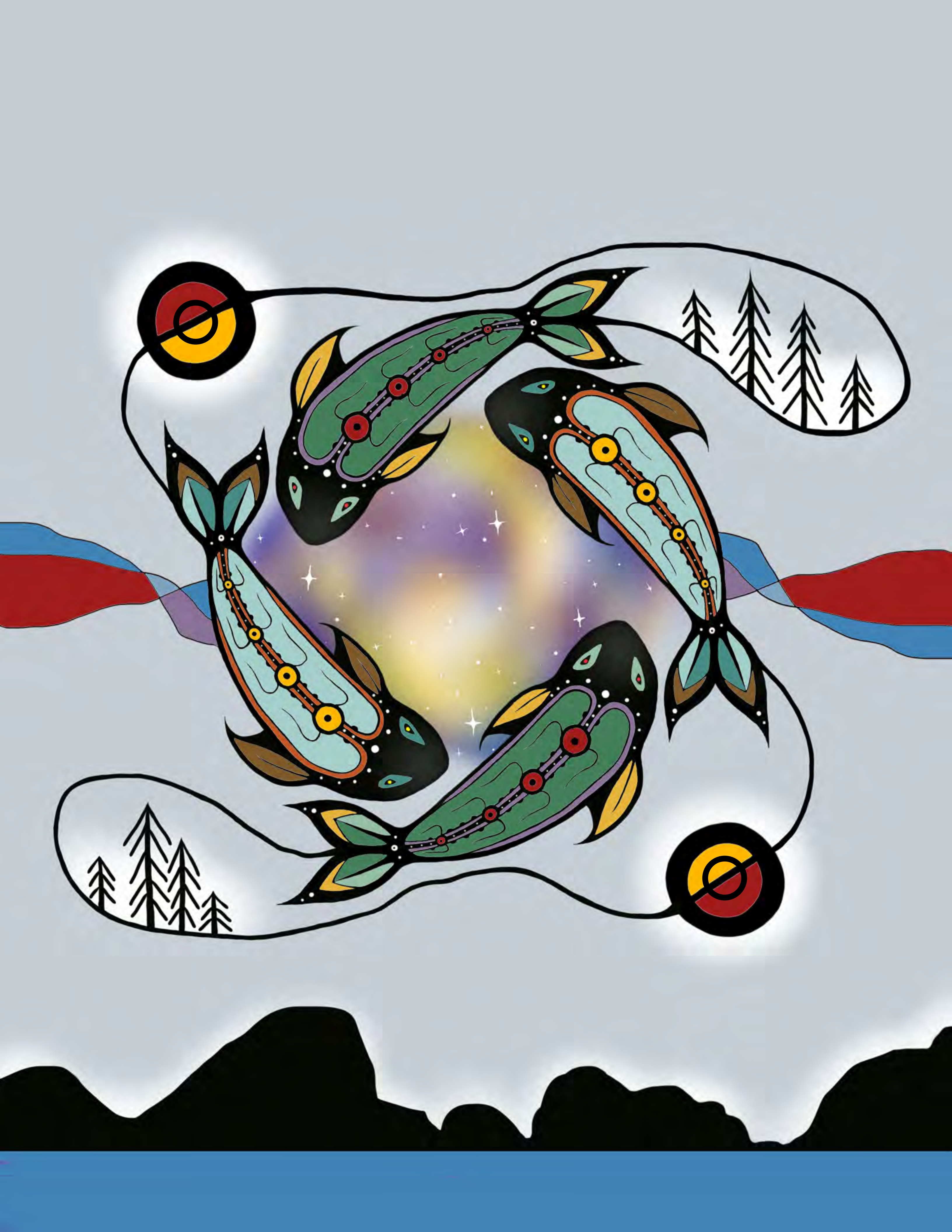

The information contained in this booklet has been put together by Saugeen Ojibway Nation (SON) Environment Office staff, technical and legal advisors. We have done our best to be accurate and neutral. Our aim is to provide information that might be helpful to SON community members as they consider the many nuclear issues they face in their Territory. The information is not intended to suggest or reflect any opinions or positions of the SON Joint Chiefs and Councils or any individual. We value your input and strive to continue to improve the information we provide to assist the SON communities.

Cover artwork by Emily Kewageshig

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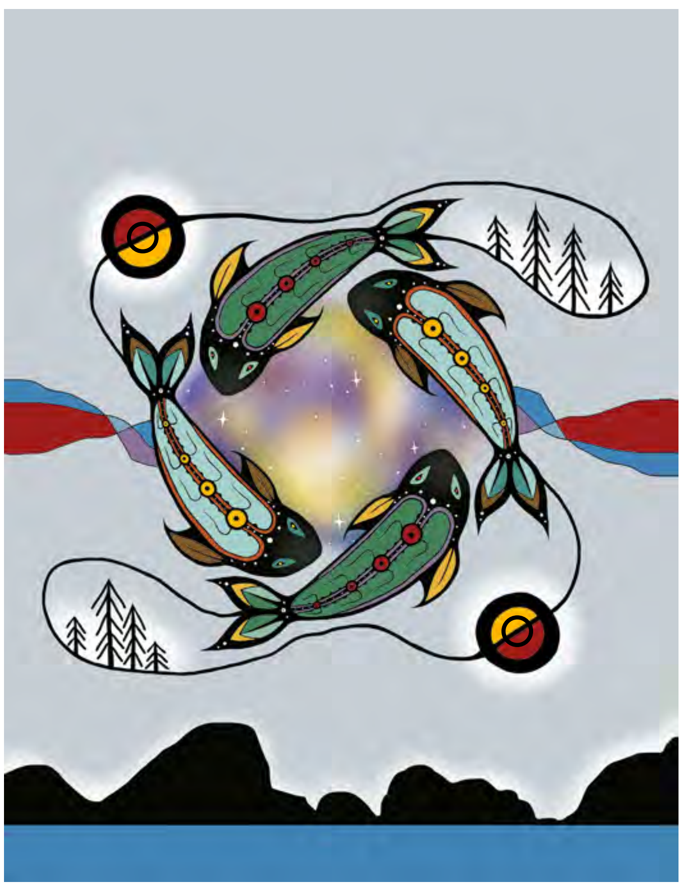
Abbreviations and Definitions



Abbreviations

Organizations

- AECL: Atomic Energy of Canada Limited
- BHWP: Bruce Heavy Water Plant
- CNL: Canadian Nuclear Laboratories
- CNSC: Canadian Nuclear Safety Commission
- HEPCO: Hydro Electric Power Commission of Ontario
- IAEA: International Atomic Energy Agency
- ICRP: International Commission on Radiological Protection
- The Joint Convention: the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
- NWMO: Nuclear Waste Management Organization
- OPG: Ontario Power Generation
- SON: Saugeen Ojibway Nation
- UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation
- WIPP: Waste Isolation Pilot Plant
- WWMF: Western Waste Management Facility

Terms

- ALARA: as low as reasonably achievable
- APM: adaptive phased management
- CANDU: CANada Deuterium Uranium
- CEAA: Canadian Environmental Assessment Act

Abbreviations

Terms

- DGR: deep geologic repository
- DSC: dry storage containers
- EIS: environmental impact statement
- HLW: high-level waste
- ILW: intermediate-level waste
- LILW: low- and intermediate-level waste
- LLW: low-level waste
- LRF: large release frequency
- MOX: mixed oxide fuel
- NGS: nuclear generating station
- RWOS: radioactive waste operations site
- SCDF: severe core damage frequency
- SNF: spent nuclear fuel
- VLLW: very low-level waste

Definitions

Base Concepts

- Activation products: uranium, plutonium and structural materials that have been exposed to neutrons in the reactor core and are now radioactive.
- CANDU: a type of pressurized nuclear reactor created in Canada that is moderated and cooled by heavy water. As well, it has a vacuum building.
- Coolant: liquid that transfers heat from the reactor core to the steam generators or turbines.
- Core: the centre of a nuclear reactor that contains fuel elements and moderators.
- Decommissioning: permanent removal of a nuclear facility from use. It includes the safe storage of waste and dismantling that turns the site into a brown field or green field.
- Disposal: putting radioactive waste somewhere with no intention of retrieving it. See storage.
- Dry storage container: after 10 years under water, spent nuclear fuel is moved to dry storage containers to cool in the air. The containers used by OPG weigh more than 60 tonnes each as they are made from high-density concrete. Each container holds 384 used fuel bundles.
- Environmental impact statement: a report that addresses the potential impact to the environment for a proposed project. Usually, it allows for public comment and input.
- Fission: the act of splitting a nucleus into two, leading to a release of energy. It may happen on its own, but normally fission happens when a nucleus destabilizes after absorbing a neutron.
- Fissionable materials: actinides including uranium and plutonium.

Definitions

Base Concepts

- Fission product: a nucleus that results from the fission of elements like uranium or from radioactive decay of those elements. It is normally highly radioactive.
- Heavy water: water that contains a higher concentration of deuterium atoms than regular water. See light water.
- Historic waste: low-level nuclear waste from activities such as radium and uranium production. The Government of Canada is responsible for dealing with all historic waste.
- Legacy issues: the historic and ongoing impacts of nuclear power on Saugeen Ojibway Nation communities and Territory.
- Light water: normal water. See heavy water.
- Meltdown: the severe overheating of a nuclear reactor core that results in a large release of radiation.
- Moderator: light water, heavy water or graphite used in a reactor to slow the neutrons by encouraging them to collide with lighter nuclei and continue the fission process.
- Mothballed: the shutdown of a nuclear plant where the facility is kept in working order, so it can start producing power again if needed. Often, this is referred to as storage with surveillance.
- Nuclear fuel cycle: refers to the steps which nuclear fuel material progresses through, from its extraction from the earth through use in reactors and to the eventual waste created. See once through fuel cycle and advanced fuel cycle.
- Nuclear reactor: a structure in which nuclear fission reactions occur under controlled conditions so that the heat produced can be used. All commercial reactors are thermal and use a moderator to slow down the neutrons.

Definitions

Base Concepts

- Radioactive decay: the process of a radioactive atom releasing energy. The characteristics of this decay, such as the type of radiation emitted, the energy of the emissions and the rate (frequency) of decay are unique to each radionuclide. Its scientific unit is the becquerel.
- Radioactive waste: radioactive material that is no longer needed or useful. It can be solid, such as tools, equipment and components that have become contaminated. It can also be water processing equipment - such as filters or resins that have been contaminated by processing radioactive water - or material, usually metal components, that have become radioactive due to neutron activation.
    - High-level waste: the most hazardous category of radioactive waste, it creates a significant amount of heat during radioactive decay and/or contains a lot of long-lived radionuclides. Currently, the international disposal solution for high-level waste is a deep geologic repository located hundreds of metres below the surface. It is mainly used nuclear fuel, which - when removed from the reactor - contains significant levels of radioactivity and emits enough radiation and heat that it must be stored under water for 10 years, after which the used fuel is not as hot. However, it still emits deadly levels of radiation and contains many long-lived radionuclides, so it is still considered high-level waste. The main differences between the three categories of waste are radioactive content (in terms of concentration) and half-life.
    - Intermediate-level waste: less common than low-level waste, it has a higher radioactivity content than low-level waste, especially in terms of long-lived radionuclides. It requires shielding (usually concrete or lead) during handling, processing and storage. Intermediate-level waste cannot be safely disposed of near the surface. Deep geologic disposal is needed to isolate it from the biosphere for thousands of years.

Definitions

Base Concepts

- Low-level waste: the most common kind of radioactive waste created at nuclear generating stations. It contains radioactive materials that will decay to insignificant quantities within 300 years. Because of its shorter half-life, the accepted standard for disposal of low-level waste is in near-surface facilities, where isolation for several hundred years is feasible.
- Very low-level waste: waste that is not under regulatory control because it meets safety criteria, but that is treated as radioactive because of its connection to nuclear activities. Most very low-level waste is soil and rubble arising from decommissioning activities.

- Radioactivity: the decay of an unstable nucleus which leads to the emission of radiation. It measures the number of radioactive decays from a radioactive material.
- Repository: a permanent place for disposal of radioactive waste.
- Reprocessing: the treatment of spent fuel to separate useful products like uranium and plutonium, resulting in less high-level waste. See nuclear fuel cycle.
- Spent fuel: also referred to as used fuel. Fuel removed from a reactor once it is no longer useful. It is treated as waste.
- Stable: incapable of radioactive decay.
- Storage: retaining radioactive waste with the intention of retrieving it at a later time. It is a temporary measure with planned future action. See disposal.

Definitions

Secondary Concepts

- Actual demand: the real amount of electricity used by consumers in the province. See available capacity.
- Advanced fuel cycle: a fuel cycle with a reprocessing step, where the usable portion of the spent fuel is separated and reused. It makes effective use of the potential energy in the uranium, but from a waste management point of view, the differences are mostly in the distant future. See nuclear fuel cycle.
- Available capacity: the amount of space available in the electricity grid in terms of the point where it cannot handle any further production. See actual demand.
- Baseload supply: includes nuclear and hydro - low-cost, reliable and supply electricity. See peaking and intermittent supply.
- Calandria tubes: in a pressurized heavy water reactor, a calandria vessel contains the heavy water moderator. Within the vessel, there are hundreds of calandria tubes which house the fuel and coolant.
- Capital: assets that are worth money and are owned by an organization or person.
- Criticality: describes when a reactor is in normal operating condition and nuclear fuel sustains a chain reaction. A reactor achieves criticality when fission releases a sufficient number of neutrons to sustain ongoing reactions. See critical.
- Deterministic effects: caused by ionizing radiation, it refers to quick physical damage that affects biological function. There is a radiation dose minimum, below which it cannot happen. Radiation sickness is one example of a deterministic effect. See stochastic effects.
- Disposal capacity: a deep geologic repository's useful life (in terms of the amount of waste stored).

Definitions

Secondary Concepts

- Immobilization materials: management of radioactive waste often includes processing to stable forms and immobilizing liquid waste as much as possible for storage, transport and disposal. The materials used include cement, bitumen and glass.
- Intermittent supply: includes wind and solar - provides electricity when the source is active. See peaking and baseload supply.
- Large release frequency: represents the probability that a failure in the vacuum building would result in a large release of radioactive materials into the environment. See severe core damage frequency.
- Milling: the process of extracting minerals from ore to produce a concentrate (for example, yellowcake).
- Mill tailings: the radioactive waste that is created in the processing of uranium ore. Uranium tailings usually contain heavy metals such as arsenic, cobalt, copper, nickel, and lead. They also contain radionuclides like thorium-230, radium-226, lead-210 and polonium-210. The volume of these tailings is much larger than the volume of uranium gathered. They are stored in above-ground buildings, submerged in water and contained by large earthen dams.
- National Research Experimental: a large nuclear reactor started in Chalk River in 1947. At the time, it was the world's most powerful research reactor. It stayed in operation until 1993 as a research facility.
- Natural uranium: contains 99.3% uranium-238, 0.7% uranium-235 and trace amounts of uranium-234. It can be used as fuel in heavy water-moderated reactors like CANDU.
- Nuclear Power Demonstration: the first power reactor in Canada. It started operations in 1962, producing 20 MW of electricity. It operated until 1987 mostly as a training facility.

Definitions

Secondary Concepts

- Once-through fuel cycle: a fuel cycle with no reprocessing step. The reasons for choosing this instead of an advanced fuel cycle are primarily economic rather than environmental. See nuclear fuel cycle.
- Overpack: after high force compaction of solid waste, the waste package is put into another container - the overpack - and stored or disposed of. They are normally cylindrical drums.
- Peaking supply: includes natural gas and peaking hydro - flexible but costly, so only used when demand is high. See intermittent and baseload supply.
- Probabilistic risk analysis: detailed examinations of a nuclear generating station's design, back-up systems, anticipated system failure rates, and the likelihood of a radioactive release into the environment.
    - Level 1 – determines the core damage frequency. Core damage is necessary for a significant release of radioactive materials from the reactor.
    - Level 2 – analyzes the amount, composition (radionuclide mix), and timing of potential releases. If the core melts, then the radioactive fuel is more likely to be released. The vacuum building has to also fail for a release into the environment, but, in this scenario, the primary barriers for the radioactive materials have been compromised.
    - Level 3 – determines the offsite consequences of an accident, including the impact on public health, agriculture and the economy. This step examines how the radiation would disperse into the environment.
- Radioactive atom: an atom that has extra energy and is therefore unstable. It releases this excess energy in the form of particles to reach a more stable state.

Definitions

Secondary Concepts

- Refurbishment: the act of renovating and updating a nuclear reactor. To be refurbished, the reactor fuel is removed, it is drained of coolant and inaccessible systems are opened so they can be inspected and replaced.
- Retubing: describes when all pressure and calandria tubes within a reactor are replaced.
- Restart: refurbishment of a nuclear plant without retubing.
- Severe core damage frequency: represents the likelihood that loss of coolant would lead to a meltdown. It does not necessarily represent a large release into the environment – just that the radioactivity is available. Usually, this means the extremely radioactive materials are out of the fuel and in the vacuum building. See large release frequency.
- Steam generator: part of a pressurized water reactor (like CANDU reactors), where hot water under high pressure creates steam to drive a turbine.
- Stochastic effects: refers to the increase in chance of getting cancer at a future date due to contact with radiation. It covers effects of radiation like malignant disease and heritable effects. See deterministic effects.
- Thermal processing: applying heat at temperatures greater than 600° celsius; it is generally used in the radioactive waste processing step prior to disposal. It can be used for solid and liquid radioactive waste. The most commonly used technology is incineration.
- Time-of-use pricing: describes usage over blocks of hours where the price for each period is constant and periods where, on average, usage costs more.

Definitions

Scientific

- Accessible biosphere: the part of the environment that creatures live in. It includes many features - ex. groundwater, surface water and marine resources - that are used by people or accessible to them.
- Actinide: any element with an atomic number of 89 (actinium) to 103. The term is often used for those above uranium (93 to 103). Actinides are radioactive, usually with long half-lives. They are therefore important elements of radioactive waste, especially used fuel. Additionally, they are fissionable in a fast reactor. See transuranic.
- Atom: a piece of matter which cannot be broken by chemicals. Each has a nucleus with positively-charged protons and uncharged neutrons of similar mass. The positive protons are balanced by negatively-charged electrons that are in motion around the nucleus.
- Bitumen: a natural material that is made mostly of hydrocarbons, ex. asphalt.
- Deuterium: a stable isotope that has one proton and one neutron in its nucleus. It occurs in nature as 1 to 6,500 atoms of normal hydrogen, which contain one proton and no neutrons.
- Element: a simple material with atoms that have the same number of protons. They cannot be broken down using chemical reactions, they only change through nuclear reaction.
- Ion: an atom that becomes electrically charged due to gaining or losing electrons.
- Isotope: an atomic element with a specific number of neutrons. Different isotopes of an element have the same number of protons but different numbers of neutrons which means they have different atomic masses (ex. uranium-235, uranium-238). Some isotopes are unstable and decay over time.

Definitions

Scientific

- Mixed oxide fuel: nuclear reactor fuel that consists of uranium and plutonium oxides. It is usually around 5% plutonium, which is the main fissile component.
- Neutron: an uncharged particle found in the nucleus of all atoms except hydrogen. Fast neutrons are created in the process of fission. Slow neutrons can cause fission in fissile isotopes such as uranium-235, plutonium-239 and uranium-233. Fast neutrons, alternatively, can cause fission in fertile isotopes such as uranium-238.
- Nuclide: elemental matter made of atoms with identical nuclei, therefore with the same atomic number and mass number.
- Plutonium: an activation product formed in a nuclear reactor. It has several isotopes, some of which are fissile. Weapons-grade plutonium is specially produced to have >90% plutonium-239, whereas reactor-grade plutonium contains about 30% non-fissile isotopes. It is the main valuable isotope recovered when used fuel is reprocessed. See nuclear fuel cycle.
- Radioiodine: the iodine isotopes that are radioactive fission products.
- Radionuclide: refers to an isotope of an element that is radioactive. All radioactive material contains one or more radionuclides. More than sixty radionuclides can be found in the environment. They fall into one of three categories:
    - Primordial: formed before Earth;
    - Cosmogenic: formed as a consequence of cosmic ray interactions;
    - Human produced: formed due to human actions. They occur in very small amounts compared to the number of natural radionuclides.

Definitions

Scientific

- Relative biological effectiveness: the ratio for determining biological damage. The RBE for alpha radiation is 20, whereas for beta, gamma and x-ray radiation it is one. This means, for the same dose, alpha radiation causes 20 times more biological damage than beta or gamma radiation.
- Transuranic: an artificial radioactive element with a higher atomic number than uranium (94 and above), for example, neptunium, plutonium and americium. See actinide.
- Uranium: a mildly radioactive element with two fissile isotopes (uranium-235 and uranium-233) and two fertile isotopes (uranium-238 and uranium-234). It is the base fuel use to generate nuclear power.

Units of Measure

- Becquerel: the scientific unit of radioactive decay, equivalent to one radioactive decay per second. When discussing radioactive waste, units greater than a single Becquerel are required since it is a very small unit.
  - Megabecquerel (MBq) = 1 x 106 Bq = 1 million decays per second.
  - Gigabecquerel (GBq) = 1 x 109 Bq = 1 billion decays per second.
  - Terabecquerel (TBq) = 1 x 1012 Bq = 1 trillion decays per second.
  - Pentabecquerel (PBq) = 1 x 1015 Bq = 1 quadrillion decays per second.

One MBq (1 million decays per second) may seem like a lot of radioactivity, but a cubic metre of normal soil contains around 800,000 Bq (0.8 MBq).

Definitions

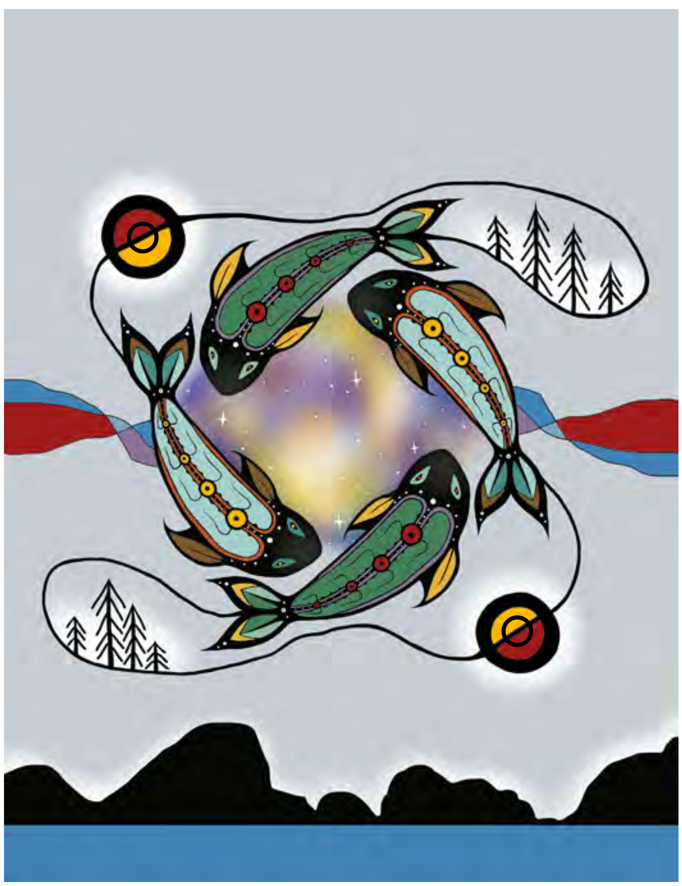
Units of Measure

- Gray: the scientific unit that determines the absorbed dose of radiation. The most common term is a milligray (mGy).
- Sievert: the scientific unit for biological damage from radiation as measured in Gray. A millisievert (mSv) is the most common term used. 1 mSv is the maximum allowable radiation exposure to members of the public in a year from nuclear facilities.

Other

- Boreholes: a drilled hole in the earth, usually for the purpose of extracting a core or releasing oil.
- Brown field: land that can be used as an non-nuclear industrial site after the decommissioning of a nuclear plant.
- Effluents: releases from a nuclear plant's operation (ex. water outlets).
- Green field: land that the owner has released for unrestricted use after the decommissioning of a nuclear plant.
- Yellowcake: also called uranium oxide concentrate. It is a yellow powder at the end of the uranium milling process. It is shipped by truck to refineries in Ontario to be converted for use in reactor fuel. Interestingly, after it has been converted to yellowcake, the uranium may actually be less radioactive than it was originally as it takes thousands of years for the natural radioactive byproducts to build up again. This is the normal form uranium is sold in.

Anishnaabekiing and Our People



Anishnaabekiing and Our People

Anishnaabekiing, Our Home

- We have been here since time immemorial
- As Anishnaabek our identity is founded on our laws, teachings, practices, experiences and relationships
- We have always had a deep and profound connection to our land and water
- They have sustained us through great time and hardships
- We have always been Stewards, caring for our Territory and ensuring that we are not destroying the land and water that support all life

Anishnaabekiing and Our People

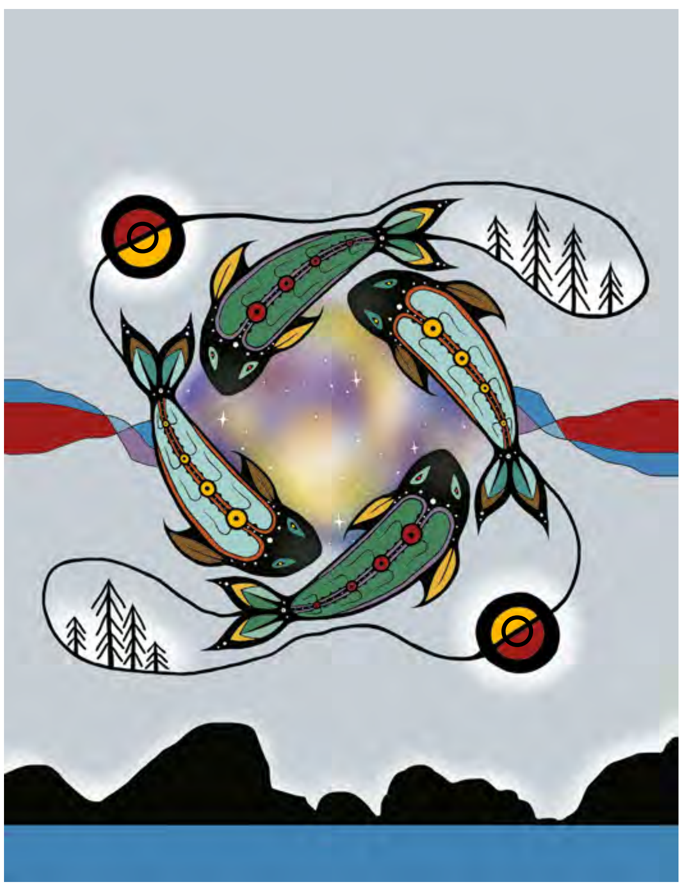
Our Relationship with Anishnaabekiing

- Our Ancestors hunted, fished, harvested and gathered medicines from all over our Territory in order to maintain the health and well-being of our nation
- In all aspects of life, Anishnaabekiing has sustained our nation and we are all responsible to care for it

Our Governance

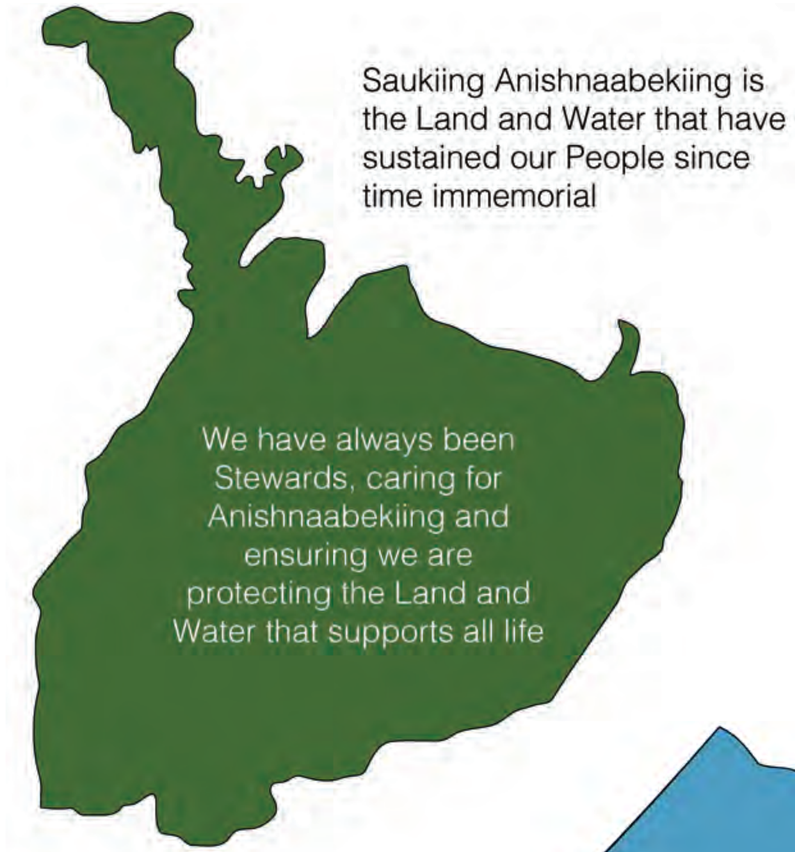
- We have descended from Anishnaabek groups that came together throughout the Great Lakes region and formed the Three Fires Confederacy
- The Confederacy worked in support of mino-bimaadziwin - living in a good way with all creation and among all Anishnaabek
- Our two communities, Neyaashiinigmiing and Saugeen, formed the Saugeen Ojibway Nation (SON) Joint Council to deal with matters that impact or may potentially impact SON rights, interests and jurisdiction

History of the Bruce Site



History of the Bruce Site

The Story of Nuclear in Anishnaabekiing



History of the Bruce Site

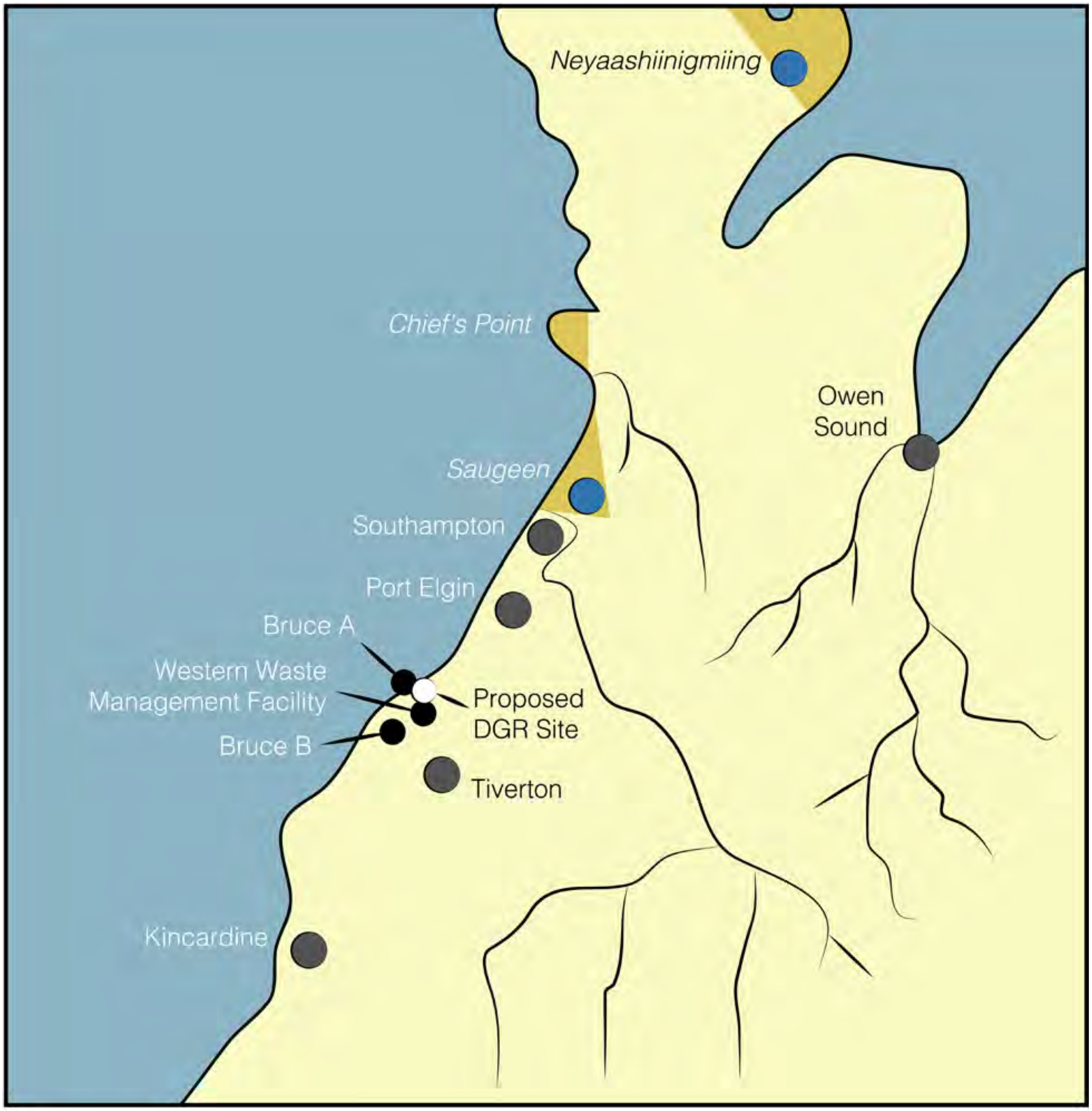
Settlement in Our Territory

- In the mid 1800s, our Ancestors entered into a series of treaties with the intent of sharing some land with the Crown
- We should have a key role in determining how our treaty lands will be used
- We have compelled the settler government to accommodate our continued use and benefit from these lands

In 1960, the government chose to bring the nuclear industry to Anishnaabekiing. We were not part of this decision-making process, nor were we consulted about its far-reaching impacts.

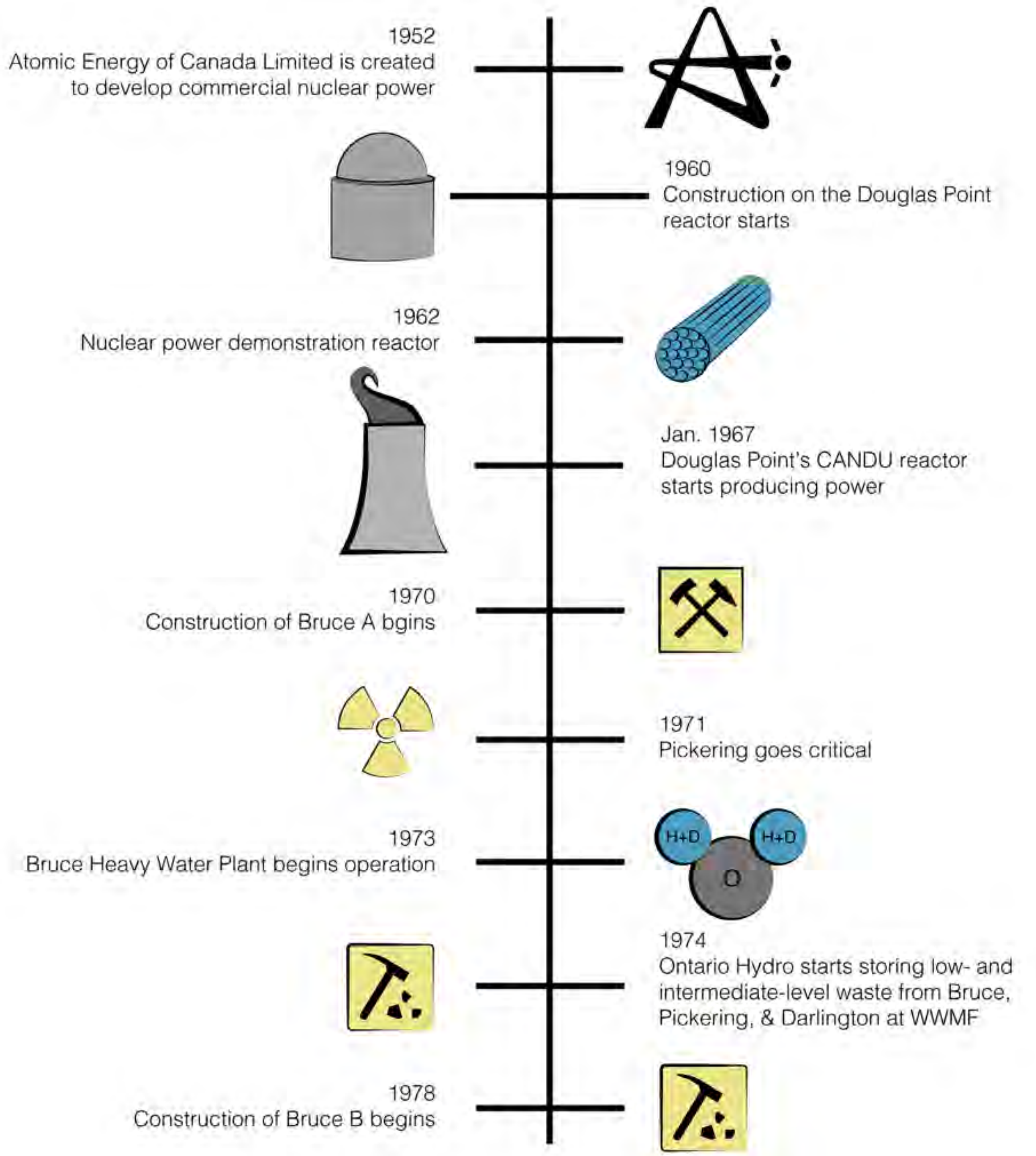
History of the Bruce Site

Settlement in Our Territory



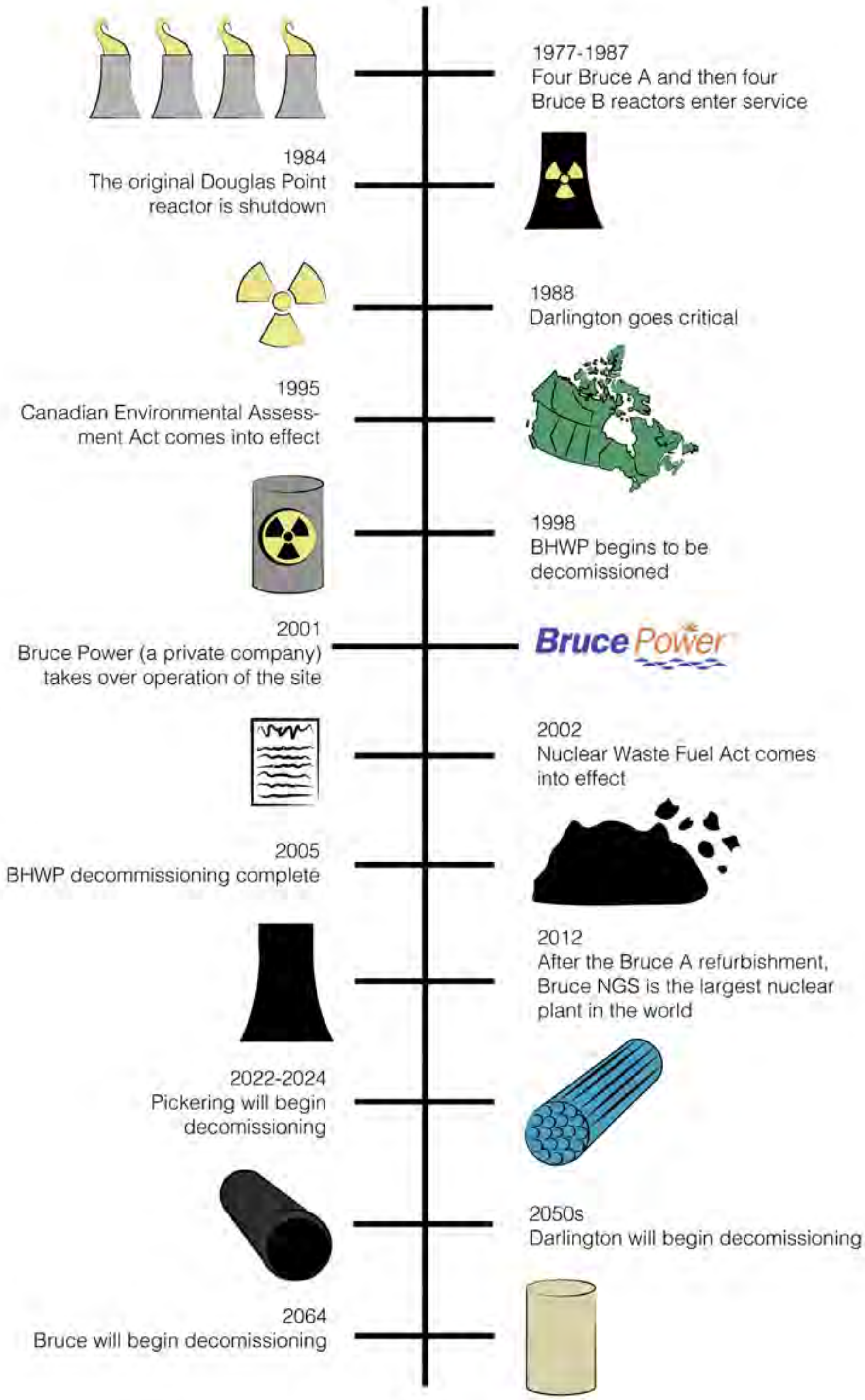
History of the Bruce Site

Timeline of Nuclear Power in Anishnaabekiing



History of the Bruce Site

Timeline of Nuclear Power in Anishnaabekiing



History of the Bruce Site

Douglas Point Nuclear Generating Station

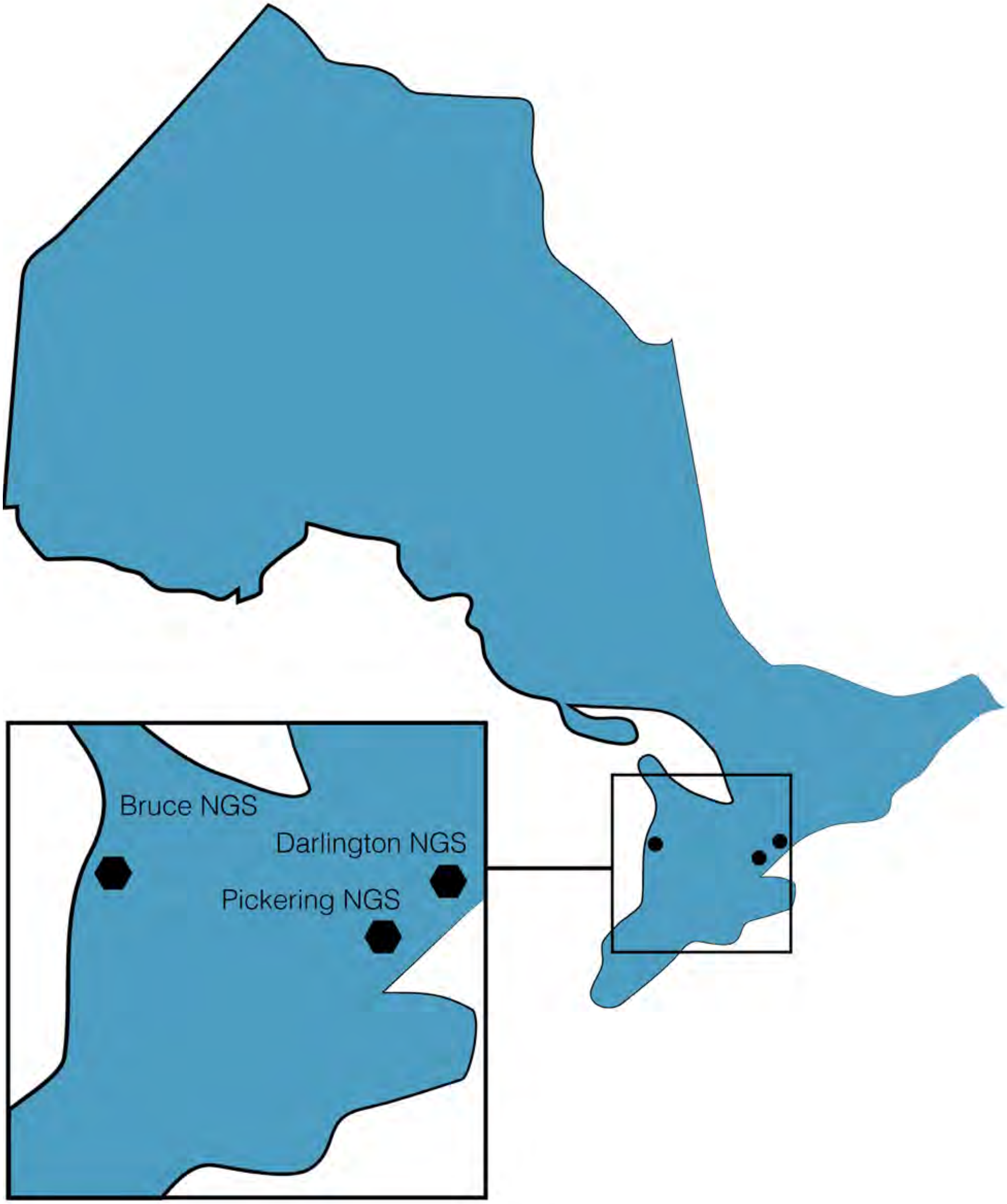
- In 1959, Ontario Hydro picked a 9.31 square km site of mostly undeveloped Crown land at Douglas Point
- Douglas Point reactor went into commercial service in September 1968
- It operated until 1984, when it was shut down and mothballed

Why nuclear? And why our backyard?

- Nuclear energy was expected to be the cheapest, cleanest generation source for electricity
- It is still cheaper than alternatives (except for hydroelectric)
- As with any thermal power plant, only some of the heat created can be converted into electricity; the rest is waste heat
- A source of cooling water is needed to make the process more efficient
- Lake Huron provides the cooling water for the Bruce Nuclear Generating Station
- At the time, Douglas Point was Crown land that had few people living on it, the land was close to a water source, and had the right kind of geology (low seismic activity)

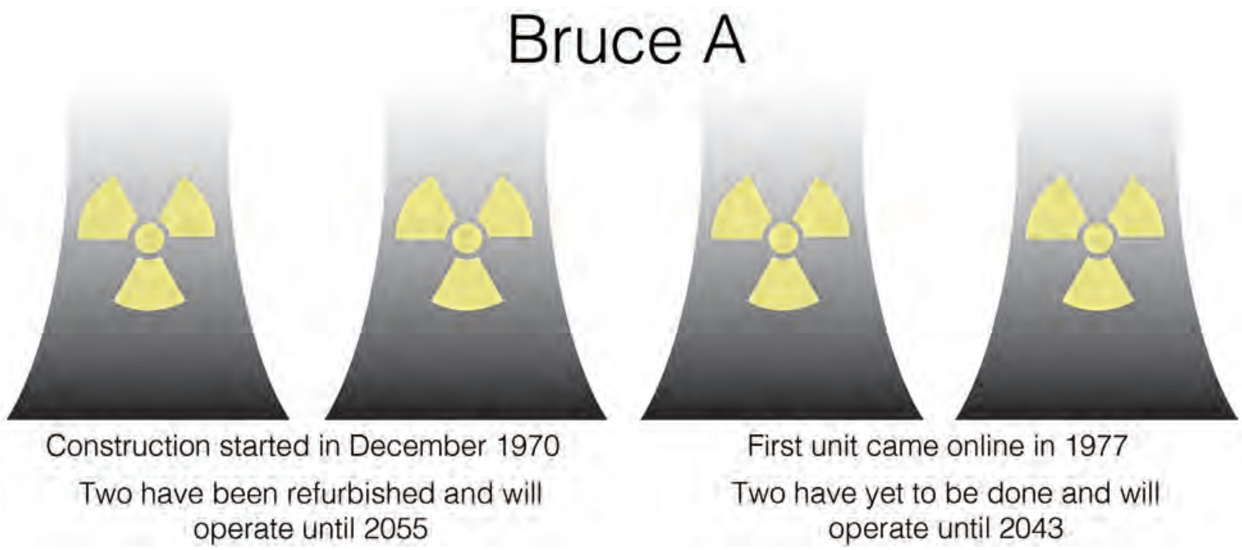
History of the Bruce Site

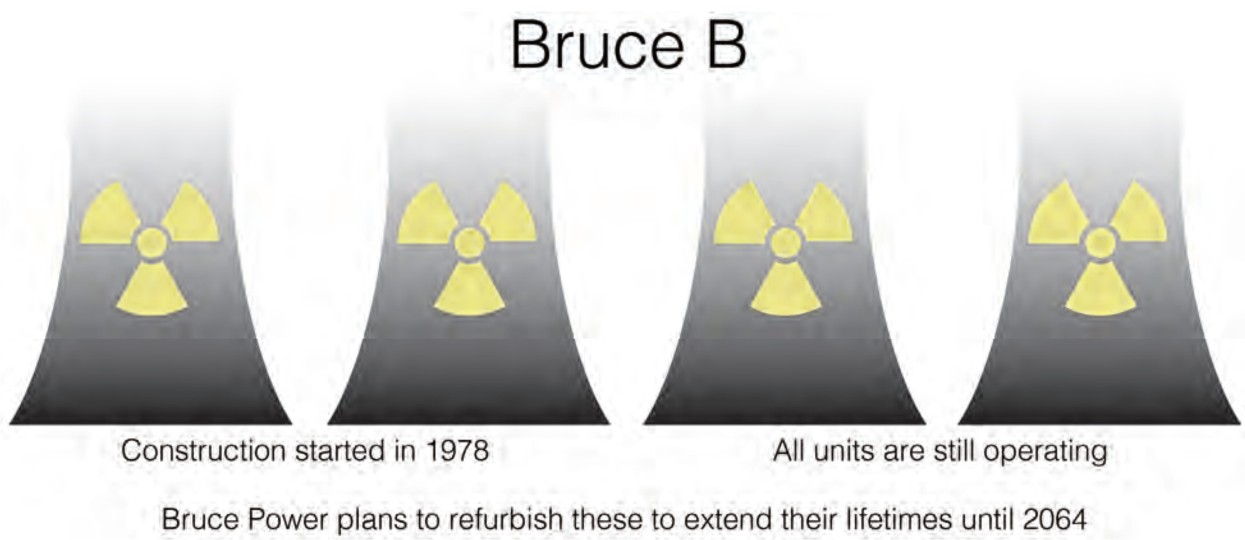
Three Nuclear Generating Stations in Ontario



History of the Bruce Site

CANDU Reactors





History of the Bruce Site

Ontario Power Generation

- Ontario Hydro, the organization that operated Douglas Point, was split up into smaller organizations, one of them being Ontario Power Generation (OPG)
- OPG owns the land that Douglas Point operated on and that the Bruce Nuclear Generating Station currently operates on
- OPG is responsible for the management of radioactive waste and for decommissioning of the Bruce A and Bruce B reactors after they are shut down
- OPG operates the Pickering and Darlington Nuclear Generating Stations

ONTARIO POWER GENERATION

What is Ontario Power Generation?

A crown corporation owned by the Province of Ontario. It owns and operates more than half of Ontario's electricity generators. It is responsible for managing all of Ontario's low- and intermediate-level nuclear waste.

History of the Bruce Site

A New Operator: Bruce Power

- In 2001, OPG handed over the operation of the Bruce reactors to Bruce Power and leased the land to them
- The initial lease period was 18 years with an option to extend for another 25 years
- In 2015, Ontario and Bruce Power announced an amended agreement that considers refurbishing six of the Bruce reactors
- The amended agreement includes an option to extend the lease until 2064

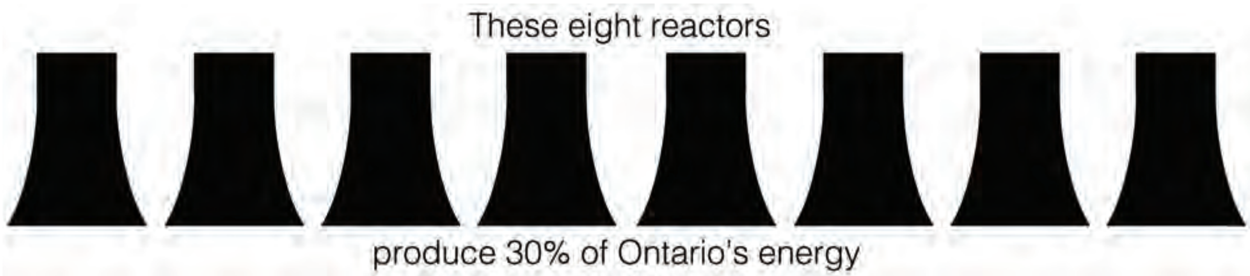
Bruce Power™

What is
Bruce Power?

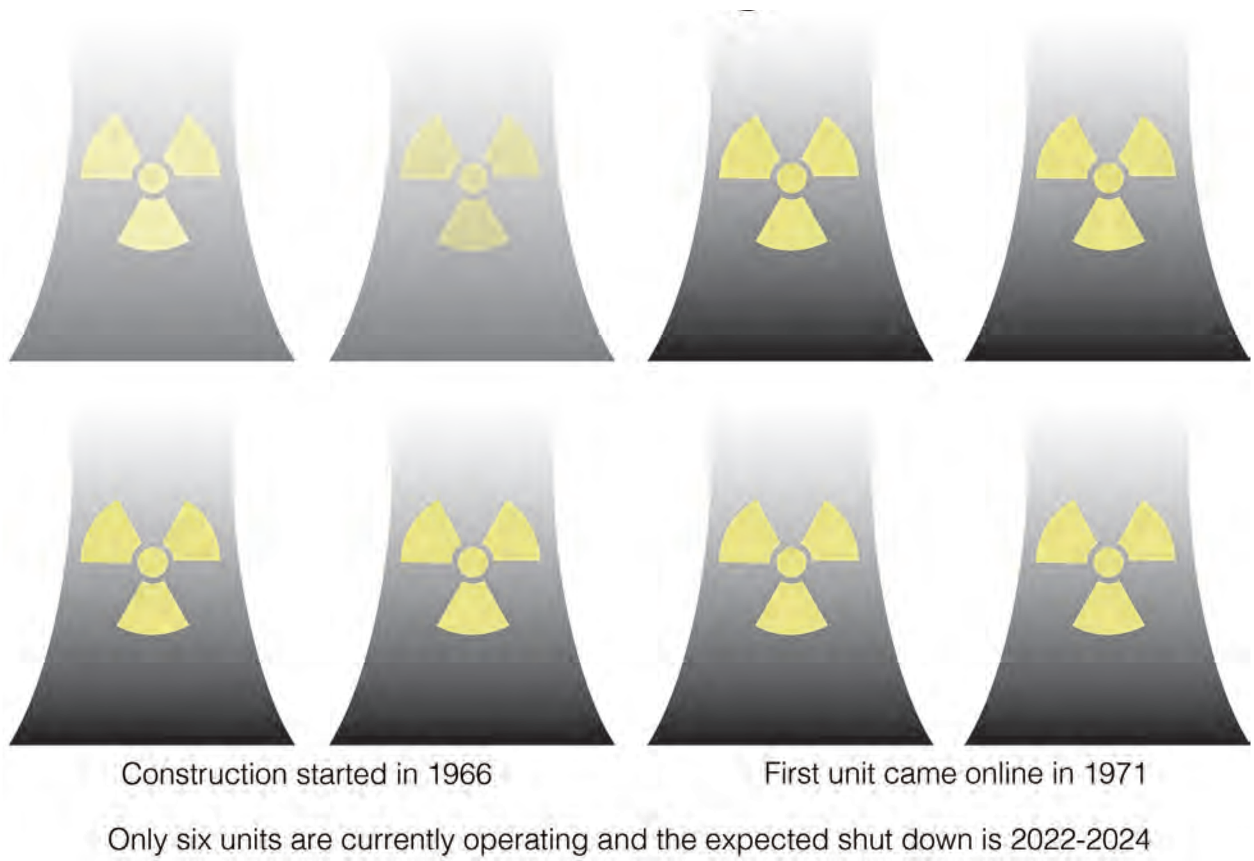
A private corporation that
owns and operates the
Bruce Nuclear Generating
Station.

History of the Bruce Site

Bruce Nuclear Generating Station



Pickering Nuclear Generating Station



History of the Bruce Site

Darlington Nuclear Generating Station

Construction started in 1982

All four units are currently operating and the expected shut down is 2055

Darlington and Pickering

These 10 OPG reactors also produce
about 30% of Ontario's electricity

to a total of 60% nuclear power

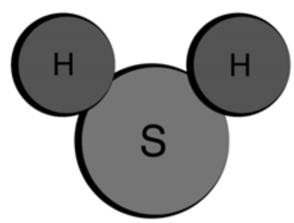
History of the Bruce Site

Bruce Heavy Water Plant

- CANDU reactors need heavy water to function
- Starting in 1969, two heavy water plants were built on the Bruce site
- The heavy water facilities operated between 1973 and 1998
- They were so successful that there is now a surplus of heavy water in Canada
- The plants were decommissioned and demolished between 1998 and 2005

Heavy Water and Hydrogen Sulfide

- The Bruce Heavy Water Plant (BHWP) used large amounts of hydrogen sulphide



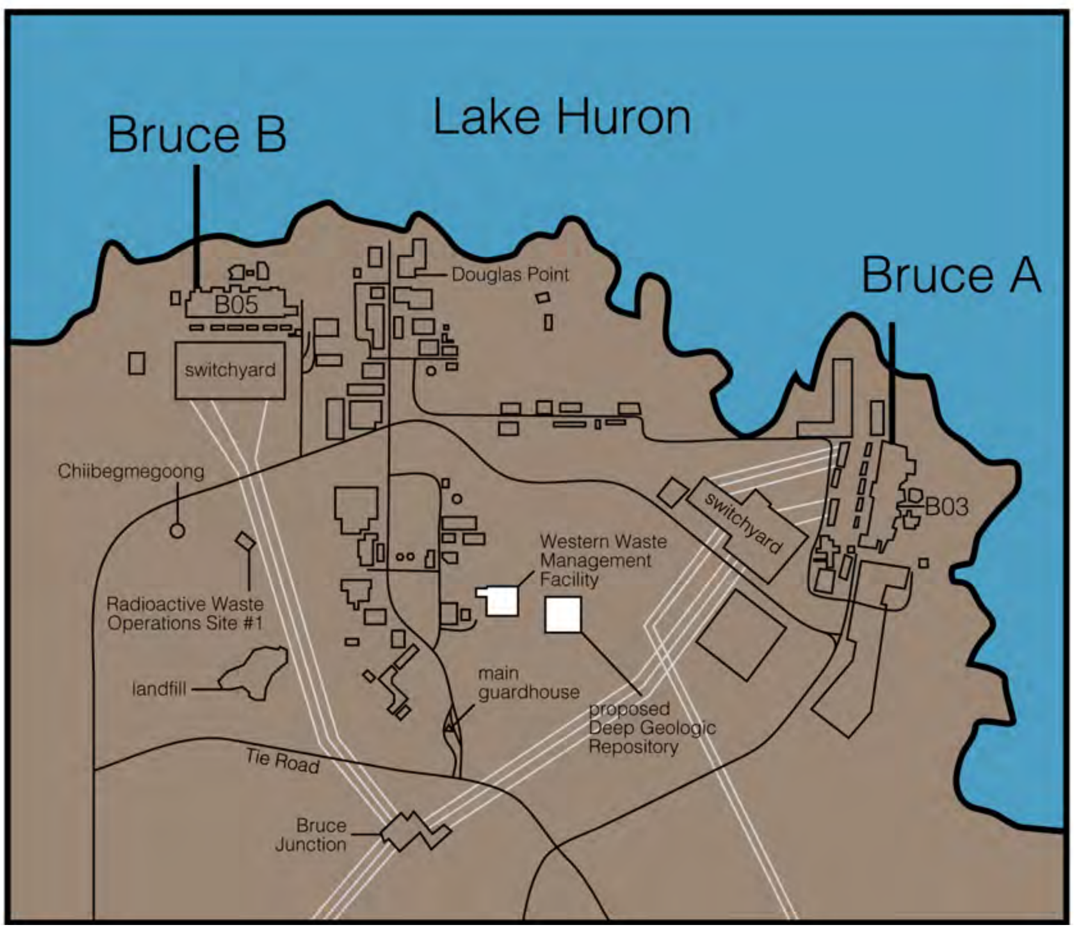
Hydrogen Sulfide

- Because of the risk of toxic gas releases, Ontario Hydro purchased Inverhuron Park for public safety
- It was then leased back to the Ministry of Natural Resources for day use only
- Overnight camping was not allowed until the BHWP was decommissioned in 2005
- There is no longer any heavy water generated at the Bruce site and the hydrogen sulphide has all been destroyed by burning it

History of the Bruce Site

Bruce Site as of 2017

- The site has:
  - One mothballed reactor (Douglas Point)
  - Eight nuclear power reactors (four at Bruce A and four at Bruce B) operated by Bruce Power
  - OPG's Western Waste Management Facility (WWMF) and various auxiliary facilities
  - Former site of the BHWP
  - Site of proposed deep geologic repository (DGR) for disposal of low- and intermediate-level waste



History of the Bruce Site

Bruce Nuclear Operations

- Total capacity of Bruce Nuclear Generating Station is 6368 MW (net)

Bruce Power produces
6,368,000 kWh every hour at
6.6 cents/kWh (wholesale price)
Or **$10 million gross revenue**
every day of operation, over
$3 billion/year.

Bruce Nuclear – International Context

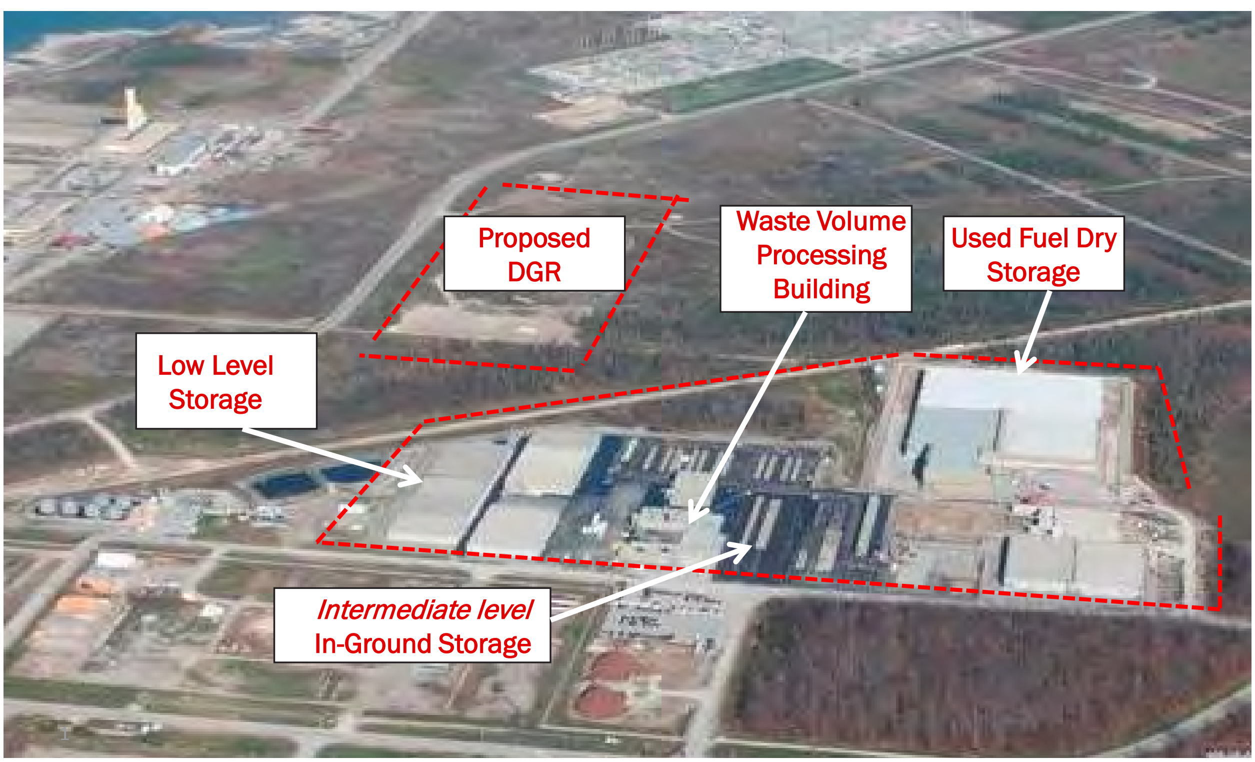
- In the United States, Palo Verde has around two thirds the generating capacity of Bruce Nuclear Generating Station
- Kashiwazaki-Kariwa station in Japan has seven reactors and a higher capacity but was shut down after an earthquake in 2007; four of seven reactors were restarted in 2009, then shut down again after the Fukushima earthquake in 2011; this plant is still shut down and not likely to restart for a considerable time
- There are two nuclear generating stations in Korea, one in the Ukraine and three in France whose generating capacities are similar to Bruce Nuclear Generating Station (above 80% of its capacity)

History of the Bruce Site

Today, the Bruce Nuclear Generating Station is the largest operating nuclear generating station in the world by both number of operating reactors and net capacity.

Western Waste Management Facility

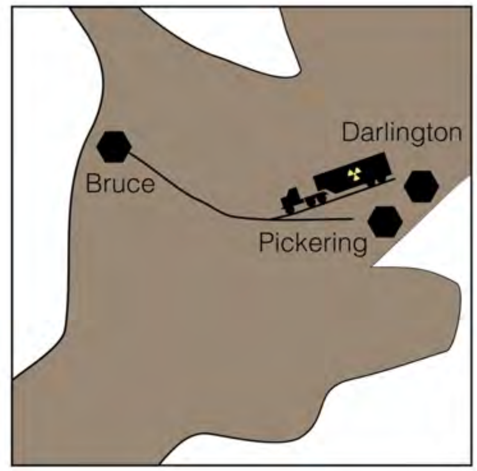
- Western Waste Management Facility (WWMF) is the place where all of the BNGS' low- and intermediate-level waste is stored
- Stores almost all of Darlington and Pickering Nuclear Generating Stations' low- and intermediate-level waste
- Stores all of BNGS' high-level waste that is in dry storage



History of the Bruce Site

Western Waste Management Facility

- In 1974, Ontario Hydro (now OPG) started accepting, processing, and storing low- and intermediate-level nuclear waste from all of Ontario's nuclear generating stations at the Western Waste Management Facility



Why did OPG start transporting waste to WWMF?

- When the first reactor was planned at Douglas Point, a nearby waste storage site was needed as part of the same project
- Environmental assessments and public participation were not part of decision-making until many years later
- Licensing approval of the WWMF only considered regulatory safety limits
- When Pickering went into operation, the waste storage site at Douglas Point was already licensed and operating, so Pickering's waste was shipped there
- We do not know exactly why this decision was made, but it is possible that it was cheaper to transport the waste to Douglas Point than to build a new waste site and infrastructure near Pickering
- Darlington followed the precedent set by Pickering

History of the Bruce Site

WWMF and Transportation

- Roughly 40% of the current waste inventory at the WWMF originates from the Bruce site; 60% is from Darlington and Pickering
- OPG figures on low- and intermediate-level waste volumes shipped, before processing:
    - Darlington: 661 m^3/year
    - Pickering: 1955 m^3/year
- Around 800 shipments of radioactive materials are made per year; a large part of this is shipments to WWMF

History of the Bruce Site

Decommissioning

- At the end of operations, reactors will be shut down, fuel and heavy water removed, and reactor buildings will be mothballed, meaning put into a state of storage with surveillance (as Douglas Point is now)
    - Pickering – 2022 to 2024
    - Darlington – 2050s
    - Bruce – 2064 (with refurbishment)
- After another 20-30 years, actual dismantling and cleanup will be done
- Waste from the decommissioning process will include very low-level waste (ex. slightly contaminated concrete), low-level waste (ex. steam generators) and intermediate-level waste (ex. reactor components such as pressure tubes)

After Decommissioning the Bruce Site

- Many decisions will have to be made about how the Bruce site will be used after decommissioning
- Depending on the use, different levels of clean-up will be required
- For example:
    - Nuclear power – minimal cleanup to allow new nuclear generating stations to replace the old
    - Non-nuclear – radioactivity removed, site prepared as an industrial use brown-field. It is cleaned up but not re-vegetated
    - Other industrial – similar to non-nuclear electricity generation
    - Non-industrial – radioactivity removed, vegetation re-planted (green-field)

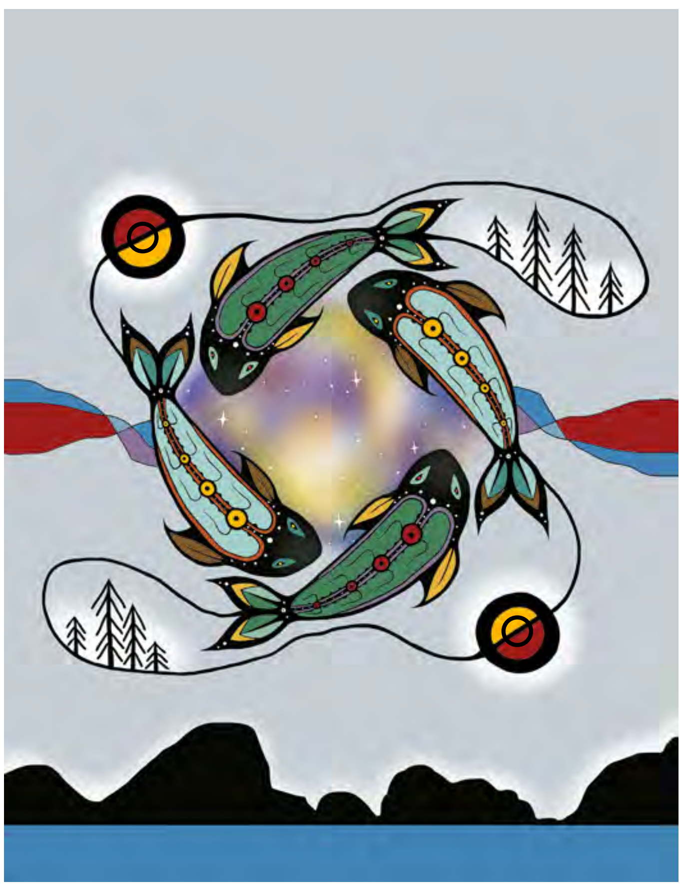
History of the Bruce Site

By the time the Bruce Nuclear Generating Station is dismantled and decomissioned, the nuclear industry will have operated in our Territory for over a century.

Why weren't we consulted?

- Key early decisions around nuclear development in Anishnaabekiing did not include our People
- Over the past two decades, the Saugeen Ojibway Nation has fought to ensure our People play a central role in decisions made in our Territory
- SON Joint Chiefs and Councils have engaged with government, negotiated with proponents, and participated in numerous hearings to make sure our voices are heard

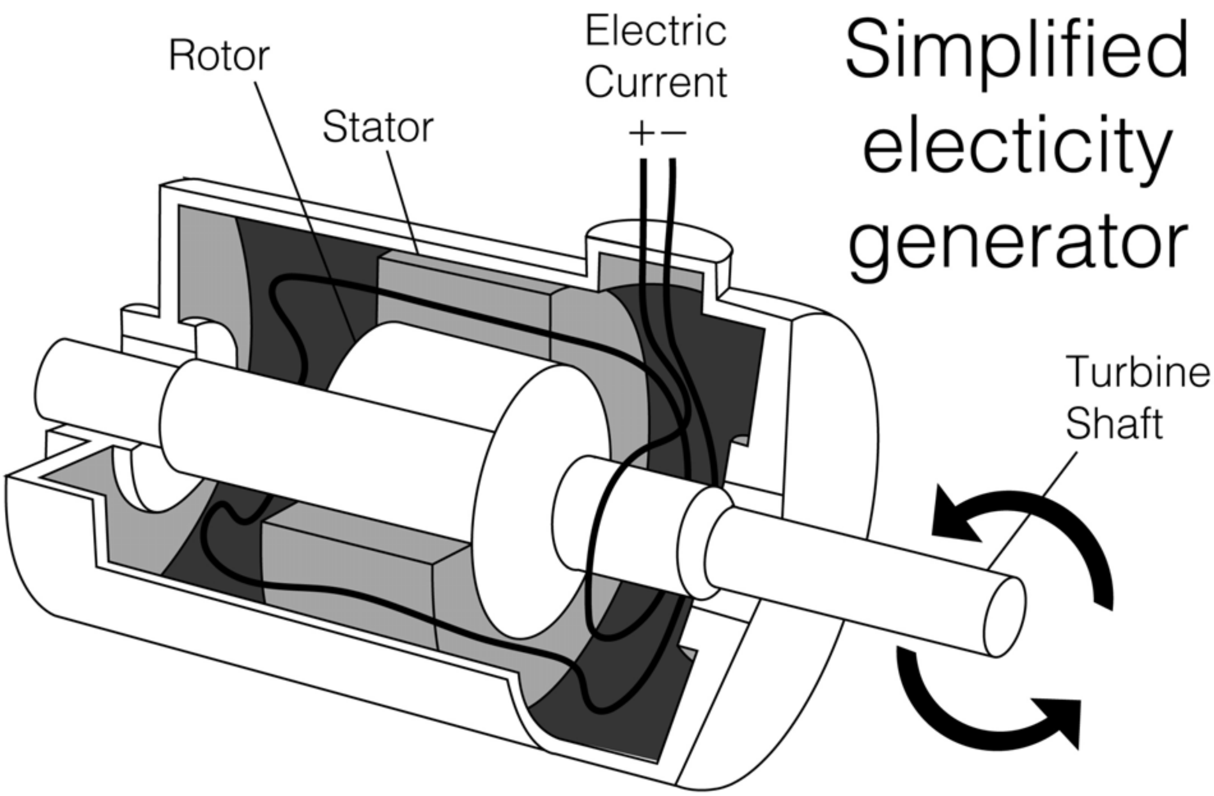
Electricity in Ontario



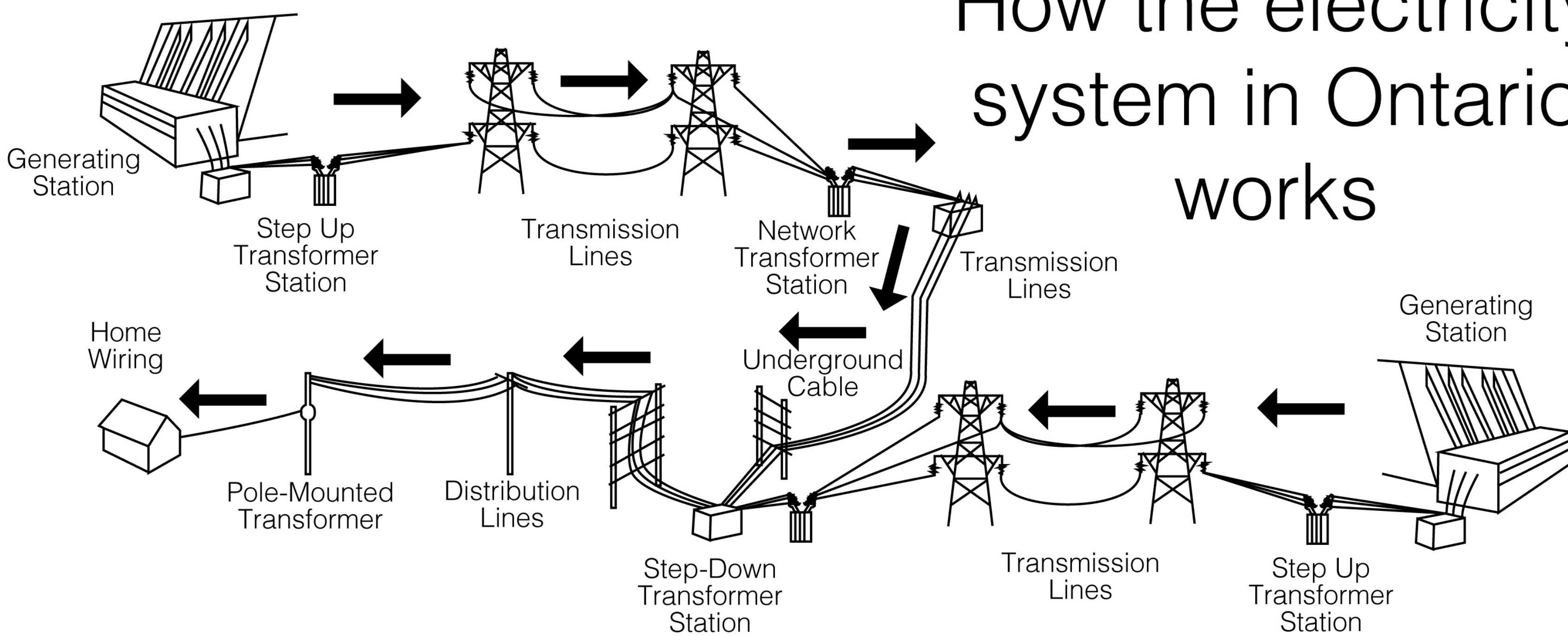
Electricity in Ontario

Generating Power

- Generating stations (nuclear, hydroelectric, fossil-fuel, wind) all do the same job: transform kinetic (moving) energy into a flow of electrons, which is electricity
- At a generating station, a generator is used to make electricity
- Energy is needed to spin a turbine, which creates a flow of electrons
- The only difference between nuclear generating stations and other types of plants is the way the turbine is made to spin. For example:
    - Hydroelectric – uses falling water to spin the turbine
    - Nuclear – uses energy from fission to heat up water and create steam which then spins the turbine

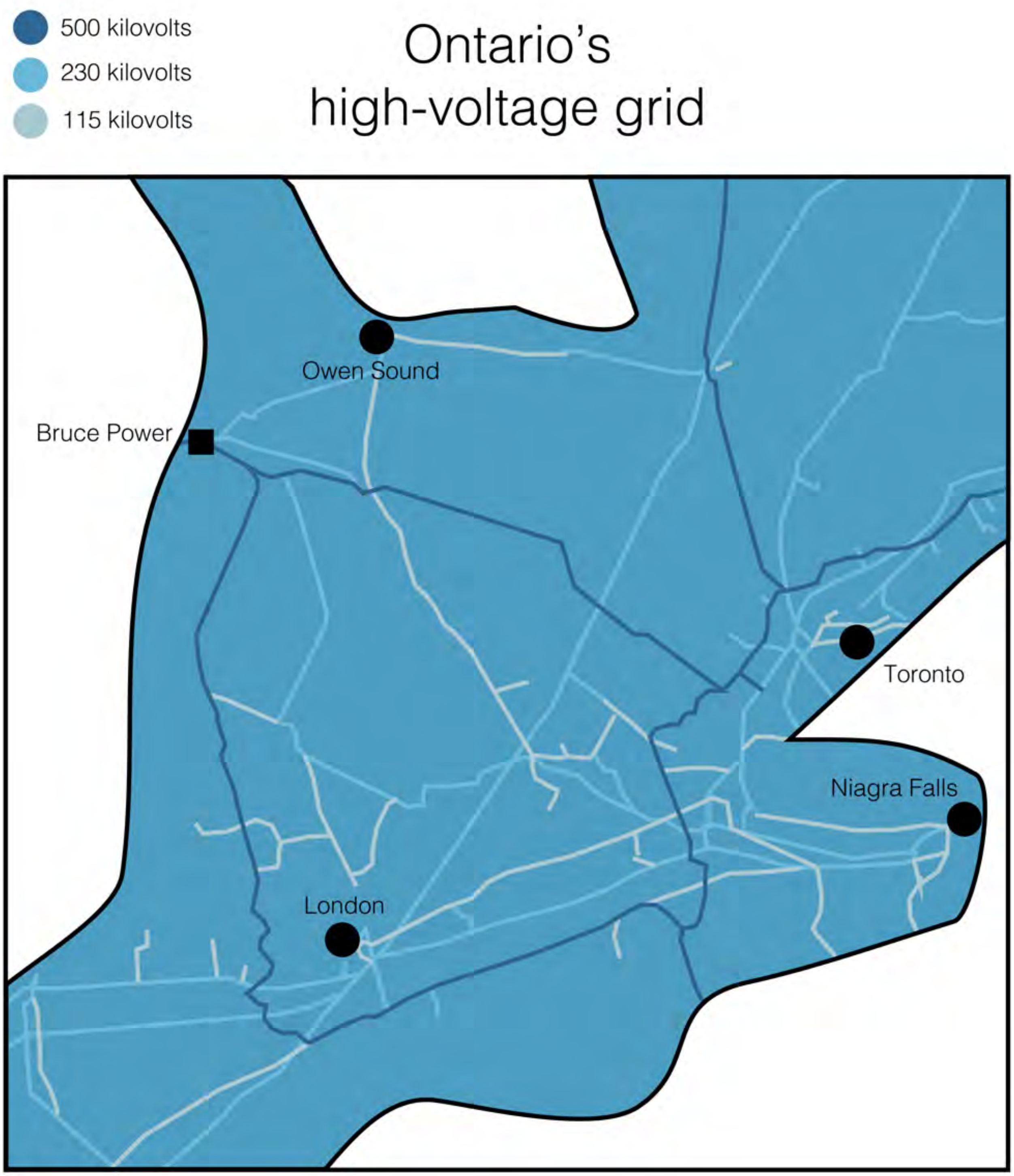


How the electricity system in Ontario works



Electricity in Ontario

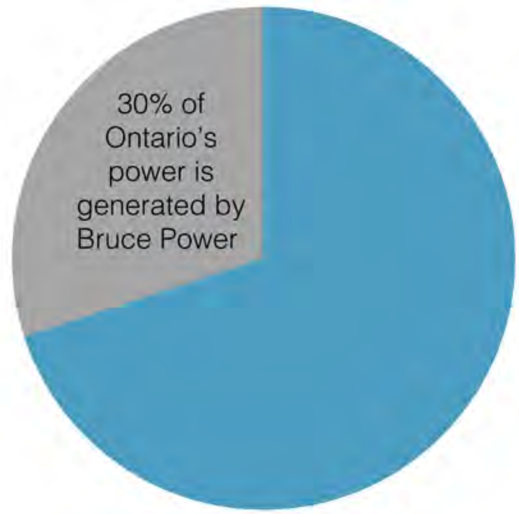
Generating Power

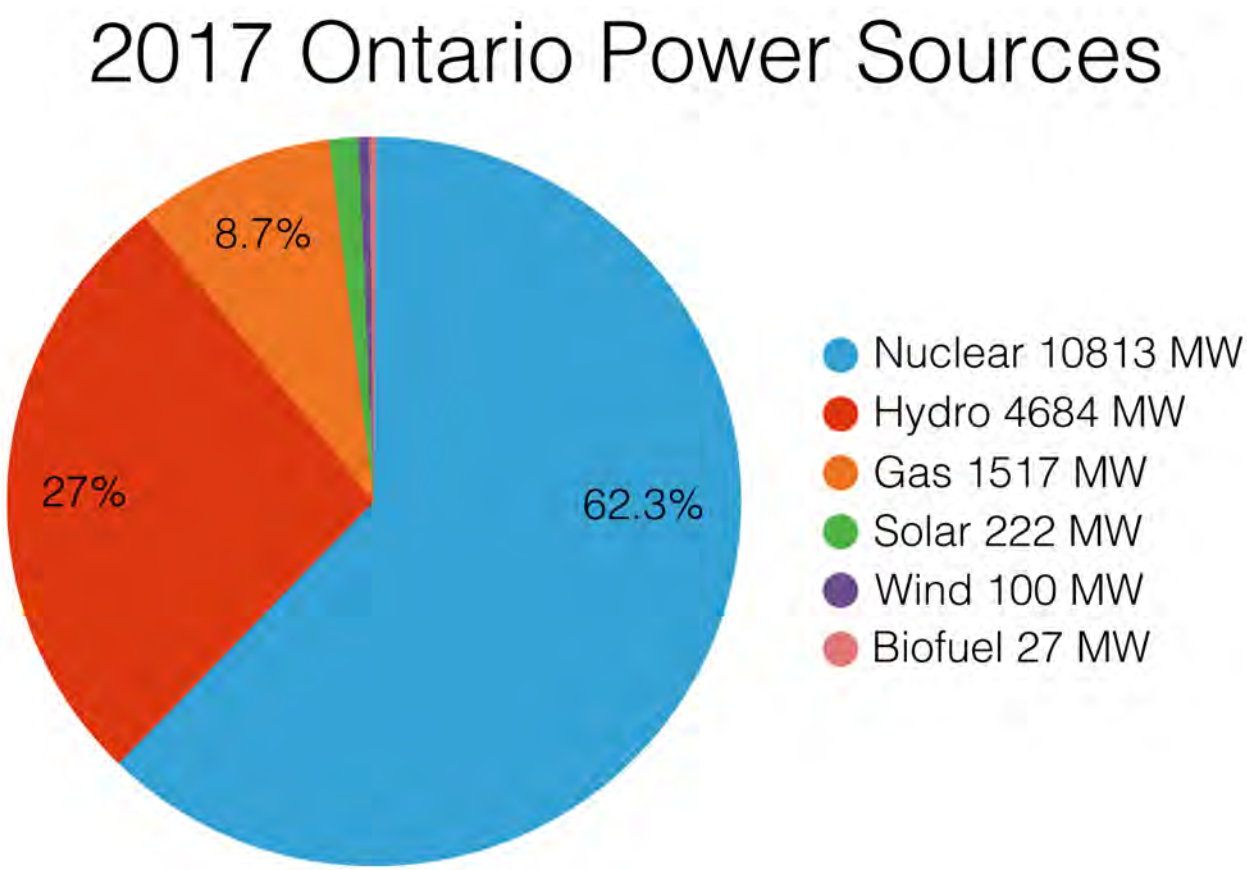


Electricity in Ontario

Generating Power

- Ontario gets its electricity from a mix of energy sources
- About 60% comes from nuclear power
- The remainder comes from a mix of hydroelectric, natural gas, and wind

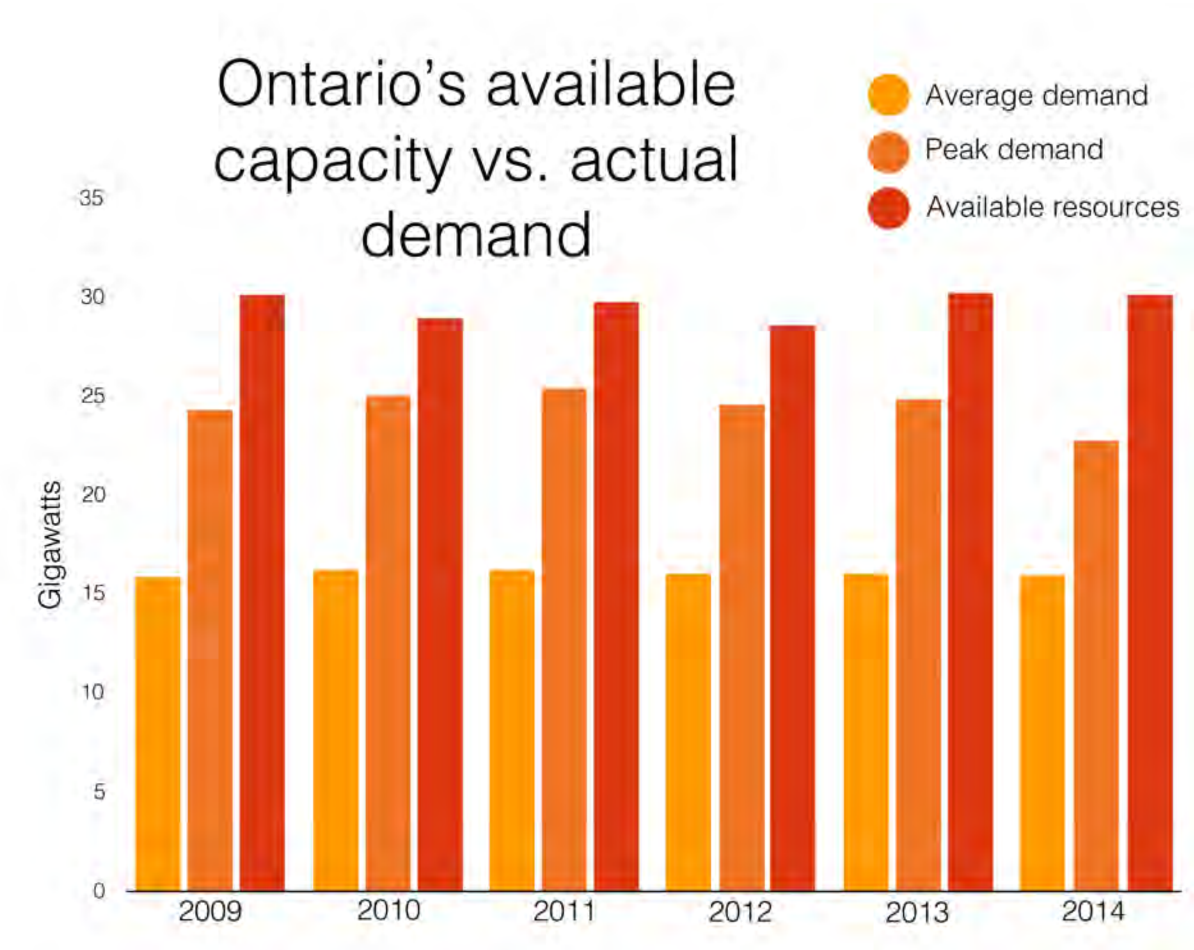




Electricity in Ontario

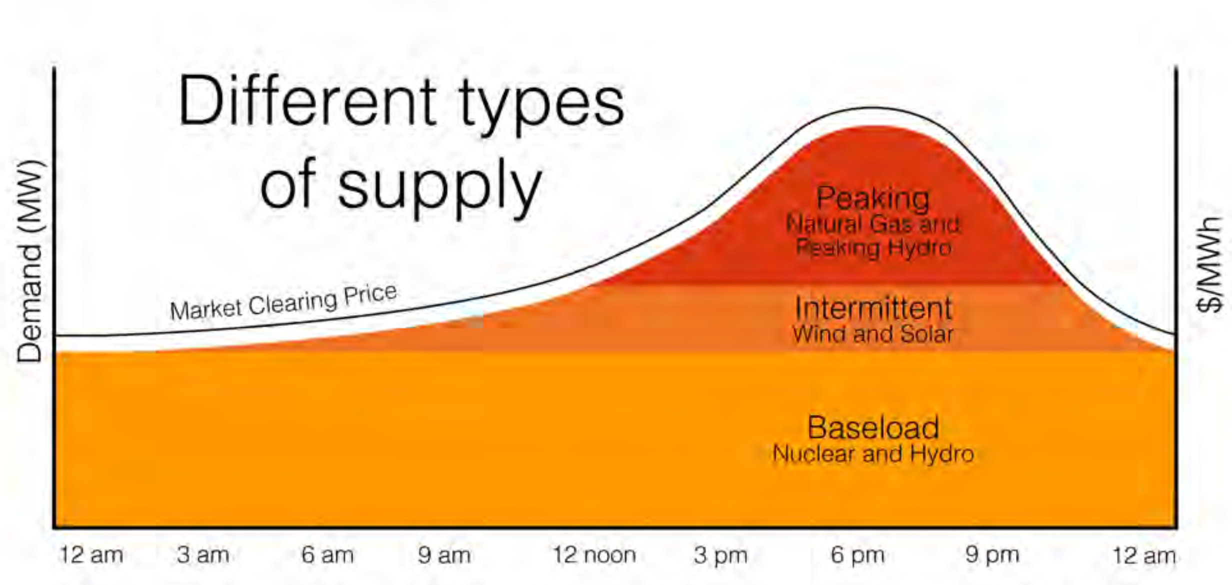
Power Demand

- We use electricity to run our lights, computers, phones, stoves, and fridges
- Electricity needs to be consumed as it is generated
- Currently, there is no economically feasible way to store large quantities of electricity
- Supply and demand for electricity must always be kept in balance
- As demand increases, supply must also increase



Electricity in Ontario

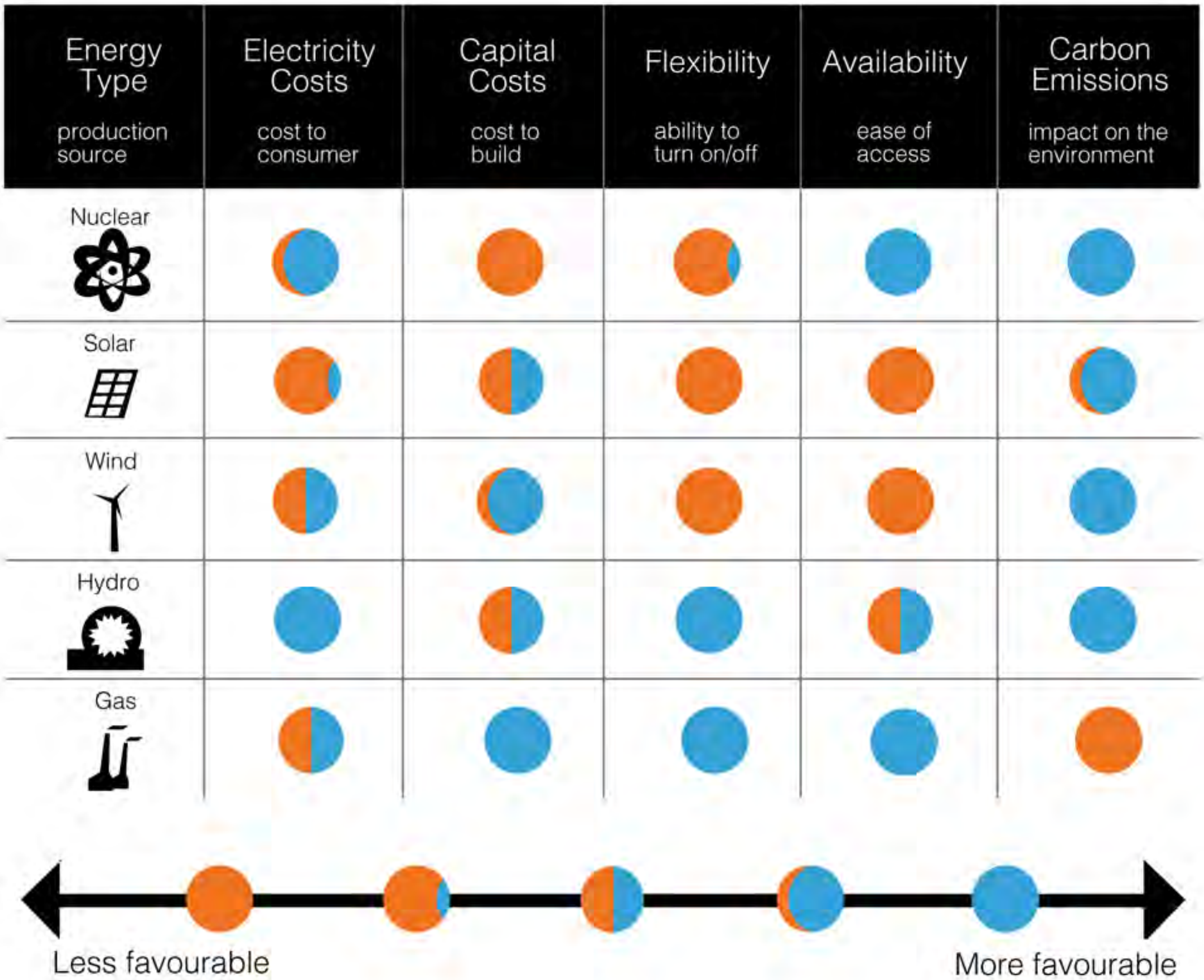
Power Supply

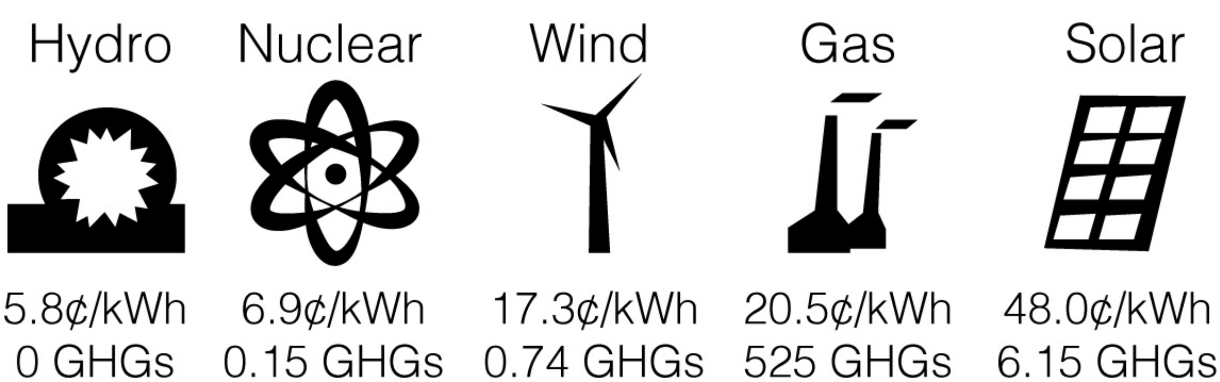


- Peaking supply (includes gas and peaking hydro)
    - Flexible and able to quickly meet demand
    - Costly, so only used when demand is high
- Intermittent supply (includes wind and solar)
    - Provides electricity when the source is active
    - Unreliable
- Baseload supply (includes nuclear and hydro)
    - Low-cost, reliable supply

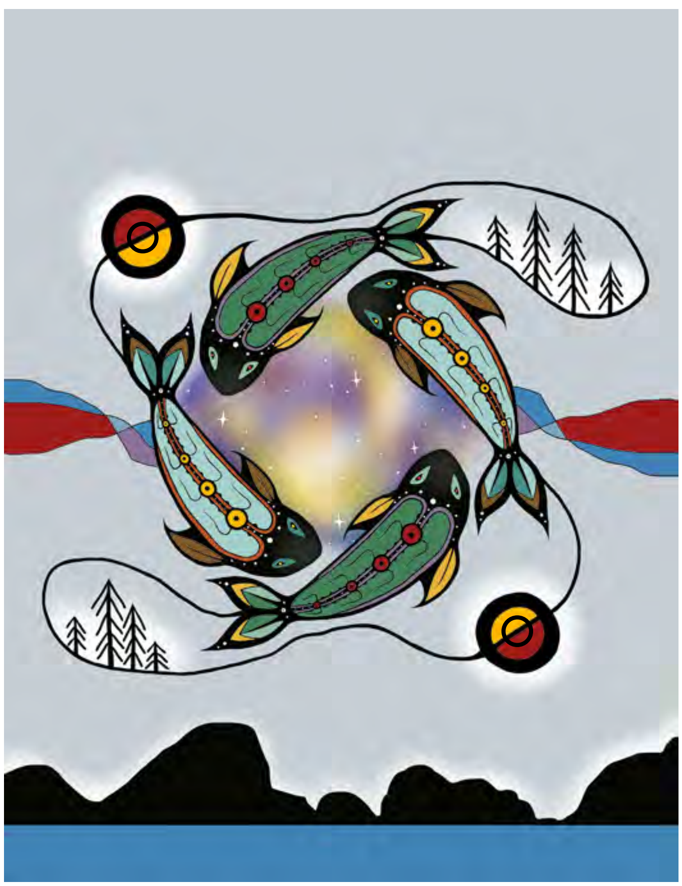
Electricity in Ontario

Power Supply





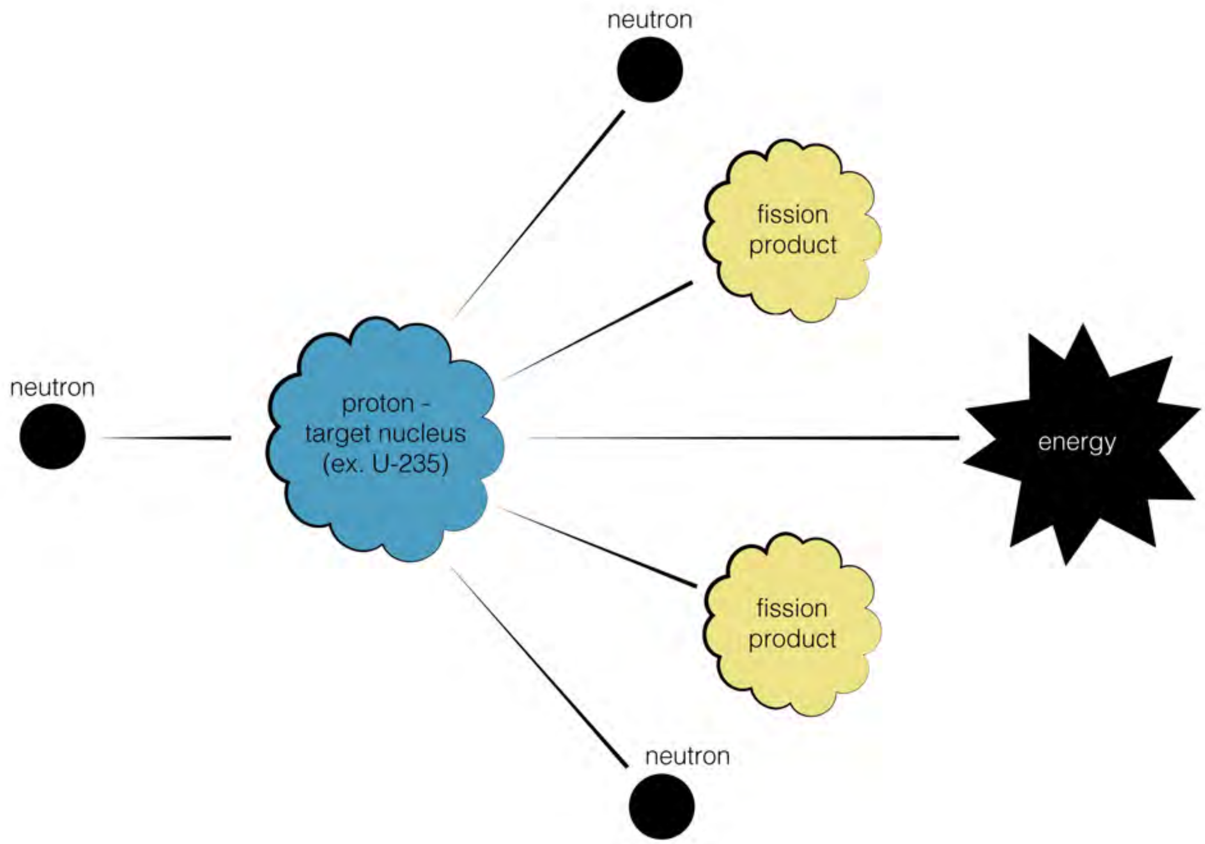
CANDU Fuel Cycle



CANDU Fuel Cycle

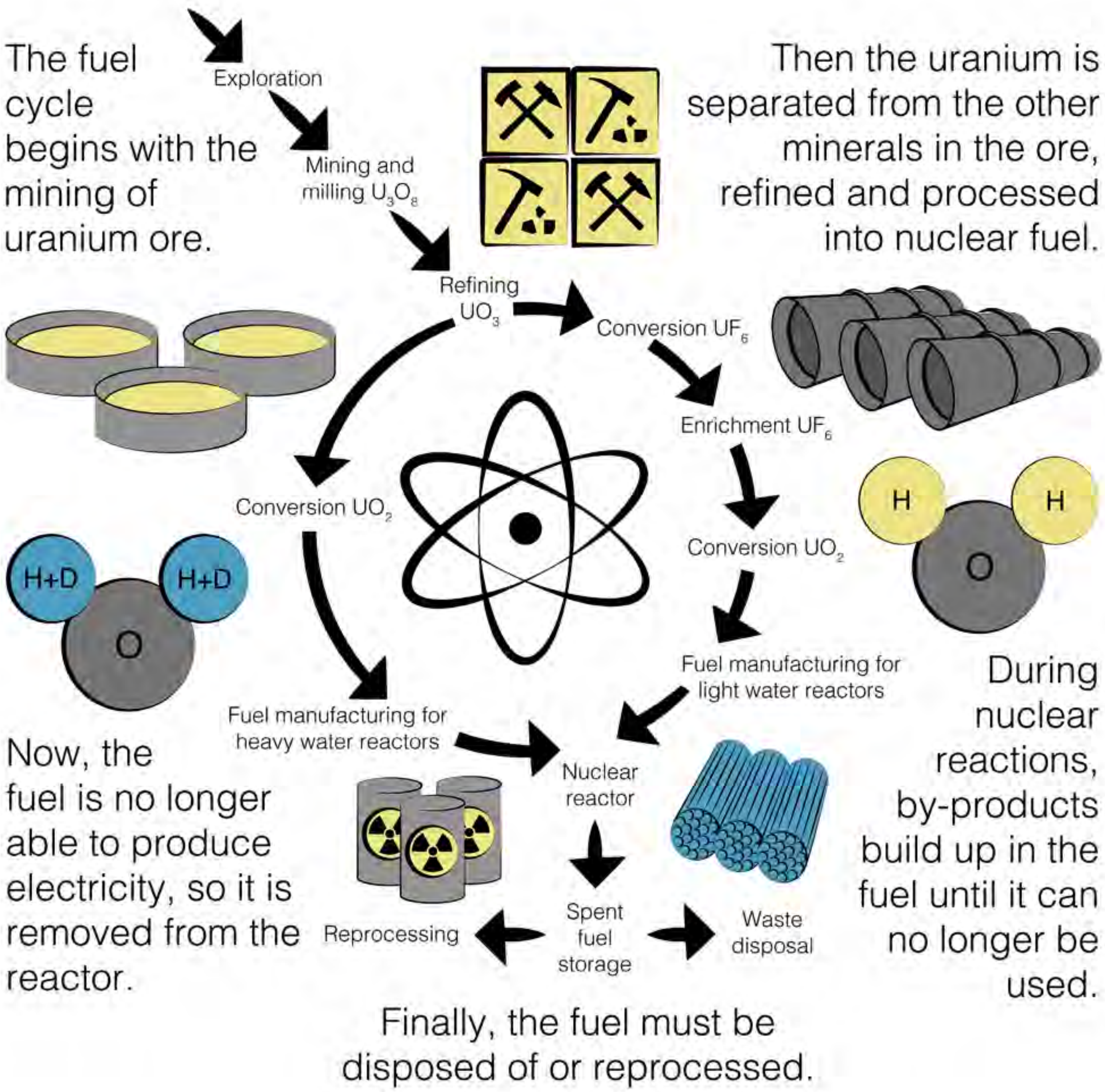
Nuclear Fission: the Source of Nuclear Energy

- When a neutron hits a uranium-235 (U-235) atom, it causes a chain reaction
- The U-235 atom then splits into several components, including two radioactive fission products, several neutrons, and lots of energy!



CANDU Fuel Cycle

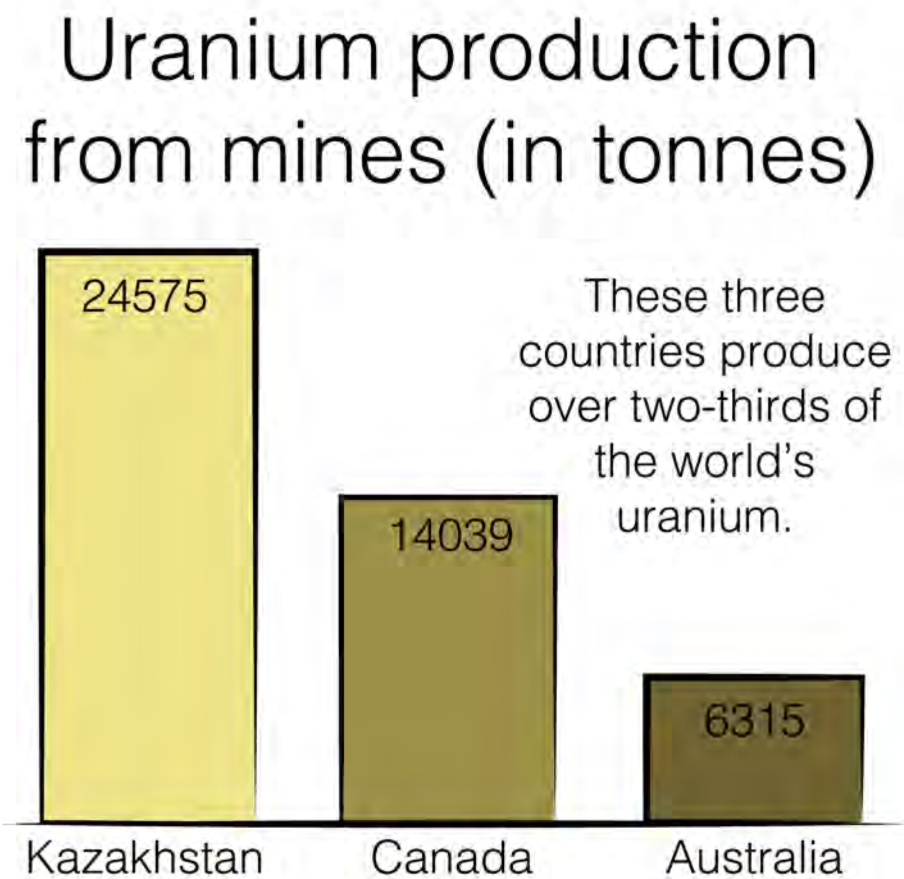
Nuclear Fuel Cycle



CANDU Fuel Cycle

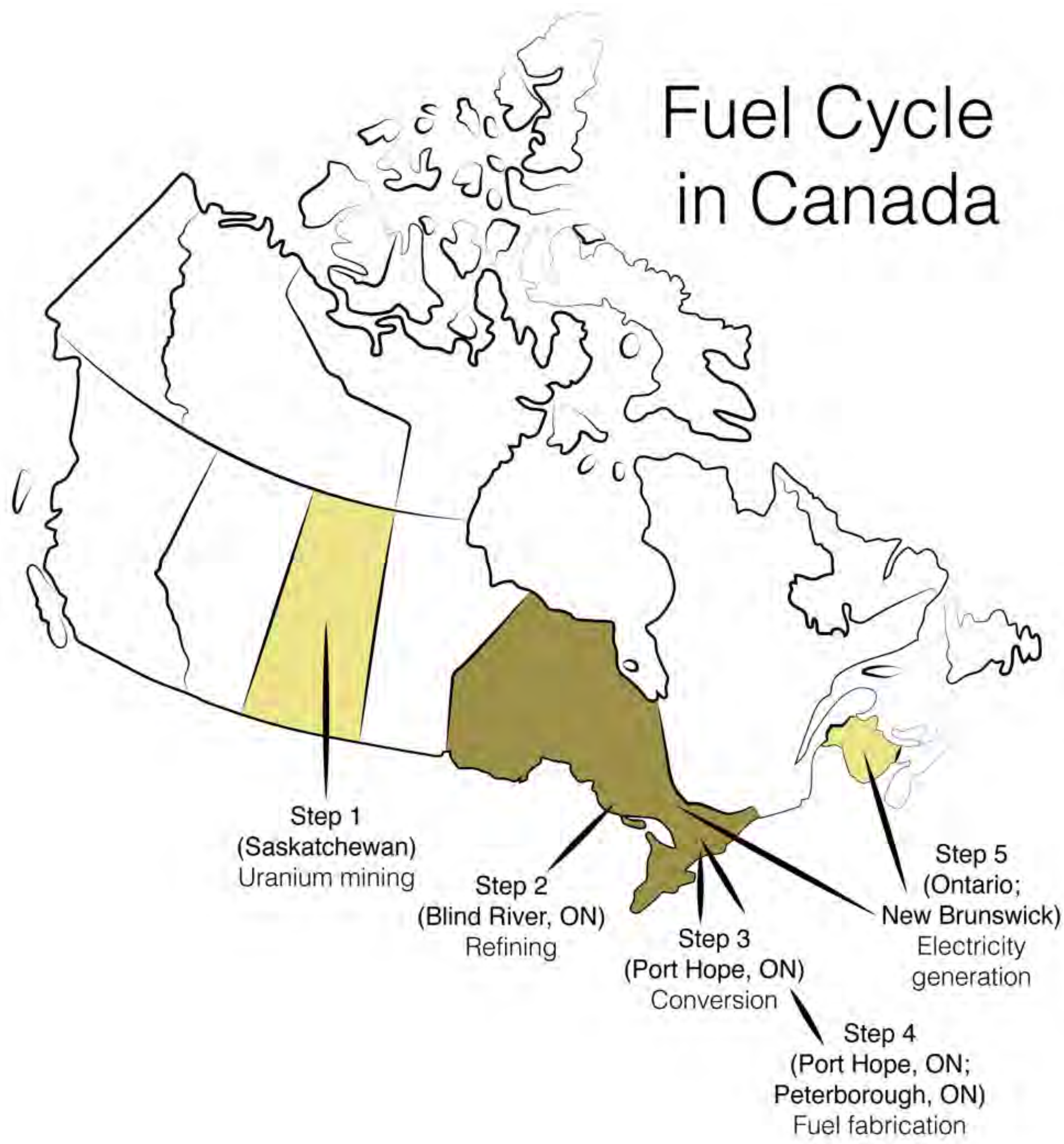
Uranium Mining

- Uranium ore deposits are located in the Earth's crust and can be found in soil, rocks, rivers, and oceans
- There is a large amount of uranium ore in Canada
- U-235 is the isotope required to support nuclear reactor operation



CANDU Fuel Cycle

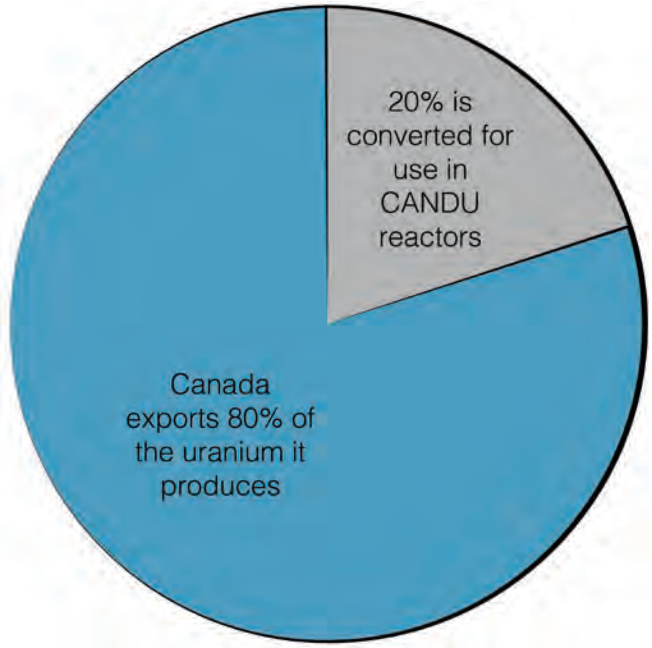
Uranium Mining - Steps

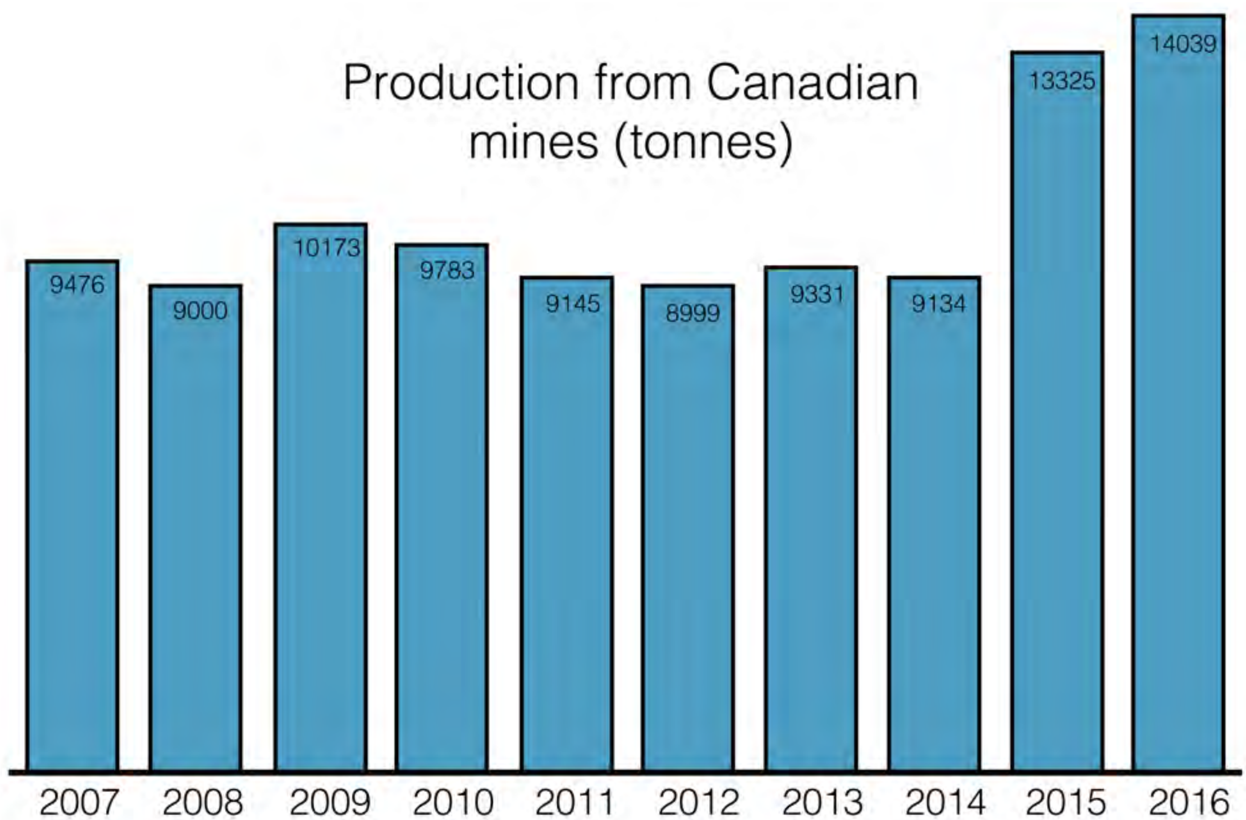


CANDU Fuel Cycle

Uranium Mining - Stats

2 Uranium processing plants in Ontario deal with 1,900 tonnes of uranium per year.





CANDU Fuel Cycle

Uranium Mining - Environmental Impacts

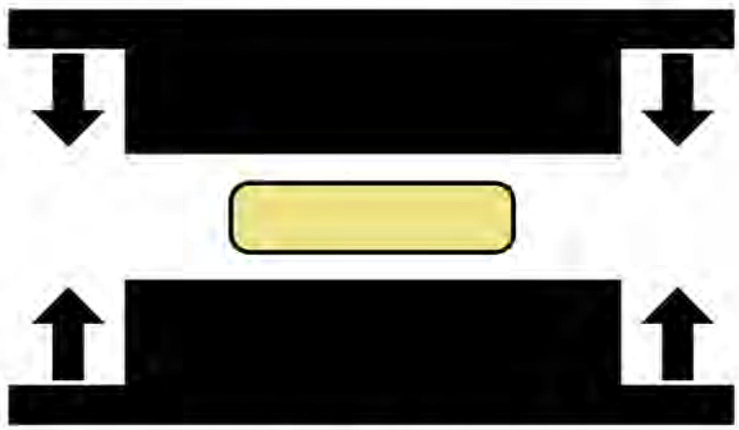
- Disturbes land
    - Open pit mines
    - Waste rock piles on surface
- Changes surface water
- Contaminates groundwater
    - Mining exposes minerals to leaching
    - Groundwater can enter an abandoned mine, therefore Canadian uranium mines are not candidates for a radioactive waste disposal site
- Creates mill tailings
    - Solid waste materials from the processing of uranium ore and chemical residues from water treatment
    - Includes many heavy metals

McClean Lake Open Pit Mine, Saskatchewan

CANDU Fuel Cycle

Fuel Fabrication – Uranium Conversion Process

#1 Uranium dioxide powder is delivered to a fuel fabrication facility. The material is put into processing containers and blended.



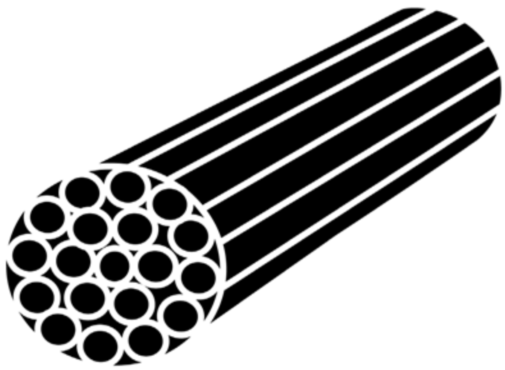
#2 The uranium dioxide powder is compressed to produce pellets.

#3 Pellets pass through a high-temperature furnace with hydrogen to harden them.

CANDU Fuel Cycle

Fuel Fabrication - Uranium Conversion Process

#4 Pellets are loaded into a fuel tube which is sealed by welding the end caps.



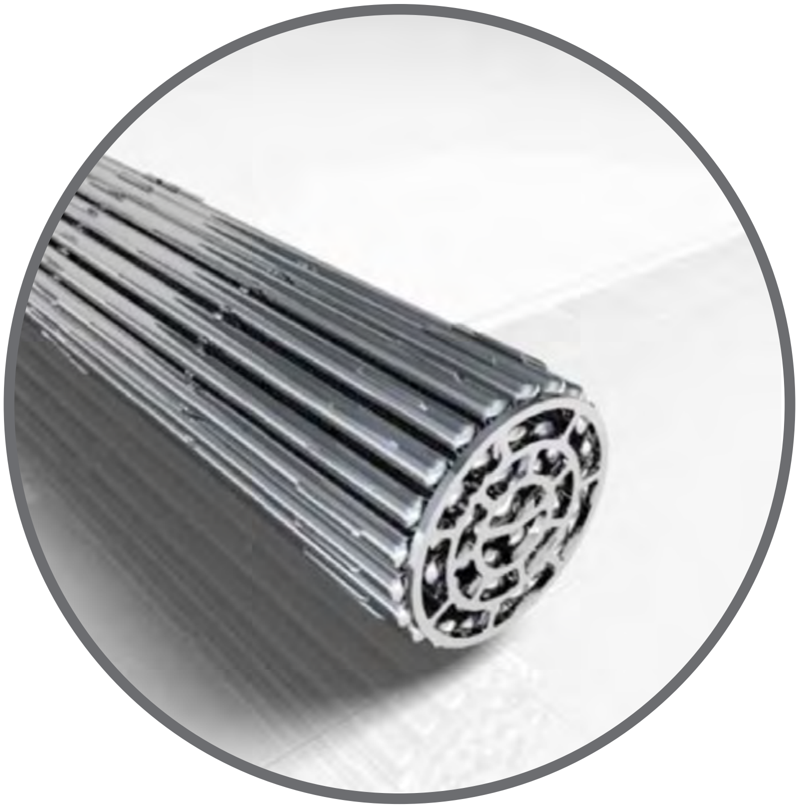
#5 Fuel tubes are assembled into bundles and end plates are welded on.

#6 After inspection and cleaning, fuel bundles are packaged and shipped.

CANDU Fuel Cycle

Fuel Bundles

- There are 6240 fuel bundles in each of the eight Bruce reactors



13 Each fuel channel in Bruce Power reactors contains 13 fuel bundles

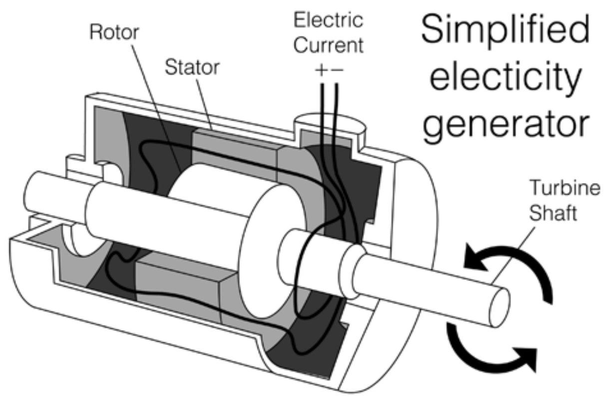
480 There are 480 fuel channels in each reactor

900 Each fuel bundle produces about 900 kWh

CANDU Fuel Cycle

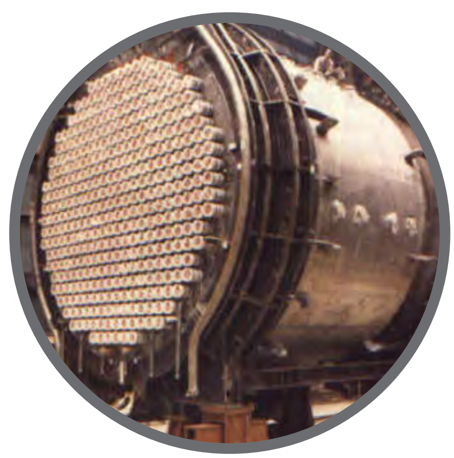
Nuclear Generating Stations

- A nuclear generating station converts:
    - Fission energy into heat
    - Heat into steam
    - Steam into the motion of turning a turbine generator
    - The motion of the turbine generator into electricity
- Again, nuclear generating stations are similar to conventional generating stations – the only difference is the heat source

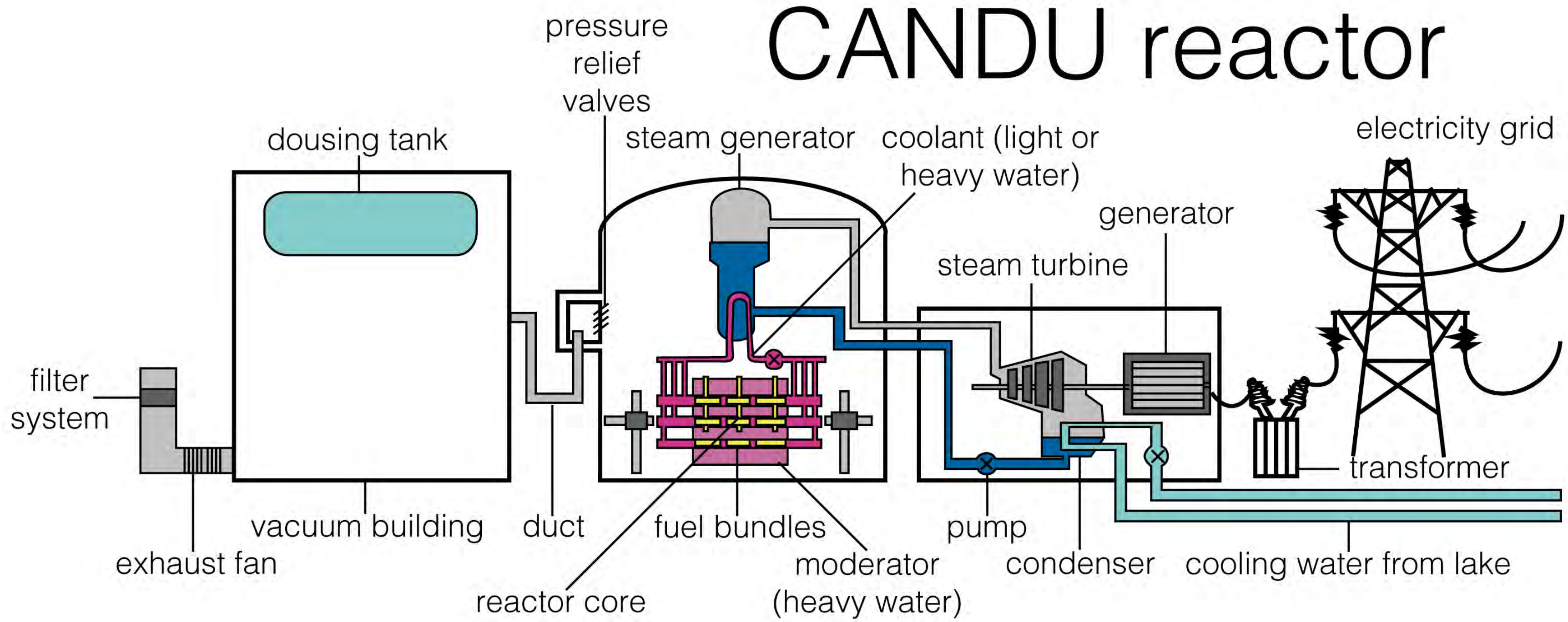


Nuclear Fuel

- CANada Deuterium Uranium
- Each fuel bundle remains in reactor for approximately one year
- During the nuclear reaction processes, fission products build up in the fuel
- Eventually, fuel assemblies are spent and changed out of the reactor
- CANDU reactors are refueled while operating

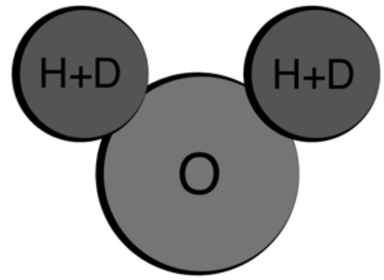


CANDU reactor



CANDU Fuel Cycle

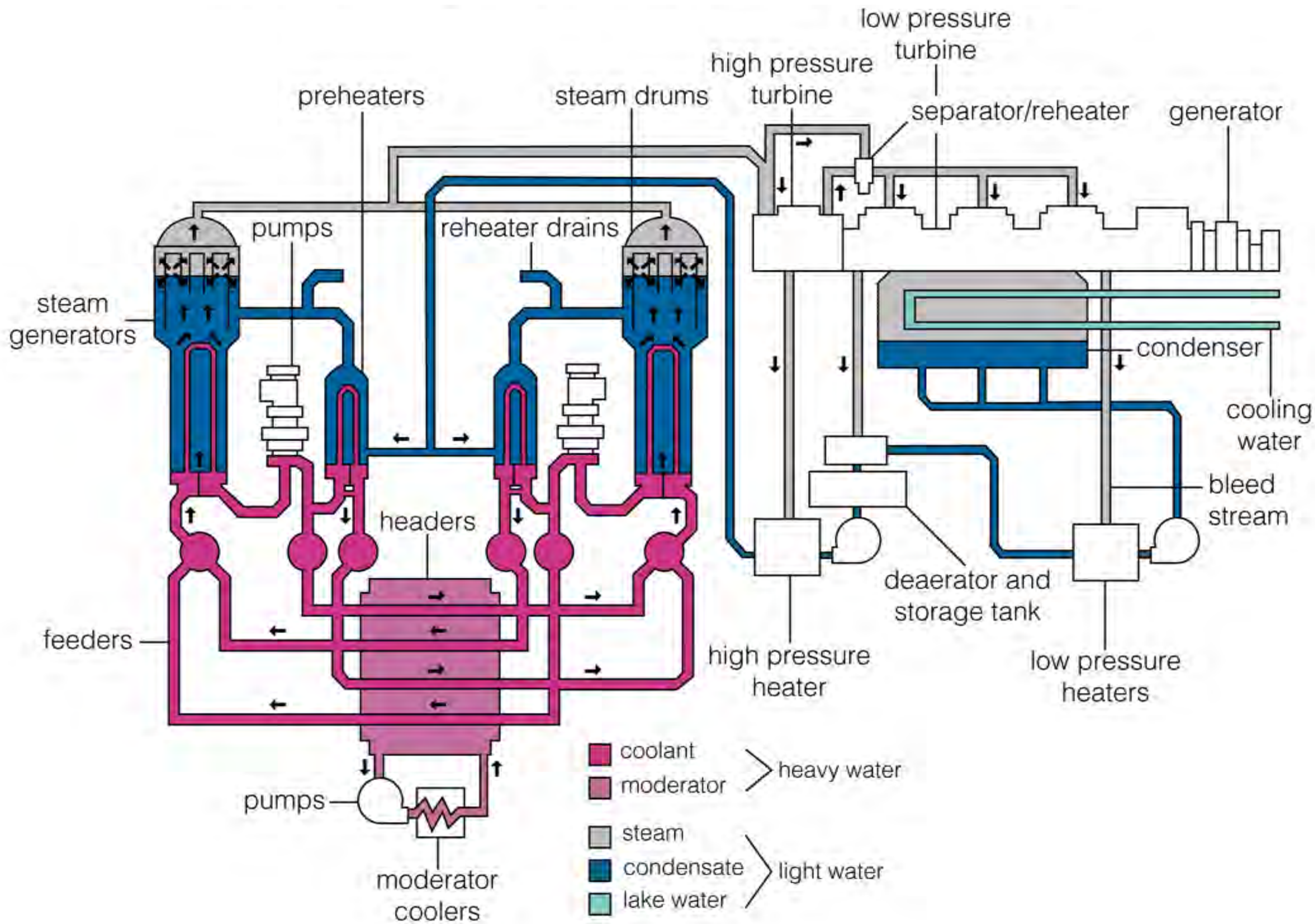
Heavy Water



- CANDU reactors need heavy water (D20) to function
- With natural uranium fuel, heavy water is needed to keep the fission reaction going
- Ordinary water (H20) absorbs too many neutrons and shuts the reaction down
- Deuterium (D) is a hydrogen atom with an extra neutron
- Approximately 0.0156% of hydrogen atoms in nature are heavy
- Heavy water itself is **not** radioactive, but the heavy water moderator and coolant in a reactor gathers radioactive materials throughout the fuel cycle process

CANDU Fuel Cycle

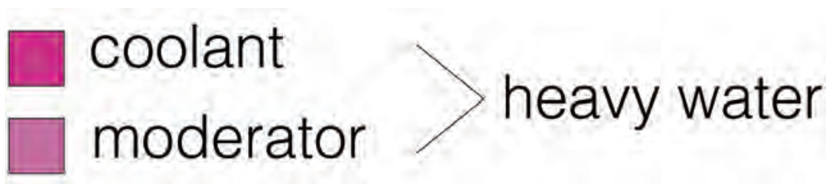
Heavy Water and Light Water Circuits



CANDU Fuel Cycle

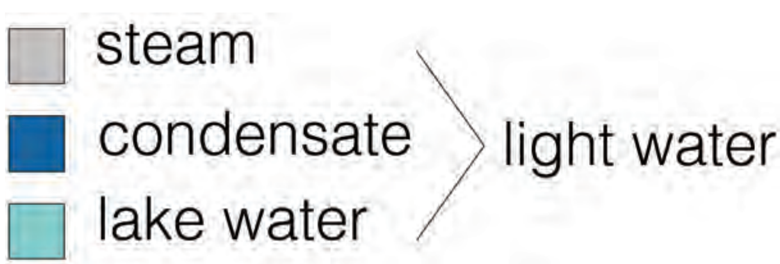
Heavy Water Circuit

- Pink in the graphic represents the heavy water closed circuit
- There are very small amounts of leakage, mostly water vapour into the air
- It is contaminated with radioactivity from contact with fuel and from formation of the tritium
- The resins used in the circuit to clean up the contamination become intermediate-level waste



Light (Ordinary) Water Circuit

- The blue and grey circuits are a demineralized light water/steam closed circuit
- Barring equipment failures, it is not radioactive
- It never comes in direct contact with the reactor



CANDU Fuel Cycle

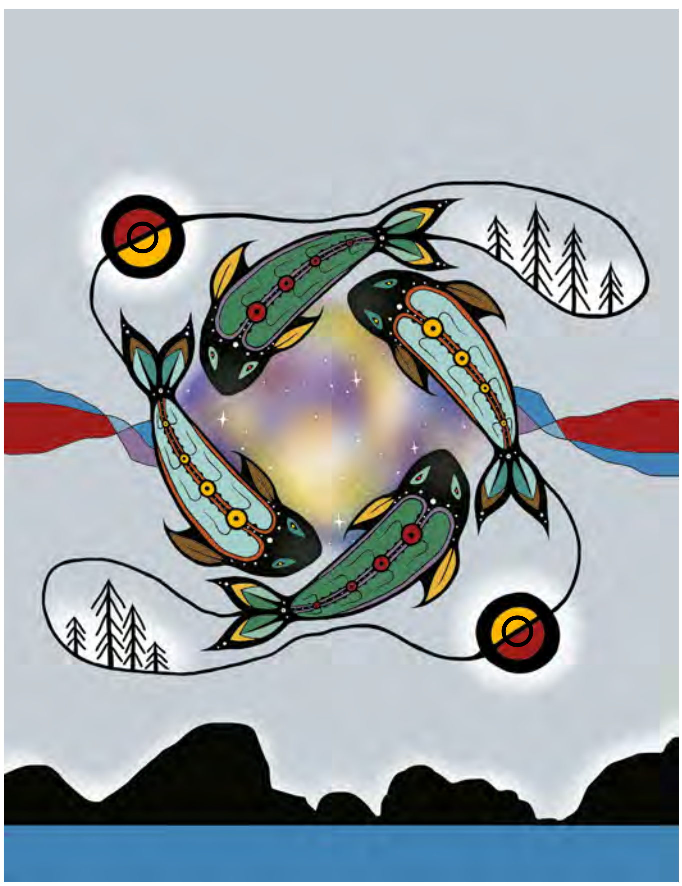
Lake Water Circuit

- The turquoise loop is lake water from Lake Huron
- It is taken from the lake, flows through the condensers where it heats up, and is put right back into the lake
- It does not pick up any contamination from the Bruce site, other than heat
- About 350 m^3 of Lake Huron water goes through the condensers every second (350,000 litres per second = an Olympic-size swimming pool every seven seconds)
- The water comes out about 10°C warmer than it went in
- This is continuously monitored for radioactivity to ensure that if anything goes wrong, it is detected and corrected

Other Nuclear Fuels

- Thorium cannot sustain a nuclear reaction, but it can be used to create a mixed thorium-uranium fuel
- Another breeder technology uses fast neutrons to create plutonium from uranium-238
- Various reprocessing and advanced fuel cycles make more effective use of energy available in uranium (and possibly thorium), but benefits are mostly in the distant future
- Reasons for choosing one kind of nuclear technology and fuel type over another are primarily economic and political rather than environmental

Nuclear Waste Management and Disposal



Nuclear Waste Management and Disposal

What is nuclear waste management?

- Nuclear waste management is the oversight of all aspects of radioactive waste, including:
    - Regulatory and political
    - Engineering and design
    - Operations and transportation
    - Long-term oversight and controls

Organizations responsible for nuclear waste in Canada

Federal - nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION

Provincial - ONTARIO POWER GENERATION

Hydro Québec

Énergie NB Power

Nuclear Waste Management and Disposal

Why is nuclear waste management important?

- Radioactive waste is dangerous for many, many years
- Nuclear waste can be a public health and safety hazard if it is not managed properly
- Long-term management of nuclear waste is a big consideration in the acceptance or rejection of many nuclear projects

Where does nuclear waste come from?

- Many different activities:
    - Operation and decommissioning of nuclear generating stations
    - Medical procedures
    - Nuclear weapons development and testing
    - Mining and mineral processing activities
- As well as potentially from any activity that utilizes radioactive materials

Nuclear Waste Management and Disposal

Storage vs Disposal

- **Storage** means putting radioactive waste in a facility or location, with intent to retrieve the waste
    - Storage requires continuous management, monitoring, and oversight
    - Storage isolates waste from the biosphere temporarily
- All the waste at the Bruce site is currently in **storage**
- Storage is not an ultimate solution for nuclear generating station waste
- Storage can be either above-ground (often in buildings) or near-surface

Limitations of Storage

- Long-term storage of nuclear waste has many drawbacks - it relies on continuing:
    - Operation of institutions like the waste generator (OPG) and regulator (CNSC)
    - Performance of the physical storage facility, as over time, a facility becomes more likely to fail

Nuclear Waste Management and Disposal

Disposal vs. Storage

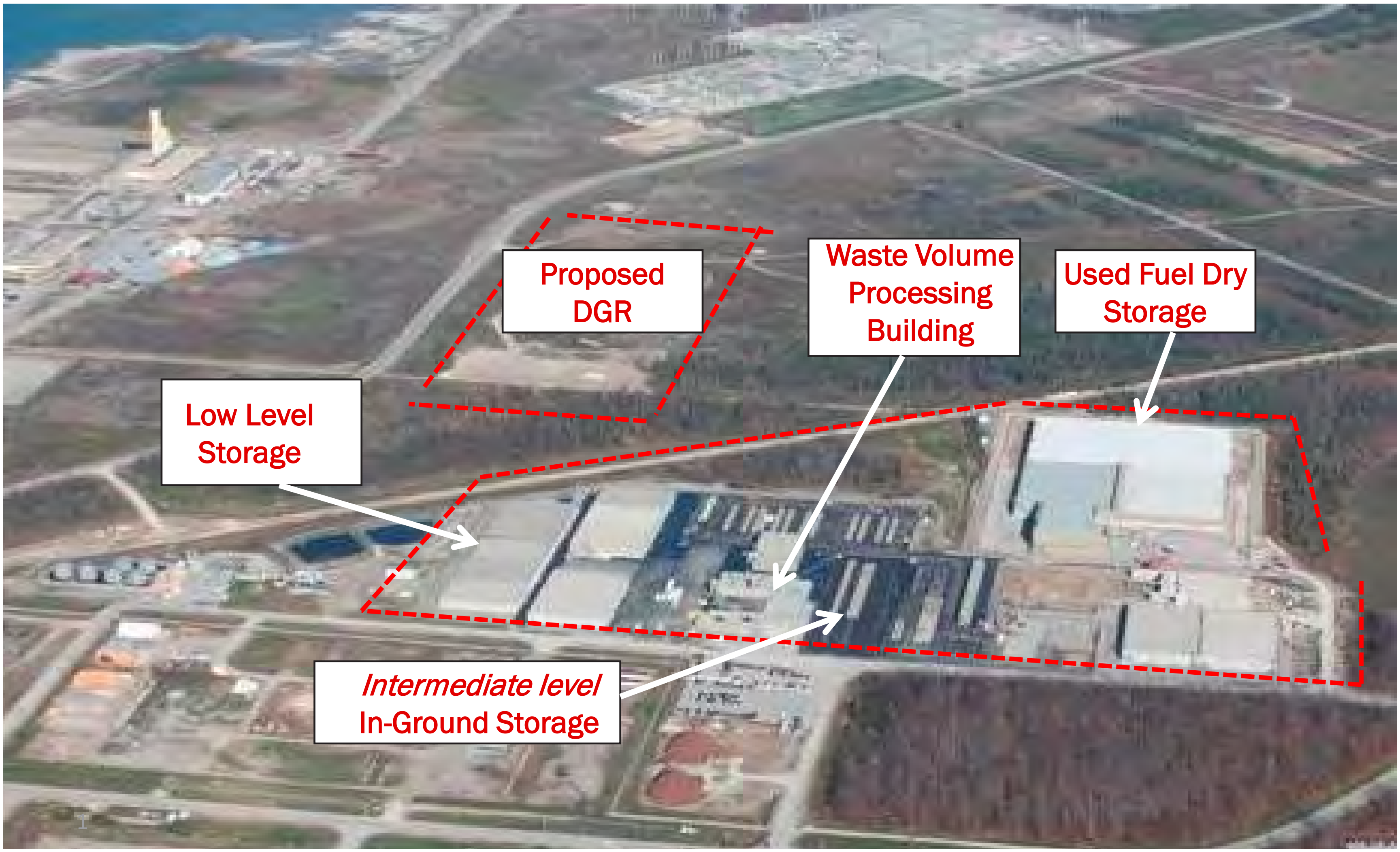
- **Disposal** means putting radioactive waste into a facility or location with no intention of retrieving it
    - Designed to contain the waste by engineered and natural features and isolate it permanently from the biosphere
    - Disposal facilities are designed for the long-term and are passively safe
    - Although waste retrieval is not intended, it may be possible
    - Ex. the proposed DGR for low- and intermediate-level waste

Goals for Disposal Facilities

- Contain the waste
- Isolate the waste from the biosphere permanently
- Reduce the likelihood of human intrusion
- Stop or reduce the migration of radionuclides

Nuclear Waste Management and Disposal

Map of the WWMF



Nuclear Waste Management and Disposal

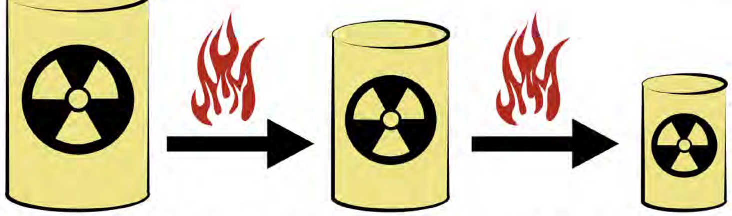
Western Waste Management Facility

- WWMF is where all of Bruce Nuclear Generating Station's low- and intermediate- level waste is stored
- Stores all of Darlington and Pickering Nuclear Generating Stations' low- and intermediate-level waste
- Stores all of the BNGS' high-level waste (used fuel) that is in dry storage

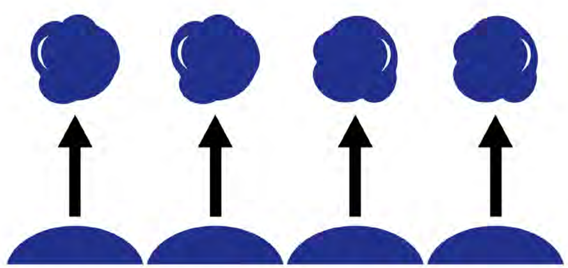
WWMF – Operations

- WWMF is a predisposal waste management facility
- Wastes are:
    - Collected and packaged
    - Volume reduced by incineration or mechanical compaction
    - Stored in concrete structures
- It is only designed as a storage facility
- Nuclear wastes will ultimately require disposal, not just ongoing storage

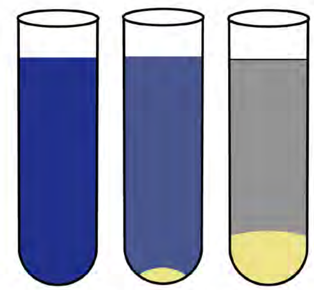
Treatment



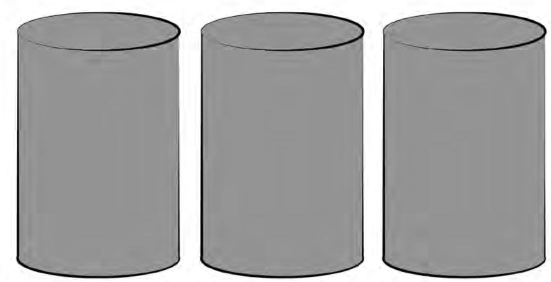
1. Reduce the size of waste by incinerating it, compacting it or taking it apart (ex. equipment).



2. Remove radionuclides by evaporating liquid waste and filtering gas.



3. Change the waste through chemical processes such as precipitation and acid digestion.



4. Change the waste ex. by solidifying it; common immobilization materials include cement, bitumen and glass.

Nuclear Waste Management and Disposal

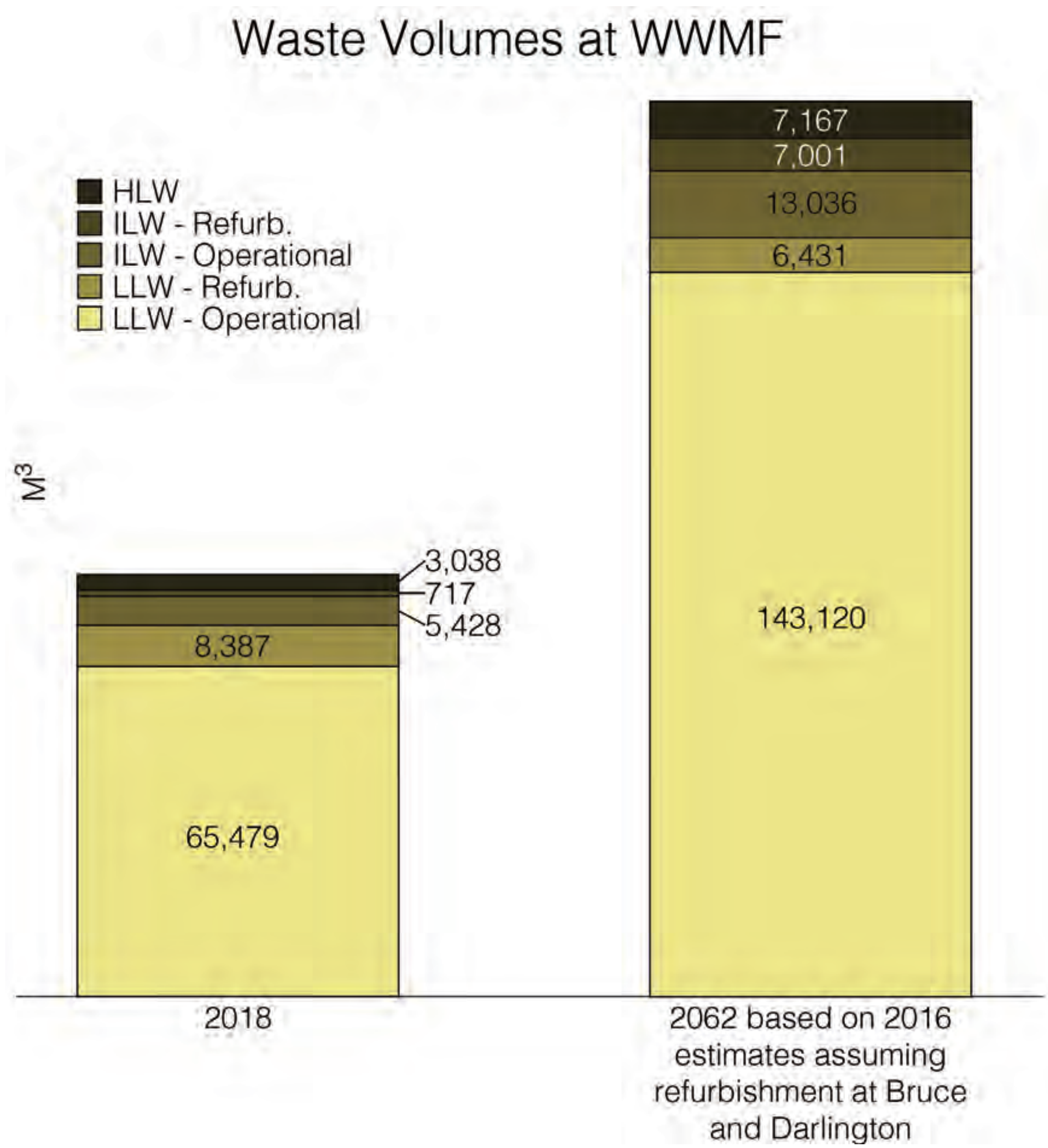
Treatment Operations

- Some low- and intermediate-level waste is incinerated
- Waste cannot be in a form that is easily dissolved by ground water so it must be stabilized
- Ash is stabilized/solidified with bitumen or concrete so that it cannot enter the atmosphere

Nuclear Waste Management and Disposal

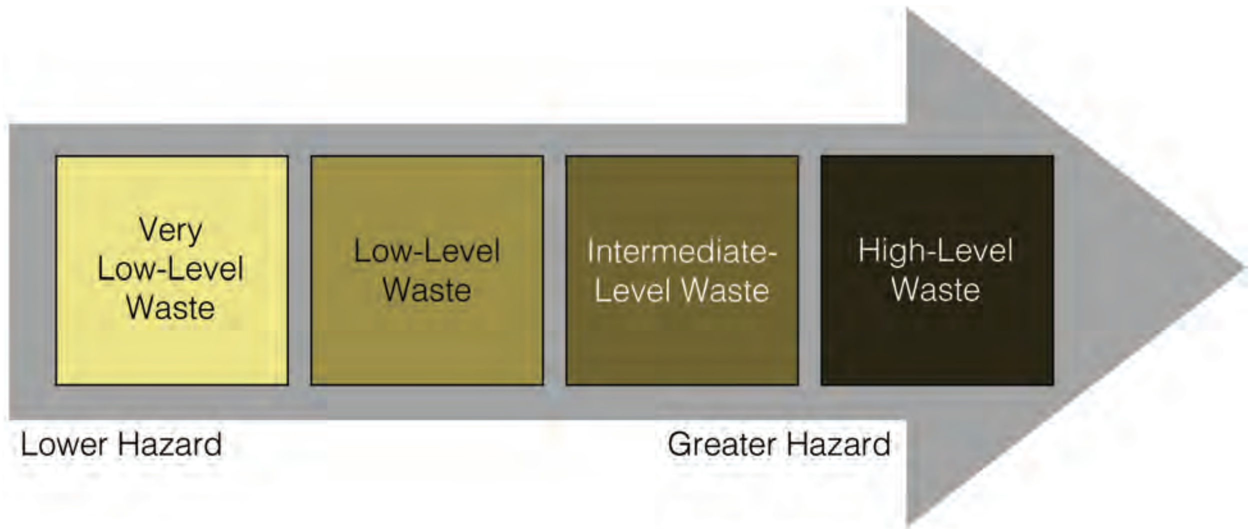
Waste Volume

- It is estimated that 170,000 m^3 of low- and intermediate-level waste will be stored at the WWMF by 2062
- That's 68 Olympic-sized swimming pools of nuclear waste



Nuclear Waste Management and Disposal

Classifications of Radioactive Waste



How does the operator decide how to classify waste?

- They know which processes and waste streams produce what kinds of waste
- Ex. used fuel is always high-level waste; resins used to clean the heavy water that surrounds the fuel are intermediate-level waste; clothing, rags etc. are low-level
- All of the waste streams are monitored to ensure they do not exceed limits for their classification

Nuclear Waste Management and Disposal

Very Low-Level Waste

- Very low-level waste (VLLW) is an occasionally used classification, representing the lowest radioactive content and risk
- Typically reserved for bulk materials only very slightly contaminated. Ex. Soils, concrete
- Disposed of in near-surface disposal facilities, with minimal engineered controls
- None of the waste planned for the DGR falls within this category

Low-Level Waste

- Low-level waste (LLW) has relatively low amounts of radioactivity
- Not a significant long-term hazard
- Shielding for worker protection during handling and storage is normally not required
- Requires isolation and containment for 100-300 years
- Can include:
    - Contaminated tools, equipment and components
    - General trash (rags, clothing, mops)
    - Medical waste
    - Bulk material, such as concrete, soil or rubble

Nuclear Waste Management and Disposal

LLW Storage at Bruce Site

- LLW is stored in above-ground containers at the WWMF
- The containers are placed in warehouse-type concrete buildings

LLW Disposal Options

- Landfill disposal
    - Similar to conventional landfills, but with additional engineered controls
        - Waste acceptance and packaging requirements
        - Covers
        - Liners
        - Monitoring
        - Access controls
- Near surface disposal
    - Engineered trenches or vaults

Nuclear Waste Management and Disposal

Intermediate-Level Waste

- Intermediate-level waste (ILW) is generated by nuclear generating stations and weapons operations
- Radioactive for up to 100,000 years
- Generally requires shielding for personnel protection
- ILW that could be placed in the DGR includes:
    - Primary system resins and filters
    - Irradiated components
    - Highly radioactive resins and filters from clean-up of primary water systems in the plant
    - Various internal components removed from the primary reactor systems, either as a part of refurbishment or at the time of decommissioning

ILW Storage at the Bruce Site

- OPG uses in-ground storage for some ILW
- This is **not** disposal, even if it is underground

Nuclear Waste Management and Disposal

ILW Disposal Options

- It would be placed in a facility constructed in caverns, vaults or silos
- Up to 100s of metres below ground
- Build facilities in or from existing mines
- Deep geologic repositories

High-Level Waste

- High-level waste (HLW) is the highest waste classification
- Represents the highest radioactivity content and associated risk
- Requires shielding to protect workers or members of the public from external exposure
- Remains radioactive for hundreds of thousands of years

HLW Management

- Managed separately from low- and intermediate-level waste
- Used nuclear fuel always categorized as HLW
- Some highly irradiated reactor core components may also be classified as HLW:
    - Primary system components
    - Primary system filters or resins

Nuclear Waste Management and Disposal

Used Fuel

- After going through the reactor (usually for about a year), fuel bundles come out highly radioactive
- Used fuel bundles are very hot and are stored under water at the reactor site for 10+ years while they cool down

On-Site Storage

- In the short-term, used fuel is stored in water filled bays

Nuclear Waste Management and Disposal

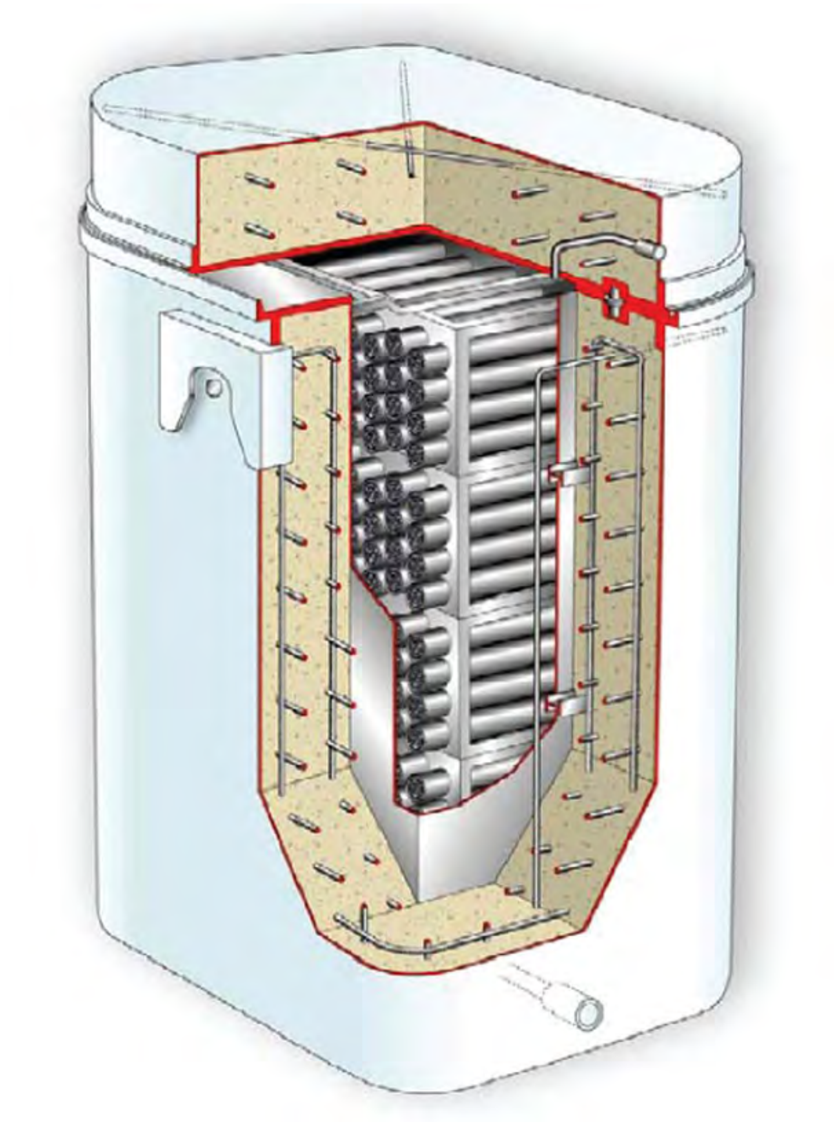
Dry Fuel Storage

- Used fuel is removed from the spent fuel bays and placed in large concrete containers weighing approximately 70 tons each
- After being loaded with used fuel bundles, each container is transferred to the Western Used Fuel Dry Storage Facility located at the WWMF site
- These containers are designed to last at least 50 years
- Used fuel from Pickering and Darlington reactors is stored in similar dry storage facilities at each of those sites
- Used fuel from Pickering and Darlington is not transported to the WWMF
- Eventually the used fuel will be removed from these casks for final disposal

Nuclear Waste Management and Disposal

HLW Disposal Options

- Dry storage facilities for used fuel are a temporary solution
- A permanent solution for the management of used fuel waste is needed
- HLW is not to be disposed of in the proposed DGR for low- and intermediate-level waste



Nuclear Waste Management and Disposal

HLW Disposal Options

- Many options were explored for HLW disposal:
    - Deep geologic repository
    - Deep sea or sediment
    - Deep drilled boreholes
    - Radioisotope transmutation
    - Outer space
    - Indefinite storage
- Almost universally, deep geologic repositories are the preferred HLW disposal option
    - 13 nations have committed to DGRs for HLW management

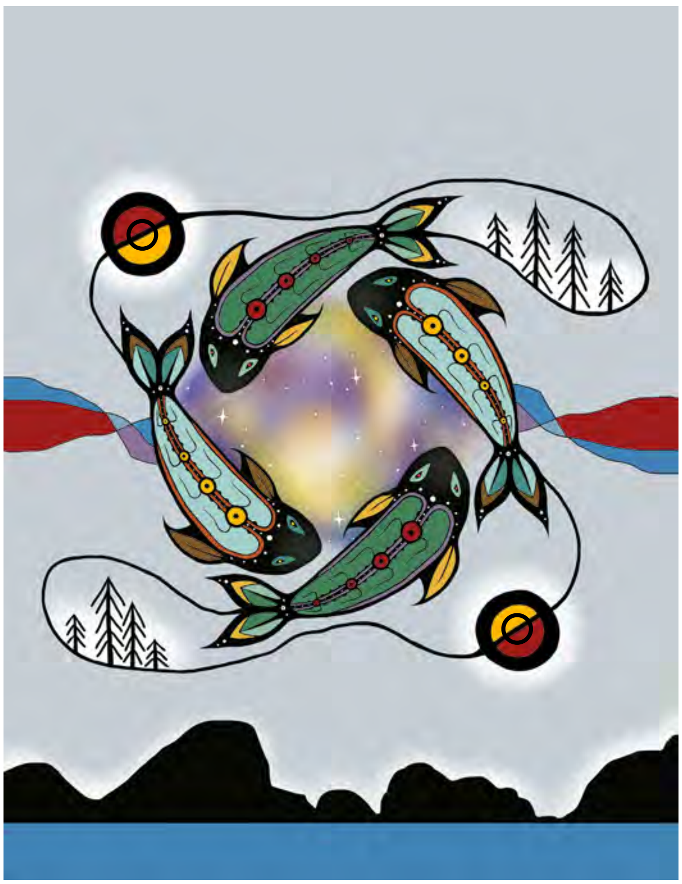
Nuclear Waste Management and Disposal

Decommissioning Waste

- All reactors in Ontario will eventually be decommissioned
- After fuel removal, reactors and associated components will be mothballed for several more decades before dismantling and demolishing
- Dismantling will result in large volumes of VLLW (ex. concrete structures), as well as significant amounts of LLW (ex. steam generators) and ILW (ex. pressure tubes)

- These decommissioning wastes are not included in the planned DGR inventory
- The amount of decommissioning waste (including refurbishment wastes) is estimated to be 135,000 m^3
- Some of the waste is low-level or very low-level and does not need to go into deep geologic disposal, but there will also be ILW (mainly reactor structural components such as pressure tubes)

Deep Geologic Repositories as Disposals for Nuclear Waste



Deep Geologic Repositories as Disposals for Nuclear Waste

Nuclear Waste Issues in SON Territory

- OPG has proposed creating a deep geologic repository (DGR) to store Ontario's low- and intermediate-level nuclear waste at the Bruce site
- The proposed DGR could hold up to 200,000 m^3 of low- and intermediate-level waste
- It could be expanded to handle decommissioning wastes

ONTARIO POWER GENERATION

What is Ontario Power Generation?

A crown corporation owned by the Province of Ontario. It owns and operates more than half of Ontario's electricity generators. It is responsible for managing all of Ontario's low- and intermediate-level nuclear waste.

Deep Geologic Repositories as Disposals for Nuclear Waste

Where did the proposed DGR Project come from?

- In the early 2000s, discussions were held between OPG and the Municipality of Kincardine (SON was never involved in these discussions)
- In 2002, a Memorandum of Understanding was signed between OPG and Kincardine providing a long-term solution for nuclear waste disposal
- This initiated a technical review of three proposed options:
    1. Continued above-ground storage
    2. Near-surface disposal in concrete vaults
    3. Geologic disposal
- Municipality of Kincardine approached OPG, who owns the waste, to seek a community-based solution
- An Independent Assessment Study concluded that all three options were feasible and presented the relative advantages of each
- Kincardine Municipal Council selected deep geologic disposal from the options
- SON was not consulted on any of this
- In 2004, a Hosting Agreement was signed between OPG, Kincardine and other neighbouring municipalities
- The agreement described the types of waste that could be placed in the DGR and also set terms for financial compensation that would go to the communities
- Expected compensation for municipalities' support was millions of dollars

Deep Geologic Repositories as Disposals for Nuclear Waste

Minimal Engagement with SON on DGR Project

- SON was excluded from all of the early planning for the proposed DGR
- In 2003, OPG first informed us of proposal to build a DGR to permanently dispose of low- and intermediate- level nuclear waste at the Bruce site
- Our leadership expressed deep concerns about the project and its impact on our rights and interests
- Also, concerns were raised about its connection to a future project for the storage of high-level waste
- From 2003-2006, OPG's engagement with SON was minimal

Canada's Decision-Making on the Proposed DGR

- The proposed DGR requires a licence from the Canadian Nuclear Safety Commission (CNSC)
- Canadian Environmental Assessment Act (CEAA) requires the CNSC to conduct an environmental assessment before making a decision on the licence
- OPG's Letter of Intent and project description were submitted to the CNSC in 2005 to start the CEAA process

Deep Geologic Repositories as Disposals for Nuclear Waste

Engagement between Canada and SON

- From 2006-2009, CNSC consulted with SON on the design of the DGR environmental review
- During this time, we learned more about OPG's proposal and gained a deeper understanding of the nuclear waste problem in our Territory
- SON leadership advocated for:
    1. A full public review of the project
    2. Consent from our communities
- In January 2009, SON Leadership and OPG signed a protocol agreement
- The agreement stated that we would require: capacity to do a full review of the DGR proposal, full participation in the environmental assessment hearings, and the ability to take any position on the project - including complete opposition

The Joint Review Panel

- Originally, CNSC was going to review the DGR through an internal study with limited opportunity for review
- SON leadership pushed for full public hearings on the project
- In 2006, the CNSC agreed with SON that the proposed DGR must be subject to a full public review by a Joint Review Panel and that SON must play a critical role in shaping the review

Deep Geologic Repositories as Disposals for Nuclear Waste

SON at the Joint Review Panel

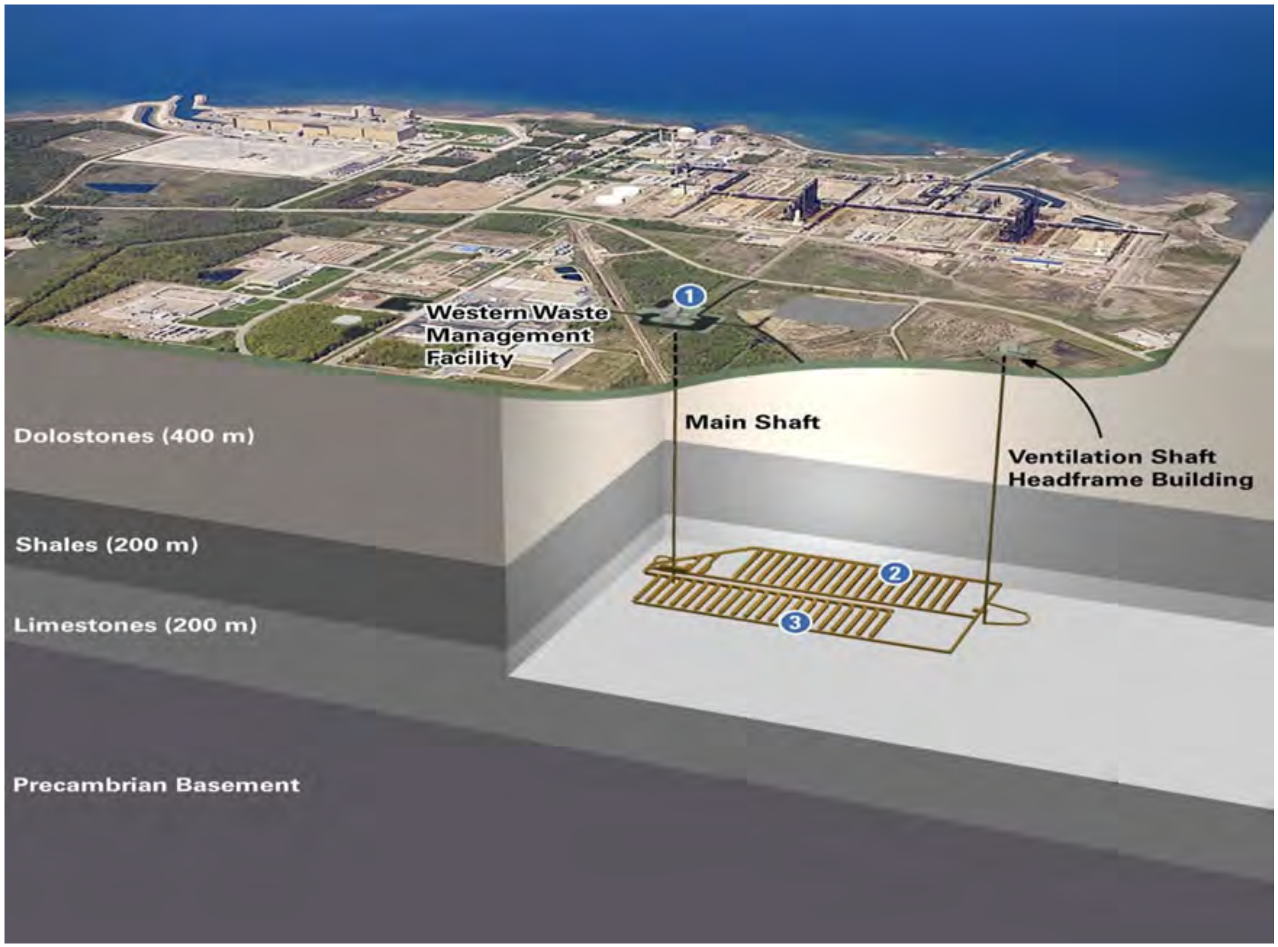
- SON participated in every step of the hearing process (33 days that took place from September 2013 to September 2014)
- SON helped shape the mandate of the Joint Review Panel and played a central role in the hearings
- Many community members were present throughout the hearings

OPG Commitments to SON

- In August 2013, just before the hearings began, OPG made a commitment to SON that finally put decisions about the project in the hands of the communities
- The commitment came after many years of intense discussions between OPG and SON Leadership
- OPG committed to us that:
    1. The proposed DGR for low- and intermediate- level waste will not go ahead without the support of our communities
    2. They will work with us to address the historical and ongoing impacts of nuclear power generation on our communities and our Territory
- After a long history of exclusion, our voices are finally being heard!

Deep Geologic Repositories as Disposals for Nuclear Waste

Proposed DGR for Low-and Intermediate-Level Nuclear Waste



Deep Geologic Repositories as Disposals for Nuclear Waste

Location of the Proposed DGR

- The surface facility would be located approximately one kilometre from Lake Huron
- Waste would be disposed of at a depth of 680 metres; Lake Huron's maximum depth is 180 metres
- Waste would be stored in a limestone rock formation, which is intended to limit the input of water and movement of radioactive material
- The geology is expected to isolate and contain the waste for more than 10,000 years

Deep Geologic Repositories as Disposals for Nuclear Waste

What is proposed to go in the DGR?

- The proposed DGR would dispose of low- and intermediate-level waste generated during normal operations and maintenance of Ontario's nuclear generating stations
    - Waste currently stored in the WWMF located at the Bruce site would be relocated to the DGR
    - Radioactive waste generated at all OPG nuclear generating stations (Bruce, Darlington and Pickering) would be transported to the DGR
- Capacity for 200,000 m^3 of waste
    - That's approximately 65 two metre deep hockey rinks full of waste

Where is OPG planning to put decommissioning waste?

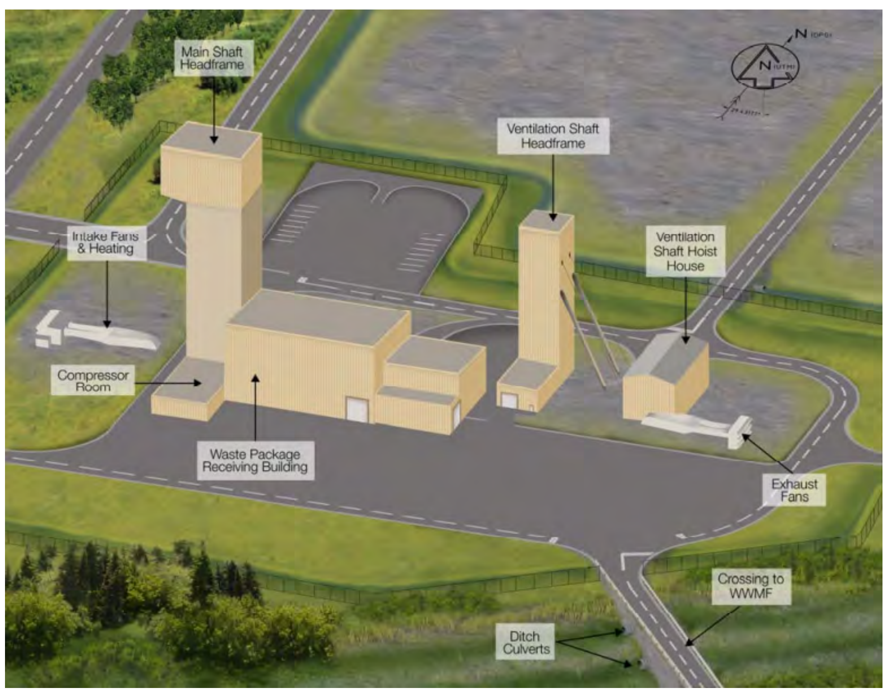
- Projected that there will be 135,000 m^3 of decommissioning waste
- Decommissioning waste is not included in the proposed DGR inventory
- The DGR could be expanded to accommodate decommissioning waste or an entirely new disposal site could be built
- There has been no formal decision made on this, but OPG would likely favour expanding the DGR due to the lesser cost

Deep Geologic Repositories as Disposals for Nuclear Waste

The Issue of High-Level Waste

- The DGR is not a complete solution to all the radioactive waste issue in the Territory or in Canada
    - High-level waste, including used nuclear fuel and other highly radioactive waste, would not be placed in the DGR
    - The DGR will not accept radioactive waste from industrial sources, medical radioactive waste, or naturally occurring radioactive materials

Proposed DGR Operations



- The operations phase of the DGR is expected to last 40-45 years, followed by closure of the facility (ex. taking down the buildings, sealing shafts)
- During the operational phase, waste is received, repackaged and moved into deep underground disposal cells
- Surface facilities will support operations, including waste receiving buildings, ventilation shaft headframes, fans, etc.

Deep Geologic Repositories as Disposals for Nuclear Waste

OPG’s Project Schedule for the DGR

- If the SON communities approve and regulatory approval is granted, it would take about five years for the DGR to be constructed
- The process of putting radioactive waste from the nuclear generating stations into the DGR would take 35-40 years
- Once all waste is disposed of, the underground cells and facilities would be closed and sealed
- After closure, institutional controls are expected to remain in place for another 300 years
- A monitoring program would be put in place to make sure the DGR is operating as expected and isolating the waste from the environment

SON’s Right to Consent on the Proposed DGR

- Canada has now expressed its support for the commitment OPG made to SON
- In August 2017, the Minister of the Environment paused the environmental assessment for the DGR to wait for the outcome of the SON Community Process

Deep Geologic Repositories as Disposals for Nuclear Waste

Siting a Location for the Disposal of HLW

- The Nuclear Waste Management Organization (NWMO) is responsible for the design and implementation of a plan for the long-term storage of Canada's used fuel (high-level waste)
- There are five sites within NWMO's selection process, also known as the Adaptive Phase Management process
- Two municipalities within the SON Territory are still involved in the siting process

nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION

What is the Nuclear Waste Management Organization?

Established in 2002, it is mandated by the federal government through the Nuclear Waste Management Act to find a long-term mangement solution for Canada's used fuel. It is funded by OPG, Hydro Quebec, New Brunswick Power Corporation and the CNSC.

NWMO Commitments to SON

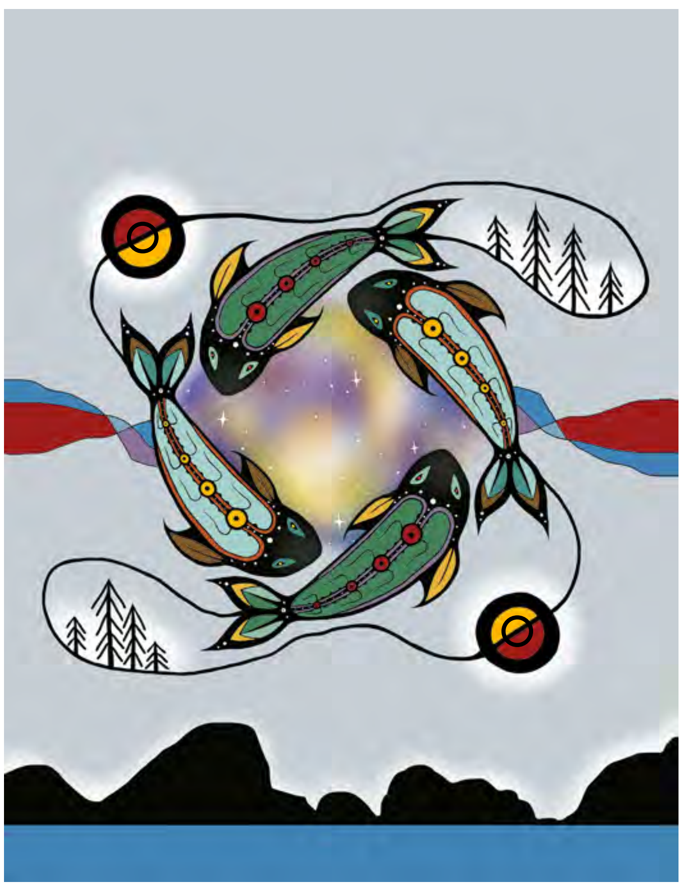
- In June 2016, after many years of intense discussions with SON leadership and teams, the NWMO committed to SON that they will not select a site for Canada's used fuel in our Territory without our consent

Deep Geologic Repositories as Disposals for Nuclear Waste

SON's Position on the WWMF

- SON has long taken the position that the WWMF is not an acceptable long-term solution for nuclear waste
- SON argued in recent licence renewal hearings for the WWMF that Canada and OPG cannot assume what the SON communities will decide on the DGR
- In response, the CNSC imposed conditions requiring additional hearings in the future, and OPG committed to working with SON on long-term solutions even if the DGR does not go ahead

An International Look at Nuclear Waste Disposal Sites

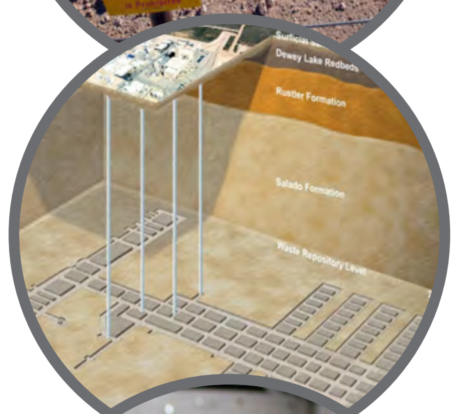


An International Look at Nuclear Waste Disposal Sites

Disposal Facilities

- *Barnwell, South Carolina*
    - This is considered a near-surface disposal facility that accepts low-level waste
    - Pictured are shielded vaults, likely containing resins and other LLW

- *WCS, Texas*
    - This is considered a near-surface disposal facility that accepts low-level waste



- *Waste Isolation Pilot Plant, New Mexico*
    - Waste Isolation Pilot Plant (WIPP) accepts a variety of intermediate-level waste from the American Department of Energy, including very long lived transuranic waste
    - WIPP is similar in design to the proposed DGR

An International Look at Nuclear Waste Disposal Sites

Disposal Facilities

- *Yucca Mountain, Nevada*
    - Proposed facility to dispose of American high-level waste

Why is a DGR being proposed for low- and intermediate-level waste in Canada?

- Deep geologic disposal is the internationally accepted solution for high-level waste, and also for many kinds of long-lived intermediate-level waste
- Low-level waste in many countries is disposed of in near-surface facilities
- In some countries, such as France, intermediate-level waste is disposed of with high-level waste
- It is likely that choice of deep geologic disposal at the WWMF was driven by the presence of intermediate-level waste

An International Look at Nuclear Waste Disposal Sites

Success and Failure of DGR Programs

- Several deep geologic disposal programmes in Canada, the US and the UK have failed before site selection or site approval stages
- Only a few DGR projects have reached construction or operation
    - WIPP for intermediate-level waste in opertation
    - Finnish low- and intermediate-level waste in operation, with a high-level waste project now under construction
    - Konrad low- and intermediate-level waste under construction
- Some DGRs have failed (ex. the German Asse II research disposal site)
- No DGR has been around long enough to reach the end of the operational stage and proceed to final closure
- In that sense, DGR technology is still untested

We have nuclear waste issues in Anishnaabekiing.

An International Look at Nuclear Waste Disposal Sites

What are the options for low- and intermediate-level waste disposal?

- Continued storage (enhanced surface management)
- Near surface disposal
    - Ex. France LLW site, Barnwell South Carolina, and WCS in Texas
    - Not acceptable for ILW – instead, it could be shipped off-site
- Shallow rock cavities
    - Ex. FSR in Sweden and Konrad mine in Germany
- Deep geologic disposal
    - Ex. WIPP in New Mexico and Yucca MT in Nevada
- These options could be done at the Bruce site or an alternative location

Options and Considerations for Nuclear Waste

- *Separate LLW from ILW:* in some other countries, such as France, ILW is disposed of with HLW
- *Send it somewhere else in Canada:* this may be possible, but other places may not want to take it
- *Send it to another country:* there are currently international agreements in place that prohibit this
- *Send it to outer space:* there are international agreements in place that prohibit this, and it's incredibly risky

An International Look at Nuclear Waste Disposal Sites

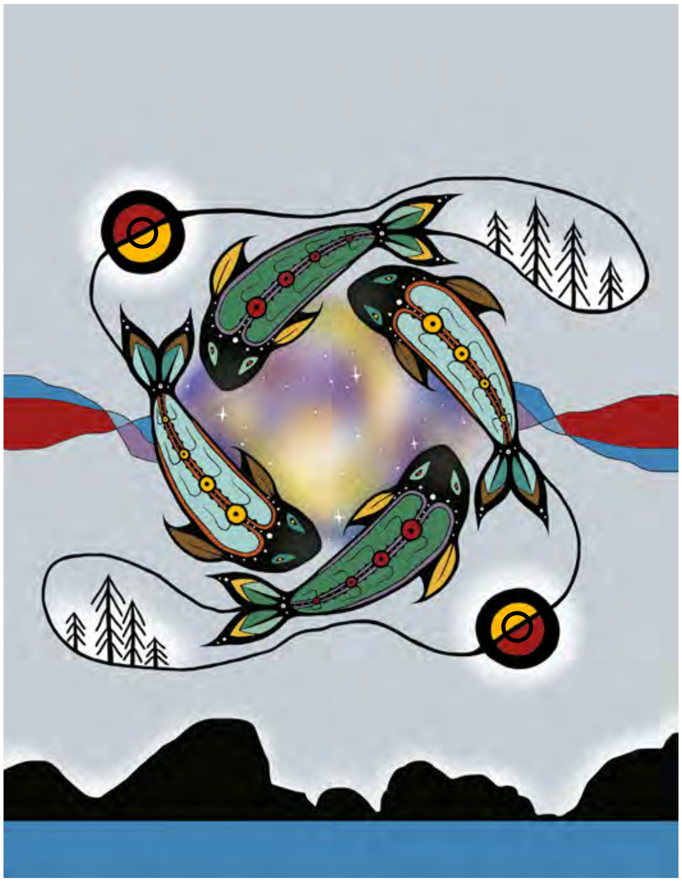
Can we reuse, recycle or reprocess nuclear waste?

- Low- and intermediate-level nuclear waste cannot be reused
- Recycling low- and intermediate-level waste is possible, but is very difficult and expensive with current technology
- New reactors are being designed that would reduce the amount of fuel waste generated in the future

Can we reuse or recycle HLW?

- Used fuel from Canada's reactors can be reprocessed
- It is possible to separate fuel that is still useable (like plutonium and uranium that was not burnt) for use in other reactors
- Canada and the USA currently do not reprocess fuel for many reasons:
    - CANDU reactors cannot use other nuclear fuels like plutonium
    - It costs too much and new nuclear fuel is still relatively cheaper
    - Plutonium can be used for nuclear weapons

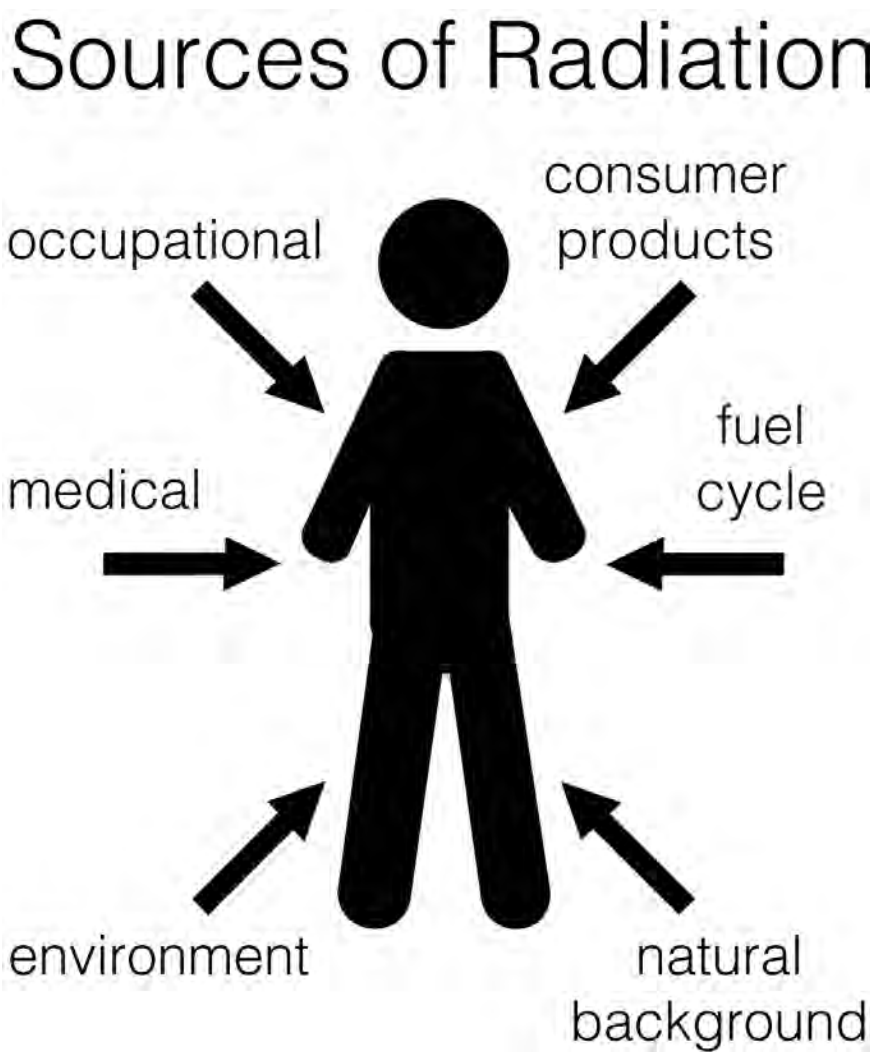
Understanding Radiation and Health Impacts



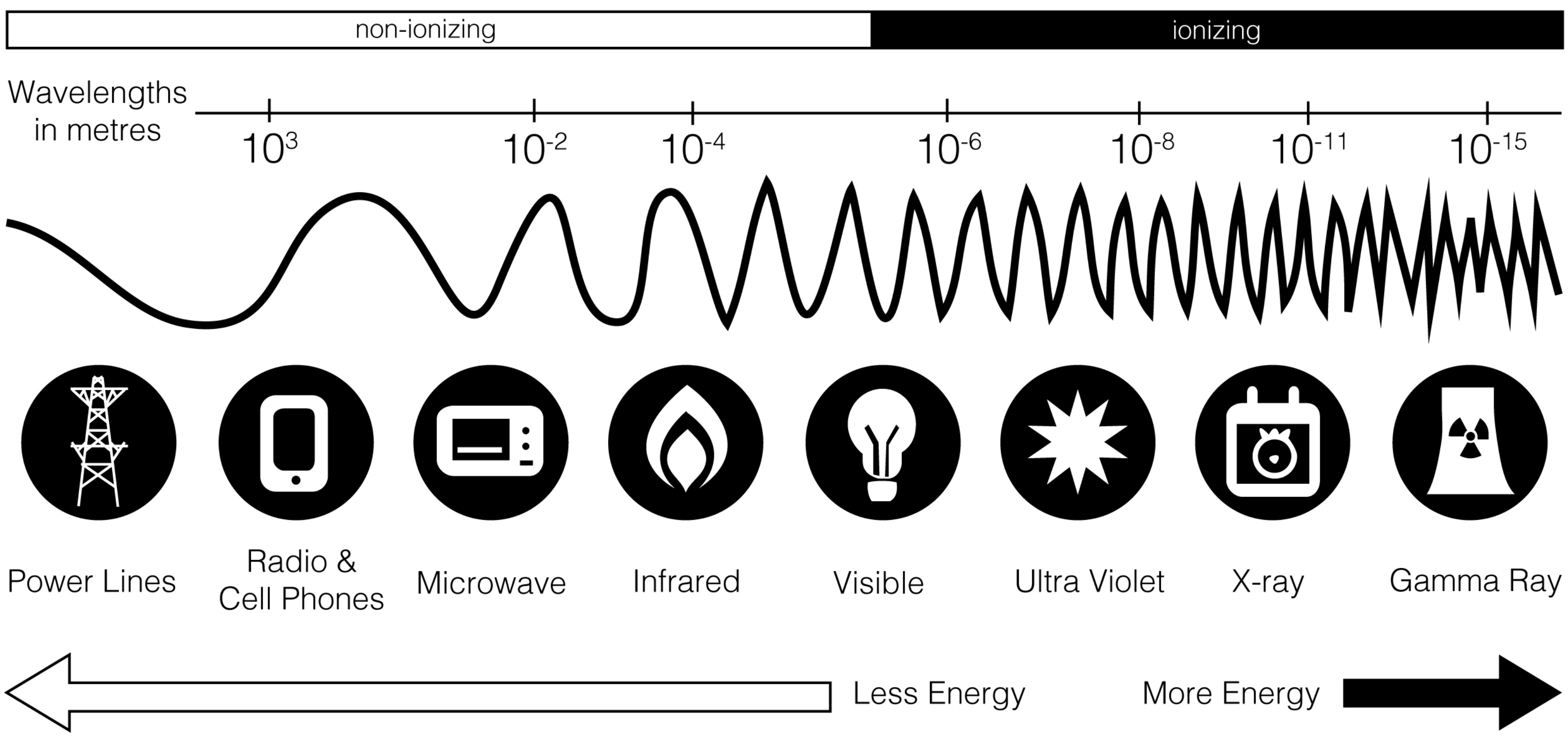
Understanding Radiation and Health Impacts

What is radiation?

- Radiation is the emission of energy as electromagnetic waves or as moving particles
- Some radiation is natural and relatively harmless. Ex. sunshine is ultraviolet radiation
- Other examples: heat, radio waves, visible light, x-rays



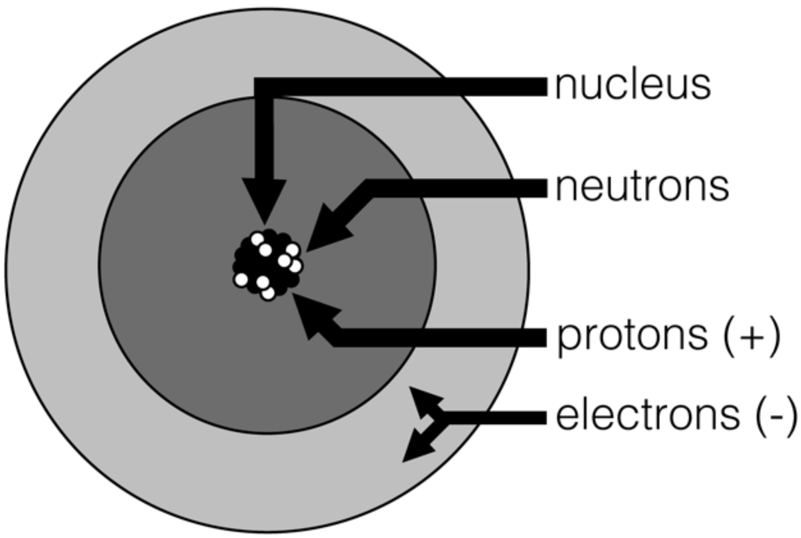
Electromagnetic Spectrum



Understanding Radiation and Health Impacts

What is an atom?

- Atoms are the building blocks of matter
- They cannot be broken down by chemicals
- An atom's nucleus has positively-charged **protons** and uncharged **neutrons**
- Negatively-charged **electrons** are in motion around the nucleus



What makes an atom radioactive?

- A radioactive atom is called a radionuclide
- Radioactivity is caused by an imbalance in the number of neutrons and protons in the nucleus of the atom
- Nuclear forces of attraction and repulsion are constantly trying to stay in balance within an atom
- The atom wants to get rid of the excess energy and does so by emitting energy to reach a stable state

Understanding Radiation and Health Impacts

What makes an atom radioactive?

- The energy emitted is what is known as radiation
- This process represents **radioactive decay**

What is ionizing radiation?

- Ionizing radiation is the harmful radiation that nuclear fission produces
- Ionization causes damage by breaking chemical bonds in other atoms and molecules
- This creates highly reactive free radicals
- Free radicals are highly charged atoms that can be linked to diseases like cancer

Understanding Radiation and Health Impacts

Radiation Exposure and Dose

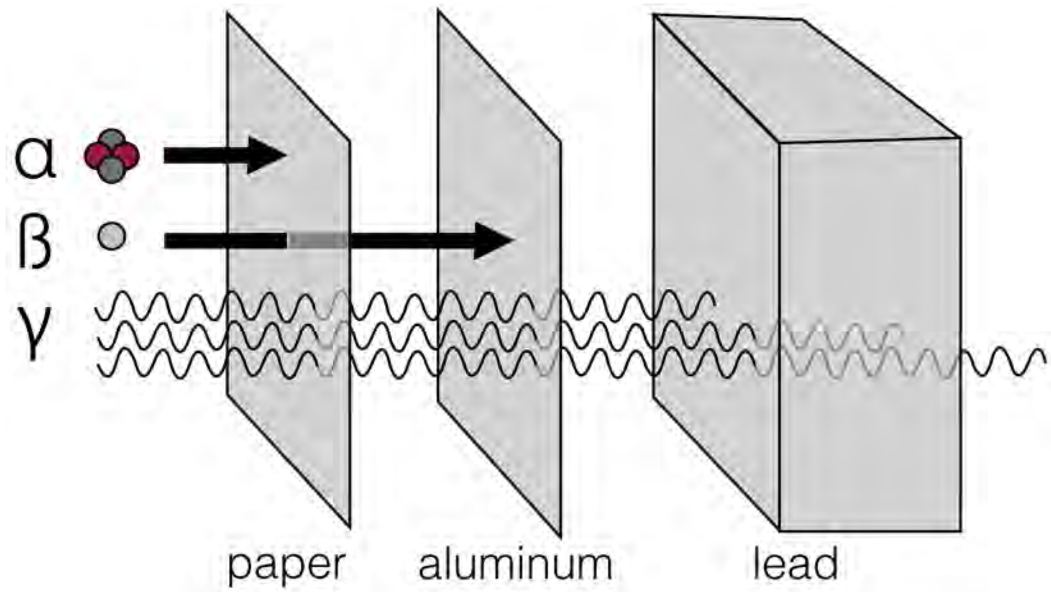
- Units of measure for ionizing radiation are gray (Gy) and sievert (Sv)
- Common terms used are milligray and millisievert
    - 1 mGy and 1 mSv are 1/1000th of a Gy and Sv, respectively
- Under normal operating conditions at the Bruce Nuclear Generating Station, 1 mSv is the annual dose limit to members of the public; 20 mSv is the limit for nuclear workers
- Annual natural background radiation exposure in Canada ranges from 1.6 mSv to 4.1 mSv
    - This variation is mostly because of radon exposure

Different Types of Ionizing Radiation

- There are different types of ionizing radiation
    - Highly energetic electromagnetic radiation (x-rays and gamma rays)
    - Nuclear particles, like alpha, beta or a free neutron
- Alpha particles are much more damaging to DNA than gamma rays
- There is concern that radioactive material that emits these particles could migrate into the water and air

Understanding Radiation and Health Impacts

Different Types of Ionizing Radiation

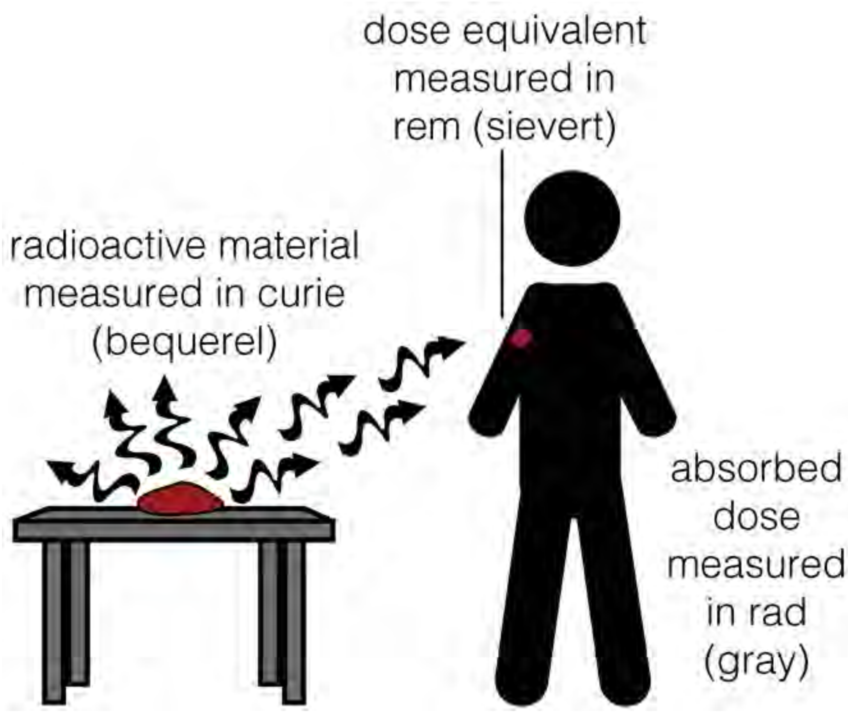


Effective Dose

- Unit of measure is the sievert
- Sievert is equal to the deposited energy (in Gy) multiplied by a relative biological effectiveness (RBE) for that form of radiation
- As discussed, for beta and gamma radiation the RBE = 1
    - 1 Gy beta or gamma dose = 1 Sv
- For alpha particles the RBE = 20
    - 1 Gy of alpha dose = 20 Sv

Understanding Radiation and Health Impacts

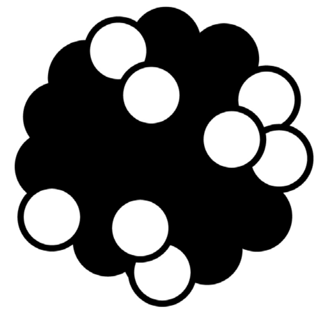
Effective Dose



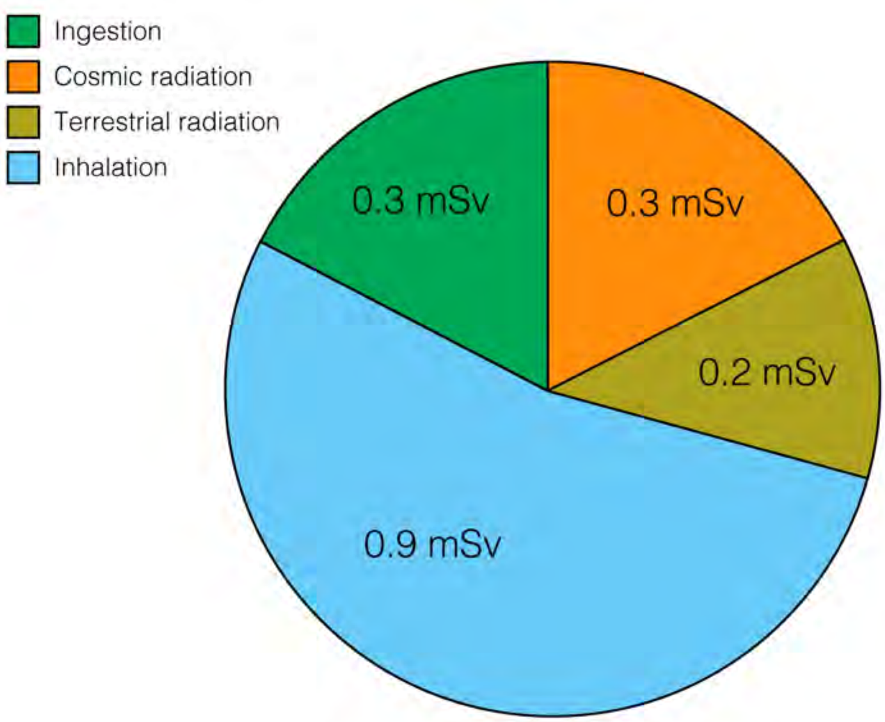
Physical Quantity	Units	Symbol	Factors
Radioactivity	Becquerel	Bq	1 disintegration per second (1 curie (Ci) = 3.7×10^{10} Bq)
Absorbed Dose	Gray	Gy	1 Joule per kilogram mass (1 Gy = 100 rads)
Dose Equivalent (biological effect)	Sievert	Sv	1 Gy multiplied by a Quality Factor that represents the relative biological damage for the type radiation delivering the dose

Understanding Radiation and Health Impacts

Natural Radiation Sources



- Radon
- Terrestrial radiation: There are radioactive elements like uranium, thorium and a radioisotope of potassium (K-40) in soil, rocks and water
    - These sources are remnants of exploding stars - they became part of the composition of our Earth during its formation
- Cosmic radiation: high energy particles from outer space absorbed in the upper atmosphere

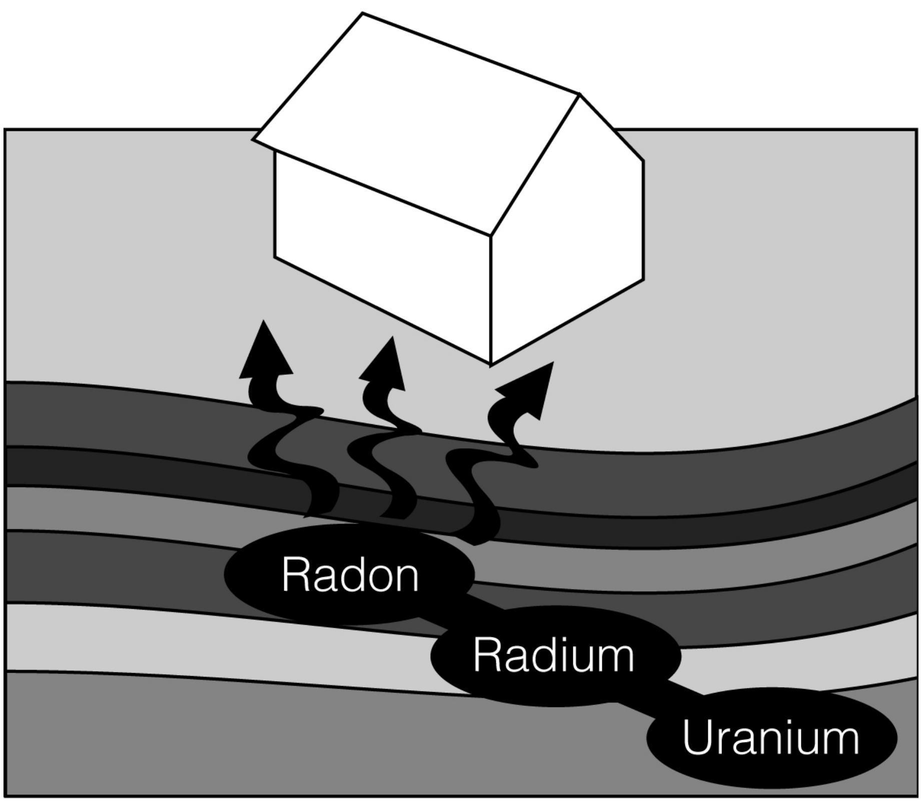


Doses from natural background radiation

Understanding Radiation and Health Impacts

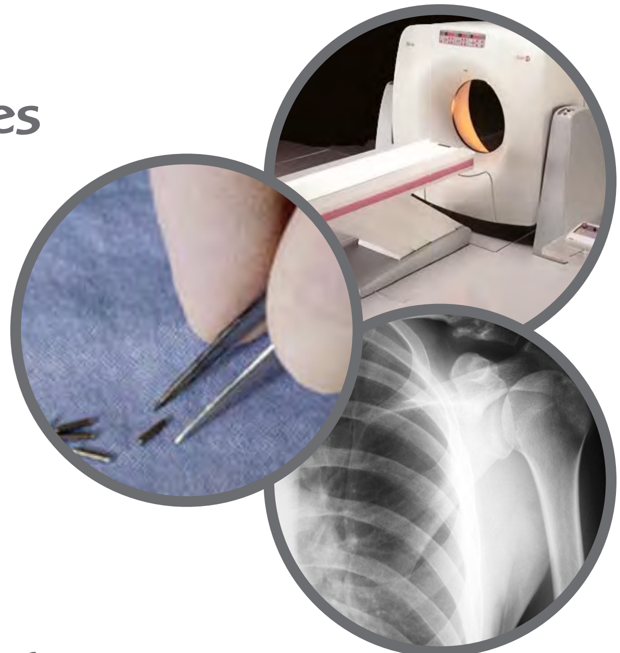
Radon

- The main source of natural radiation exposure is radon
- It is a colorless, tasteless radioactive gas that occurs naturally in the environment
- It comes from the uranium naturally found in rocks and soils
- Radon exposes Canadians to an average of 0.9 mSv annually (in a range from 0.4 to 3.2 mSv)
- It can seep through foundation cracks and accumulate in buildings
- CNSC: “Radon is the largest source of naturally occurring radiation exposure for Canadians as members of the general public due to its presence in buildings and houses.”



Understanding Radiation and Health Impacts

Medical Radiation Sources



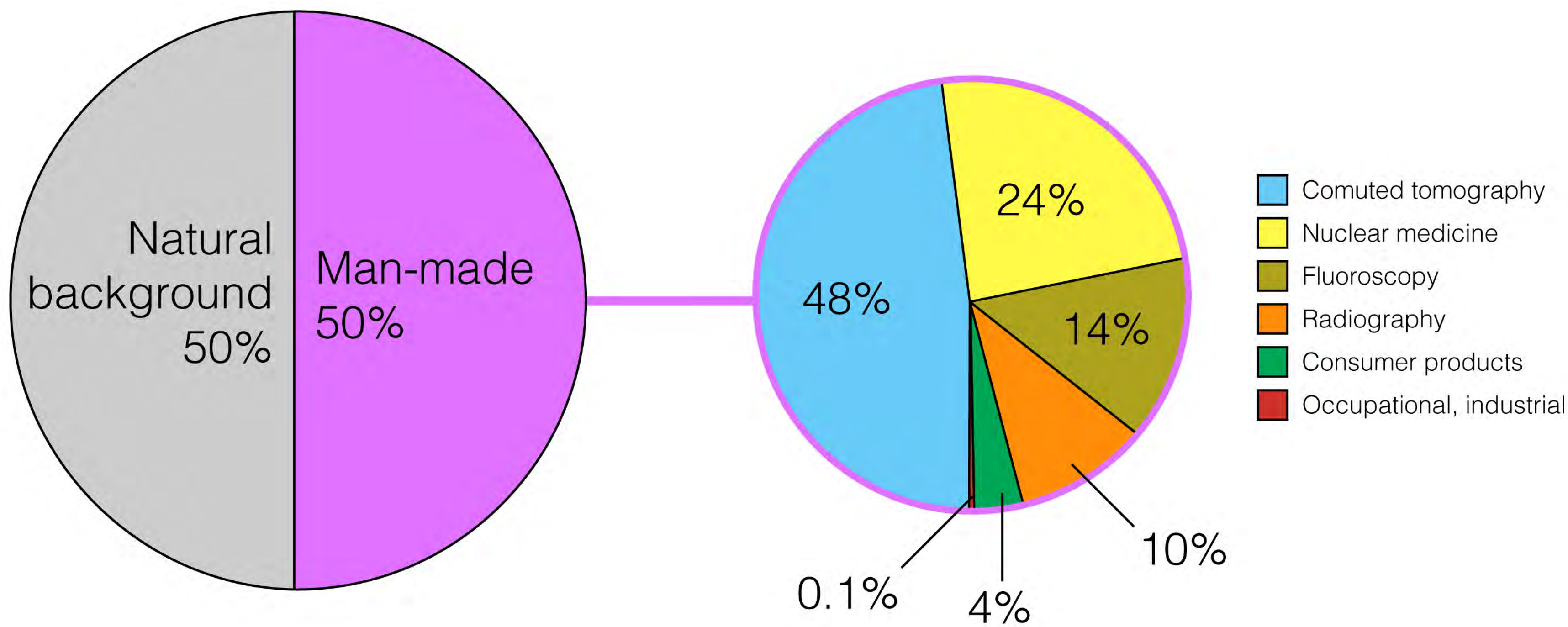
- CT scanners
- Brachytherapy
- Nuclear medicine scans
- X-rays

Household Radiation Sources

- Uranium in Fiestaware
- Am-241 in smoke detectors
- Tritium watches
- Thorium in lantern mantles
- K-40 in bananas
- Tritium signs

Understanding Radiation and Health Impacts

Man-made Sources of Exposure



Understanding Radiation and Health Impacts

Radiation Doses of Interest

Dose (mSv)	Description
0.01	Daily natural dose
0.01	Standard dental x-ray
0.025	Transcontinental flight
1/yr	Public limit from nuclear facilities
1.1/yr	Average occupational dose received by radiation workers
1.5	Abdominal x-ray

Dose (mSv)	Description
5	Mammography exam
6.2/yr	Background dose to US individual
10	Abdominal CT
20/yr	ICRP limit for radiation workers
50/yr	Occupational limit in USA

Understanding Radiation and Health Impacts

Harmful Effects of Ionizing Radiation

- Exposure to ionizing radiation can be harmful
- At high dose levels, immediate damage to biological cells and systems
    - That's why radiation therapy is used for medical cancer treatment – it kills cancerous cells
- At lower doses, biological cells can be repaired or replaced
- Misrepair can lead to cancerous cells

Cellular Radiation Damage

- When ionizing radiation contacts a cell, it may:
    - Pass directly through the cell without causing any damage
    - Damage the cell but the cell will repair itself
    - Affect the cell's ability to reproduce itself correctly, possibly causing a mutation
    - Kill the cell – the death of one cell is of no concern, but if too many cells in one organ die, the organism itself might die

Understanding Radiation and Health Impacts

DNA

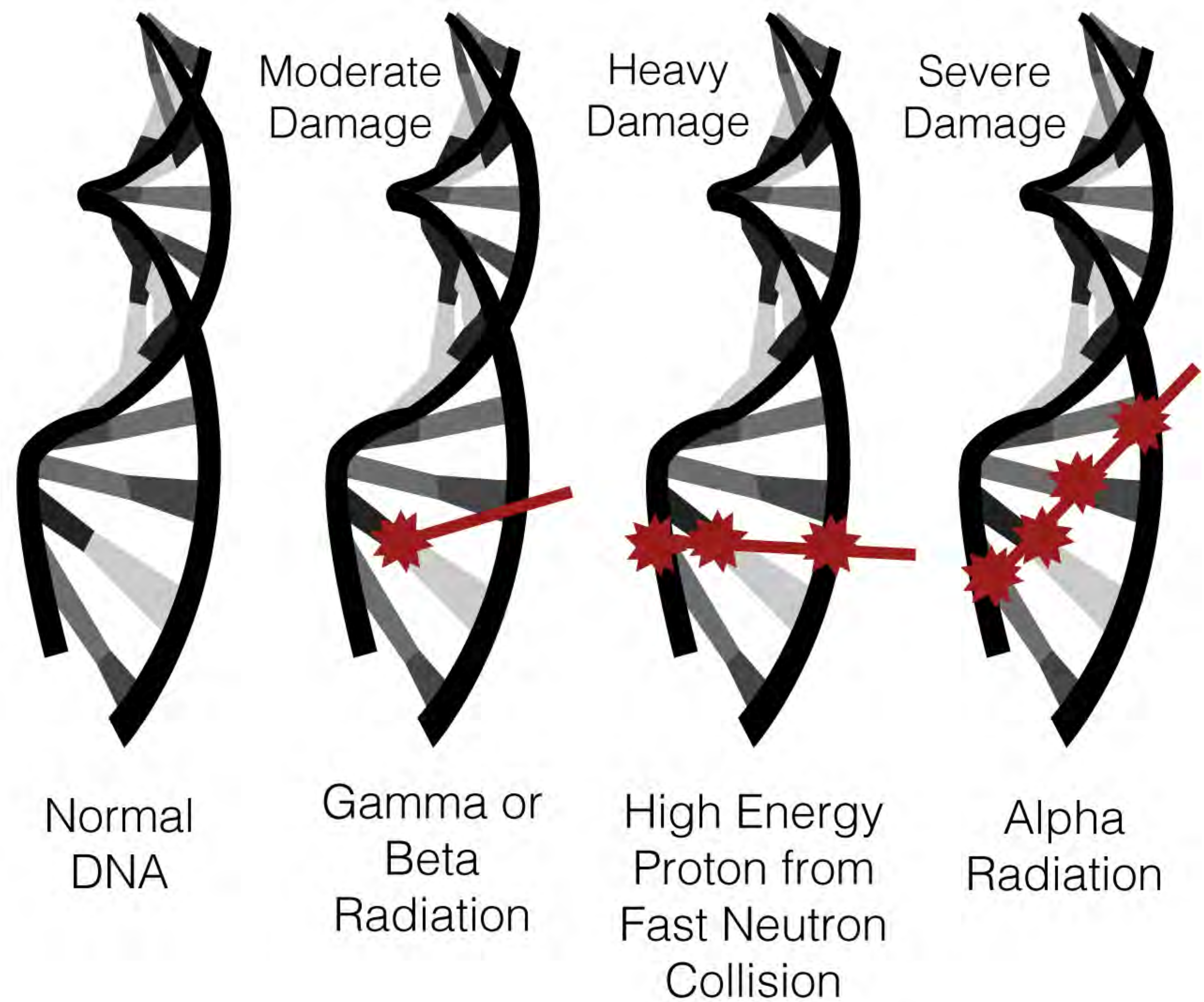
- Deoxyribonucleic acid (DNA) is a molecule that carries the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms

Radiation Damage to DNA

- Radiation can damage a cell's DNA – it can cause:
    - Single and double strand breaks
    - Deletions of parts of the genome
    - Damage to the basic DNA building blocks or direct DNA damage
- Some of this damage is unique to radiation exposure
- The body's natural defenses can repair most of this cellular and DNA damage
- However, repair mechanisms are not always perfect
- Most result in eventual cell death but some can cause a cell to become cancerous

Understanding Radiation and Health Impacts

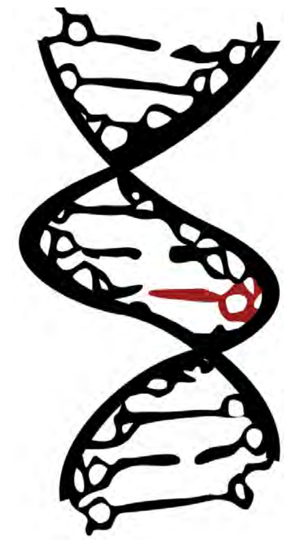
Radiation Damage to DNA



Understanding Radiation and Health Impacts

DNA Damage

- Some scientific evidence says that a single cell DNA mutation can lead to cancer – although this is very, very unlikely to happen
- DNA damage is caused by many other sources other than ionizing radiation
- National Institute of Health: “Our DNA suffers millions of damaging events each day.”

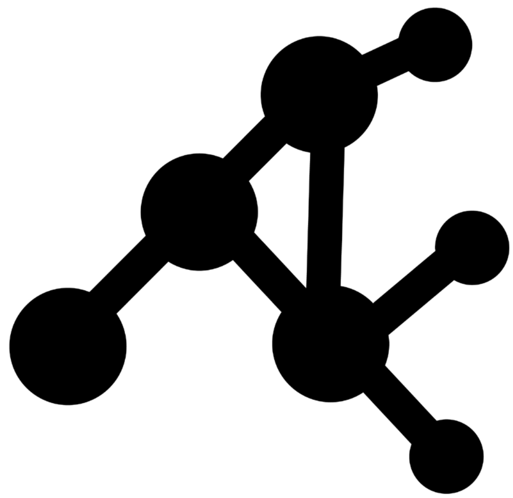


Biological Effects

- There are two types of biological effects caused by ionizing radiation:
    - **Deterministic effects:** immediate physical damage affecting biological function
    - **Stochastic effects:** increased chance of cancer at some future date

Understanding Radiation and Health Impacts

Deterministic Effects



- Deterministic effects are medical symptoms that occur only when a certain radiation dose level has passed
- Radiation sickness is a deterministic effect – which means that a certain dose of radiation must be reached before this symptom will happen
- Radiation doses below 100 mGy are not expected to show any deterministic effects
- The radiation levels we are exposed to, either from background or the nuclear facilities at the Bruce site, are well below the threshold for any deterministic effects

Understanding Radiation and Health Impacts

Deterministic Effects

Deterministic Health Effect	Dose Equivalent	Time to Onset (with no treatment)
No direct health implications	1 mSv (public annual dose limit from nuclear facilities)	
No direct health implications	6.2 mSv (annual average background radiation dose)	
Maximum permitted annual dose for a Canadian nuclear worker	50 mSv per year (100 mSv over any 5 years)	
Reduced red and white blood cells	250 – 1000 mSv *	
Nausea, vomiting, mild radiation sickness	500 – 1000 mSv *	Hours to days
Severe radiation sickness (50% chance of death without medical treatment)	4000 mSv *	a few weeks to a few months
Destruction of intestinal lining, internal bleeding, leading to death	10,000 mSv *	1-2 weeks
Central Nervous System damage, loss of consciousness, death	20,000 mSv *	hours

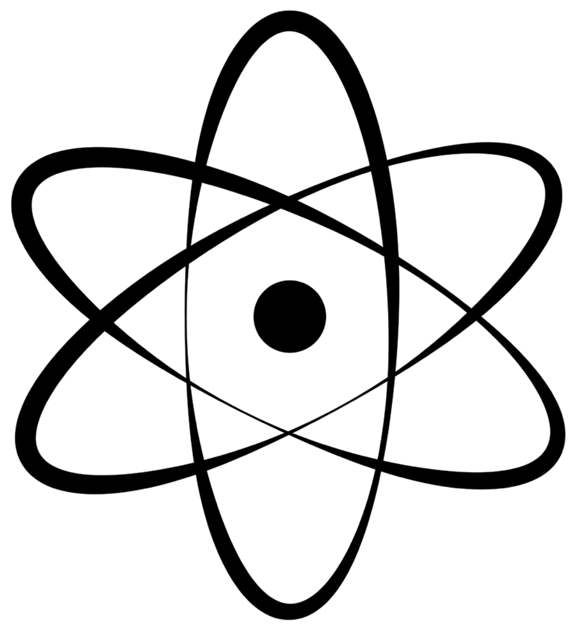
Understanding Radiation and Health Impacts

Stochastic Effects

- Stochastic effects are those with a probability of occurrence
- Examples include malignant disease (cancers) and heritable effects
- Probability of occurrence increases as the radiation exposure does
- This implies that any radiation exposure carries potential risk
- This is true even for natural background radiation exposure as well
- A certain dose of radiation may not cause a deterministic effect, but still carries a risk of stochastic effect – for instance, an increased risk of cancer in the future

Radiation and Cancer

- Radiation causes biological damage at the cellular level and can cause cancer
- However, cancer can be caused by many different environmental and biological functions



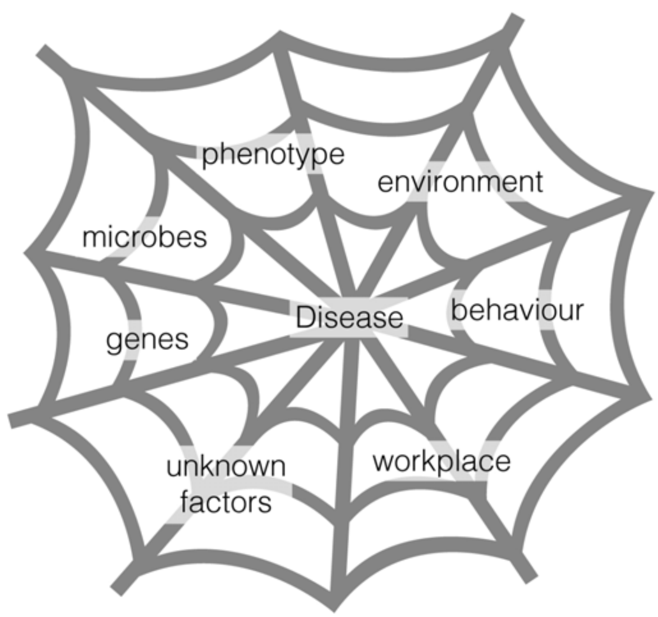
Understanding Radiation and Health Impacts

Did radiation exposure cause the cancer?

- No way of knowing the cause of a particular cancer; the exception to this is rare cancers where the only possible cause is radiation
- We can calculate the probability that a particular type of cancer might be caused by radiation exposure
- Some organs are more sensitive to radiation than others
    - If a person receives a relatively high dose of radiation to the organ that developed the cancer then it's more likely that the cancer was caused by radiation

Probability of Causation

- Probability of Causation (PC): the likelihood that a particular cancer might have been caused by a given exposure to radiation
- It takes into consideration the radiation dose received (in the specific organ), the radiosensitivity of the organ, and the normal, expected, incident of cancer for the organ, considering the person's age
- It is not proof that the radiation caused the cancer, but an expression of the probability



Web of Causation

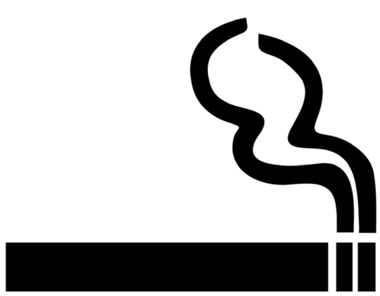
Understanding Radiation and Health Impacts

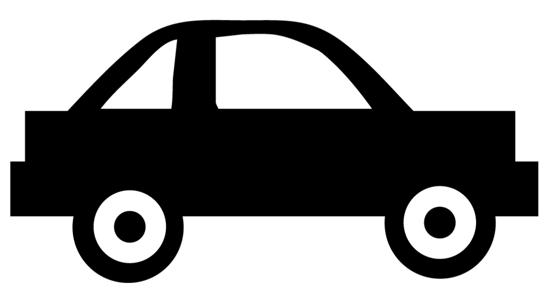
Occurrence of Cancer and Genetic Effects

Effect	Natural Occurrence	With 1 mSv of Whole Body Radiation
Cancer Cases (solid & leukemia)	2,500 in 10,000	1 in 20,000
Genetic Effects	1,000 in 10,000	1 in 10,000

Comparing Risks

- Examples of typical risks of an early fatality
    - Smoking (lifetime): 1:4
    - Agriculture industry (per year): 1:2600
    - Vehicle accident (per year): 1:6000
    - Falls (per year): 1:20,000
    - Home fire (per year): 1:50,000
    - Airplane crash (one trip): 1:1,000,000





Understanding Radiation and Health Impacts

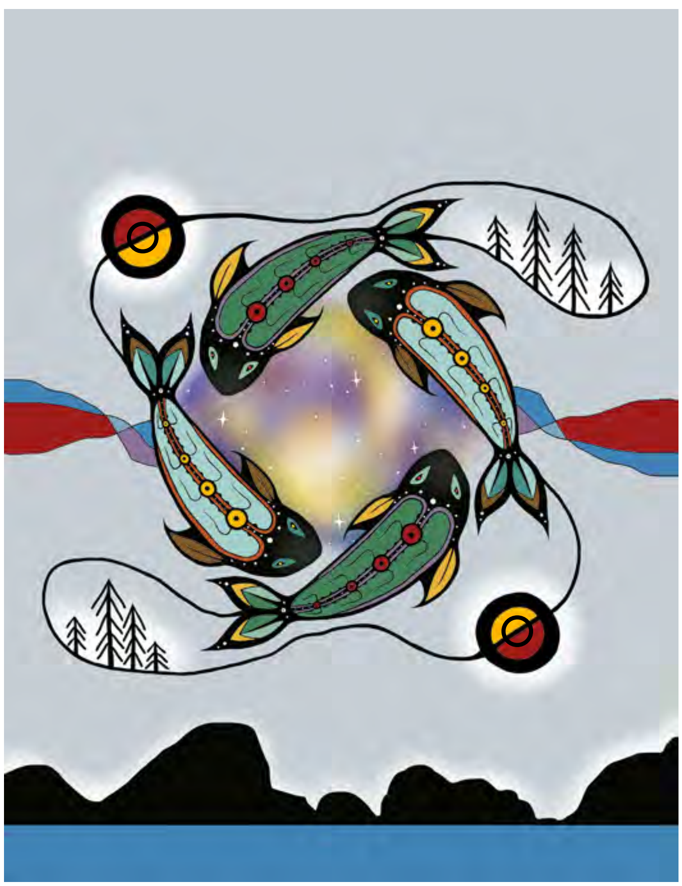
Incidence of Cancer Around Ontario Nuclear Generating Stations

- CNSC completed a study to determine radiation doses to those living within 25 km of the Pickering, Darlington, and Bruce Nuclear Generating Stations
- It compared cancer cases with the general population of Ontario from 1990 to 2008
- There is no consistent pattern of cancer across the populations living near the three facilities studied
- Some types of cancer in the communities were higher than expected (excess cancer) and some were lower than expected

Summary

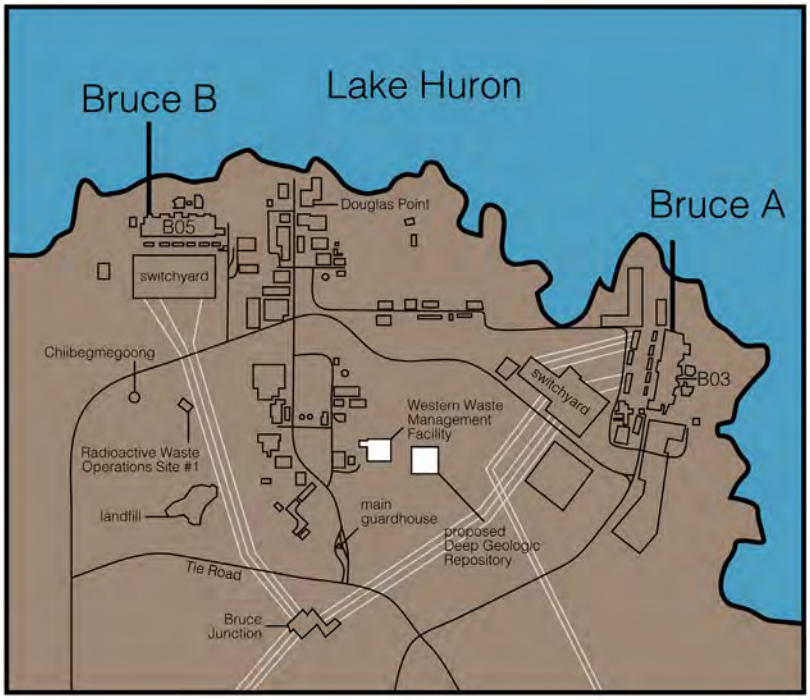
- We are exposed to ionizing radiation every day as part of our natural environment
- Can radiation cause cancer? The answer is yes
- The chances of getting cancer is low at the natural background levels
- Overall risks are low compared with typical risks encountered in every day life
- Accidents are a different issue and concern

Radiation from the Bruce Site



Radiation from the Bruce Site

Map of Bruce Site



Western Waste Management Facility

Radiation from the Bruce Site

Bruce Power and CNSC

What is Bruce Power?

A private corporation that owns and operates the Bruce Nuclear Generating Station.

What is the Canadian Nuclear Safety Commission?

The federal regulator for the generation and use of nuclear energy and materials. They are mandated to protect human and environmental health.

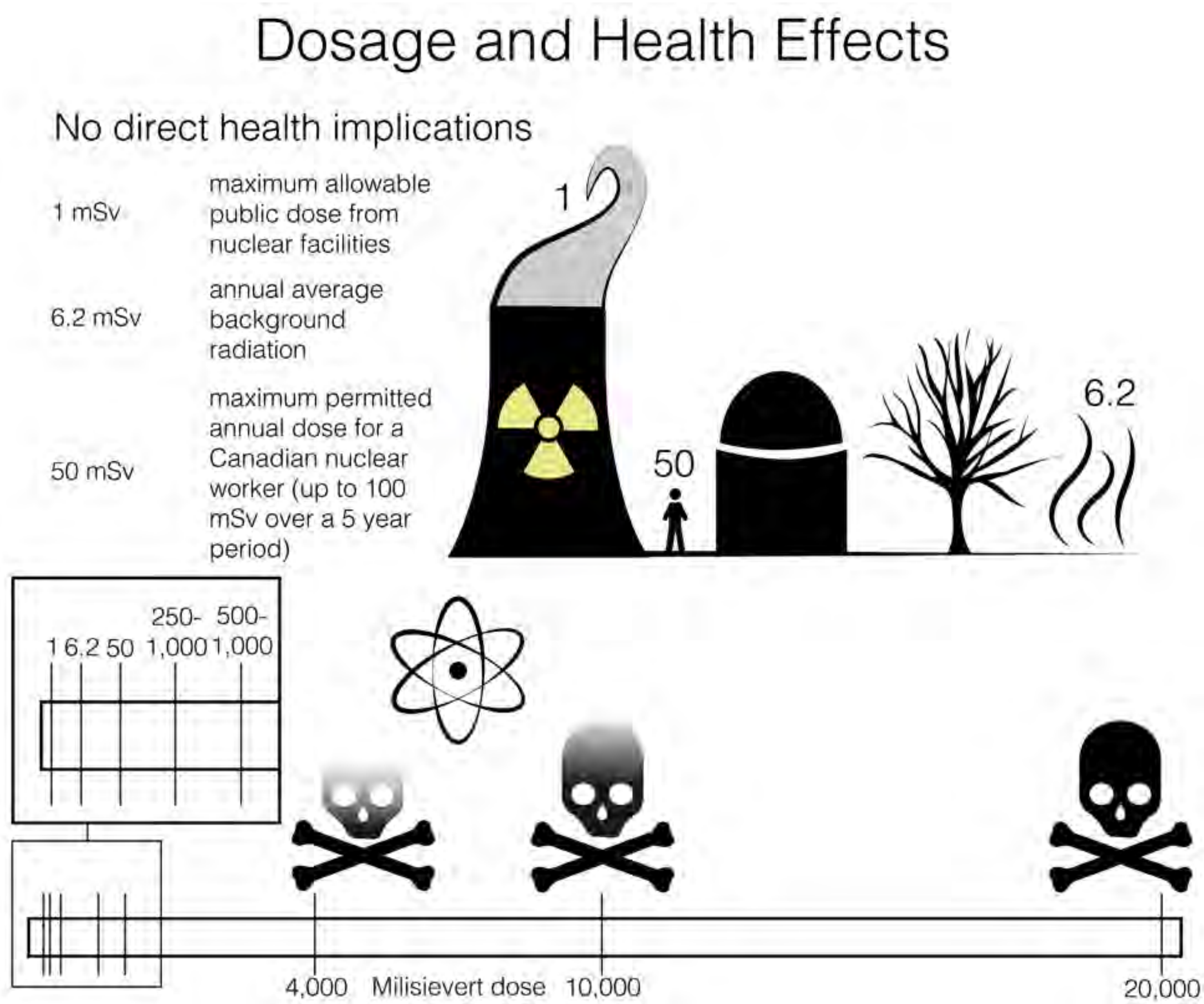
Regulatory Limits to Radiation Exposure

- There are limits to the allowable release of radioactive materials and radiation exposure from the BNGS and WWMF
- CNSC follows the guidance and recommendations of the International Commission on Radiological Protection (ICRP)

Radiation from the Bruce Site

Radiation Dose Limit

- The limit on radiation exposures to public from all nuclear facilities is 1 mSv per year
- This is less than radiation exposure received from natural background radiation



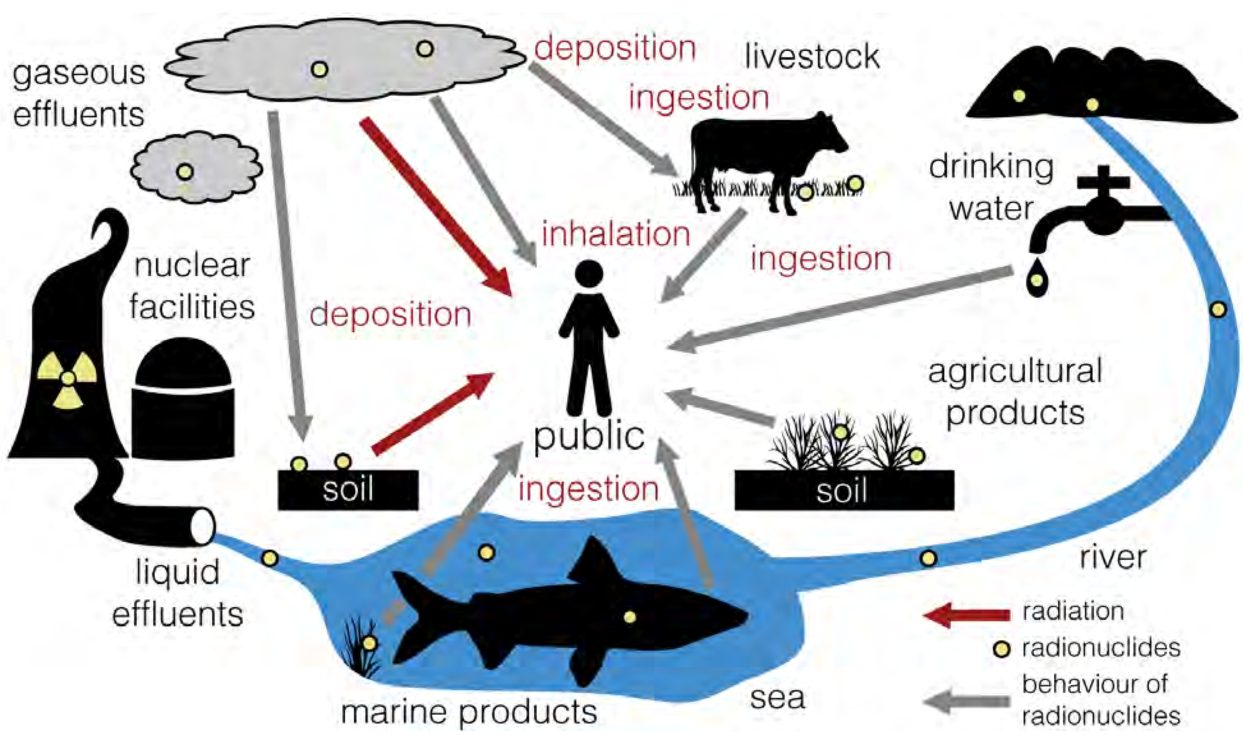
Radiation from the Bruce Site

Radiation from Facilities at the Bruce Site

- Over the years, the facilities at the Bruce site have released radioactive materials into the air and lake; this happens on a routine basis and is part of the generating station's normal operations
- Releases are controlled and monitored by Bruce Power to stay within the annual dose limit
- CNSC performs reviews and inspections to verify this data

Environmental Monitoring

- Environmental monitoring is conducted by Bruce Power and CNSC on the Bruce site and the surrounding communities
- They sample foods, fish, water, and soils from the surrounding areas and analyze these samples for radionuclides of concern



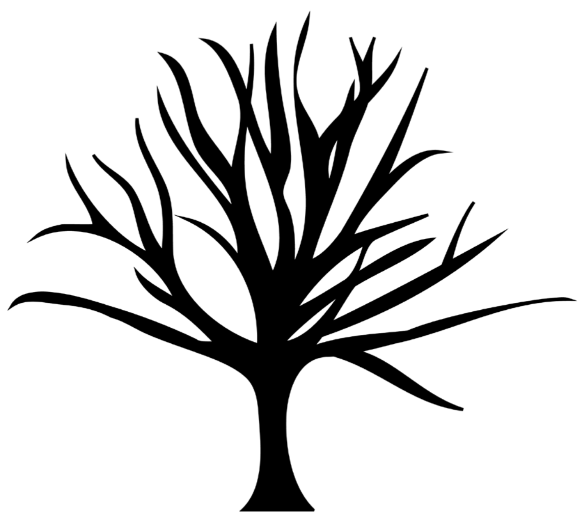
Radiation from the Bruce Site

Purpose of Environmental Monitoring

- Sampling the environment is a way of confirming that radioactive releases from the plant are appropriately controlled
- Provides for an assessment of any long-term build-up of radioactive materials in the environment

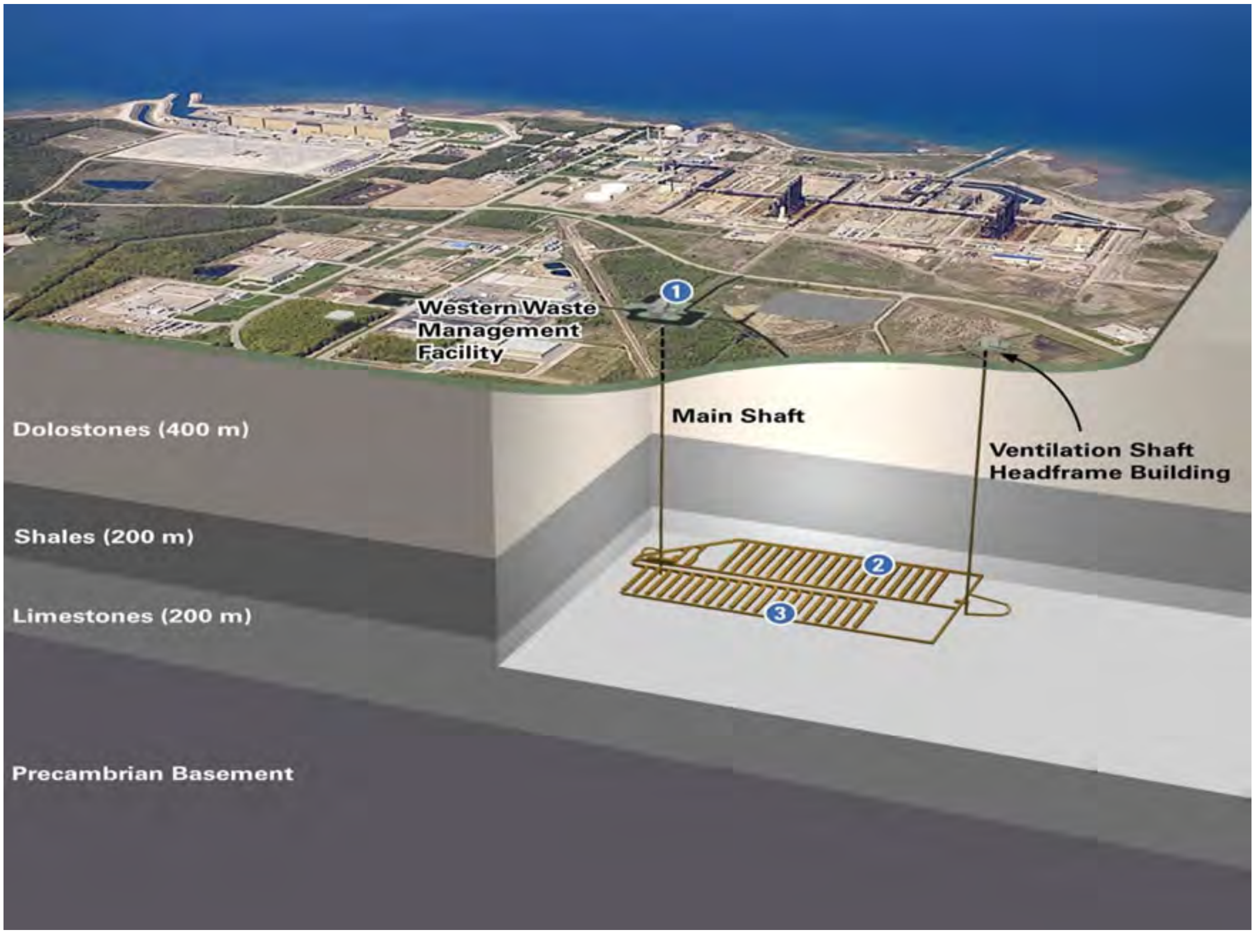
Is this hurting the environment?

- Releases from the Bruce site and WWMF cause very small increase in radiation levels in the environment
- Results from environmental monitoring shows that there are detectable increases in tritium and carbon-14 in water samples
- Levels are not significantly above natural background levels
- It represents small increases in the risks that can be associated with our natural background radiation exposure
- There is no observable increase in health effects or harm to the environment



Radiation from the Bruce Site

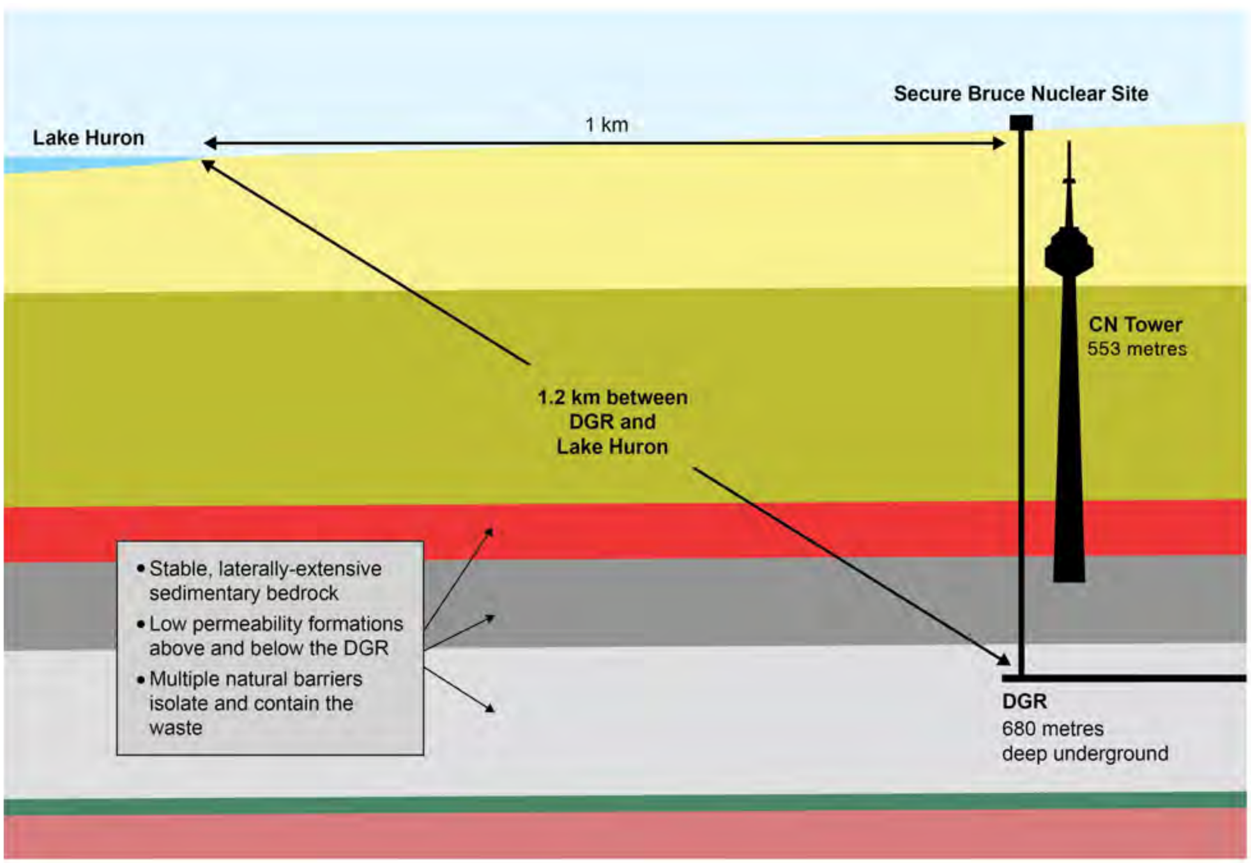
Proposed DGR at the Bruce Site



Radiation from the Bruce Site

Radiation and the DGR

- OPG has proposed a DGR for low- and intermediate-level waste in Anishnaabekiing
- Proposal is to dispose radioactive waste deep underground in a stable rock formation
- Their thinking is that radioactive waste would remain fixed and isolated from biosphere (the land, air, and water)

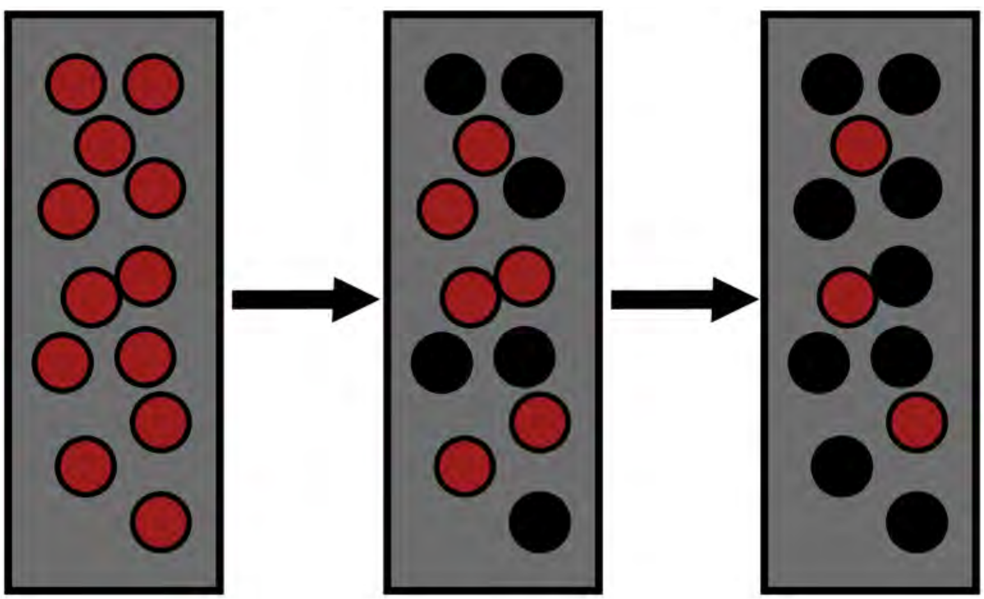


Radiation from the Bruce Site

What is half-life?

- Materials that are radioactive will decay - which means they become less and less radioactive as time passes
- Half-life is a way to measure the decay process
- Radioactive decay is a random process for any single atom
    - The more likely an atom is to decay, the shorter the half-life
    - The time it takes for ½ of the radioactive atoms to decay is its half-life

Radioactive Half-Life



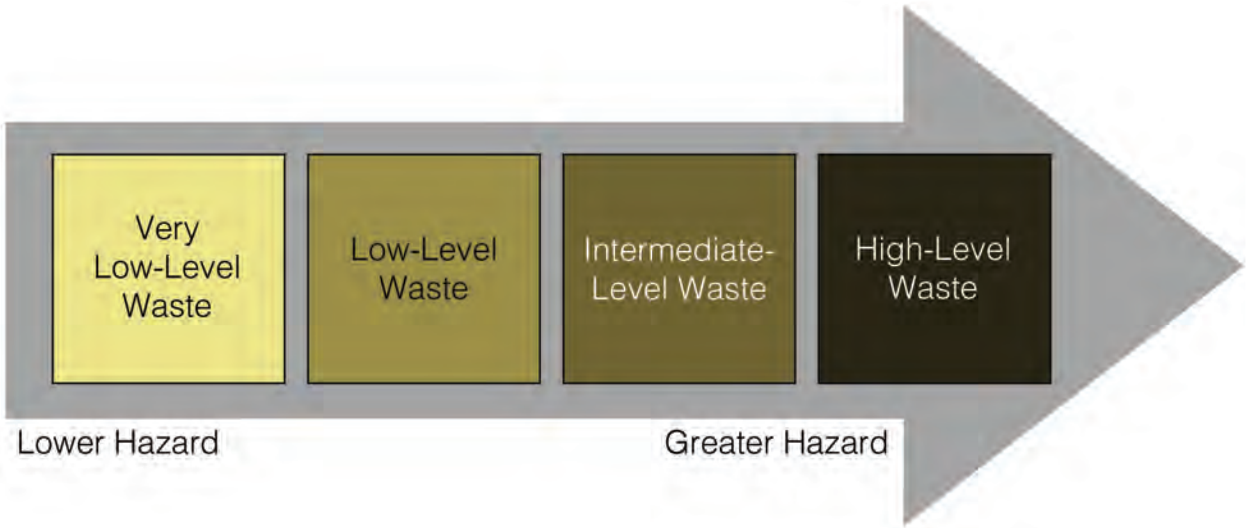
50% red (radioactive) atoms remain after one half-life

25% (half of a half) red atoms remain after two half-lives

Radiation from the Bruce Site

Classifications of Radioactive Waste

- IAEA recognizes four classifications of radioactive waste



Low-Level Waste

- Requires isolation and containment for 100-300 years
- Relatively low amounts of radioactivity
- Not a significant long-term hazard
- Shielding is generally not required
- It can include:
    - Contaminated tools, equipment and components
    - General trash (rags, clothing, mops)
    - Medical waste
    - Bulk material, such as concrete, soil or rubble

Radiation from the Bruce Site

Intermediate-Level Waste

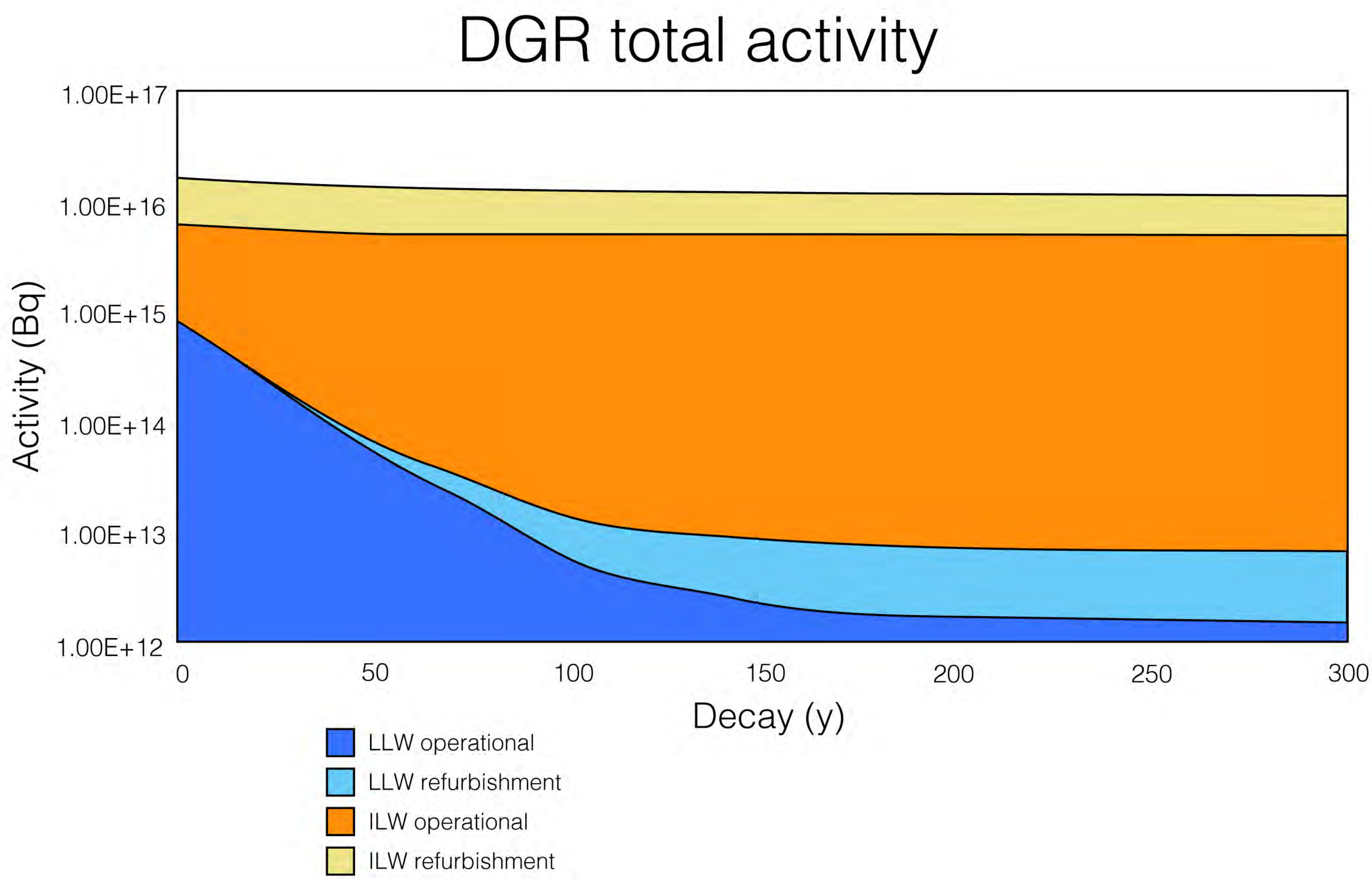
- Requires isolation and containment for up to 100,000 years
- Contains higher amounts of radioactivity
- Generally requires shielding for personnel protection
- Typically includes:
    - Primary system resins and filters
    - Irradiated components

Half-life of DGR Radionuclides

- Cesium-137 (Cs-137)
    - A long-lived radionuclide with a 30-year half-life
    - Major radionuclide in reactor waste
    - In 300 years (or 10 half-lives), only one one-thousandth (1/1000th) of the initial amount still radioactive
- Carbon-14 (C-14)
    - A very-long-lived radionuclide with a 5730 year half-life
    - It will remain radioactive for more than 10,000 years

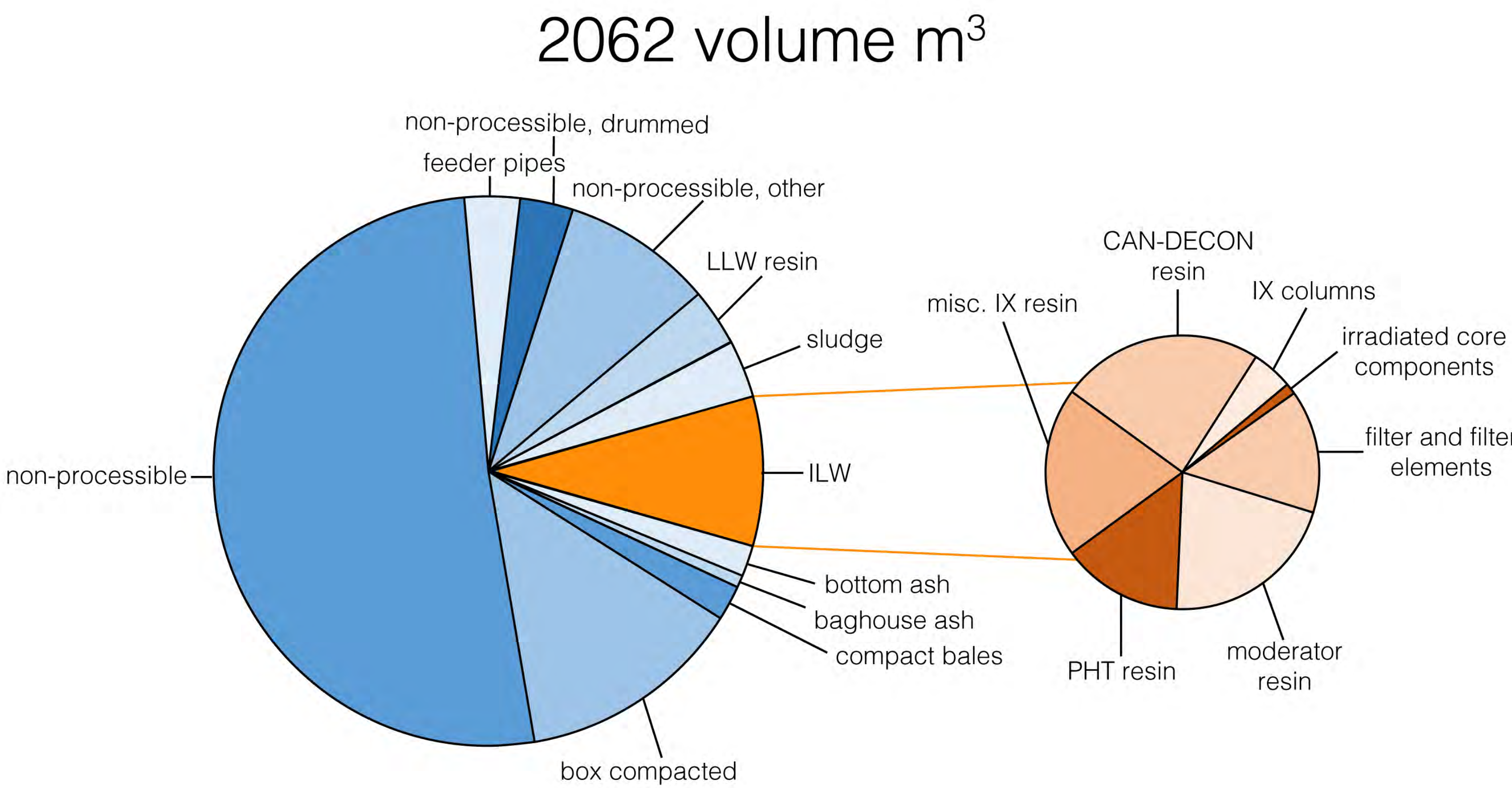
Radiation from the Bruce Site

Radioactivity in the Proposed DGR



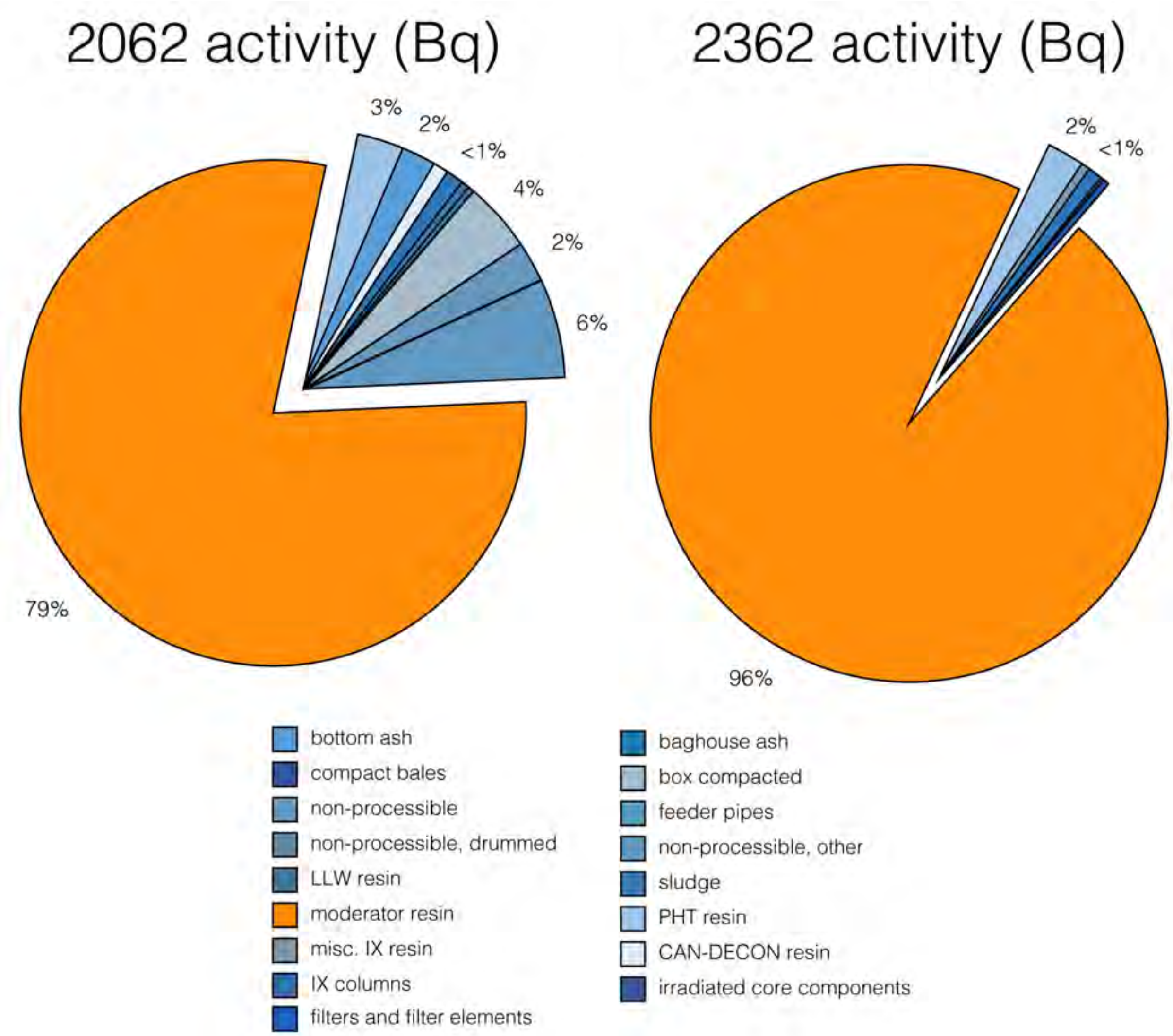
Radiation from the Bruce Site

Waste Volume in the Proposed DGR



Radiation from the Bruce Site

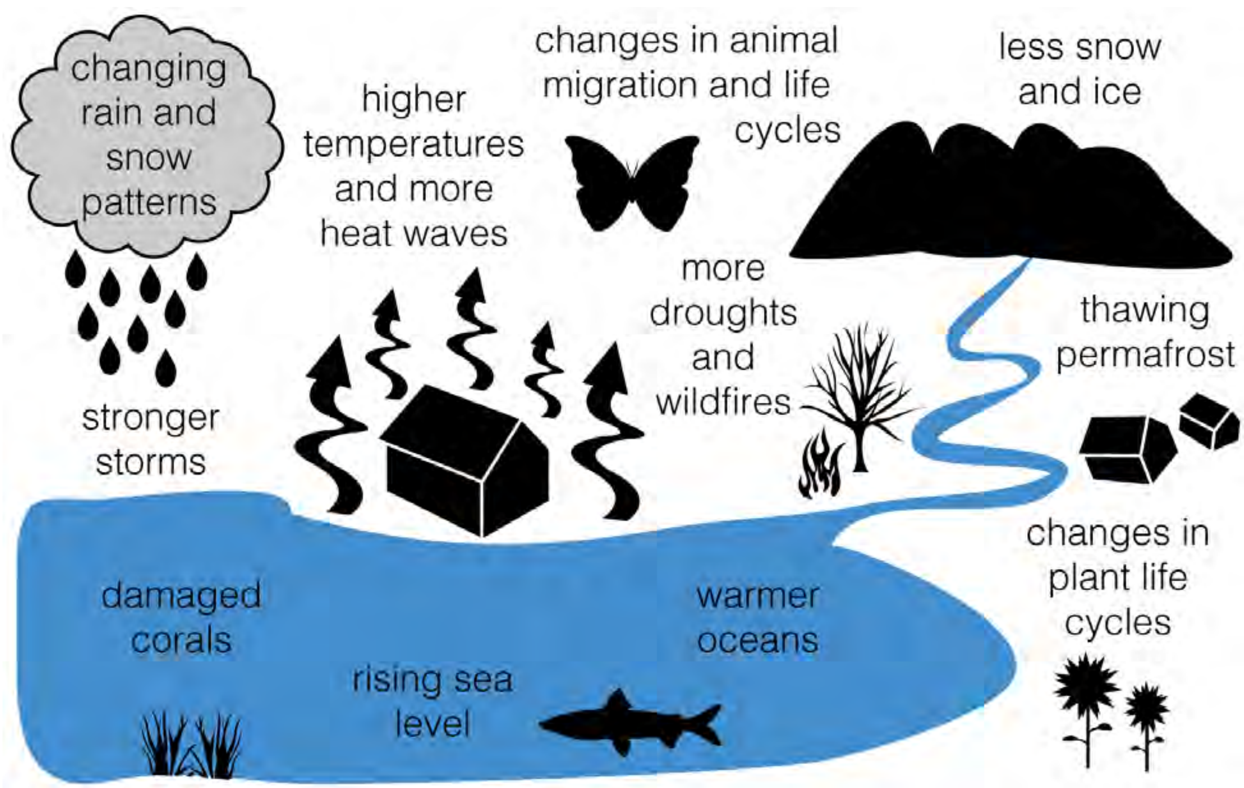
Radioactivity in the Proposed DGR



Radiation from the Bruce Site

OPG's Modelling of the Proposed DGR

- OPG has done modeling of the environment and studies of the geology in the region
- Variations and uncertainties in the data are looked at
- The results are intended to represent many possible outcomes
- These assessments rely on many pieces of information that are used to construct the model



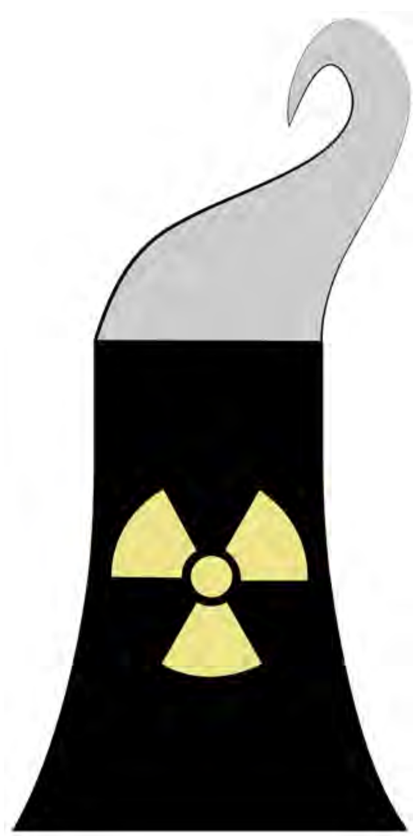
Radiation from the Bruce Site

What do OPG's assessments and models say?

- OPG has concluded that under **normal operations**, the potential radiation doses from the proposed DGR would be small compared to the limits
- Studies show that the groundwater in these rock formations is basically immobile (it only moves a few centimetres each year)
- If the waste **were** to migrate to the surface biosphere, the radioactivity levels would have already decayed to small fractions of the natural radioactivity in the soil and rocks
- Considering reasonable variations (uncertainties) in the modeling assumptions, projected levels still remain below limits

Limited Information

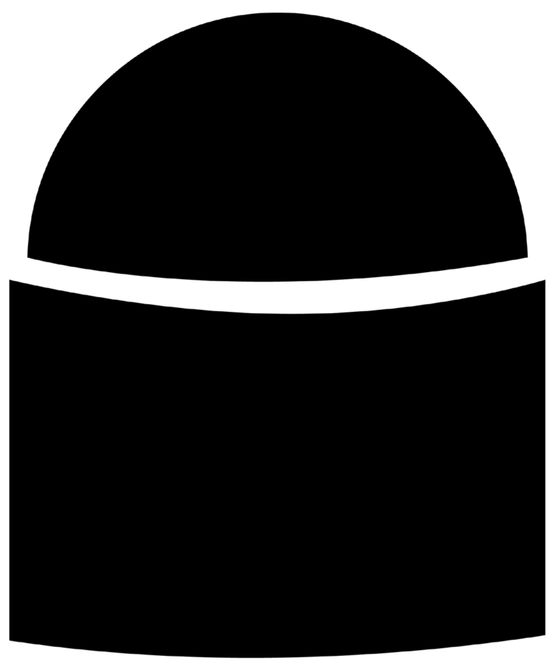
- Modeling assumptions were based on limited site data
    - Characterization based on a few boreholes for specific geology coupled with more general geological studies of the surrounding area formations
- Only during site excavation would details of the geology be available
- At this time, assumptions can be corrected to improve the accuracy of the model
- If the geology is significantly different – cause for unacceptable site



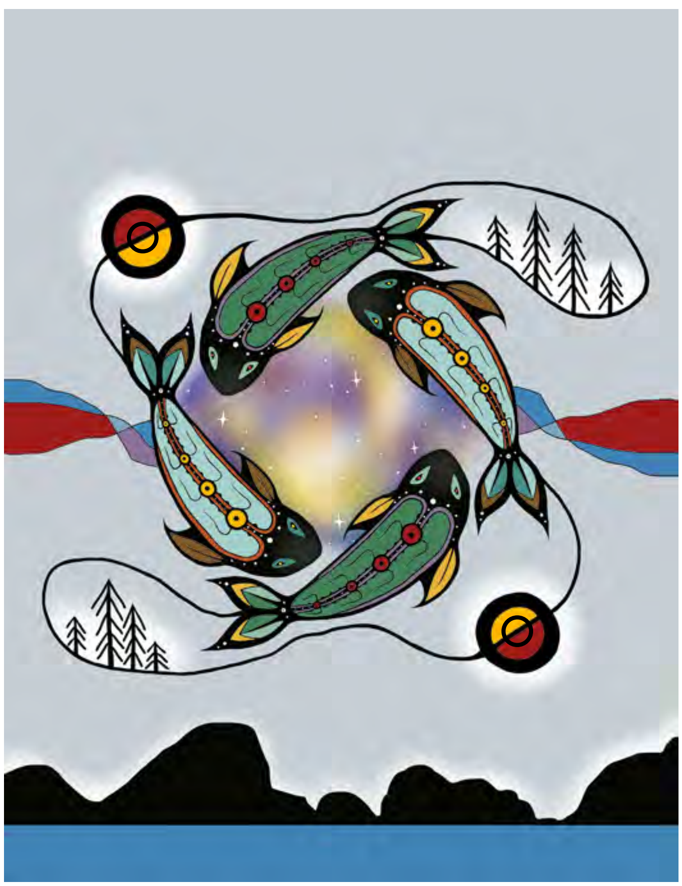
Radiation from the Bruce Site

Can there be a safe level of assurance considering the uncertainties?

- It is not possible to calculate exactly how the geologic formation will perform far into the future
- Precise modeling and prediction of the geological modeling is not always necessary
- What is needed is an adequate model that takes into consideration the unknowns, uncertainties and the what ifs



Nuclear Accidents and Emergency Response



Nuclear Accidents and Emergency Response

The What Ifs

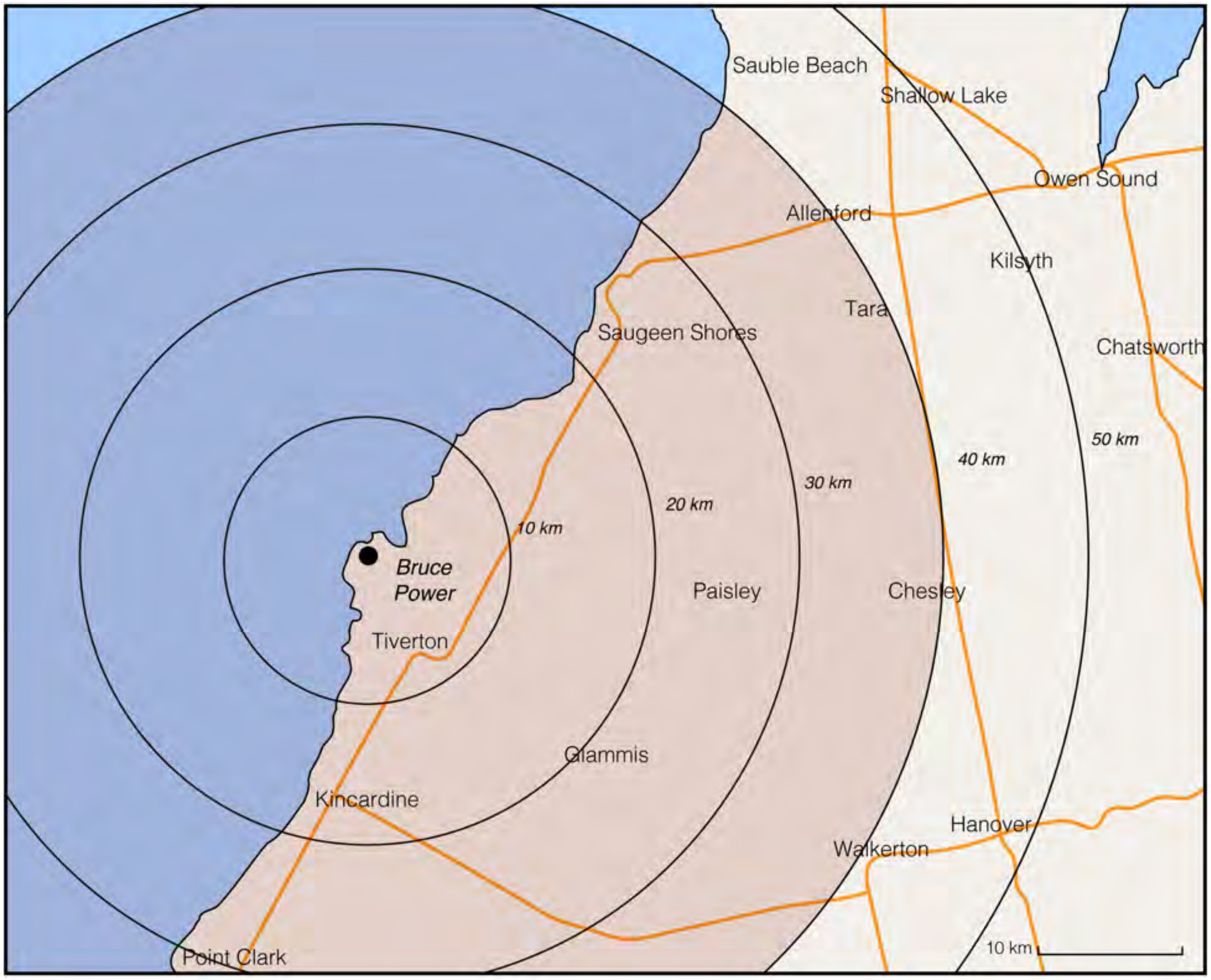
- Chernobyl and Fukushima show the devastating effects a nuclear generating station accident can have on people and the environment
- If the BNGS operates safely, it is assumed there will be no accidents and no release of radioactivity that contaminates the land and water
- If the geology for the proposed DGR is tight, it is assumed it would contain the radioactive waste for more than 10,000 years and there would be no release of radioactivity that contaminates the land and water
- However, accidents do happen and there are risks involved

Risks and Benefits

- In everyday life, there are benefits and associated risks
    - There is a benefit from electricity provided by the BNGS
    - The financial benefit is from employment and the associated economy (Kincardine and surrounding area)
    - There is a risk of radiation exposure
    - The risk of long-term environmental damage from a nuclear accident also exists
- Saugeen Ojibway Nation has been burdened with all of the risk but little to no benefits
- There can never be no potential for a nuclear accident

Nuclear Accidents and Emergency Response

Exclusion Zone Distances from the BNGS



Nuclear Accidents and Emergency Response

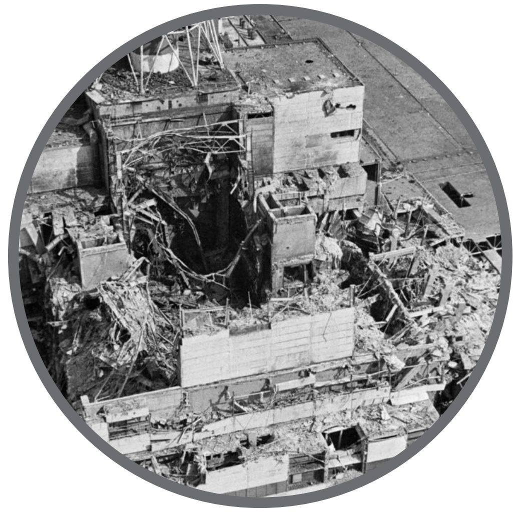
A Brief Perspective on Chernobyl and Fukushima

- The accidents at Chernobyl and Fukushima are real nuclear disasters
- Both caused catastrophic environmental damage
- Both were easily preventable
- Lessons have been learned to improve future designs and minimize or prevent future operational events

Chernobyl

Nuclear Accidents and Emergency Response

Chernobyl



- Occurred on April 26,1986
- The reactor design had unsafe operating characteristics
- While performing a systems test, a reactor went super critical, creating massive amounts of energy resulting in a steam explosion that blew the reactor apart
- There was no containment to prevent the release of massive amounts of radioactive material into the environment
- 30 workers died and hundreds of others had harmful radiation injuries
- 220,000 people had to be evacuated and relocated from the surrounding area
- The current Exclusion Zone covers an area of 2,600 km^2
- Roughly equal to the area from the Bruce site out to about 40 km, which would encompass Saugeen Shores and Kincardine with the outer reaches approaching Owen Sound

Nuclear Accidents and Emergency Response

Chernobyl

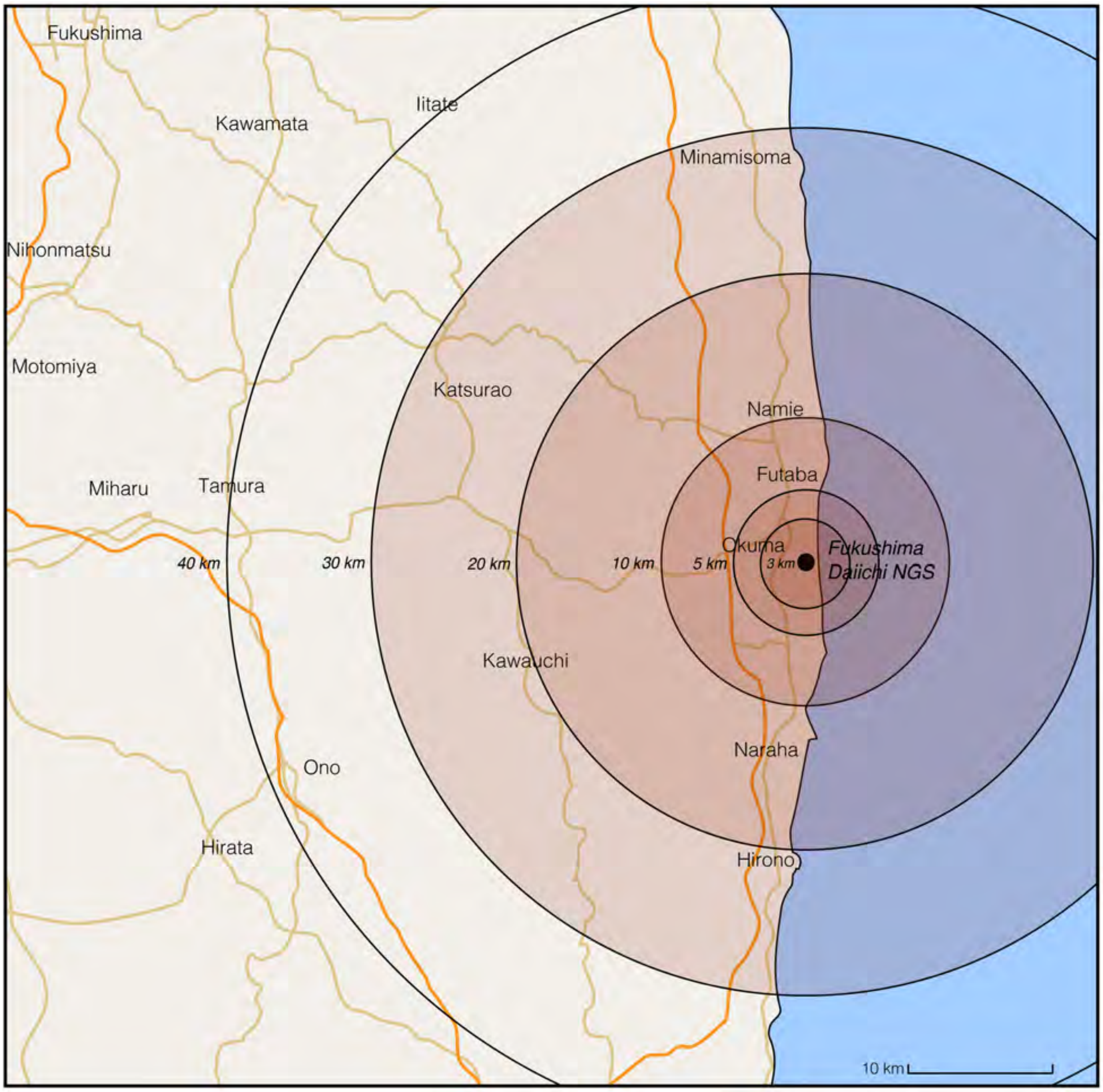
- Currently, 10 times the area of surrounding lands (30,000 km^2) have some restrictions on land use, particularly for agricultural purposes
- There have been observed increases in thyroid cancers among children who were exposed to higher levels of radiation from the accident, predominantly through the consumption of milk and vegetables from areas that had become contaminated
- There is no evidence of additional health effects
- Protective measures - including evacuation and stopping people from eating contaminated food - were slow in being initiated

Chernobyl – Effects on Flora and Fauna

- Flora and fauna in the immediate area felt devastating effects
- These were caused by exposure to radiation early in the accident (from releases to the atmosphere)
- Because of the radioactive contamination taken up by the animals and plants, they are not suitable for human use
- Over time, the flora and fauna recover, but there can be lingering effects

Nuclear Accidents and Emergency Response

Fukushima Daiichi Nuclear Power Plant



Nuclear Accidents and Emergency Response

Fukushima Daiichi Nuclear Power Plant

Nuclear Accidents and Emergency Response

Fukushima Daiichi Nuclear Power Plant

- On March 11, 2011, a tsunami was caused by an offshore earthquake
- The Fukushima Daiichi Nuclear Power Plant safely shutdown and the tsunami did not damage the plant
- However, some important safety systems were flooded
- The sea wall to protect against flooding was inadequately designed
- The Japanese regulators were aware of the issue with the sea wall height, yet did not force the utility to make the necessary improvements to the height of the sea wall

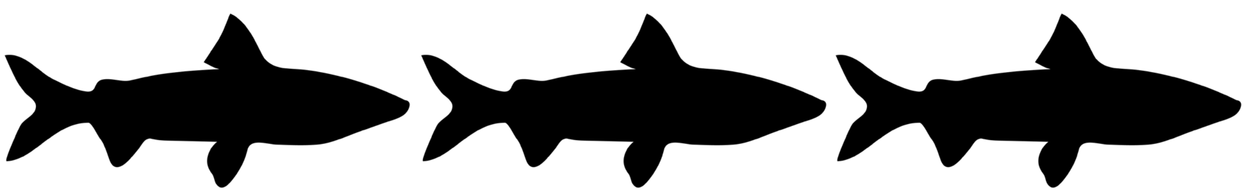
Fukushima

- Immediately after the accident, the government ordered residents in a 3 km radius of Fukushima to evacuate
- As the government became aware of the seriousness of the accident, the evacuation area was expanded to a 20 km radius from the plant
- Four days after, the government instructed residents living 20-30 km from the plant to stay inside their homes
- Initially, there were approximately 81,000 people evacuated

Nuclear Accidents and Emergency Response

Fukushima

- The initial releases dispersed over the Pacific Ocean and did not cause widespread radiation exposure to people or contamination of land
- Winds then shifted to the northwest; land in that direction was significantly contaminated by the radioactive plume
- Most lands in the other directions were spared significant radiation exposures and widespread contamination
- Elevated levels of radioactive materials in the ocean water and fish was detected



- Restrictions were placed on fishing, which caused additional issues for the local fishermen and economy
- Restrictions were also placed on food crops
- Six years after the accident and after much effort to decontaminate the lands and buildings, some 300 km^2 to the northwest (to a distance of 35 km from the site) remain restricted
- Restrictions on the harvesting of fish and invertebrates in the offshore water up to 10 km from the plant remain in place
- Restrictions continue to be lifted as land areas are decontaminated and ocean radiation levels decrease

Nuclear Accidents and Emergency Response

World Health Organization

- The World Health Organization concluded there were no acute radiation injuries or deaths among the workers or public
- The lifetime radiation-induced cancer risks other than thyroid cancer are small - they are much smaller than lifetime cancer risks
- A possibility for increased childhood thyroid cancer remains under study
- WHO: "Similar to what was observed and reported for the Chernobyl population, the displaced Fukushima population is suffering from psycho-social and mental health impact following relocation, ruptured social links of people who lost homes and employment, disconnected family ties and stigmatization."

An accident at the Bruce site?

- Chernobyl and Fukushima are examples of environmental catastrophes
    - They are examples of grossly inadequate, unsafe designs and negligent operations
    - They also show the failures of reactor designers, operators, and regulatory agencies who were to oversee and protect the public and environment
- The BNGS, WWMF, and the proposed DGR all contain significant quantities of radioactive materials
    - Each poses its own set of potential mishaps and accidents that could lead to varying degrees of radiation exposure and contamination of the surrounding land and water

Nuclear Accidents and Emergency Response

Bruce Nuclear Generating Station

- The BNGS reactors generate large amounts of energy
    - If an accident were to happen, thermodynamic forces at BNGS could widely disperse radioactive materials into the environment
- In abnormal operating conditions, the reactors are automatically shut down
- Safety systems ensure the reactor is cooled and in a safe shutdown condition
- Large amounts of radioactive decay heat still remain
- If the nuclear core is not cooled after shutdown, heat can build up and damage the fuel, or even melt it
- Cooling is required for months as the decay heat diminishes

Differences from Fukushima or Chernobyl

- There are differences in BNGS reactor design and operation that prevent Fukushima- or Chernobyl-type accidents
- Chernobyl did not have a containment to prevent a massive release of the radioactive materials directly into the environment
- BNGS has a reactor building which includes ruggedized containments enclosing the reactor and its components
- It also has a vacuum building which is maintained at negative pressure and designed to capture any radioactive releases during an accident

Nuclear Accidents and Emergency Response

No Such Thing as Zero Risk

- Even with the increase in safety design and operational measures, some low-level risks remain
- These risks and potential consequences are evaluated
- The likelihood of events is examined, along with the probability of system failures leading to fuel melt, containment failure and release of radioactivity into the environment

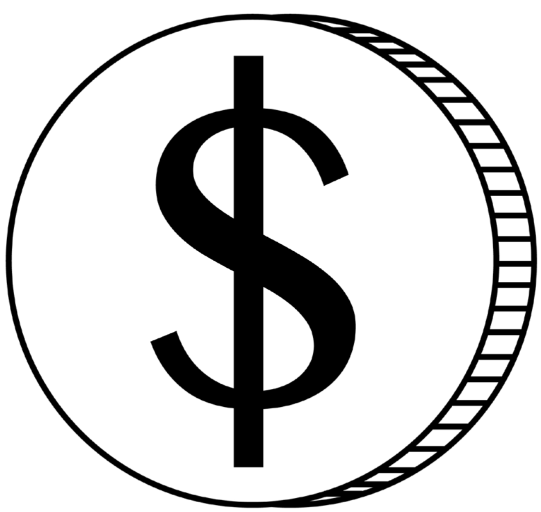
Probabilistic Risk Analysis

- An integrated safety analysis is performed for a nuclear generating station; it examines the:
    - Siting characteristics (ex. seismic events)
    - Design of safety systems
    - Probability of events leading to an accident
- The probabilistic risk analysis (PRA) gives an indication of the probability of events occurring, leading to major fuel damage (melt) and possibility of release into the environment under accident conditions

Nuclear Accidents and Emergency Response

What is the PRA for the BNGS?

- PRA calculated at a 1 in 120,000 likelihood per year of a severe accident at a single Bruce reactor leading to environmental contamination and evacuation of surrounding areas
    - Flipping a coin, this represents flipping heads 17 times in a row
- For all eight reactors in a 60 year operating life, the cumulative PRA is 1 in 625
    - This probability is a little better than flipping heads nine times in a row
- Emergency response measures are put in place to prevent or limit the actual doses to people, and to theoretically keep doses within the allowable limits



Nuclear Accidents and Emergency Response

Probabilistic Risk Analysis

Cause of death	One-year odds	Lifetime odds
All motor vehicle accidents	8,938	113
Car occupants	47,718	606
Motorcycle riders	74,735	948
Exposure to smoke, fire and flames	114,539	1,454
Fall on and from stairs and steps	141,571	1,797
Drowning and submersion while in or falling into swimming pool	485,605	6,162
Fall on and from ladder or scaffolding	752,688	9,552
Air and space transport accidents	767,303	9,737
Cataclysmic storm (hurricanes, tornadoes, blizzards, dust storms and other cataclysmic storms)	5,017,918	63,679
Flood	7,526,877	95,519
Bitten or struck by dog	9,032,253	114,622
Earthquake and other earth movements	9,297,907	117,994
Lightning	13,744,732	174,426

Nuclear Accidents and Emergency Response

Potential Accidents for the WWMF

- A large amount of radioactive waste is being stored at the WWMF
- It does not have the thermodynamic force to widely disperse the radioactive materials into the environment
- Two general types of accidents: a fire and waste container failures
- As evaluated by OPG, none of the given scenarios result in public exposure over the regulatory limit
- None are expected to cause offsite contamination or radiation dose concerns

Potential Accidents for the DGR

- Similar to the WWMF, the proposed DGR does not have thermodynamic forces that could widely disperse radioactive materials into the environment
- Accidents could occur during operation but with limited dispersion of radioactive materials outside the immediate area
- Some localized land contamination could occur and clean-up would be required
- Accidents that are of concern for the proposed DGR are mainly associated with human intrusion or failure of barriers

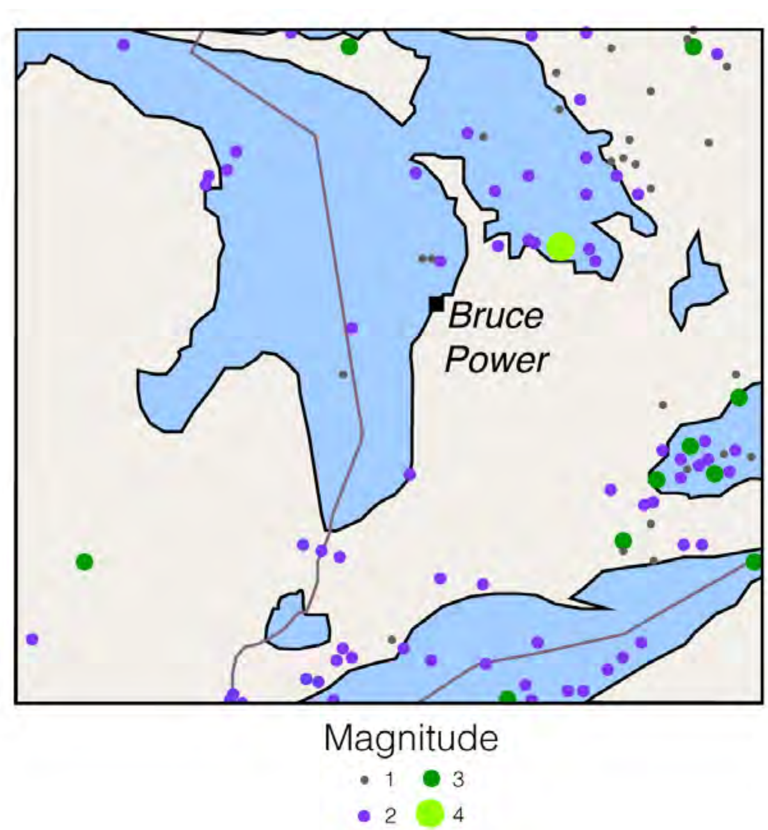
Nuclear Accidents and Emergency Response

Seismic Safety for the BNGS and DGR

- Earthquakes pose a special challenge for nuclear facilities
- A site with nearby active faults is generally unacceptable for nuclear facilities
- Detailed examinations of the surrounding geology, faults, and historical records of seismic activity have been completed

Earthquakes

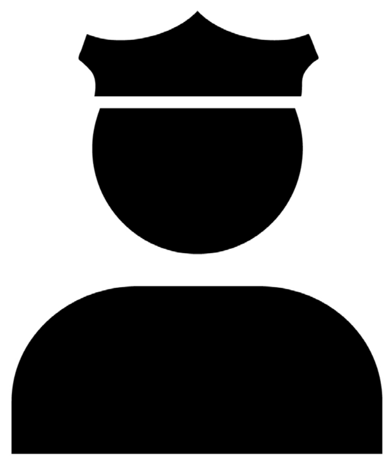
- An average of 1,500 earthquakes occur each year in Canada
- Only about 100 of these above three on the Richter scale (or are strong enough to be felt by humans)
- There are no modern day records of damaging earthquakes within several hundred kms of the Bruce site
- The area is considered to be tectonically stable with low rates of seismicity



Nuclear Accidents and Emergency Response

Emergency Preparedness and Response

- Being prepared is an important part of responding to and protecting against any type of emergency
- Plant operators have the primary responsibility for controlling and mitigating damage to the generating station
- Also, they have to notify offsite stakeholders and organizations
- Offsite organizations have the primary responsibility to take action in the surrounding communities
- Preparedness and response involve many players, including federal and local agencies and community services (ex. fire stations, hospitals, and transportation sectors)

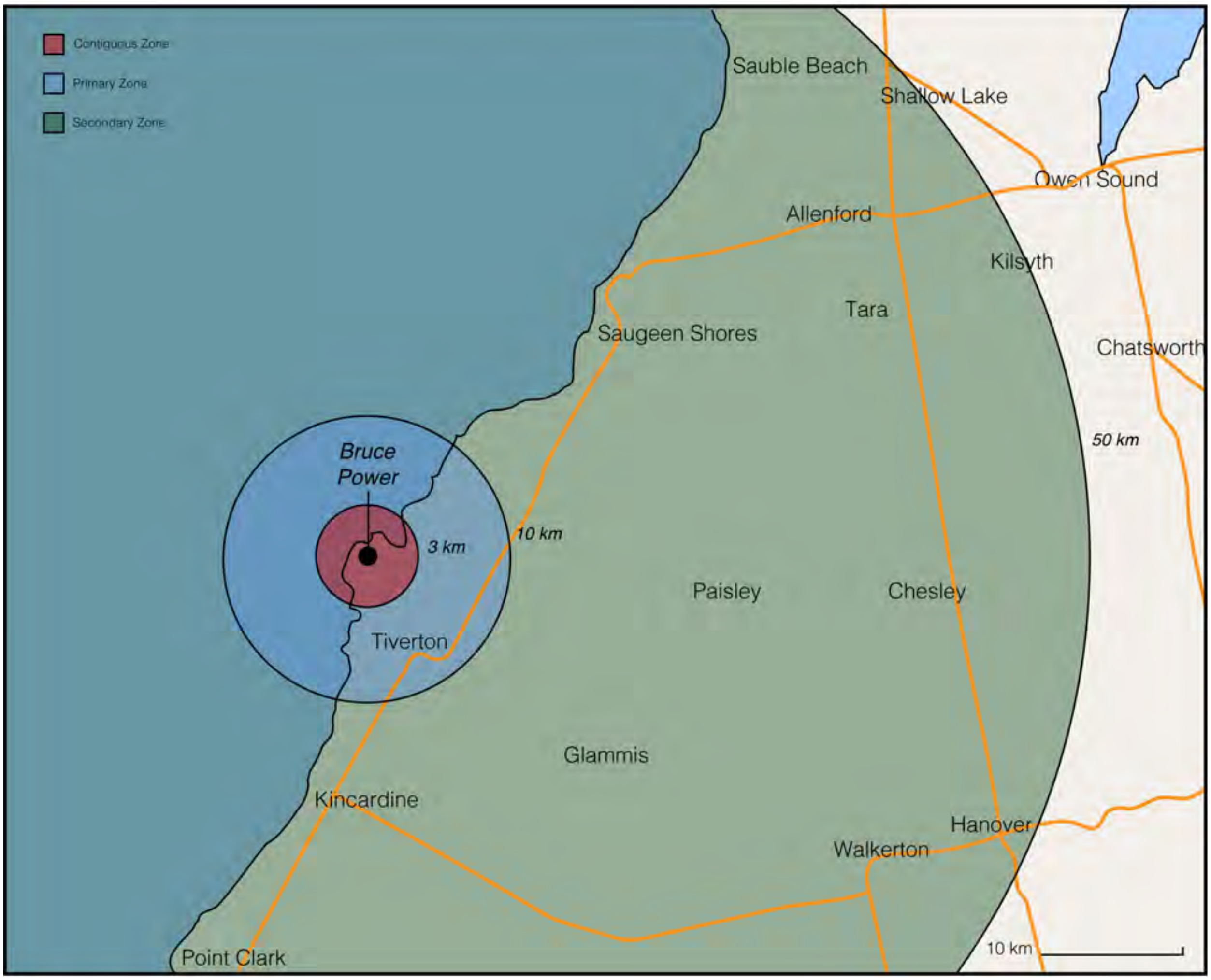


Emergency Planning Zones

- Contiguous Zone extends 3 km from the generating station. It requires the ability to alert the population at any time
- Primary Zone extends 10 km from the station. Potassium iodide pills to block uptake of radioactive iodines must be available
- Secondary Zone extends from 10 km to 50 km. Radiation monitoring and education of residents and agricultural producers is required, however, evacuation is not anticipated or planned

Nuclear Accidents and Emergency Response

Emergency Planning Zones



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Potassium Iodide for Thyroid Protection

- Potassium iodide (KI) taken before or shortly after exposure to radioactive iodine can limit the radiation dose to the thyroid
- Radioactive iodine poses an exposure risk, especially for infants and children, where breathing contaminated air or eating contaminated food or milk could result in significant doses to the thyroid
- Care must be taken to prevent allergic reactions to KI
- This is not an issue for the WWMF or DGR as these radioiodines have decayed to stable elements

Summary

- BNGS has emergency response protocols and is primarily responsible for safety and control of the Bruce site and to notify offsite stakeholders
- Local and provincial authorities are engaged and have the responsibility to protect people