Nuclear Applications: Nuclear Power, Medicine, Food Irradiation & More!

Nuclear Power

- Nuclear power uses energy from fission to create electricity.
- As of January 2017, 11% of the world's electricity and 16% of Canada's electricity comes from nuclear power.[1]

[1](http://www.world-nuclear.org/)

There are currently 18 commercial nuclear power plants in Canada. Pictured here is the Pickering generating plant in Pickering, Ont.

Nuclear Power

- Over 440 commercial reactors currently operate in 31 countries.[2]
- There are also 245 research reactors and 180 nuclear reactors used to power ships and submarines.[3]

[2,3](http://www.world-nuclear.org/)

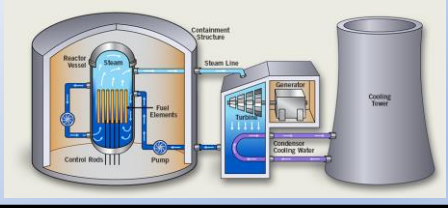
Nuclear Power

Map of Canada's Commercial and Research Reactors

- Canada is a leader in nuclear research and technology:
  - World's largest exporter of uranium
  - Creates much of the world supply of radioisotopes used in medical diagnosis and cancer therapy
  - Supplies 75% of global Co-60, used to sterilize single-use medical supplies
  - Exports reactor systems (CANDU)

How a Reactor Works

- Heat from fission reactions transforms water into steam. The steam then turns turbines to generate electricity.

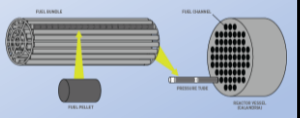


How a Reactor Works

- In Canada, we use CANDU (Canada Deuterium Uranium) reactors. These were invented in Canada, use deuterium oxide (also known as heavy water) as a moderator/coolant, and uranium as a fuel.
- CANDU reactors use natural uranium, of which 0.7% is U-235, the isotope that most readily undergoes fission. ^{235}U fissions by absorbing a neutron and producing 2 to 3 neutrons, which initiate on further fission reactions.
- A typical reactor has five main parts: the core, a moderator, a coolant, control rods, and shielding.

1. The Reactor Core - Calandria

- Contains the uranium fuel.
- Small U pellets are inserted into zirconium alloy pressure tubes (used because Zr does not absorb neutrons and is highly resistance to corrosion).
- These tubes then placed together into a fuel bundle.



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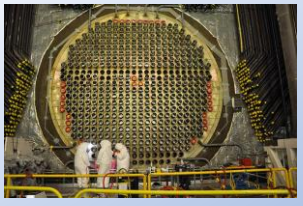
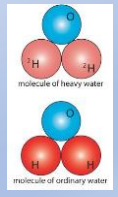


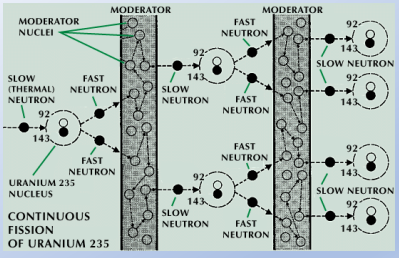
- Fuel bundles are then placed by the hundreds into the reactor core – known as the Calandria in the CANDU reactor.

2. The Moderator

- Once fission is initiated, fast moving neutrons will be released as part of the products.
- The moderator slows down these neutrons, without capturing them, thus increasing the chance of further fission reactions.
- In the CANDU reactor, heavy water (water comprised of two deuterium atoms rather than H-1) is used as the moderator.



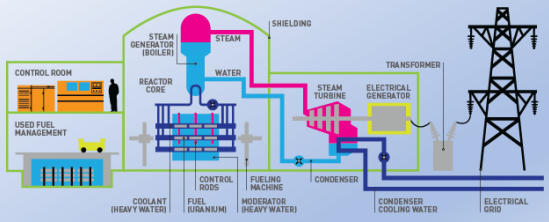
How a Moderator Serves to Control the Rate of Reaction



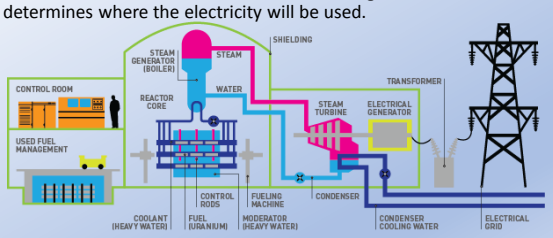
3. The Coolant

- The coolant is a fluid circulating through the core that absorbs and transfers the heat produced by nuclear fission.
- At the same time, the coolant maintains the temperature of the fuel within acceptable limits.
- In CANDU reactors, the coolant is the same as the moderator: heavy water.

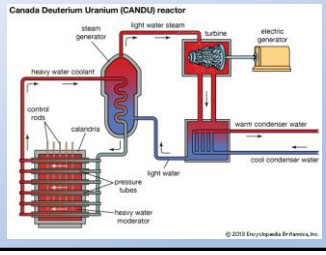
- After absorbing heat from the nuclear reactions, heavy water coolant is then circulated to the heat exchange / steam generator (boiler) to produce the steam to drive turbines.



- The turbines turn a series of conducting wires through a powerful magnetic field. This creates a current (electricity) that can be transferred via a transformer to a grid that determines where the electricity will be used.

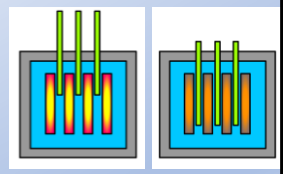


- After driving the turbine, the steam is cooled by <u>cold water</u> which is pumped from a nearby lake or river. This cool water is then pumped back to be reused in the process again.



4. Control Rods

- Serve as a safety feature to control the rate of reaction.
- These rods are made of B, Cd or other material capable of <u>absorbing neutrons.</u>
- When needed, they can be inserted into the reactor to reduce the number of neutrons and thus stop the fission process.



5. Shielding

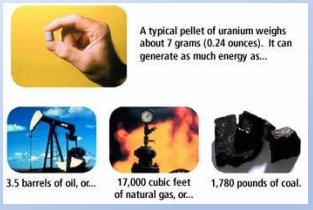
- Refers to a structure surrounding the reactor and its steam generators, typically a metre-thick concrete and steel structure.
- Serves as a <u>safety feature</u>.
- It is meant to protect the reactor from intrusion and to protect those outside from the effects of radiation in the event of serious malfunction.

Further Safety Features

- Designed to account for human error, equipment failure, and external risks such as earthquakes. For example:
  - Control room operators spend over 8 years in training
  - Duplication of critical control components
  - Automatic shutdown and emergency cooling systems
  - Back up electricity
  - Containment systems

Advantages of Nuclear Power

- Nuclear fission is a very efficient source of energy, so small amounts of fuel are required.



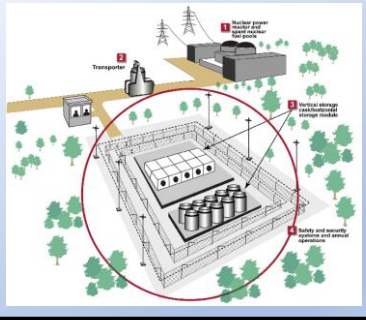
Advantages of Nuclear Power

- Less environmental impacts compared to burning fossil fuels (no greenhouse gas emissions).

- Reliable.
- Low volume of waste to dispose of.

Disadvantages of Nuclear Power

- While in small volumes, spent fuel is radioactive and special measures must be taken to protect human health and environmental impacts.



Disadvantages of Nuclear Power

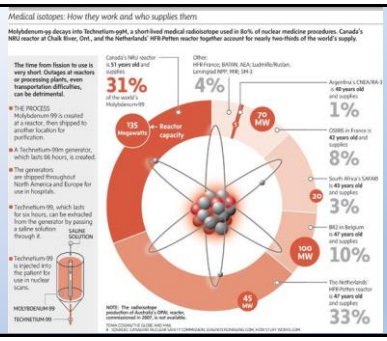
- Risk of unforeseen events / disaster.

Chernobyl, 1986

Fukushima, 2011

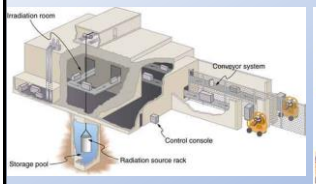
Nuclear Medicine

- Canada supplies a significant amount of the world's medical isotopes:
  - **Molybdenum-99:** Used for medical diagnosis (imaging) of the brain, thyroid, heart, lungs, liver, kidney, spleen and bone marrow
  - **Iodine-125:** Used in prostate cancer treatment, in-vitro diagnostic kit, bone densitometry devices
  - **Xenon-133:** A medical diagnosis tool, especially for scanning lungs.
  - **High Specific Activity (SA) Cobalt-60:** Used in cancer treatment applications



Food Irradiation

- Similar to X-raying luggage at airports, a source of ionizing radiation (such as Co-60) is directed at food to destroy insects, bacteria and other microorganisms.



Further Applications

- Medical Imaging
- Smoke Detectors
- Crop Irradiation
- Water Desalination
- Nuclear Weapons
- Radioisotope Thermo Electric Generators
- Nuclear Rockets

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