NUCLEAR POWER

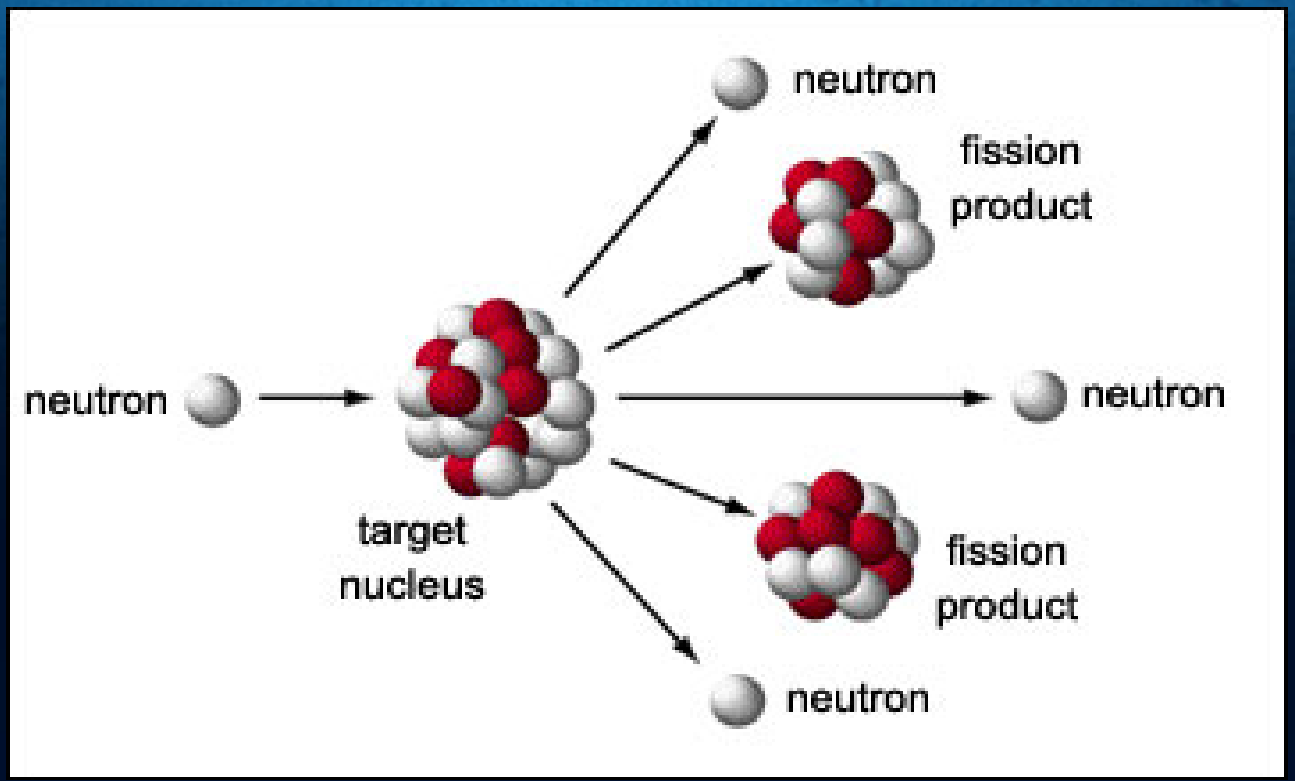
Rahul Edirisinghe, David Levy, Bennett Parmington, Joshua Stillman, Elise Van Pelt, Cainaan Webb

What is Nuclear Power?

Nuclear Power is the energy, generally electric, that is produced through fusion or fission events. Fission, however, is the main source of nuclear power and will be what we will focus on.

What is Nuclear Fission?

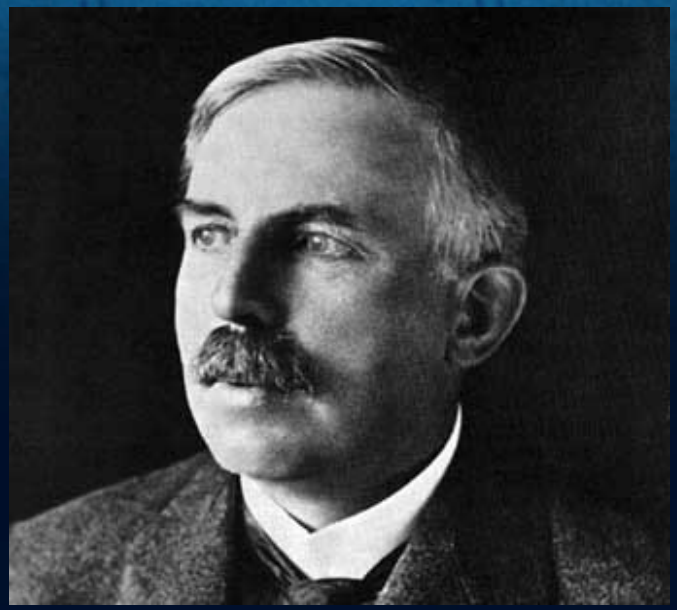
Fission occurs when a neutron hits another nucleus and causes it to split into two nuclei of similar mass. Neutrons are also produced, which can then bombard other nuclei, causing more reactions. This is called a *chain reaction* . A supercritical mass is needed to sustain a chain reaction. This means that on average more than one neutron expelled from a fission event hits another nucleus.



The Origin of Nuclear Power

Ernest Rutherford is the "Father of Nuclear Physics"

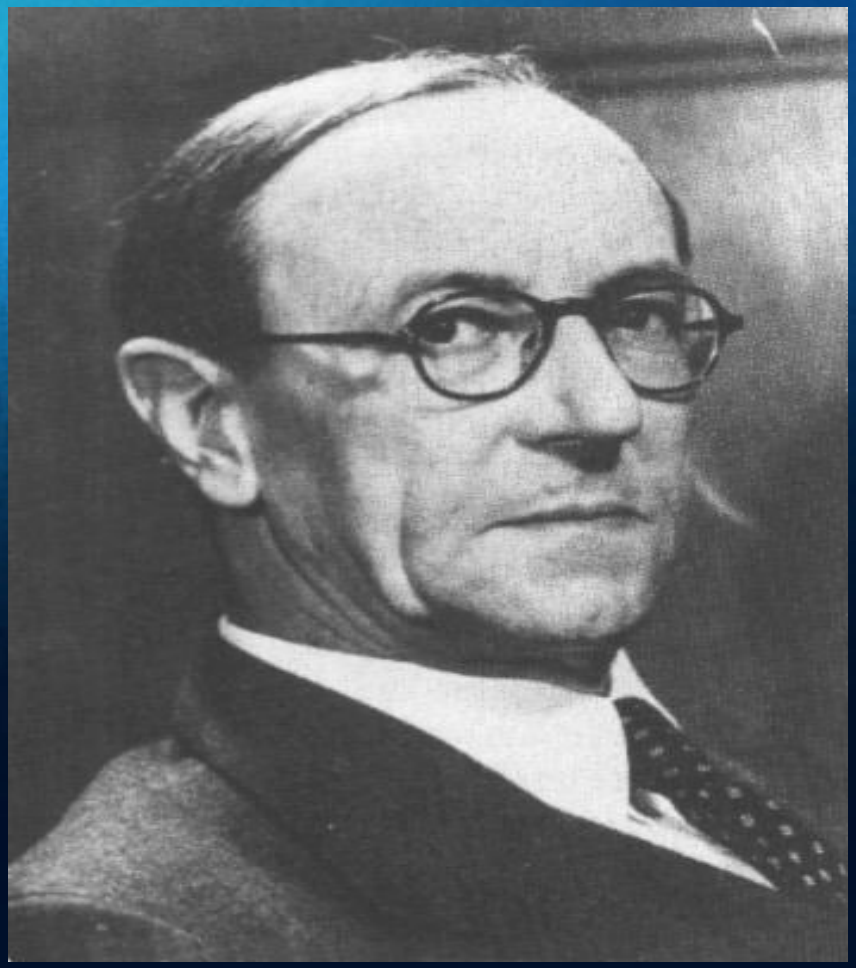
- Split an atom in 1919
- Alpha Particles were used to bombard a Nitrogen atom
- High energy proton was emitted
- Later, two of his students did a similar experiment with a proton accelerator and Lithium to produce two Helium nuclei



Discovery of the Neutron

James Chadwick discovered the neutron in 1932
- Used various sources of data to calculate the mass

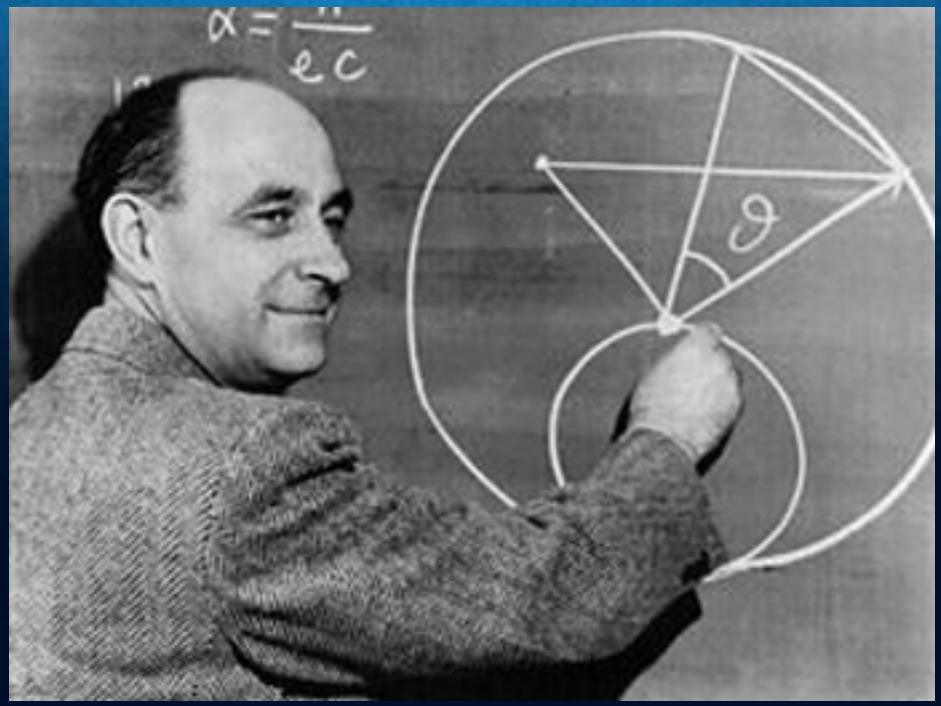
The discovery of the neutron was important to the development of nuclear fission because neutrons are an important part of initiating and sustaining a chain nuclear reaction.



The First Nuclear Fission Event

- Enrico Fermi accomplished the very first Nuclear Fission event in 1934

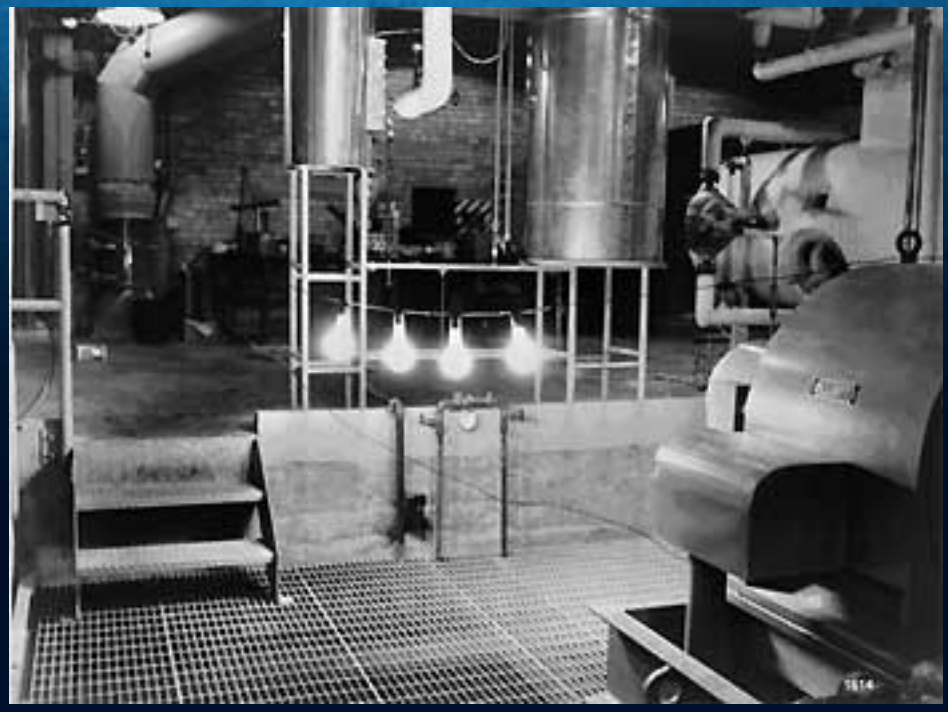
- Uranium was split using the bombardment of neutrons
- Uranium is still the most common reactor fuel. Plutonium can also be used.

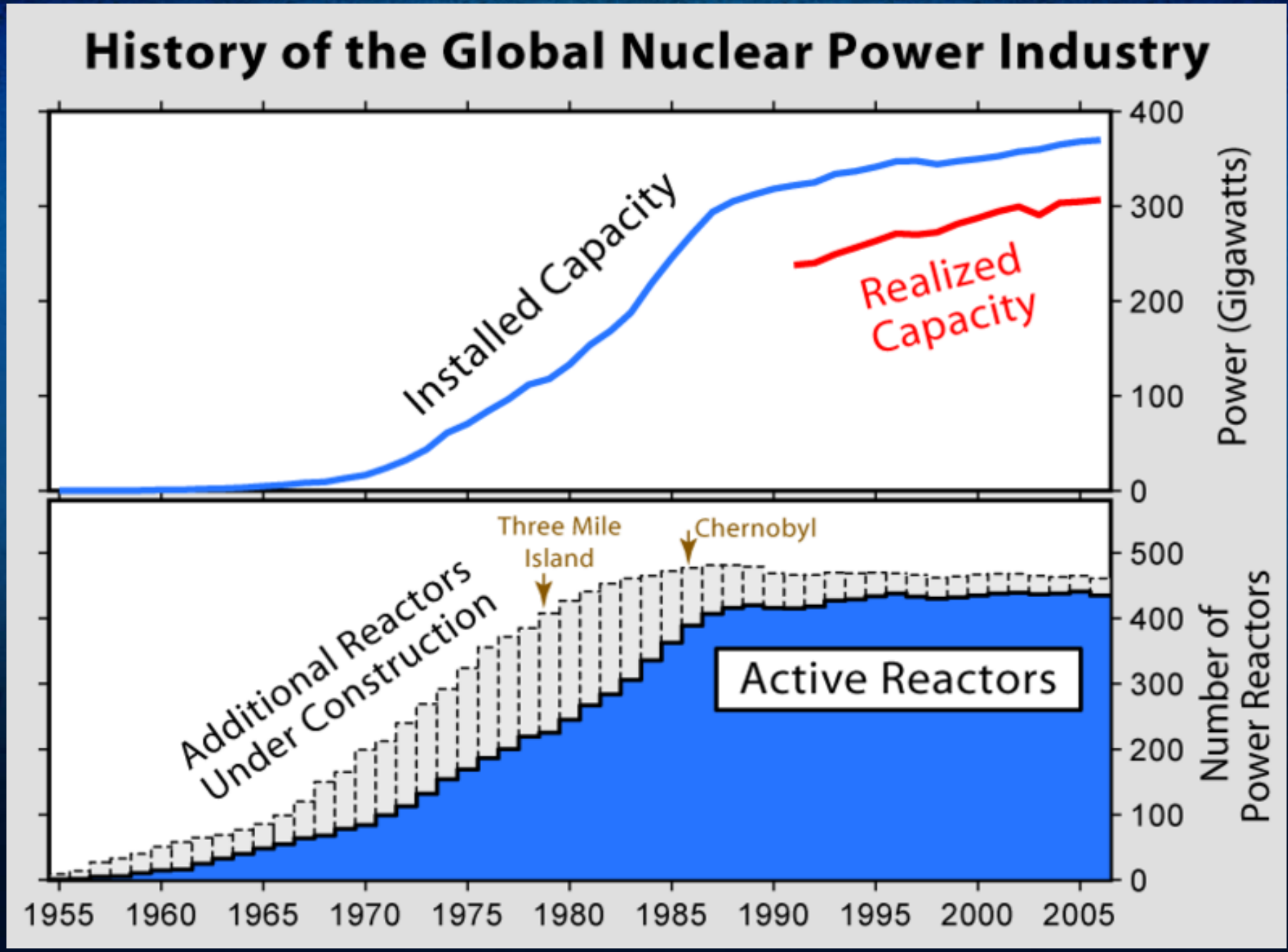


Obninsk Nuclear Power Plant

- Once it was discovered that fission could result in a chain reaction due to the production of neutrons, many countries began investing in the potential of nuclear fission.

-Obninsk was the first nuclear power plant.
-In the USSR, 1954





The top part of the graph is the power available from Nuclear Power. The bottom half of the graph shows the increasing number of reactors.

Uses

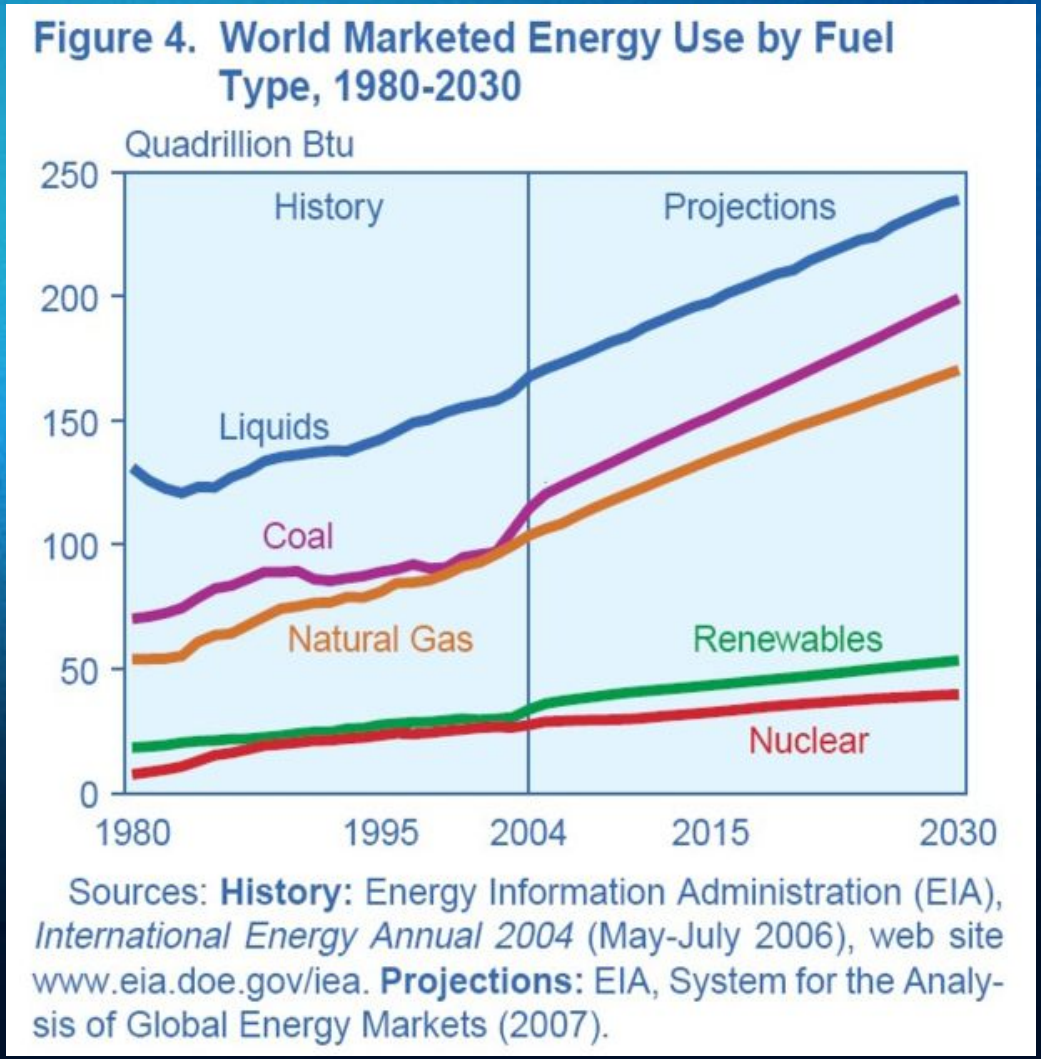
Produces Energy

- In 2009, 15% of the world's electricity came from nuclear power

Boats used for both the military and civilians

- Over 150 ships are propelled by more than 220 nuclear reactors

Accelerates spacecraft and artificial satellites



The Materials for Fission

Nuclear Fission to create power requires several key ingredients:

Nuclear Fuel:

Can be either Uranium-235 or Plutonium-239

Obtaining and Processing Uranium

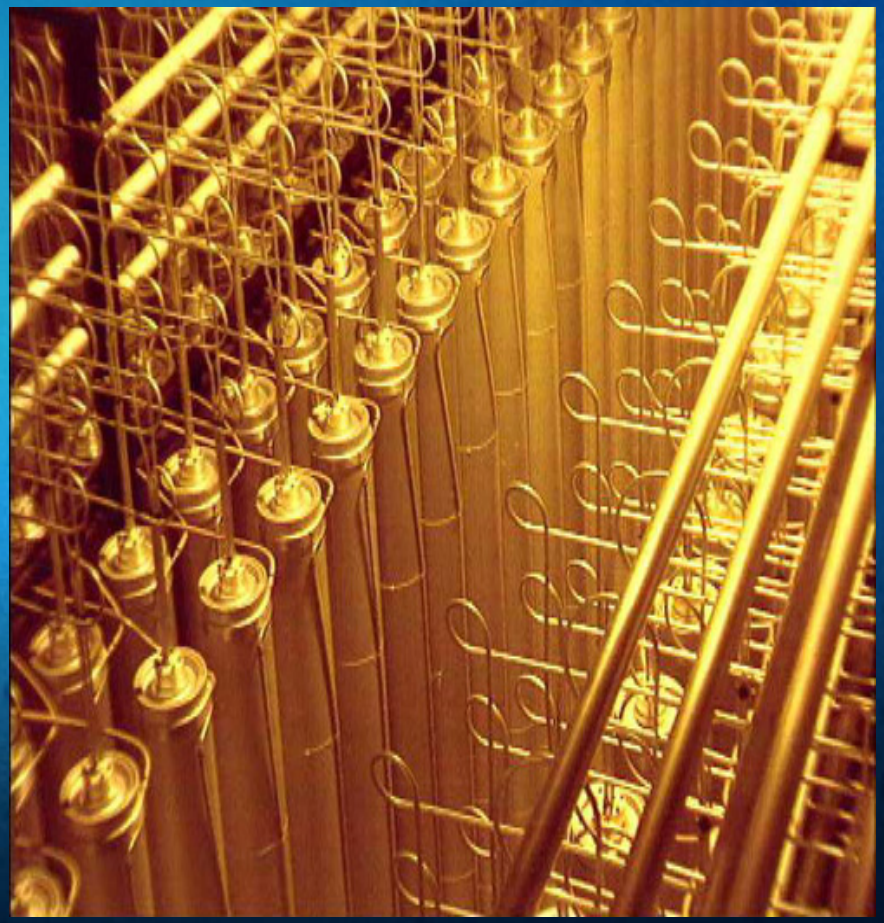
Only .7% of the world's Uranium is the U-235 Isotope, with the rest being U-238. In order to obtain this, most fuel is enriched by centrifuges, which rapidly spin and use the minuscule weight difference of 3 neutrons to separate the isotopes. On average, about 3.5% U-235 is needed for nuclear fuel. The result is turned into pellets that are used in reactors. The rest, Depleted Uranium, is used to for weapons, tank armor, and munitions

Plutonium

Often produced in nuclear reactors, it can also be turned into fuel.

Yellowcake, unprocessed Uranium in transport form

Centrifuges separating U-235 from U-238

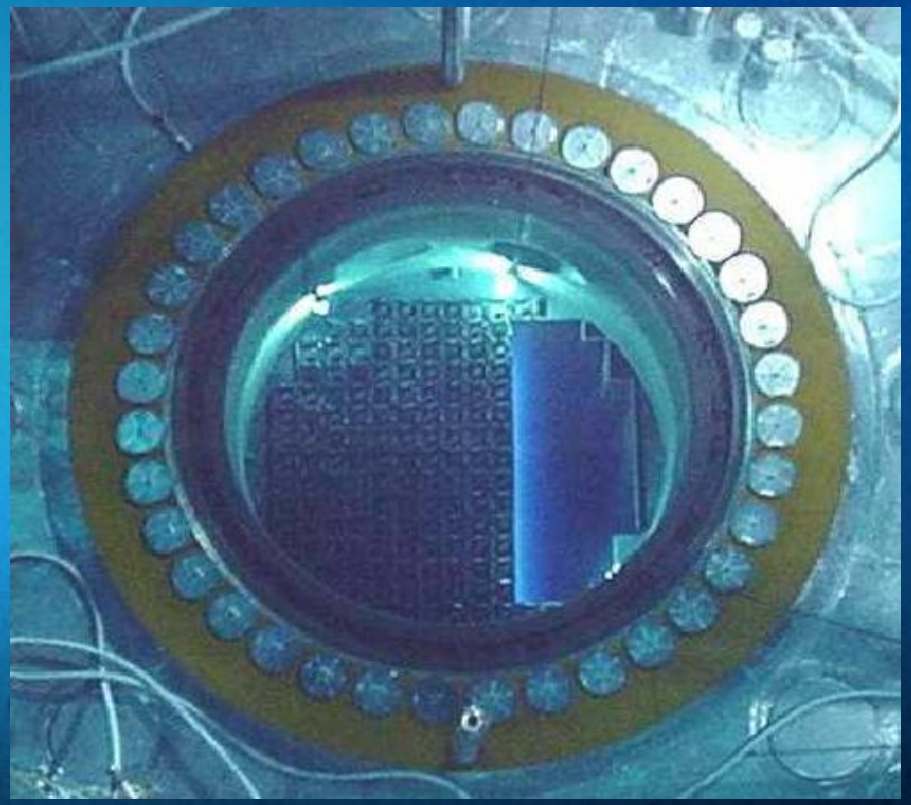


Nuclear fuel assembly

Reactor Core

A nuclear reactor core contains

-Nuclear fuel rods bundled together
The fuel is SLIGHTLY supercritical-
If left alone, the fuel would eventually melt the reactor



-Control rods: contain materials which absorb neutrons, slowing the reaction

-Coolant: Often purified water, this removes the heat to cool the reactor. The heat is carried away and used to turn water into steam.

-The reactor core itself is often submerged in water to help contain the

Power Generation

-The superheated and pressurized steam which is created from the heat of the reactor is pumped into a room where it turns the turbine.

-The turbine is connected to a generator, which uses electromagnetism to generate a stream of electricity.

Pros & Cons of Nuclear Power

Pros

* Relatively low levels of Carbon Dioxide are emitted, making Nuclear Power a cleaner energy source and less of a contributor to Global Warming
* Nuclear Power is a very reliable energy source because of the low input of an energy required
* Just one nuclear power plant can produce a lot of electrical energy
*Despite the possible accidents, nuclear energy is one of the safest forms of energy production

Cons

* Radioactive waste is very dangerous
* Although plants can be made with high protection against accidents, accidents can still happen. Nuclear accidents can be devastating
* It takes 20-30 years to build a new power plant
* Nuclear power plants could be targets of terrorist attacks
* Uranium is the energy source used in nuclear power and it is scare - it will only be available for the next 30-60 years

Complexities Can Cause Difficulties

- Nuclear power plants are such complex structures that even the best built have an incalculable amount of things that could go wrong.
- One of the more complex things about nuclear power plants are the live spans of the power systems. It can take from 100 to 150 for the lifecycle of a power plant to be completed, from its construction to the disposal of its last radioactive wastes.

Looking Closer at Radioactive Waste

A fission reaction of a material such as Uranium leads to radioactive waste products. These products cannot be destroyed and their radioactivity cannot be turned off. Therefore, the safe confinement of such by products creates an array of problems.

Organizations such as the Department of Energy and the Nuclear Regulatory Commission are responsible for safely storing radioactive waste.

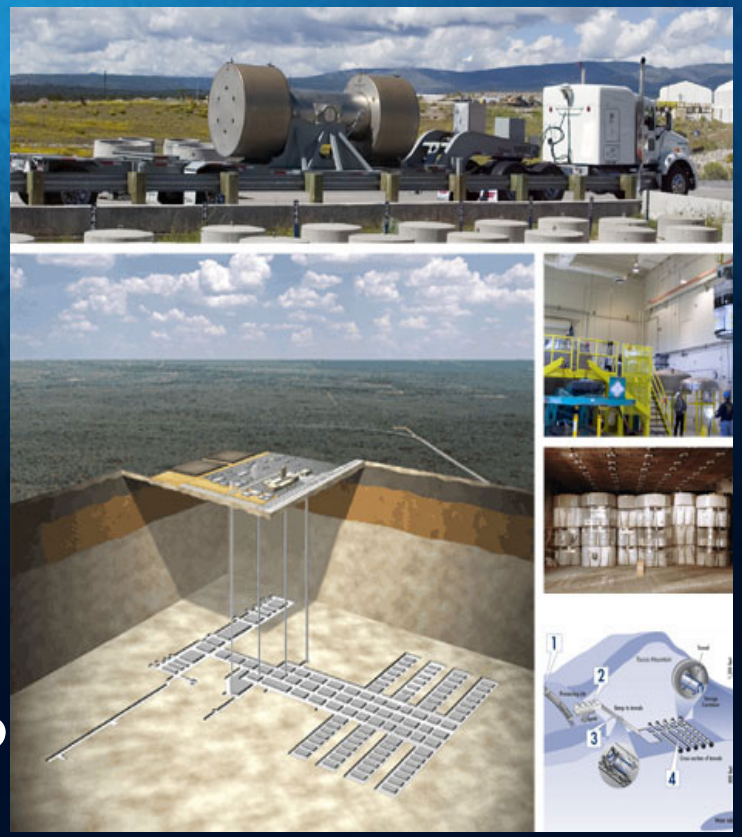
Waste is classified as High-Level or Low-Level based on the level of radioactivity.

Storage of waste can either by in a wet or dry environment.

Wet Storage of Radioactive Waste

This is the most common storage method. It involves the containment of radioactivity in specially designed rods under at least twenty feet of water in pools, which are frequently located at the reactor site.

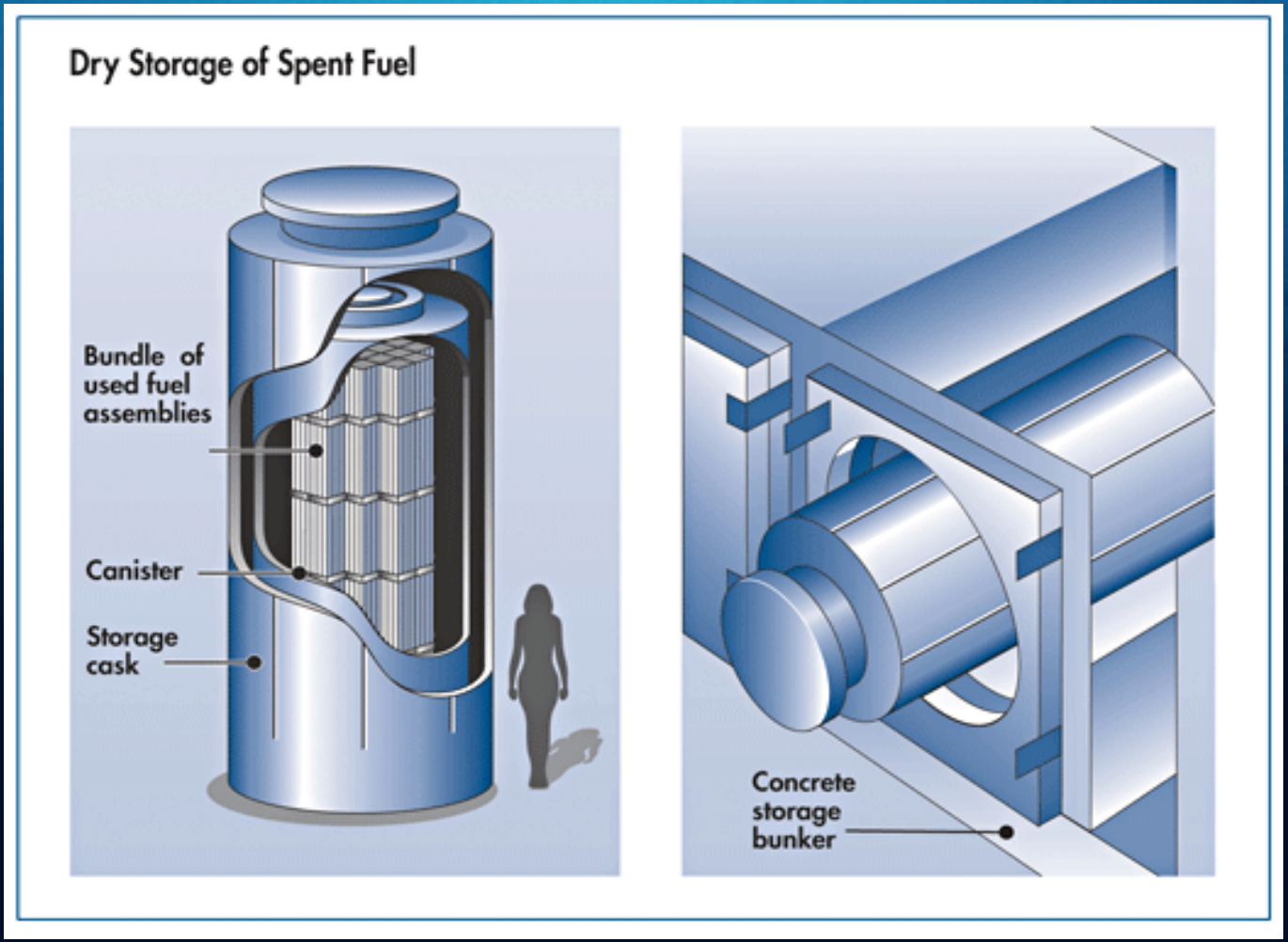
Rods need to be kept away from each other in order to prevent them from reacting with each other and causing an uncontrolled nuclear reaction.



Wet storage facility in
Carlsbad, New Mexico

Dry Storage of Radioactive Waste

Dry storage casks can be used to contain waste by surrounding it by inert gas. The casks are generally made out of metal or concrete



What about possible accidents?

If the reactor system is not properly cooled, such as because of a severe compound failure, the reactor containments are at risk of becoming too hot and possibly melting. If the reactor containment melts, the radioactive materials both used in the reaction and produced by the reaction can be released into the world, causing major problems and damage. This is called a **meltdown**.

Radiation is dangerous because it can damage and kill cells. Its damage is dependent on the level of exposure. High levels of 3,000 to 4,000 times the natural background level can cause severe cell damage and death resulting in the destruction of organs and a loss of bodily functions, leading to a rather rapid onset of severe disability of death.

Moderate radiation acts more slowly, with the ability to slowly harm cells and cause cancer.

The Three Mile Island Accident

In 1979, due to a flaw in the cooling system, a partial-meltdown occurred in the reactor core of Unit 2 at the Three Mile Island Nuclear Generating Station.

Enormous amounts of radioactivity was released, as a result.

No immediate deaths resulted, but the radiation emitted had devastating effects.

The Three Mile Island Nuclear Generating Station

The Chernobyl Disaster, 1986, Ukraine

Control rods were removed in order to increase power output for a test. However, with less rods drawing heat away from the core, the core overheated, resulting in a meltdown. The pressure inside of the core was also dangerously low because of a decrease in the amount of incoming water.

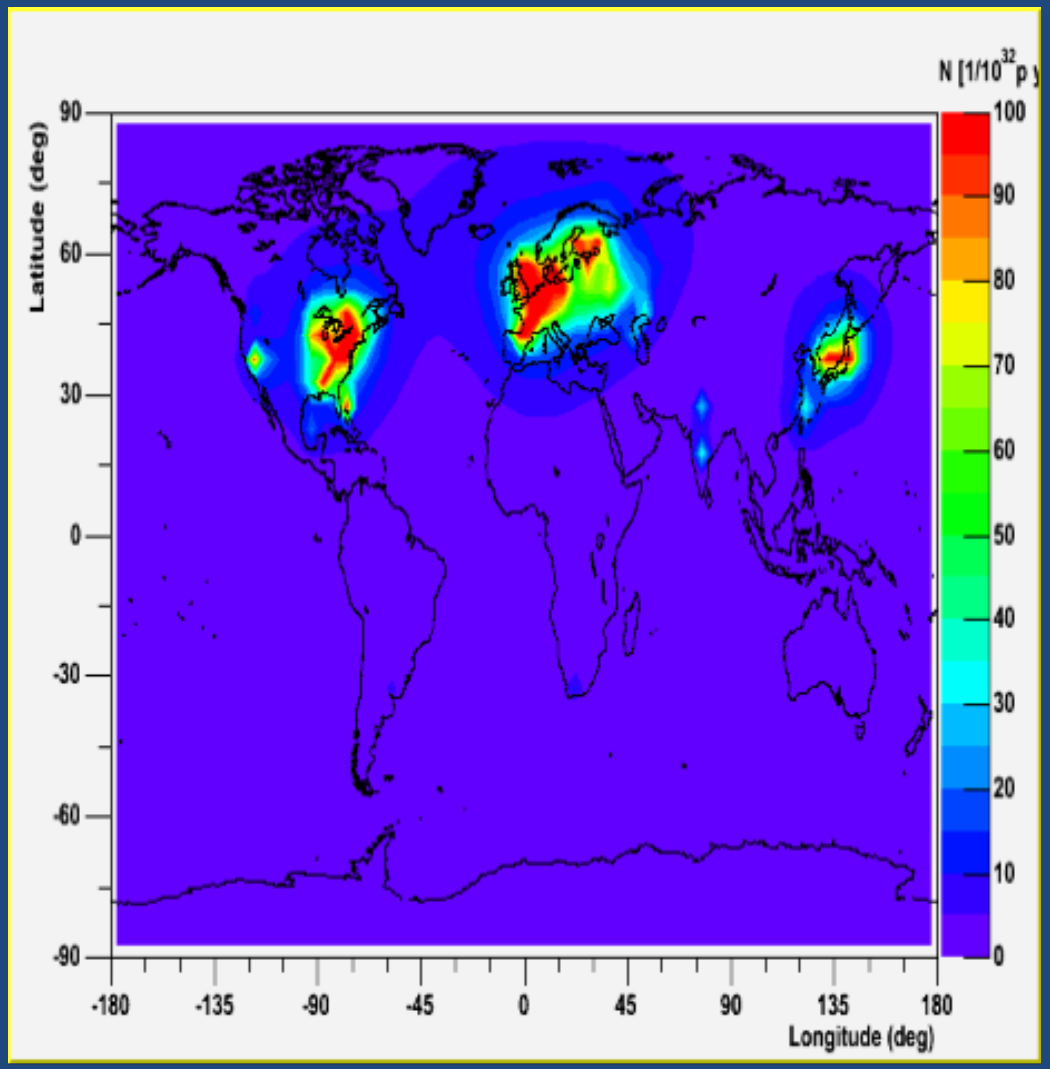
A meltdown of a reactor occurred when safety guidelines were overlooked, resulting in the deaths of thousands from both the explosion and fire related causes, and also from the resulting radiation exposure.

The Chernobyl Disaster

Despite possible accidents, Nuclear Energy is considered to be safe

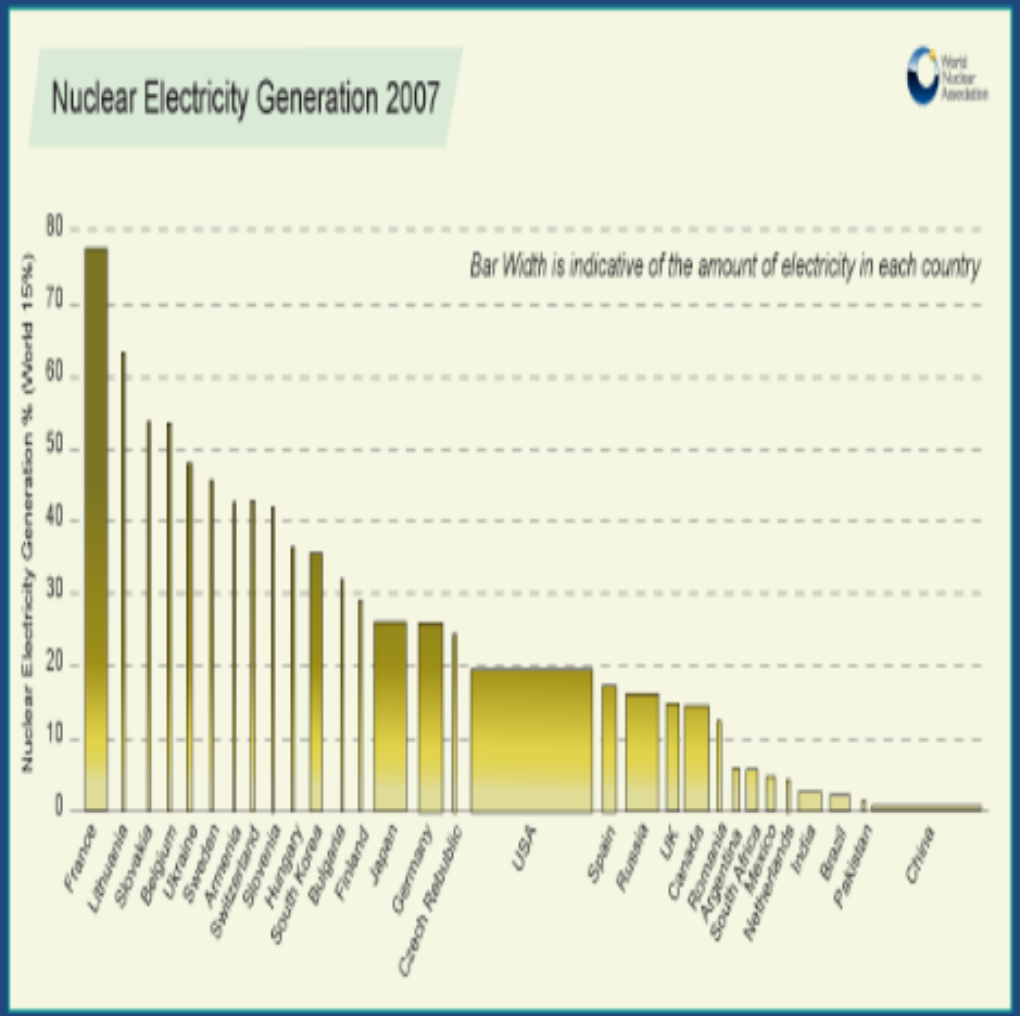
Although accidents can occur, they are not likely when safety guidelines are met. Strict safety rules are established to make nuclear power plants as safe as possible. Although there is always the possibility that an accident can occur, nuclear energy is often considered safe because of the lack of pollution and green house gases produced. Burning fossil fuels, a common fuel source, creates Carbon Dioxide emissions that contribute to global warning. Also, pollution from such plants can cause respiratory problems and many other diseases. Since nuclear energy avoids these types of pollution, in this way it is better for mankind and the environment.

Nuclear Power Around The World



- This map shows the flux of neutrinos that are created by nuclear reactors around the world.
- Countries generating high amounts of nuclear power are in red and are at the top of the intensity scale.
- As we can see from the map, the worlds biggest producers of nuclear energy are Eastern Europe, The United States, and Japan.
- All of these countries are members of the IAEA (International Atomic Energy Agency), an autonomous organization which promotes the peaceful use of nuclear energy and seeks to inhibit its use for any military purpose. The IAEA reports directly to the United Nations

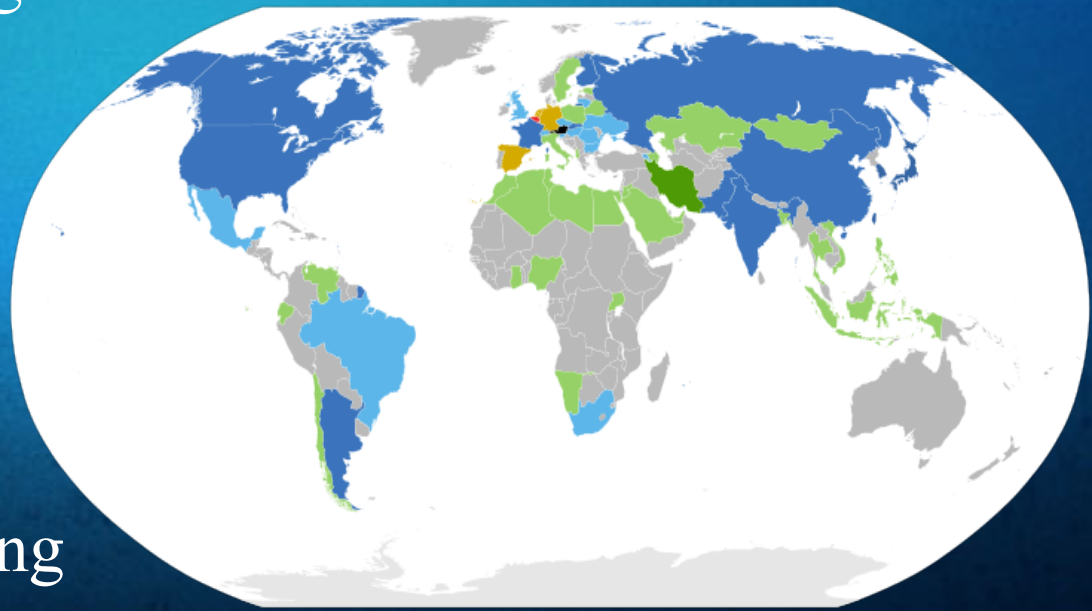
International Nuclear Energy Production



- Currently there are around 450 nuclear power plants on Earth, that together produce about 15% of the world's total energy use.
- The US has the biggest nuclear power program with 104 reactors in operation.
- Two big proponents and users of nuclear energy are France, which meets about 77% of its nation's energy needs through it's 58 nuclear power plants, and Japan, which uses nuclear power to account for about 30% of its nation's energy needs with 54 plants in operation.
- Russia and China are currently undertaking the most ambitious plant growth projects, with 16 and 21 plants under construction respectively. France will be overseeing and aiding in the creation of these plants to ensure their safety and adherence to IAEA guidelines.

Global Uses

- Operating reactors, building new reactors
- Operating reactors, planning new build
- No reactors, building new reactors
- No reactors, planning new build
- Operating reactors, stable
- Operating reactors, considering phase-out
- Civil nuclear power is illegal
- No reactors



Changing Acceptance of Nuclear Power

- Nuclear power is under serious consideration by more than 30 countries that do not currently have it. For example, Italy is one of many developed countries without any nuclear reactors and is consequently the world's largest net importer of electricity. By changing their laws on nuclear programs they can better provide cheaper, domestically produced energy and shy away from their foreign electricity dependency.
- Many countries such as Italy, Poland, Norway, Ireland, and Serbia have referendums, to stop work on nuclear power programs, that were set in place in reaction to the accident at Chernobyl. Italy, having realized that a lack of nuclear power is costing its people around 45% more than the European Union average for electricity prices, plans to build new nuclear power plants within 3 years. Slowly but surely, other countries are also lifting their bans to adopt newer, more progressive energy programs that aim to put nuclear power at the forefront for meeting domestic energy needs.

Why is Nuclear Power Important?

As fossil fuels become more limited, it is vital that we look for other energy sources. Despite the possible problems with Nuclear Power, there remains great potential in Nuclear Fission. It is important to keep in mind, however, the risks. Because of this, it is vital that safety precautions are always met and that continuing research is done to ensure that Nuclear Power is as efficient and safe as possible.