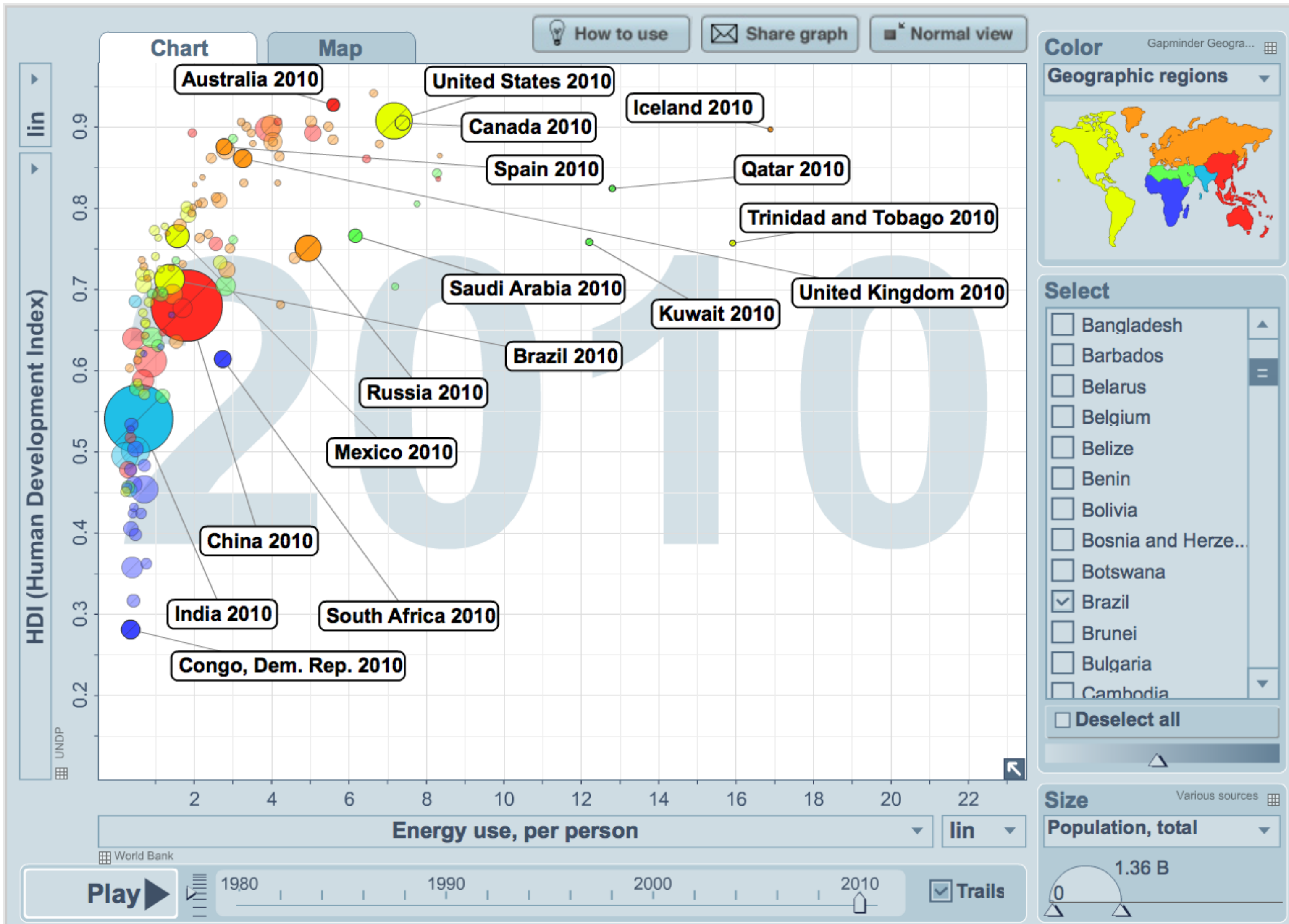
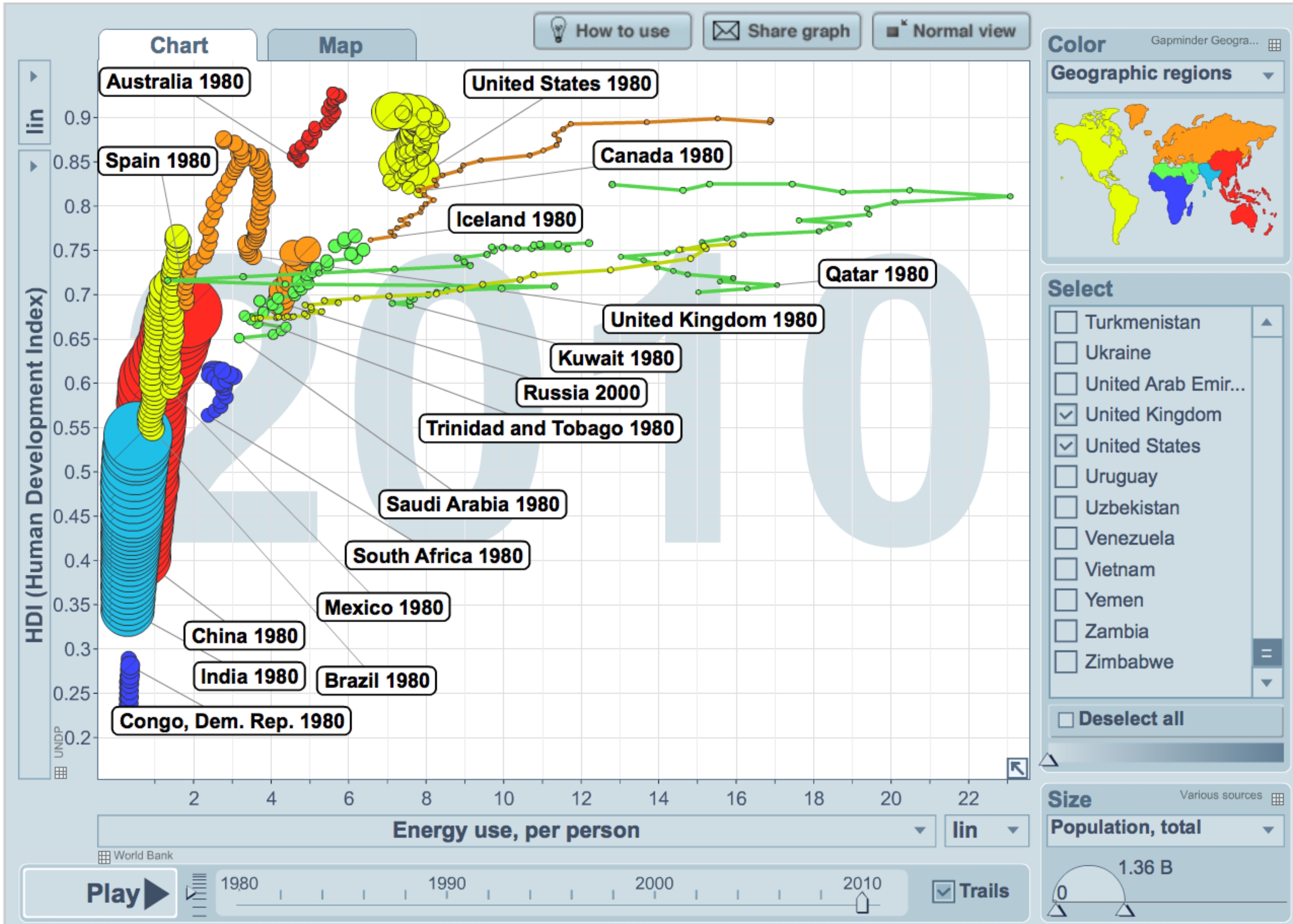
Electricity Enables Human Development



Energy use is shown in Tonnes of Oil Equivalent (or TOE)
Visualization from **Gapminder World**, powered by Trendalyzer from www.gapminder.org

As nations develop they move up and to the right



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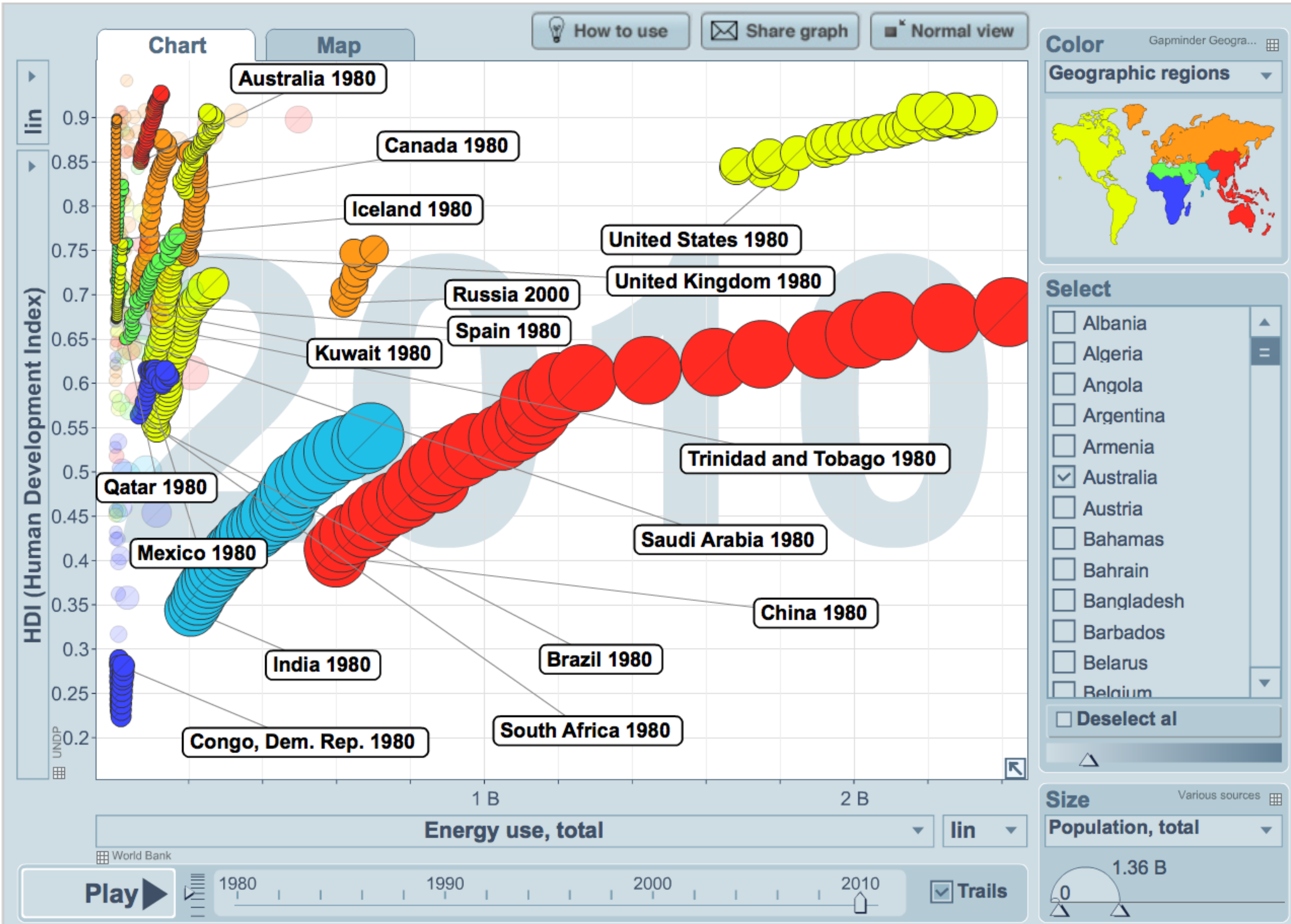
Per Capita Use is Informative, But Can Be Misleading



Energy use is shown in Tonnes of Oil Equivalent (or TOE)
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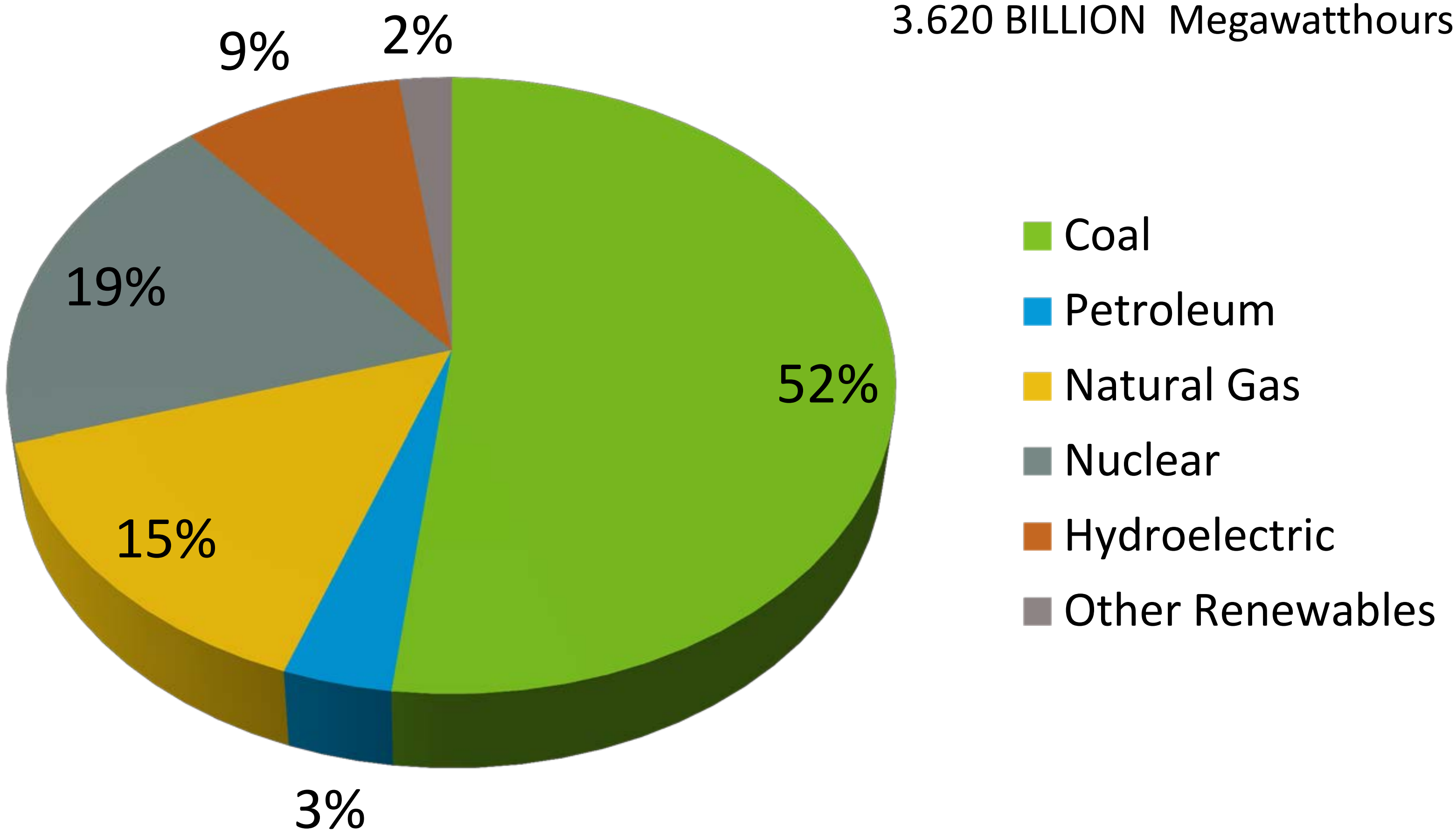
Why do we need *NUCLEAR* energy?

U.S. Electric Generation in 1998

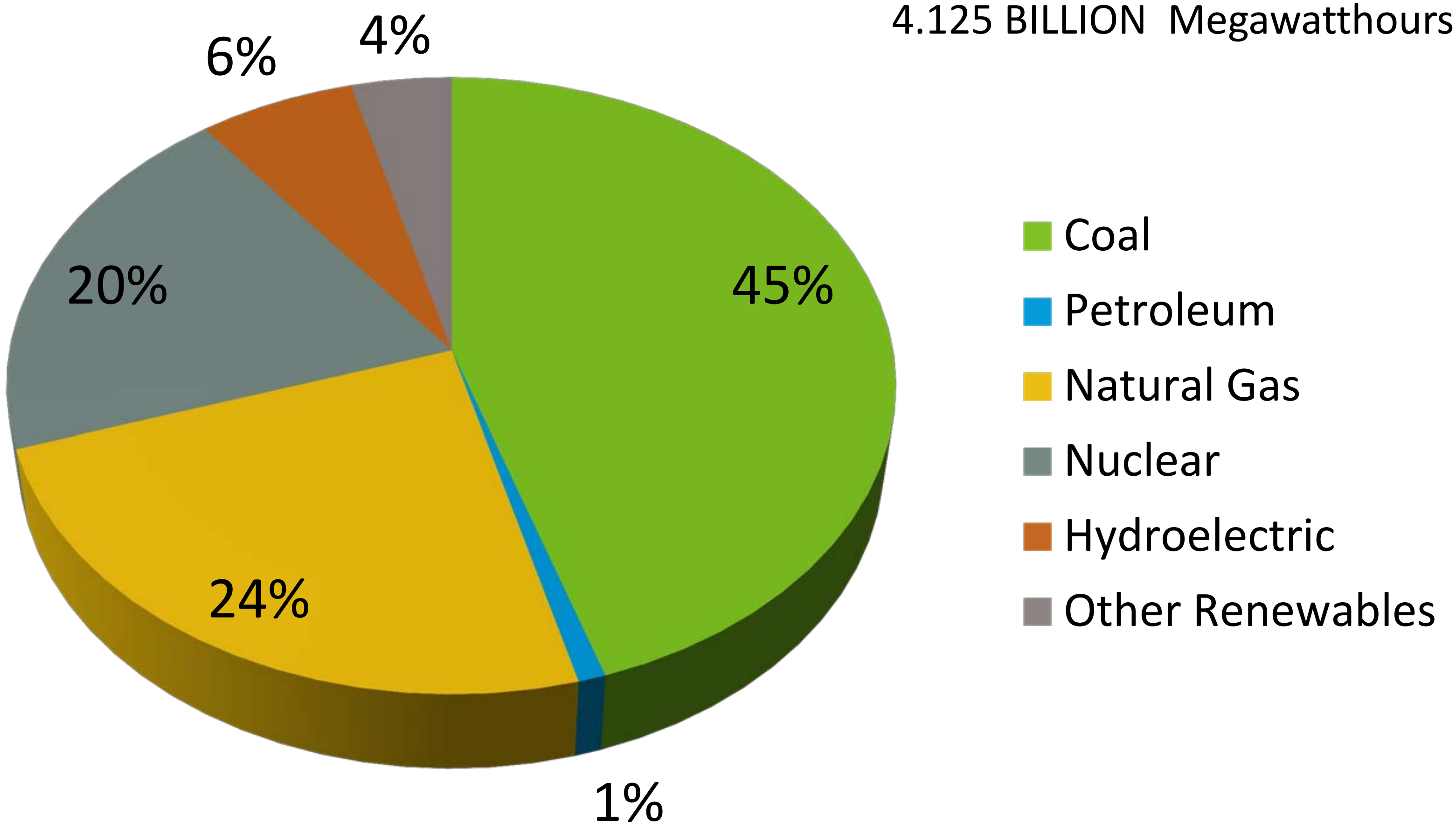
3.620 BILLION Megawatthours Total



Source: Electric Power Annual 2010
U.S. Energy Information Administration

U.S. Electric Generation in 2010

4.125 BILLION Megawatthours Total

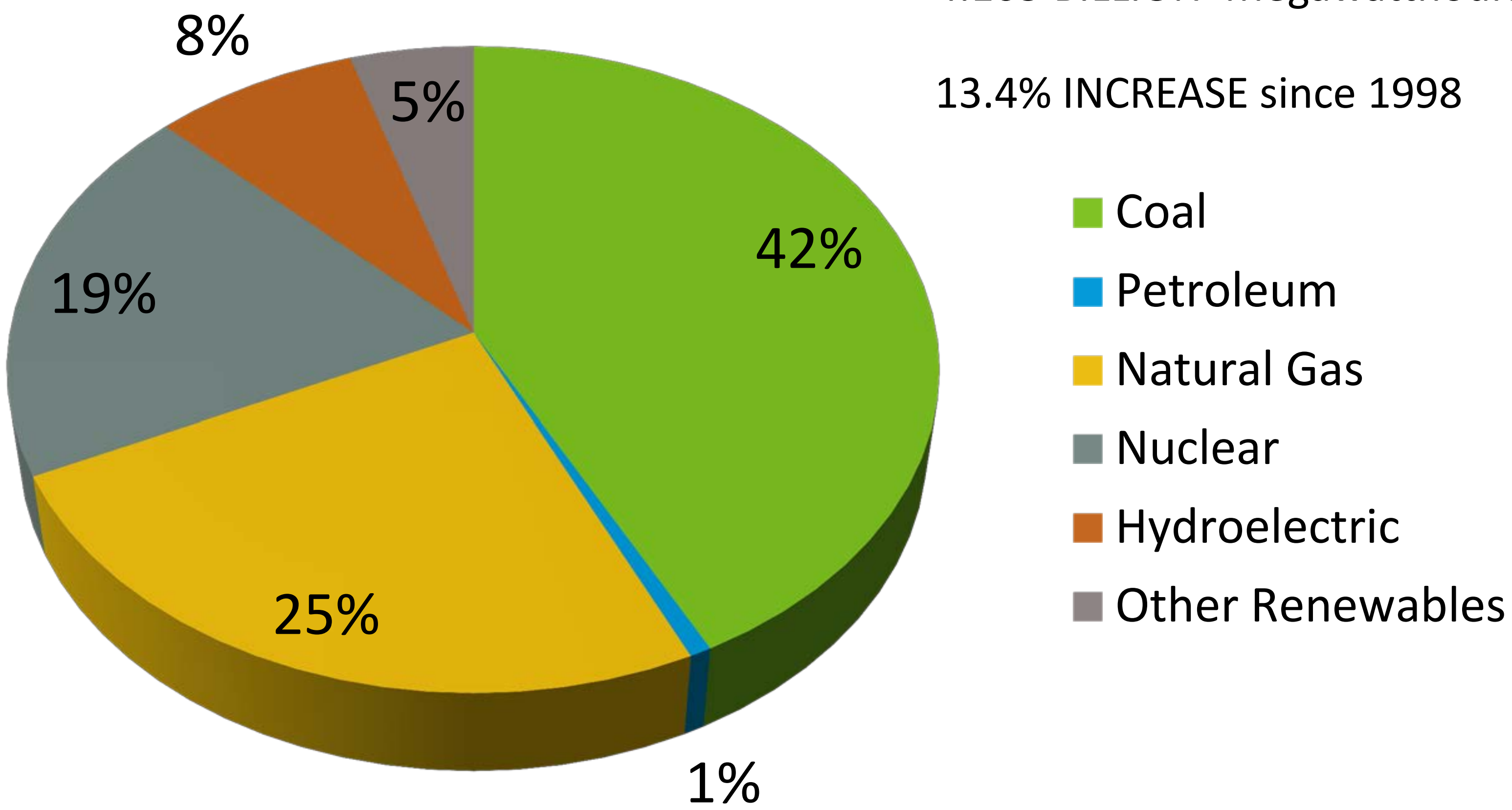


Source: Electric Power Annual 2010
U.S. Energy Information Administration

U.S. Electric Generation in 2011

4.105 BILLION Megawatthours Total

13.4% INCREASE since 1998



Source: Electric Power Annual 2010
U.S. Energy Information Administration

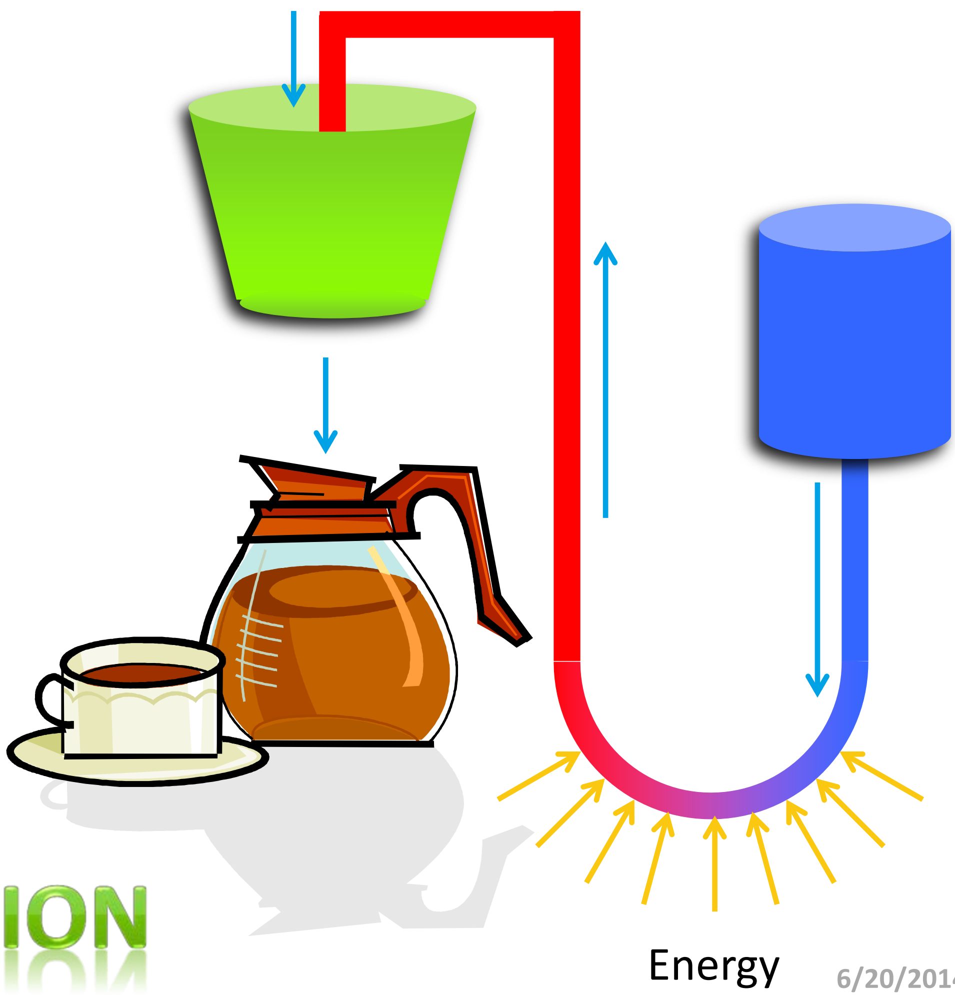
Let’s move on to a truly important energy engineering question.

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?

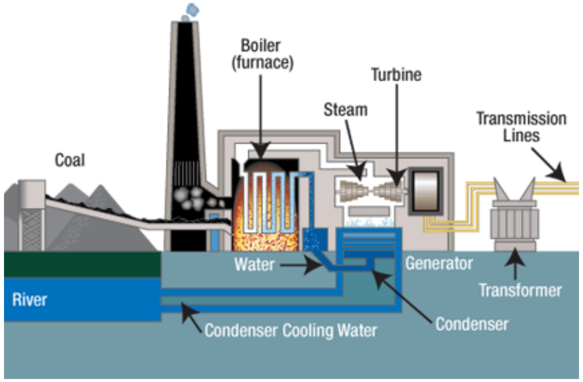
Coffee Pots: The Naked Truth

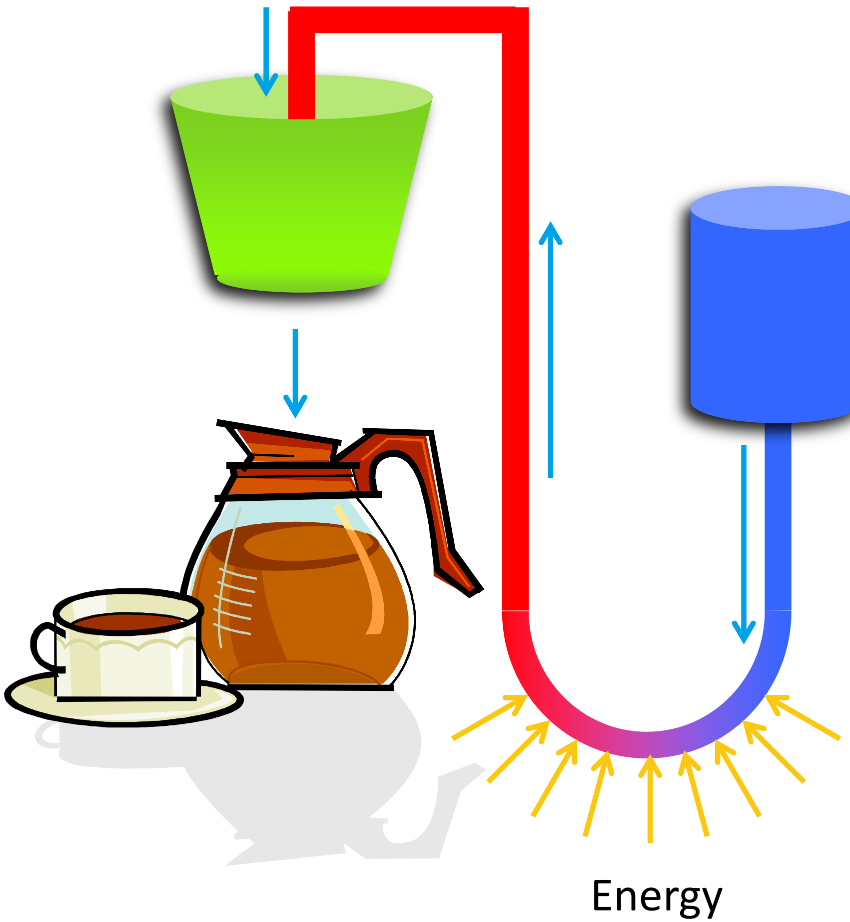
- Water absorbs **energy**
- Water's **density** decreases with temperature
  - Steam's density is MUCH lower than liquid water
- Hot, low density water rises to filter basket
  - Added energy enables water to do some useful work



NATURAL CONVECTION

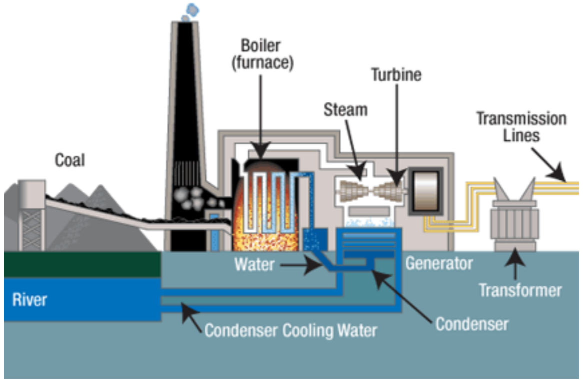
What does this have to do with *NUCLEAR ENERGY*?

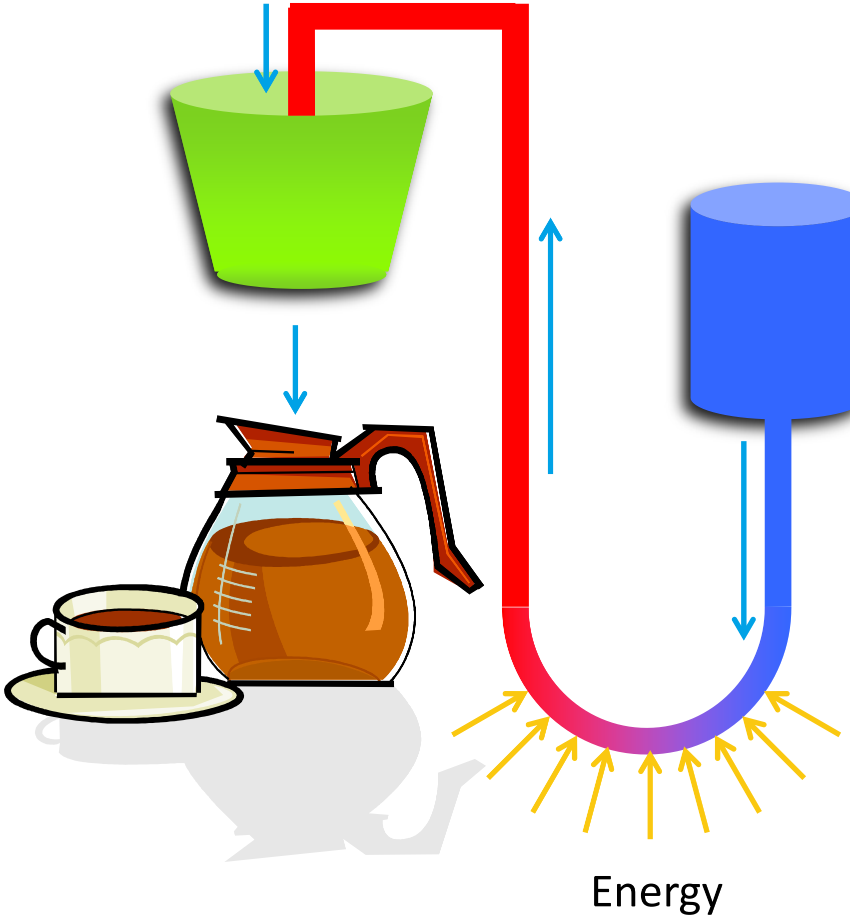




How is a Power Plant like a Coffee Pot?

This is worth a closer look.

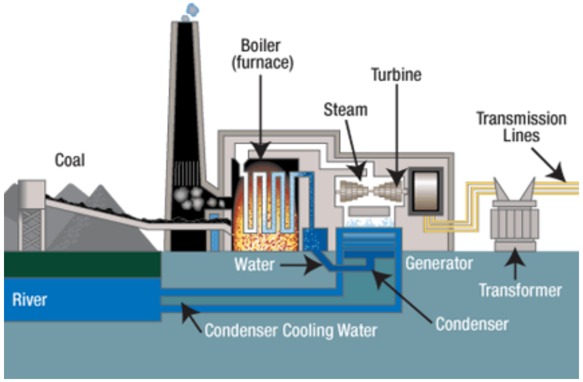


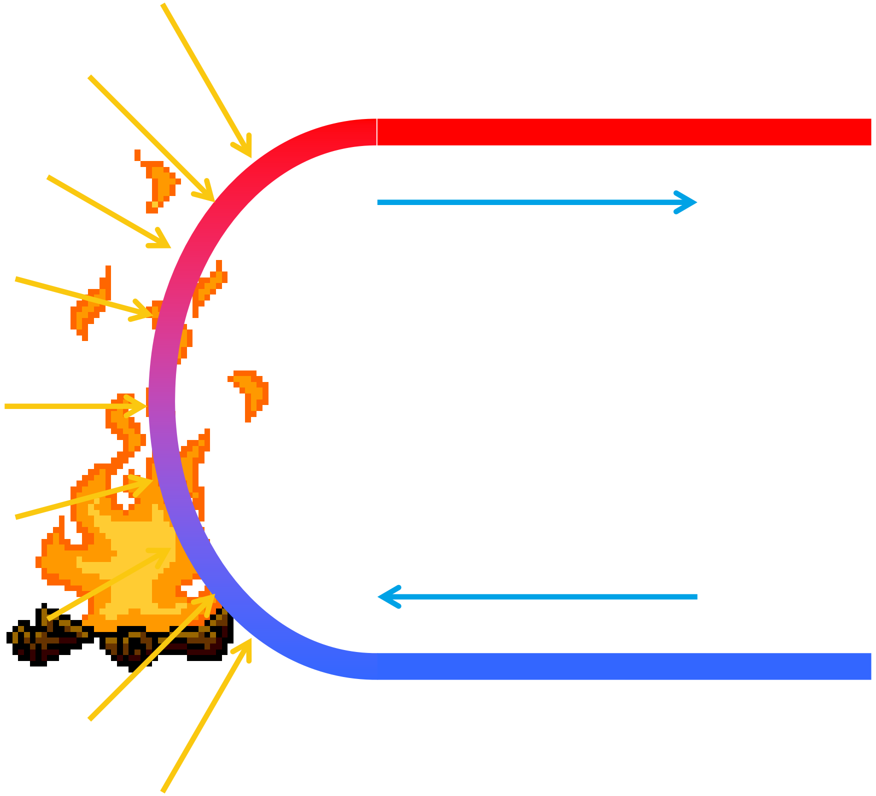


How is a Power Plant like a Coffee Pot?

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

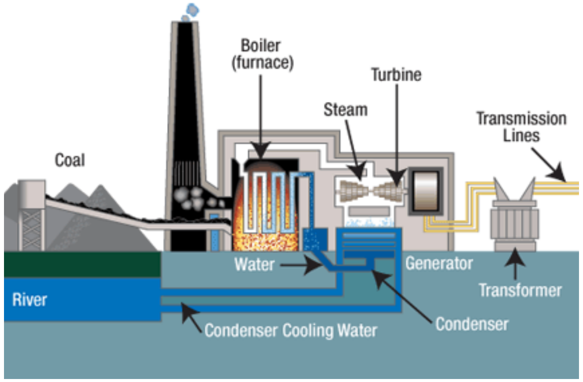
Next we should probably look at things from a different angle.

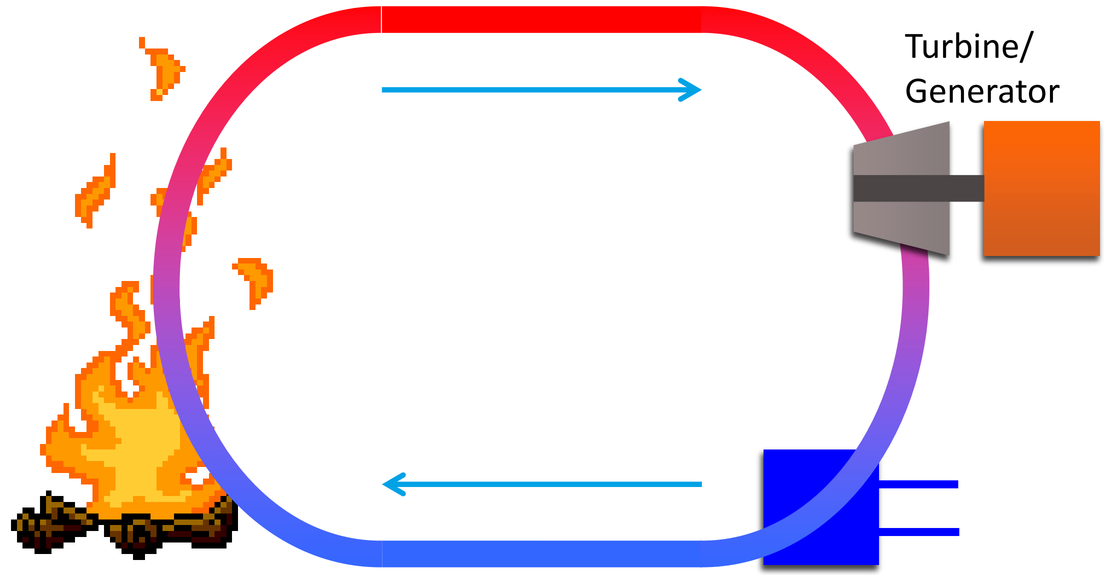




How is a Power Plant like a Coffee Pot?

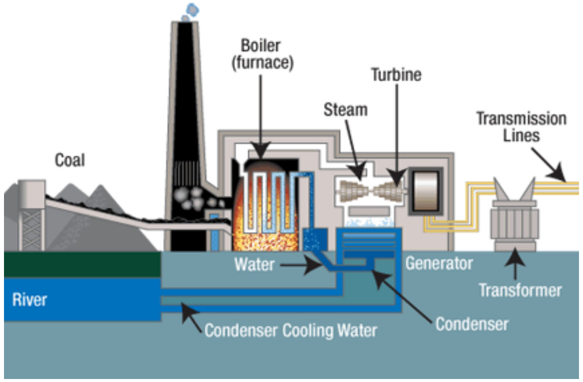
We need a bigger heat source than a coffee pot's hot plate.
Now let's make some electricity!

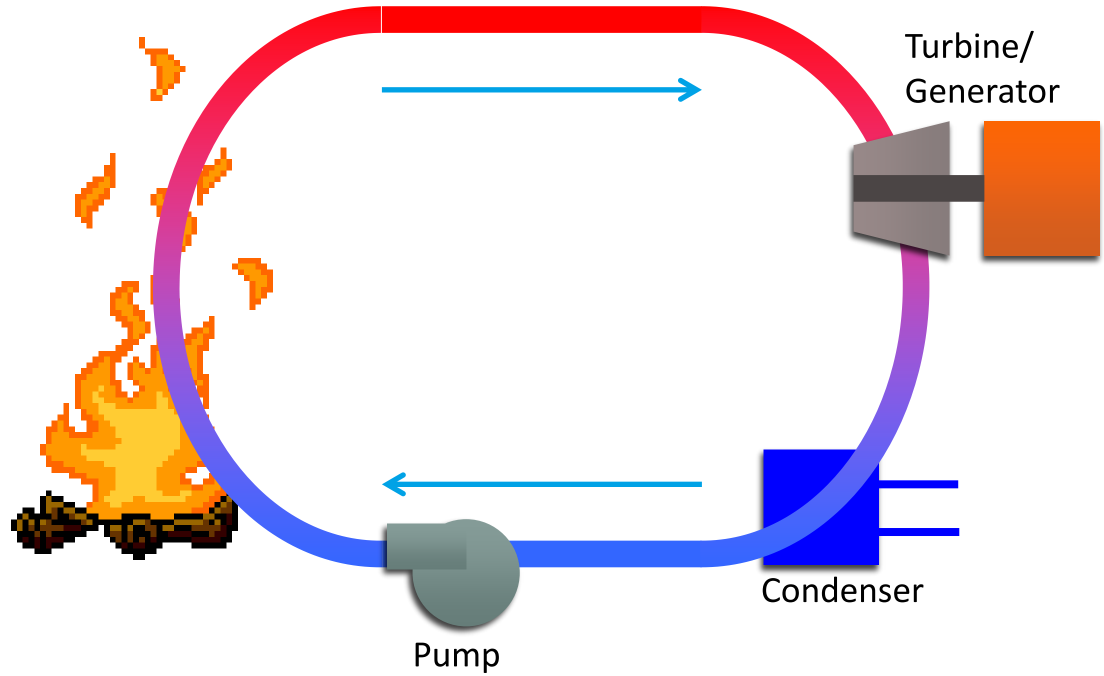




How is a Power Plant like a Coffee Pot?

How do we control how much electricity we make?





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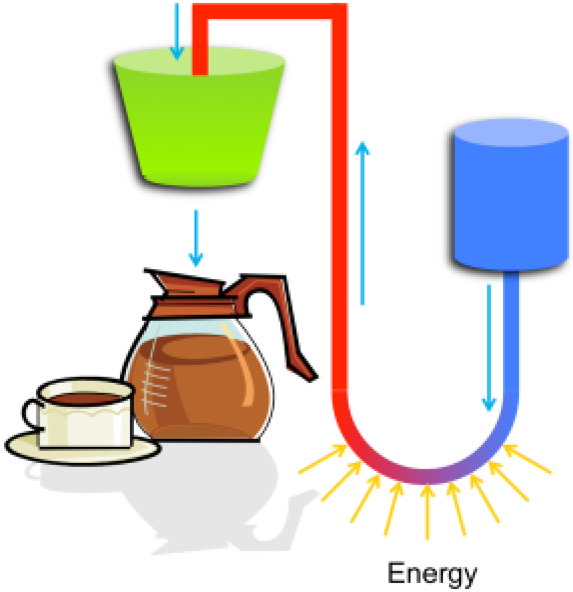
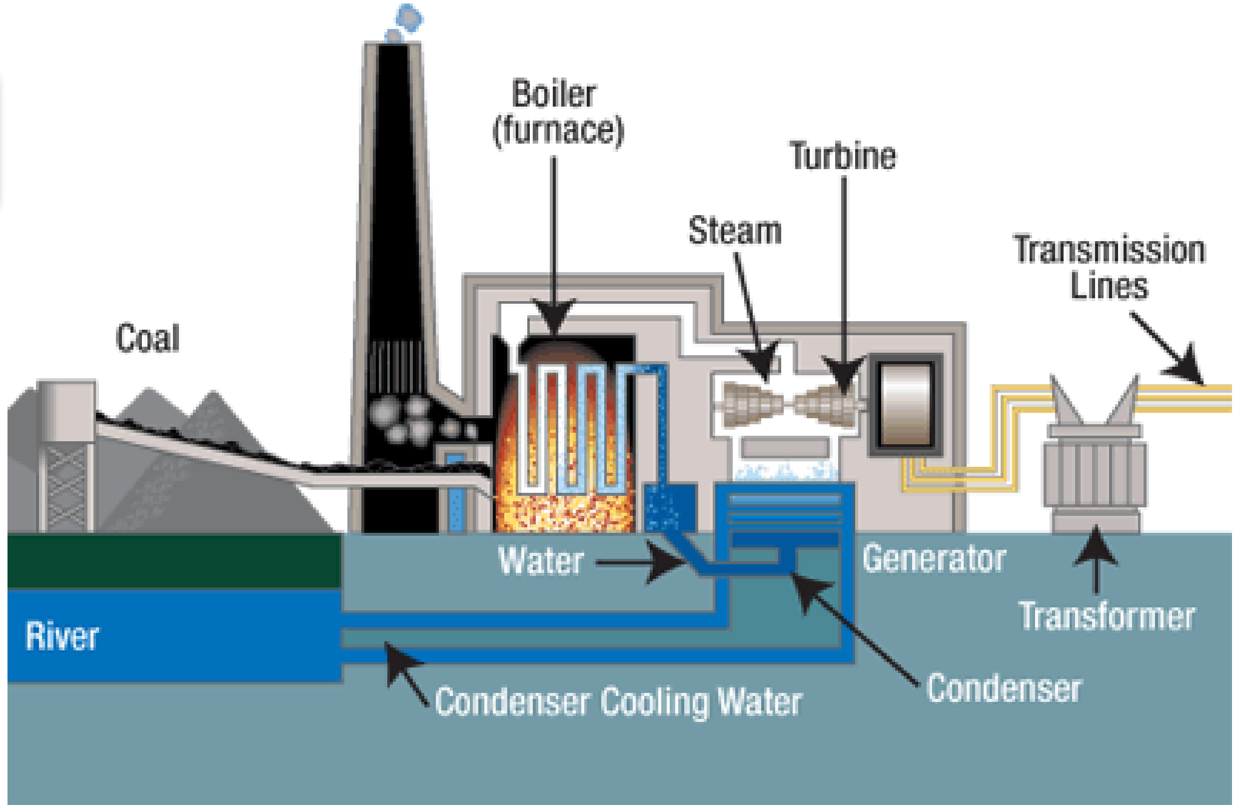




How is a Power Plant like a Coffee Pot?

A closer look at a coal fired power plant.

How is a nuclear power plant different?

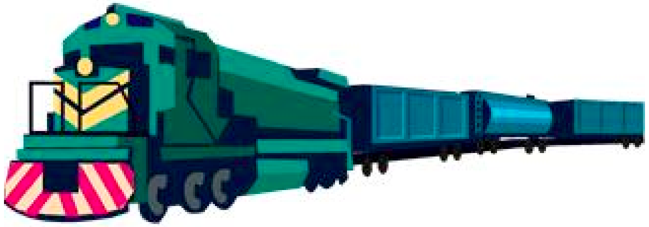
It's the Fuel!

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

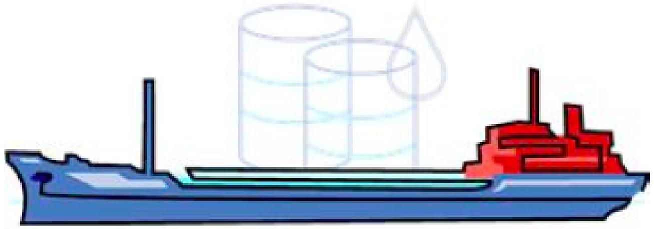
It’s the Fuel!

TO POWER 1000 HOMES

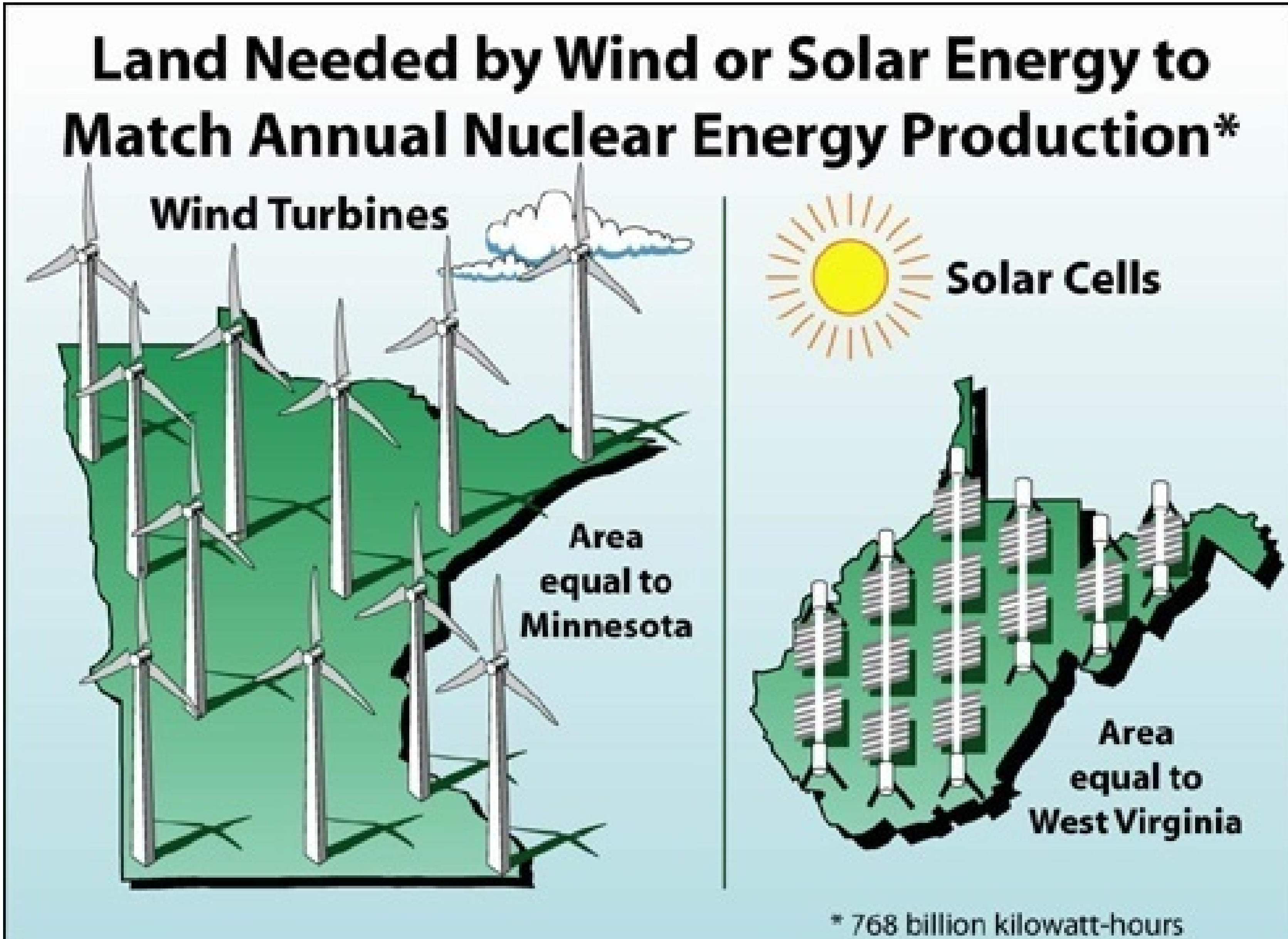
150 Tons of Uranium



2,100,000 Tons of Coal



10,000,000 Barrels of Oil

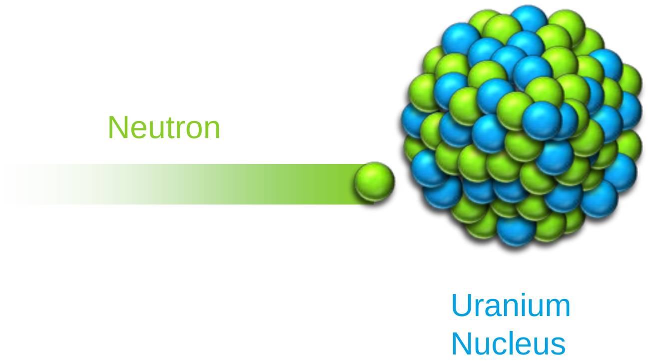

Land Needed by Wind or Solar Energy to Match Annual Nuclear Energy Production*
Wind Turbines
Area equal to Minnesota
Solar Cells
Area equal to West Virginia
* 768 billion kilowatt-hours

It's the Fuel!

The spent fuel used to generate all of the energy used in one American's lifetime would fit in here

What is Nuclear Fission?

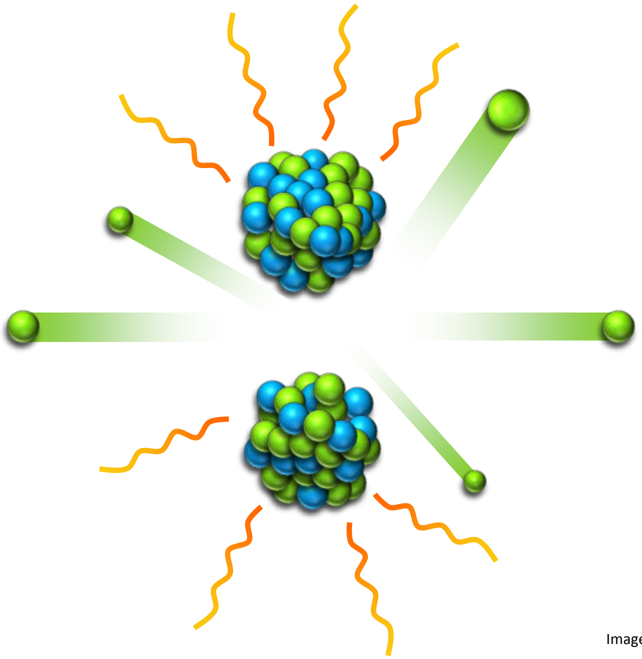
- If the nucleus of a heavy atom (such as Uranium) absorbs a **neutron**, the nucleus can become unstable and split.
- This is called NUCLEAR FISSION.



Images: Original art by Dave Pointer

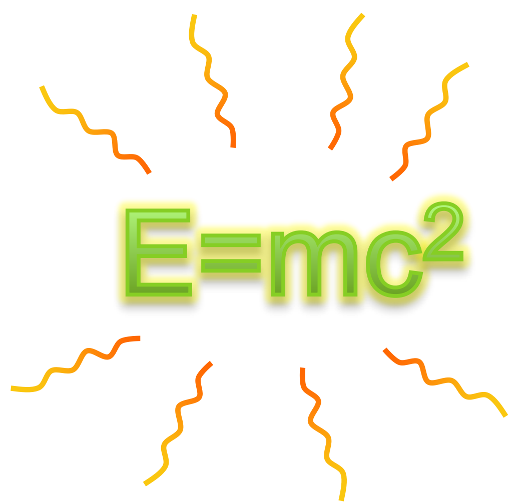
What is Nuclear Fission?

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



Images: Original art by Dave Pointer

What is Nuclear Fission?



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

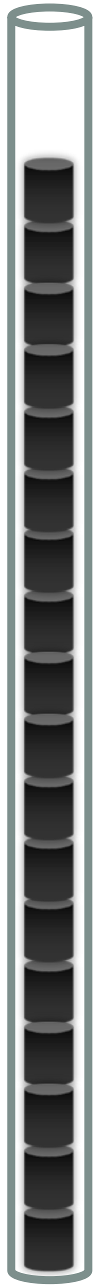
Images: Original art by Dave Pointer

Let's Build a Nuclear Power Plant

Let's Build a Nuclear Power Plant

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

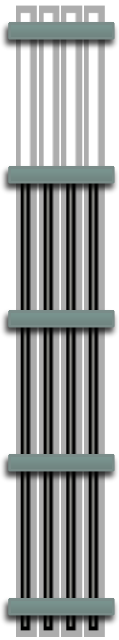
Let's Build a Nuclear Power Plant



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

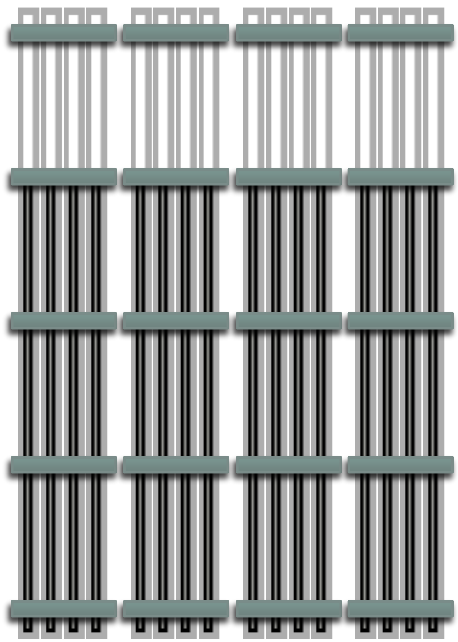
And sealed inside a metallic alloy case, called the **cladding**, to form a **fuel rod**

Let's Build a Nuclear Power Plant



The **fuel rods** are grouped together in a regular array or **fuel assembly**

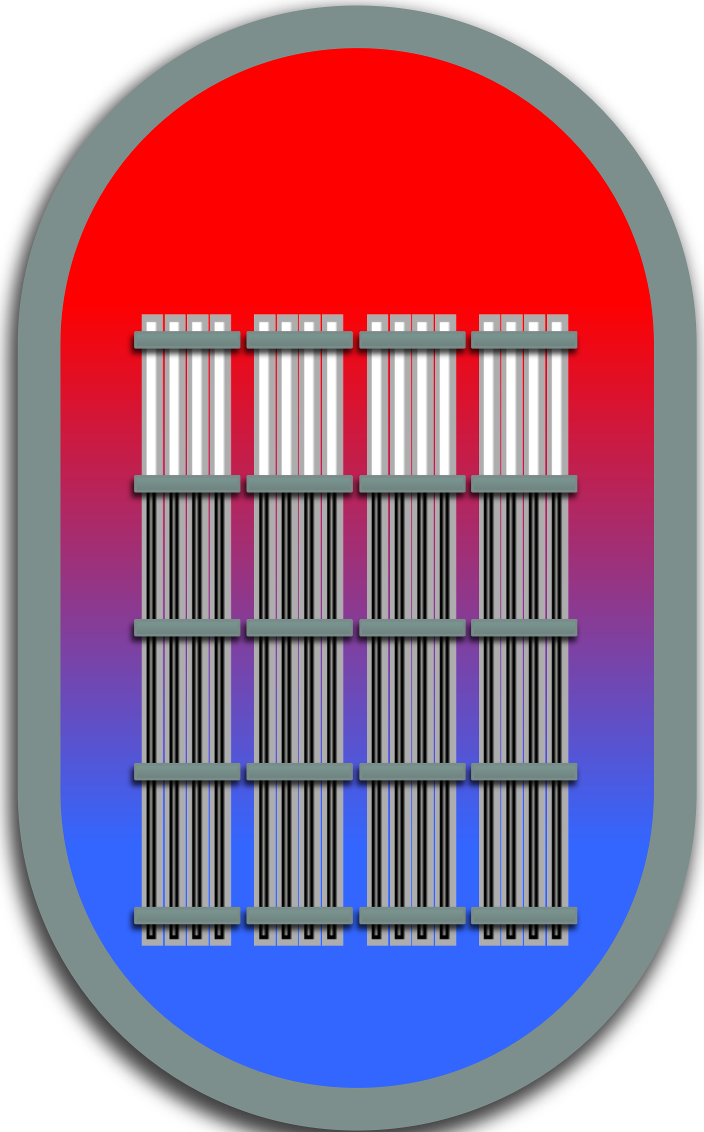
Let's Build a Nuclear Power Plant



The **fuel rods** are grouped together in a regular array or **fuel assembly**

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

Let's Build a Nuclear Power Plant



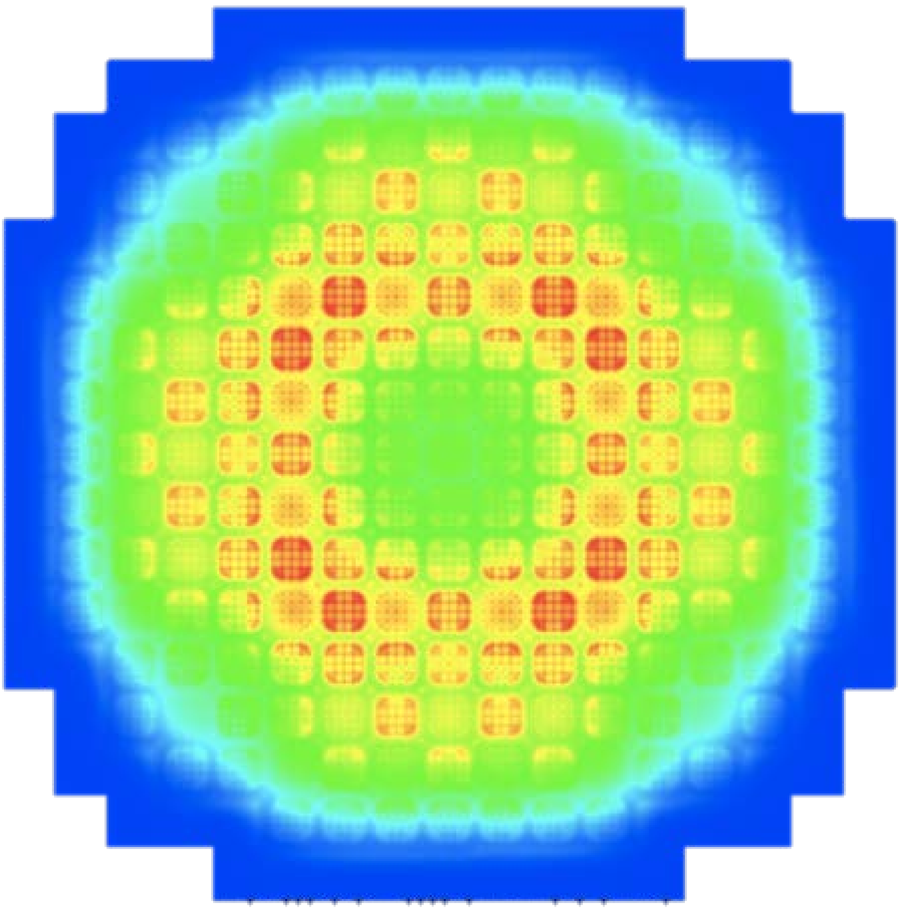
The **fuel rods** are grouped together in a regular array or **fuel assembly**

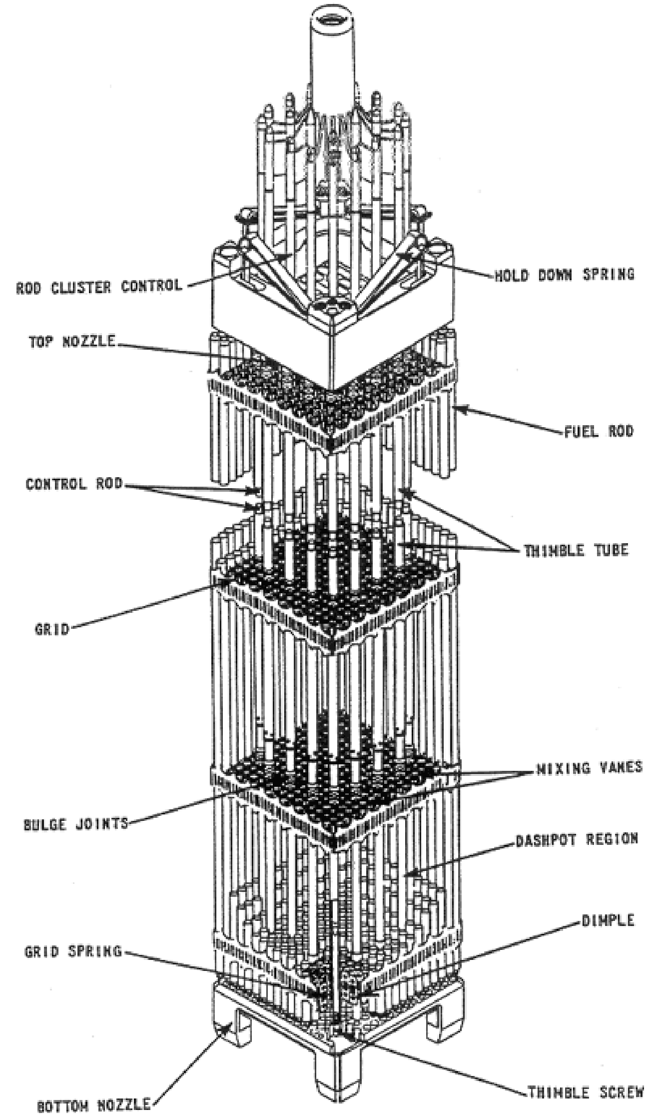
The **fuel assemblies** are arranged in a larger regular array or reactor **core**

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

A Reality Check

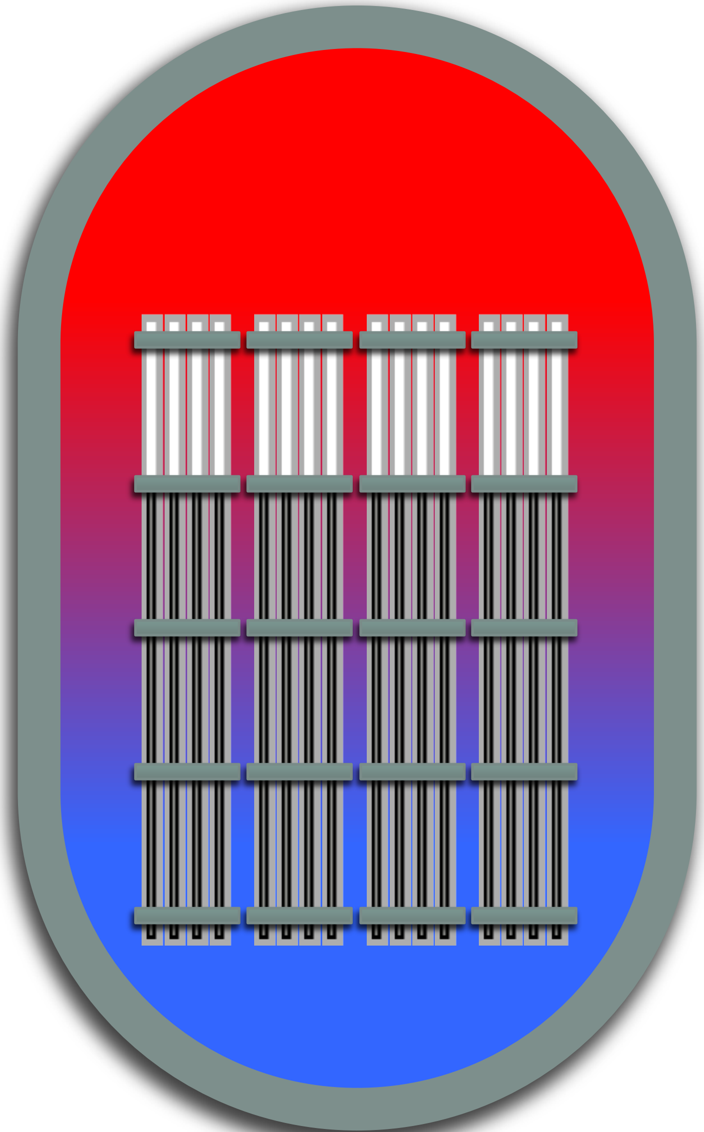
Fuel Assembly and Reactor Core Design are Complex Engineering Challenges





Reactor Fuel Assembly

Let's Build a Nuclear Power Plant



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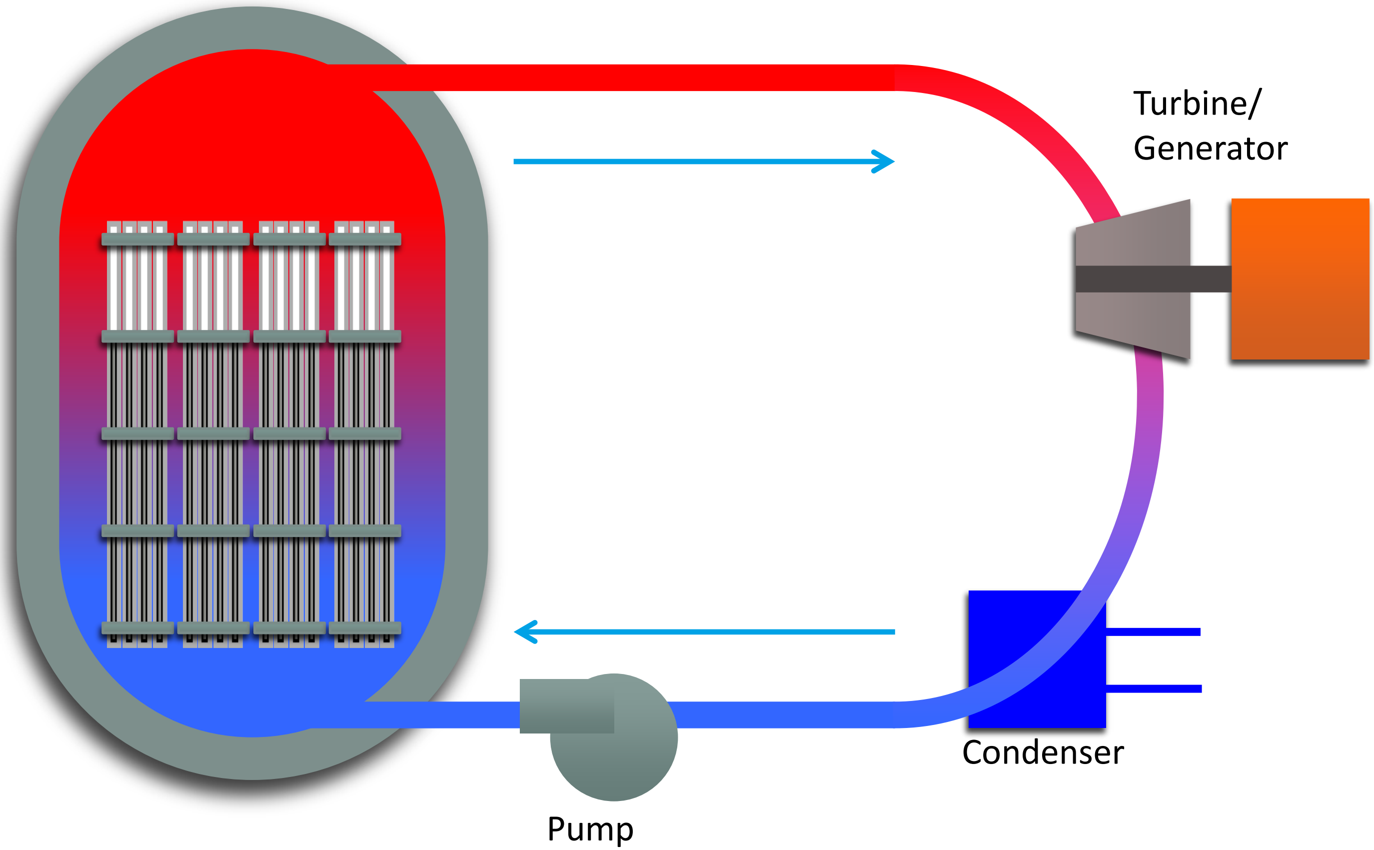
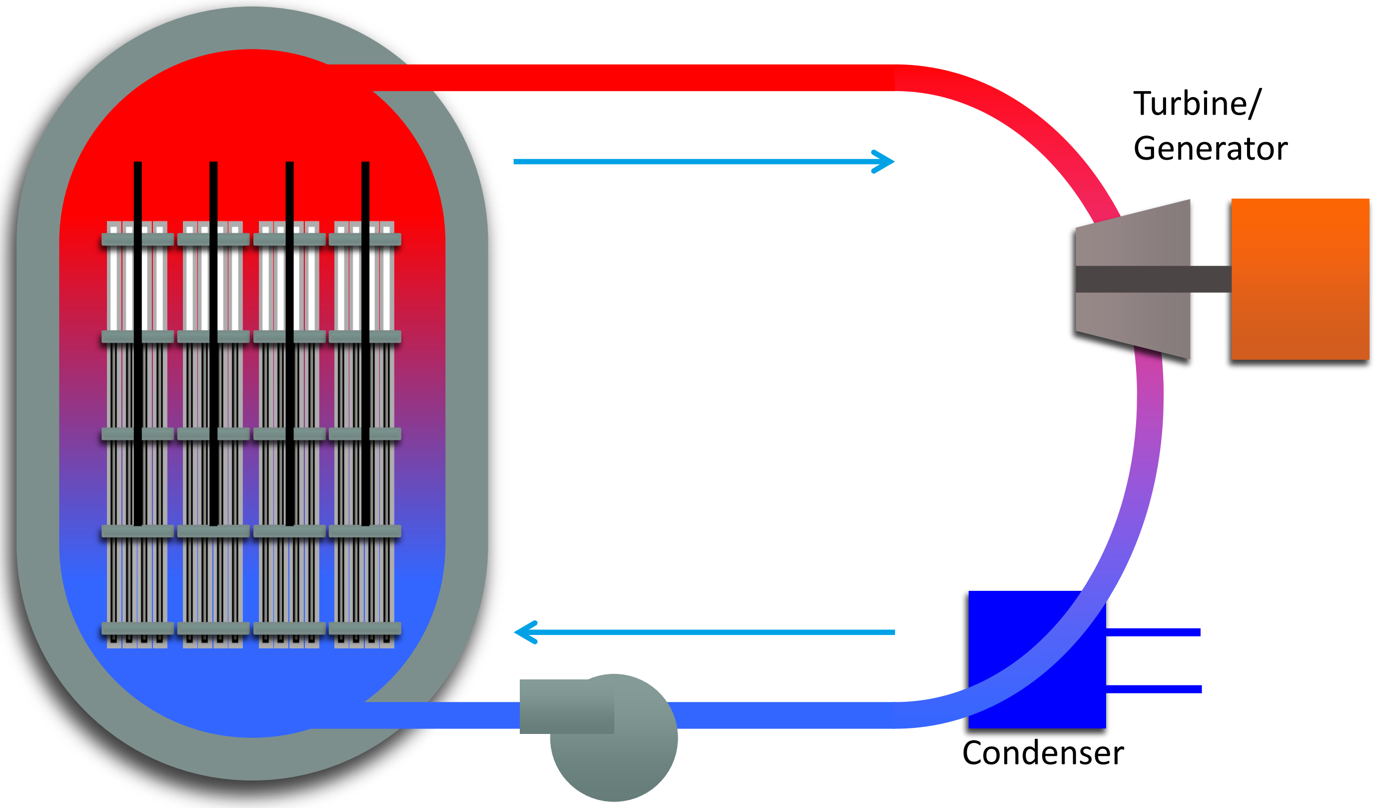
Let's Build a Nuclear Power Plant



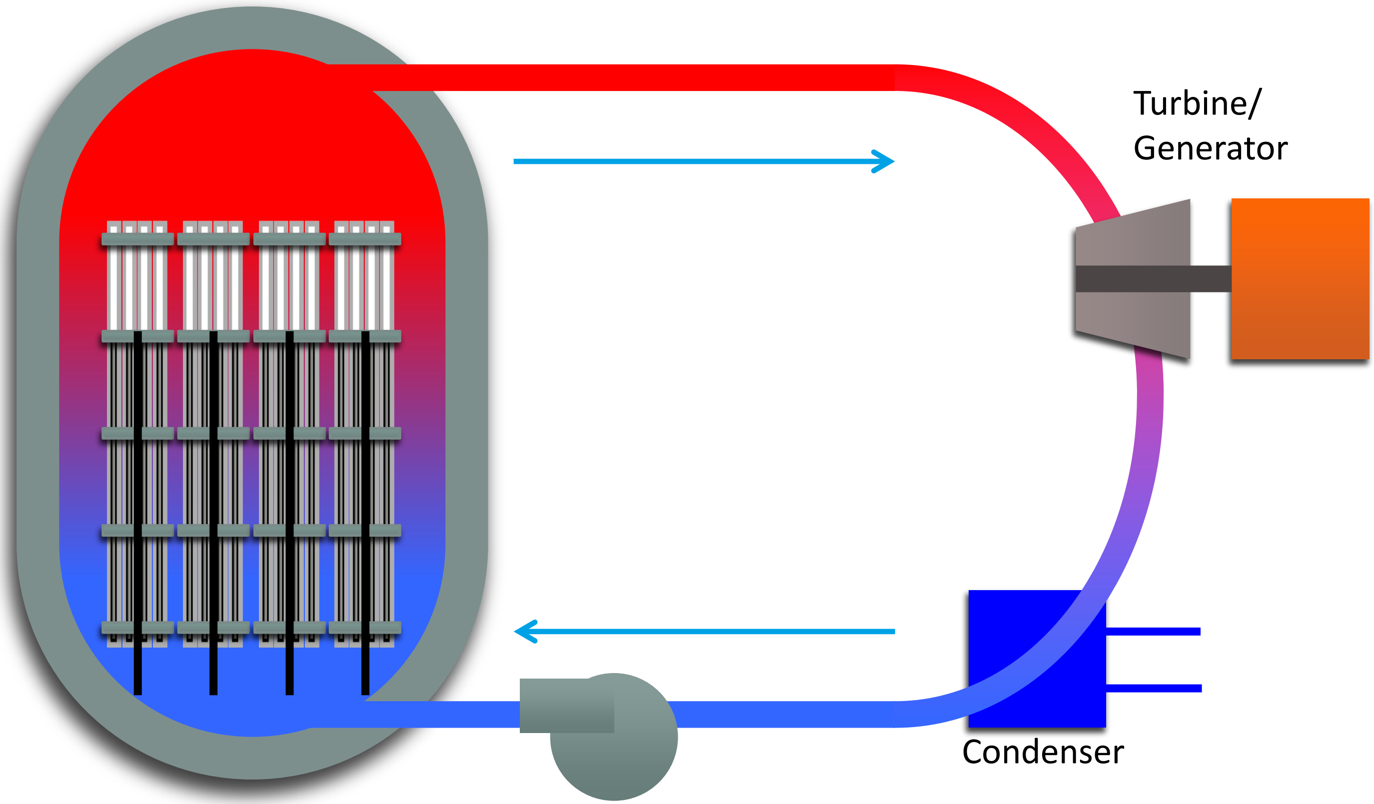
In a nuclear power plant, the **reactor core** replaces the burning fossil fuel as the energy source

Let's Build a Nuclear Power Plant



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

Let's Build a Nuclear Power Plant

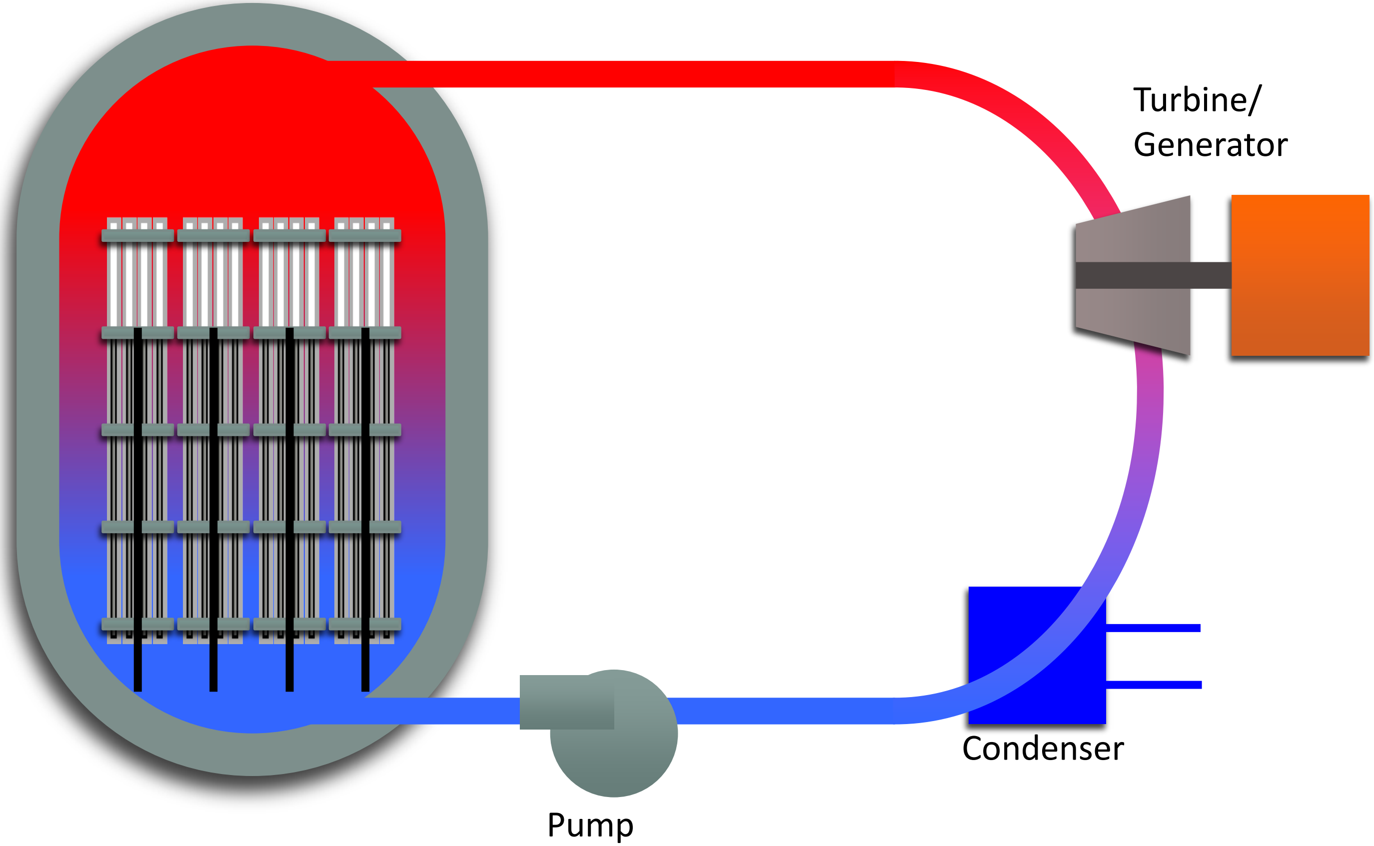


Control rods absorb neutrons and are used to stop/start the reaction

What's so CRITICAL?

- CRITICAL → k=1
  - # of Neutrons Produced = # of Neutrons Absorbed
- SUB-Critical → k<1
  - # of Neutrons Produced < # of Neutrons Absorbed
- SUPER-Critical → k>1
  - # of Neutrons Produced > # of Neutrons Absorbed

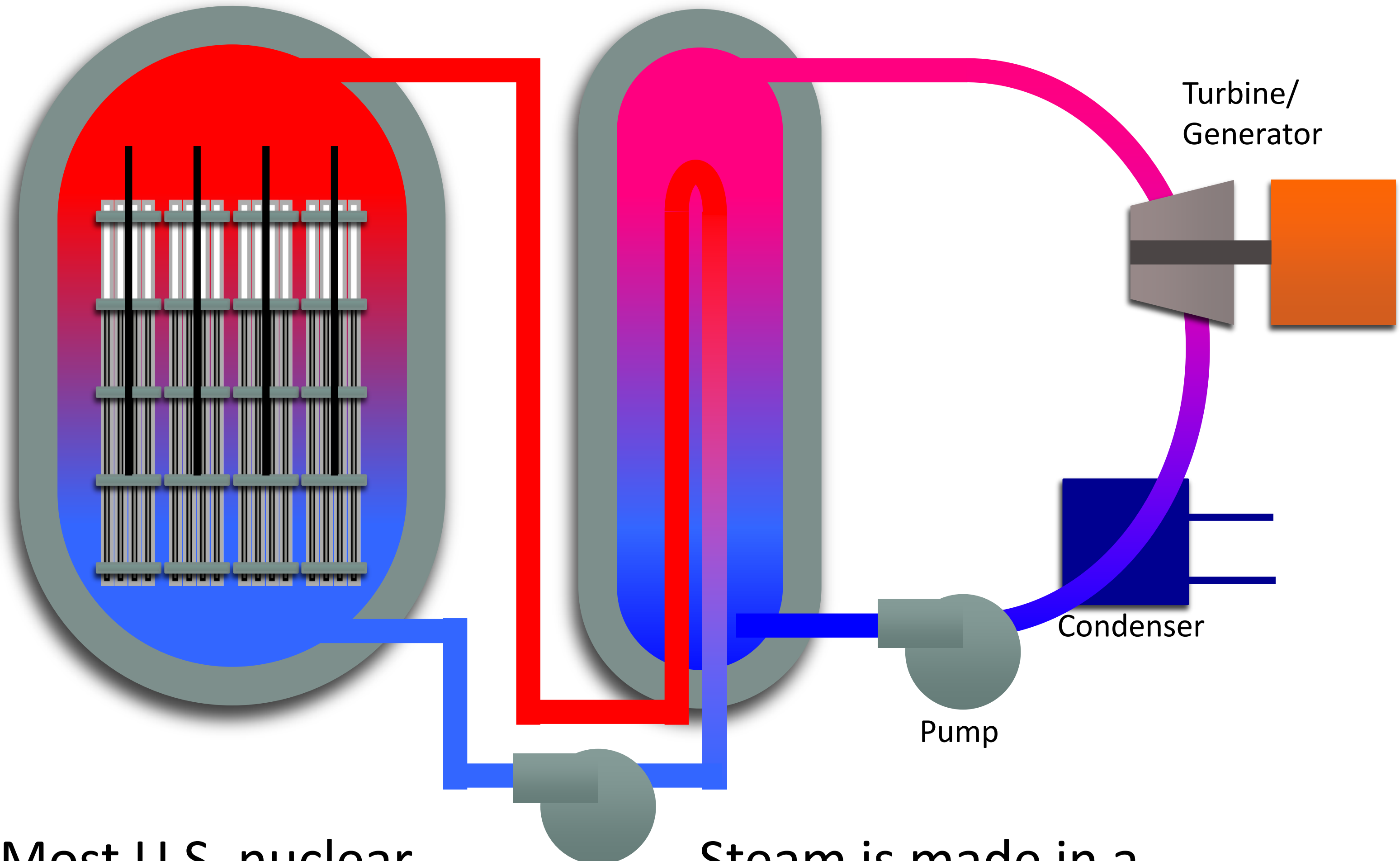
Boiling Water Reactor (BWR)



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

They're called **BWRs** or **Boiling Water Reactors**

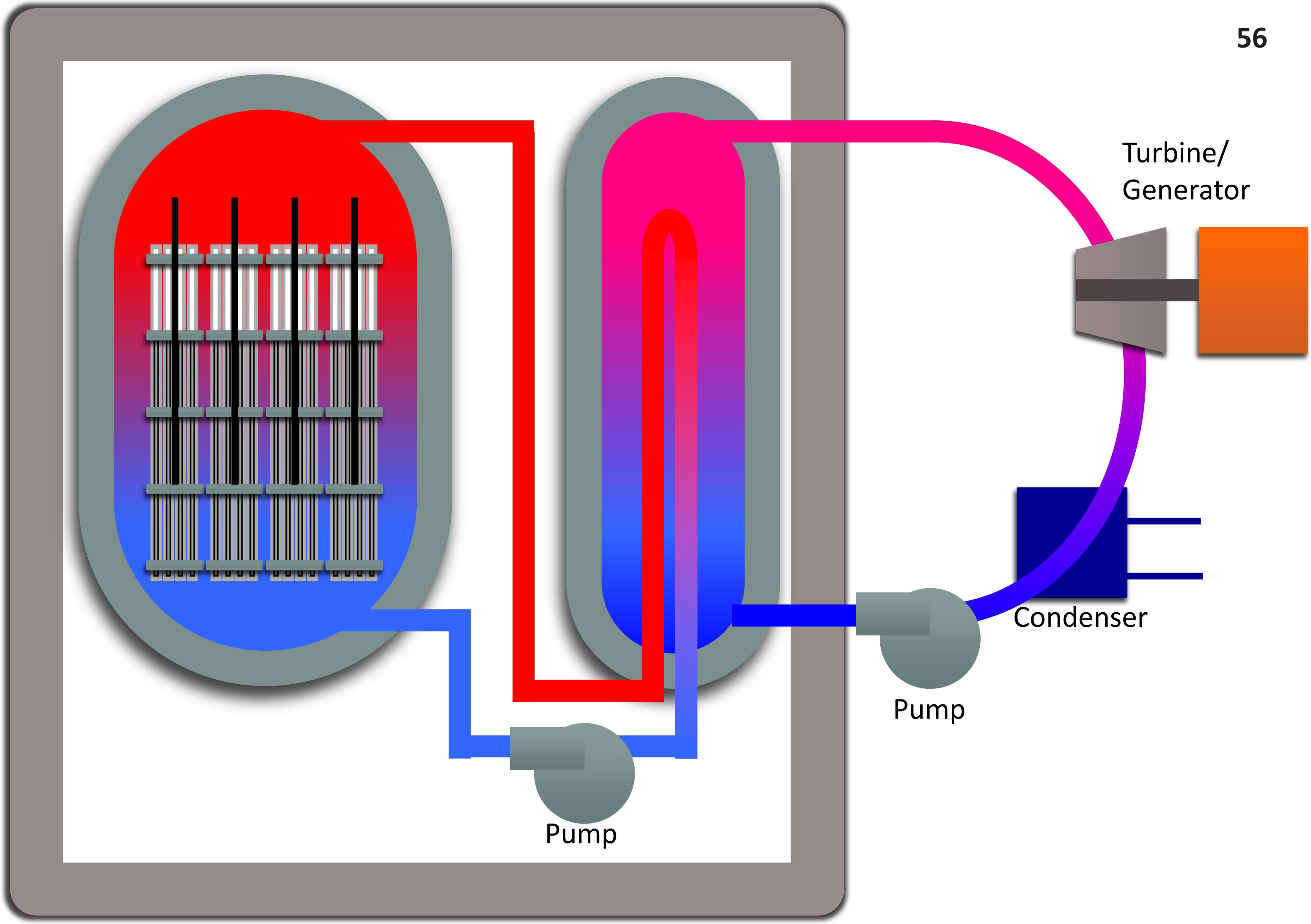
Pressurized Water Reactor (PWR)



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

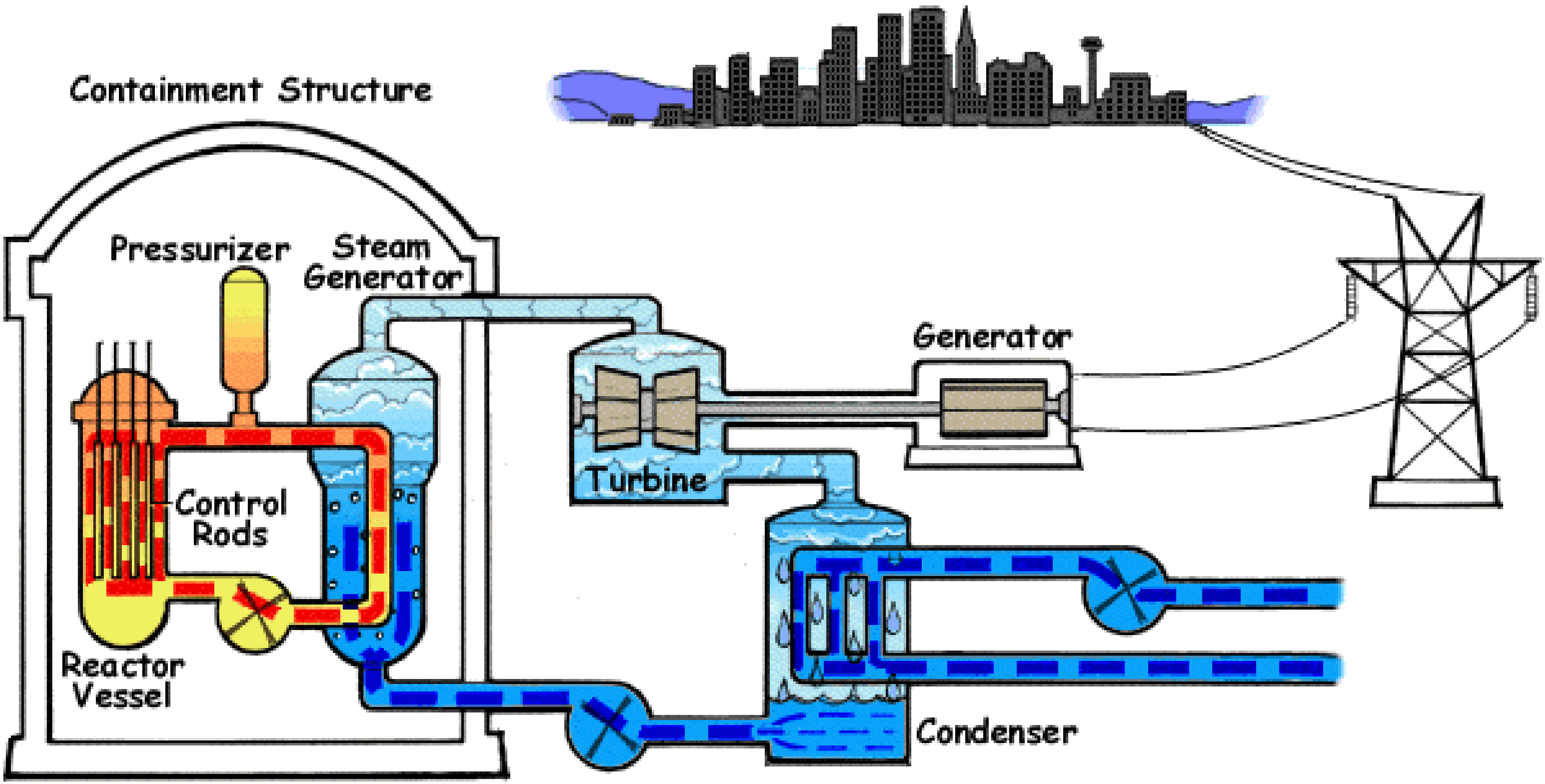
Steam is made in a **steam generator** rather than directly in the **reactor core**

PWR Containment

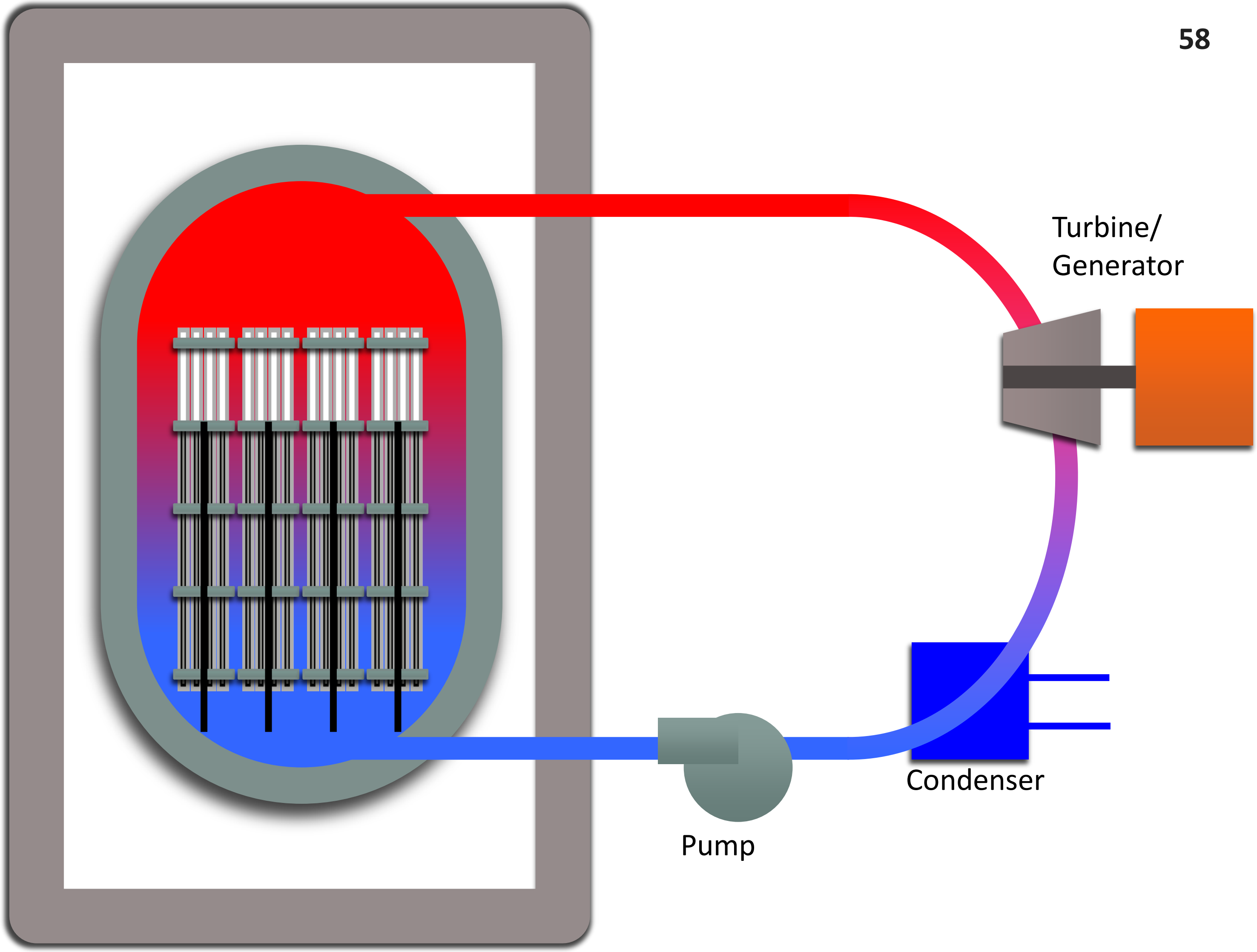


The entire reactor sits inside a large concrete and steel **containment building**

Pressurized Water Reactor



BWR Containment



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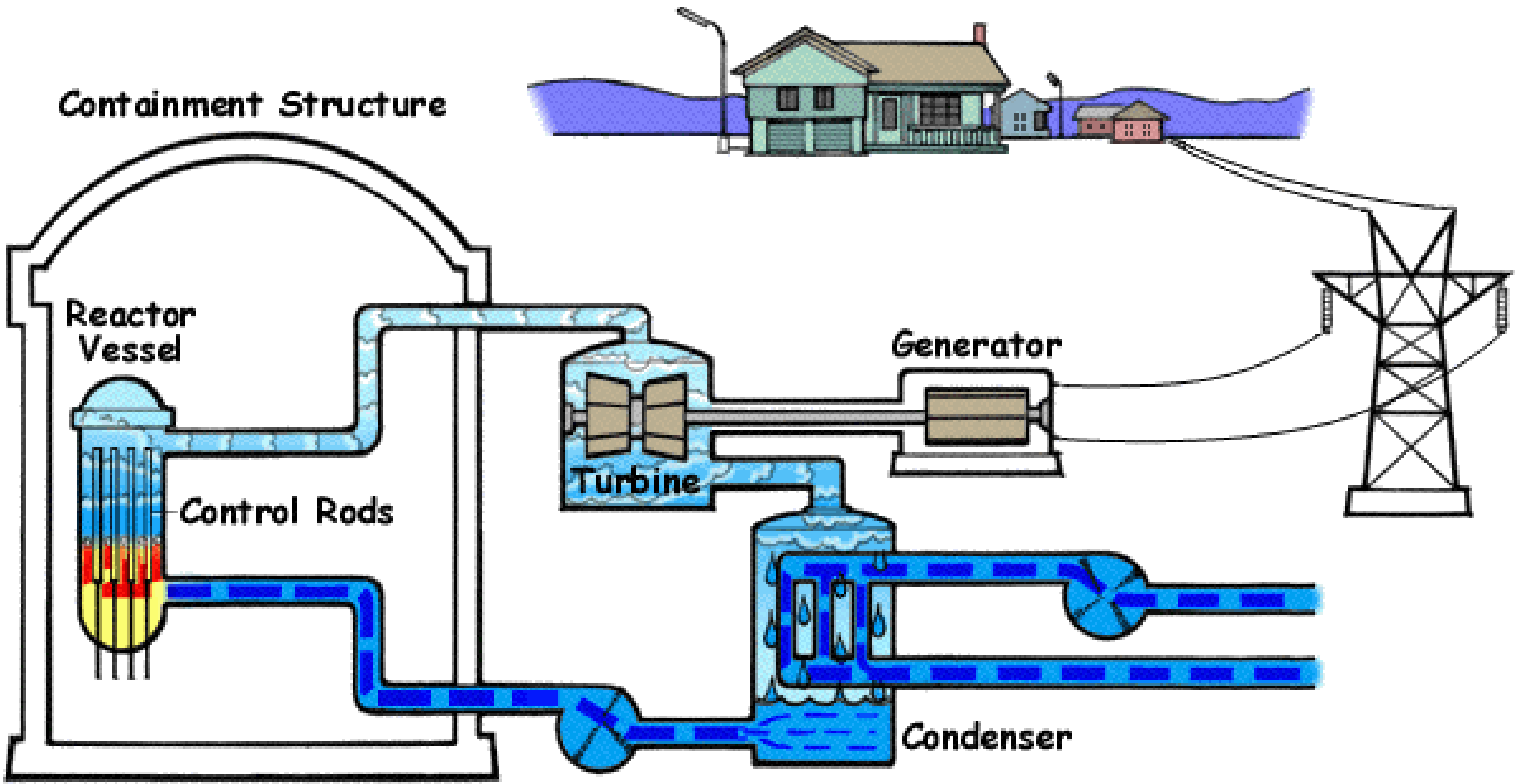
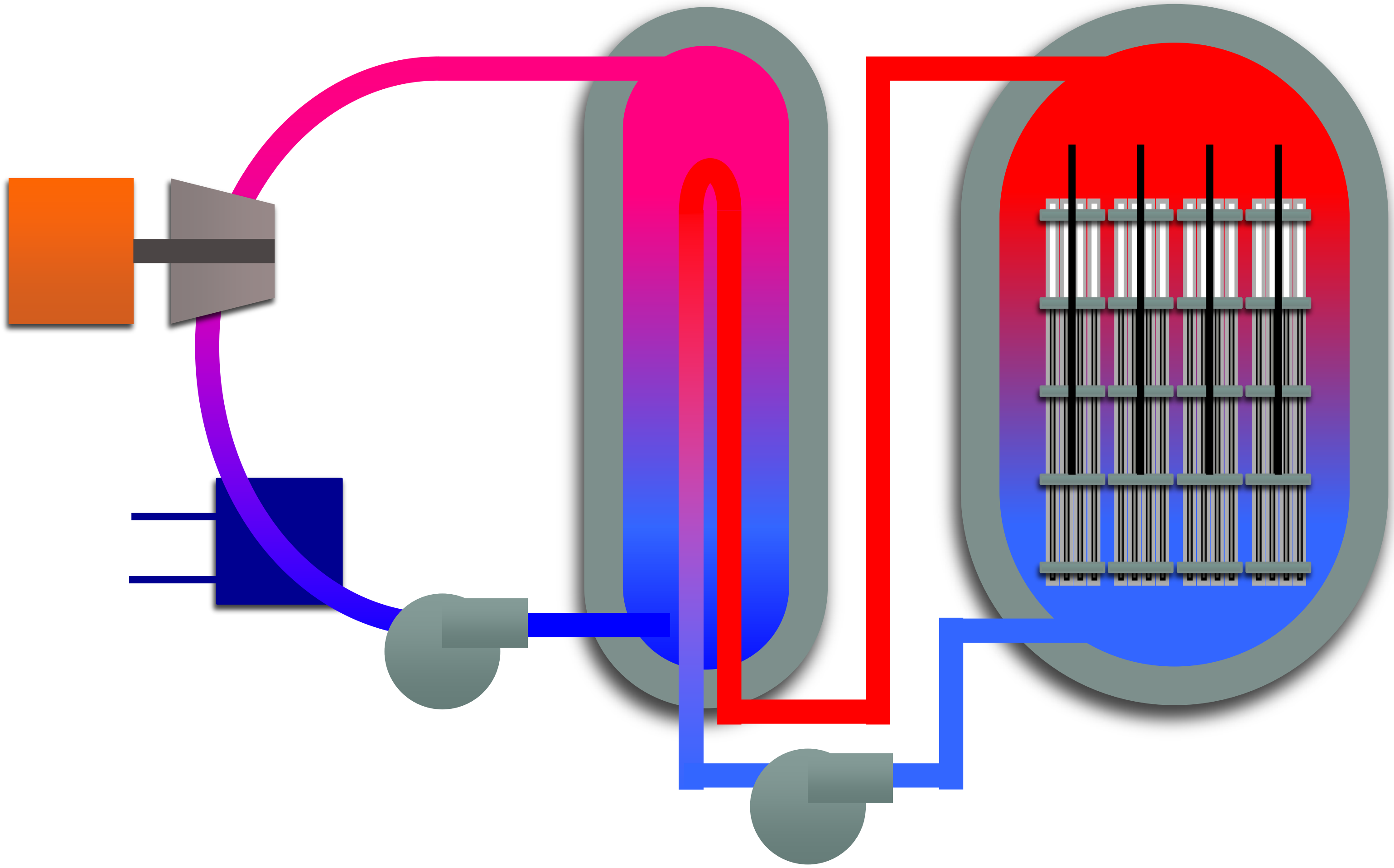
Boiling Water Reactor

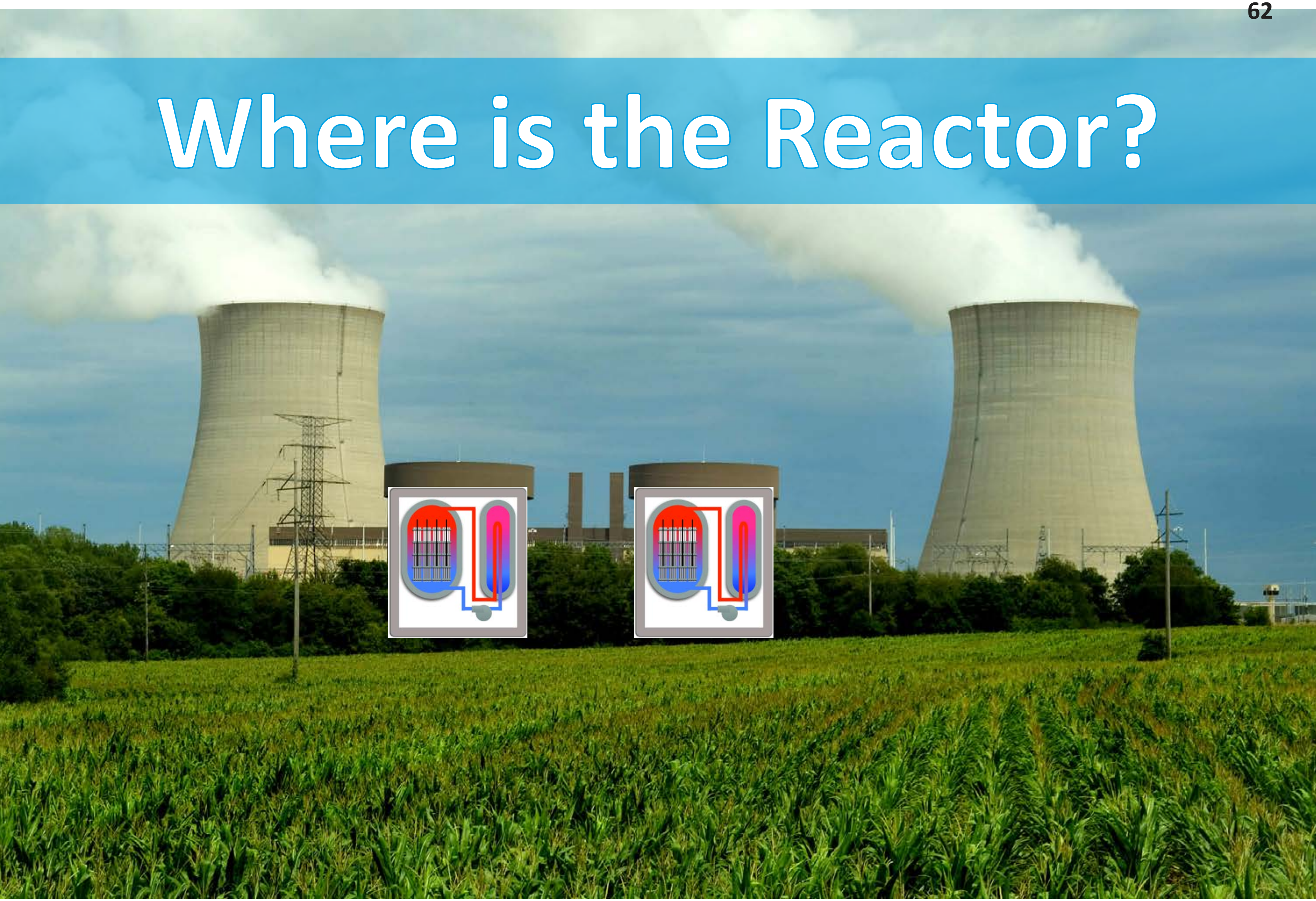


POP QUIZ!!!



Where is the Reactor?

Where is the Reactor?

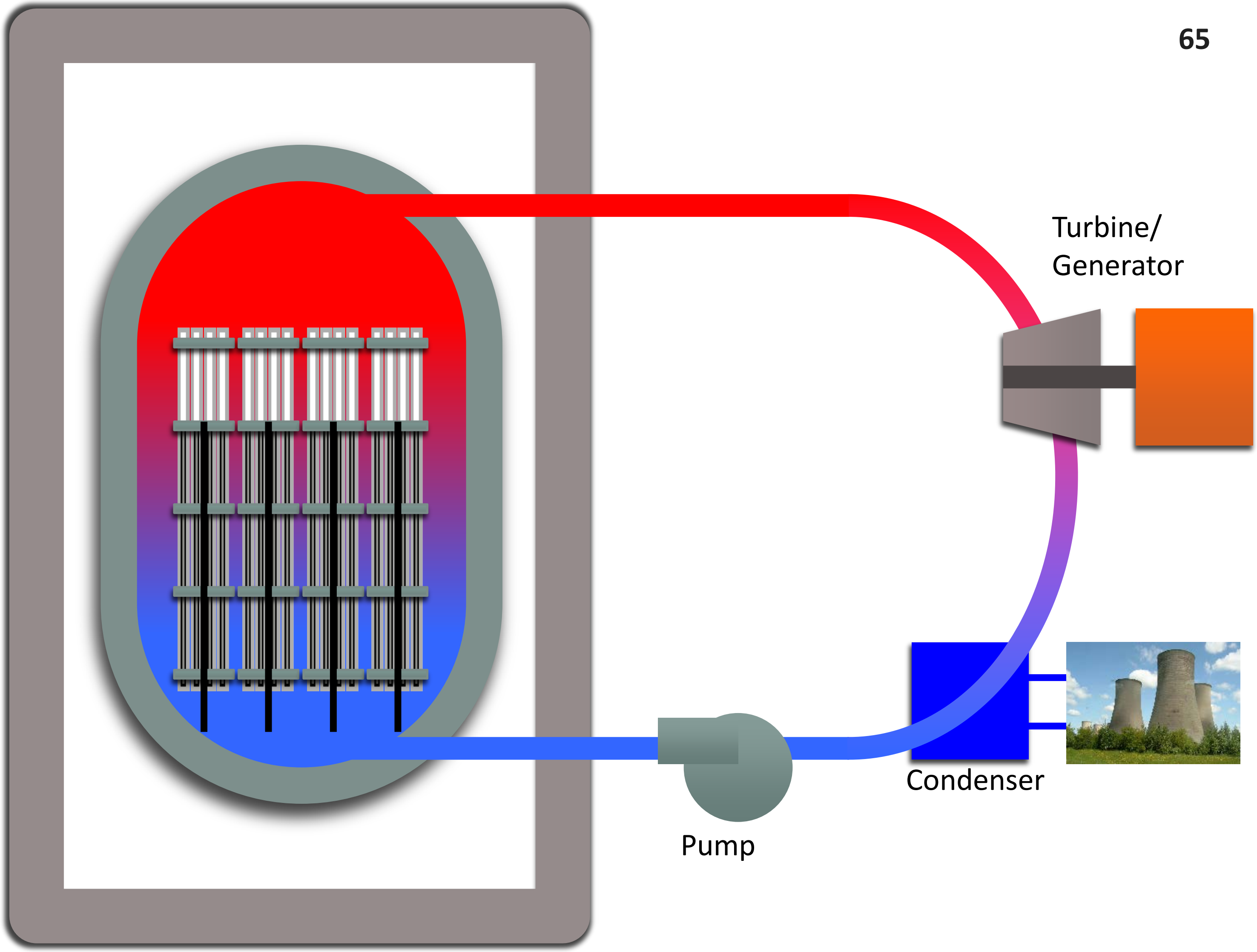



Then what are these?

Cooling Towers

They chill the cold water used by the condenser.

BWR Containment



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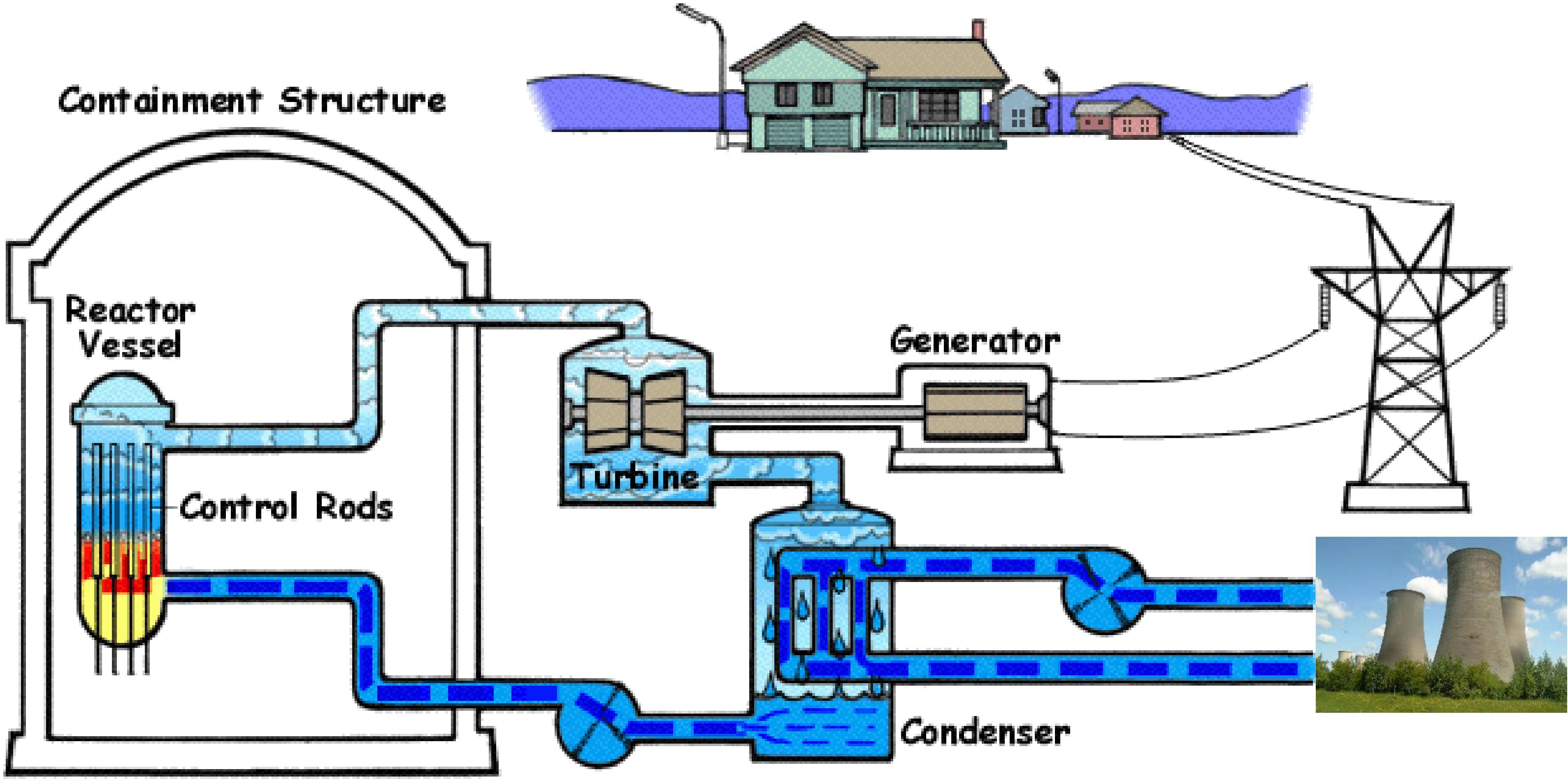
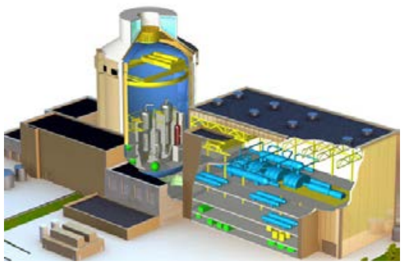
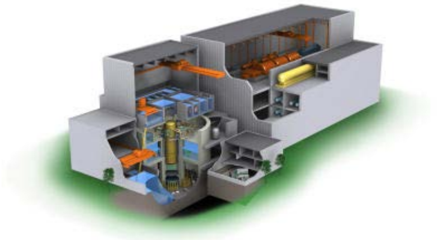
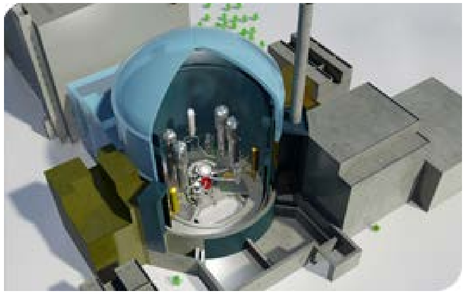
Boiling Water Reactor



What have we left out?







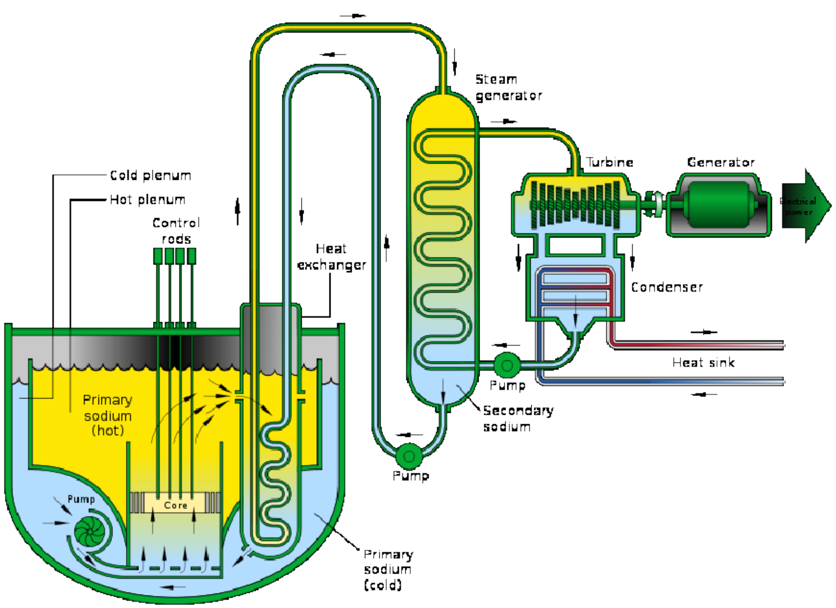
- Instrumentation
- Systems for optimizing efficiency
  - Control system components used by operators
  - Steam system components for thermodynamic efficiency
- Equipment to support outages and refueling
- Safety Systems

A few words about SAFETY

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

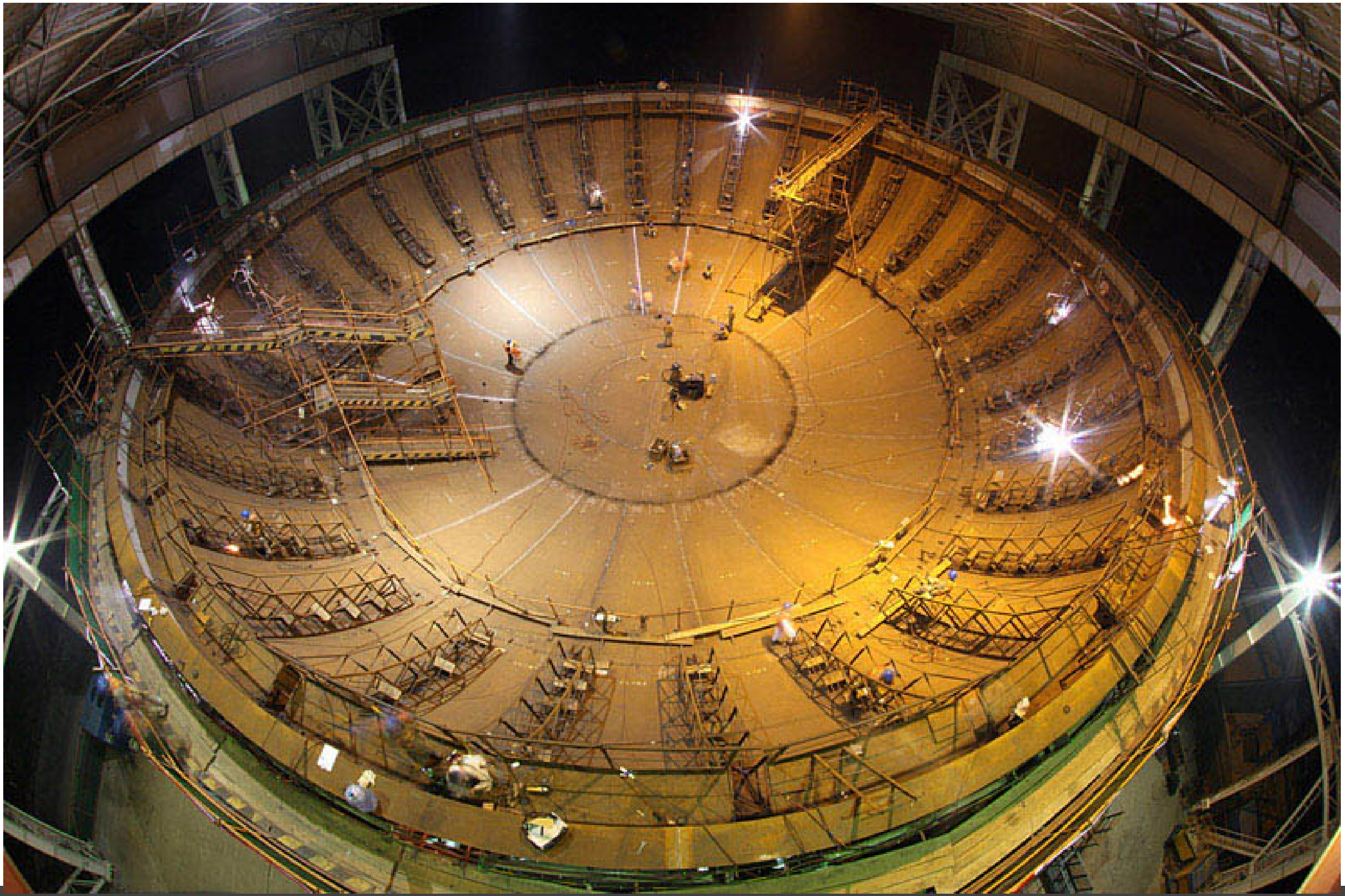
Advanced Reactors

- 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
  - Stronger passive safety features which rely on natural forces
  - Enable alternative fuel cycles

Progress in China – January 29 Photo



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Questions?

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