Physics

2024

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Generating Electricity: Nuclear Energy

Nuclear energy provides about 15% of Canada's electricity. As of 2023, Canada has 19 nuclear reactors. 18 are in Ontario. One is in New Brunswick.

So how does nuclear energy generate electricity? Let's find out.

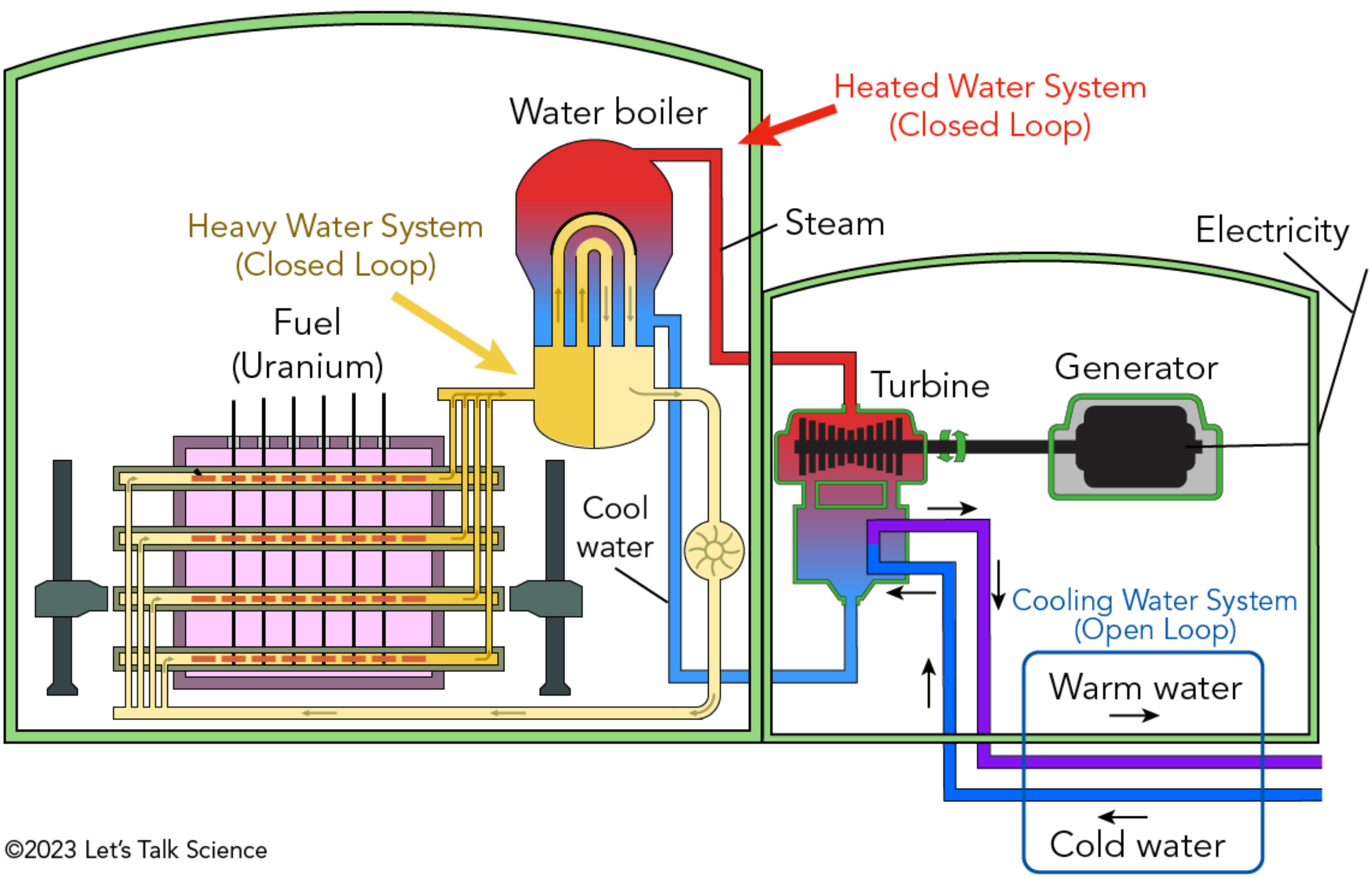
People often use **thermal energy** to generate electricity. Thermal energy is another name for "heat energy." Thermal energy heats water. The heated water forms steam. This steam powers an electricity generator. In many places, including Canada, people burn fossil fuels to get this heat. Some examples of fossil fuels are:

- coal
- oil (petroleum)
- natural gases

Nuclear reactors also use heat to generate electricity. But nuclear power plants don't burn fossil fuels for heat. Instead, they use **uranium** for fuel. Uranium is a chemical element. It gives off energy naturally. A lot of uranium in Canada comes from the Athabasca Basin. That is a region in Northern Saskatchewan.

In nuclear reactors, uranium atoms are split apart through a process called **fission**. When many atoms split at the same time, there is a huge release of energy. This energy is released in the form of heat. The heat energy warms **heavy water** in a closed loop of pipes. Heavy water is water that uses an **isotope** of hydrogen called **deuterium (D_2O)** instead of regular hydrogen atoms (H_2O).

The heavy water heats normal water in a second closed loop of pipes.



The parts and systems in a nuclear power plant (Let's Talk Science using an image by Inductiveload [CC BY-SA 2.5] via Wikimedia Commons).

This boiled water forms steam. The steam flows to a **turbine**. The turbine is connected to a **shaft** that spins. This shaft runs through the turbine into a generator. The generator turns the shaft's mechanical energy into **electricity**.

A third system of pipes contains cool water. This is pumped in from a nearby body of water like a lake. Heat energy from the steam is transferred to this water. This **condenses** the steam back into water. It also makes the cool water, from outside, warm. Then the warm water is released back into the nearby body of water and the water inside the closed pipes goes back to be boiled again.

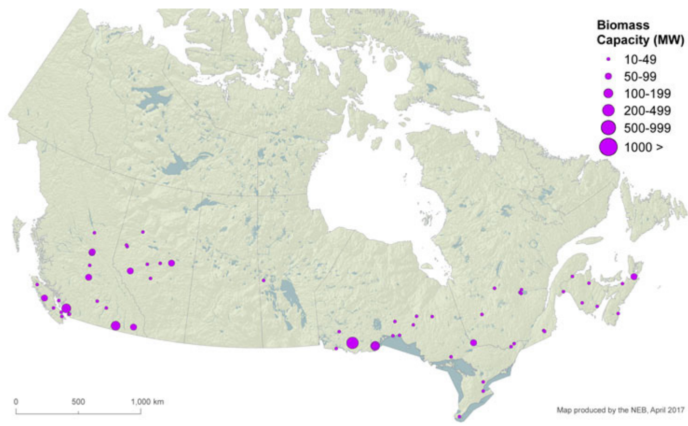
Uranium fuel is **radioactive.** That's why it can generate electricity. But as it gets used in a reactor, the fuel contains less and less energy. Over time, there is not enough energy to keep the fission reactions going. When that happens, the fuel is considered to be "spent". However, this fuel is radioactive.

Nuclear reactors have the advantage that they do not give off carbon dioxide when they are running. One of their disadvantages is that they produce radioactive spent fuel. This fuel can be dangerous to humans for thousands of years, so it must be stored carefully. Canada stores spent fuel in pools of water with concrete walls and floors about two metres thick. After seven to ten years, the fuel is safe enough to be moved to storage containers made of concrete and steel.

Another disadvantage is that the mining of uranium and the building of nuclear reactors and nuclear waste storage facilities, all produce carbon dioxide. Overall, nuclear reactors are responsible for a small amount of **greenhouse gases** during their lifespans.

Biomass in Canada

1.4 percent of Canada's electricity comes from biomass. Biomass is the third largest renewable source of electricity in Canada. The electricity generated from biomass increased 54% from 2005 to 2015. Most biomass plants are in British Columbia, Ontario, Quebec, Alberta, and New Brunswick.



Map of biomass power plants in Canada (Source: Canada Energy Regulator).

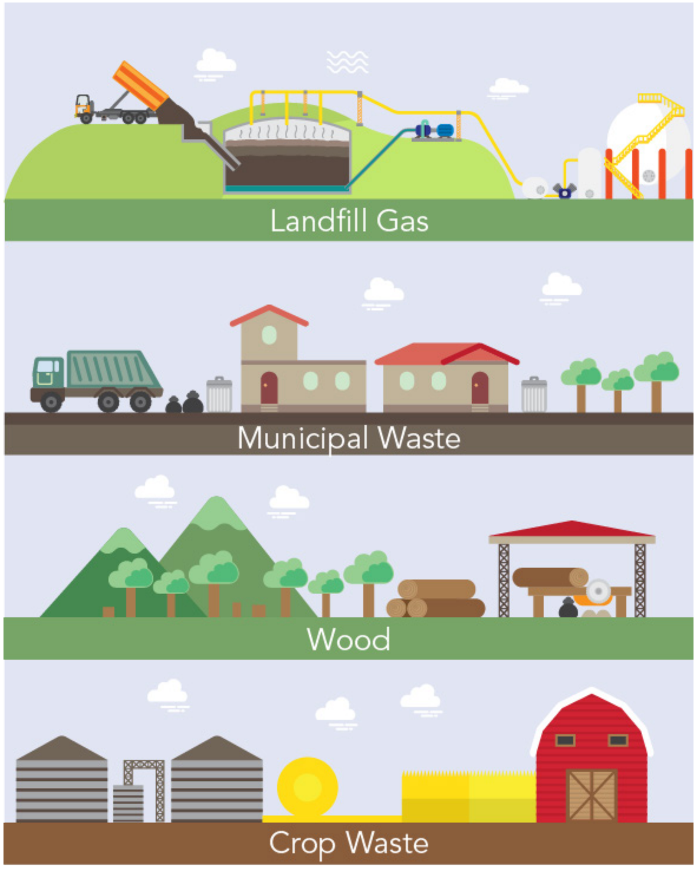
> Did you know?
> Canada is the world's second-largest exporter of wood pellets. Wood pellets are a type of biomass. Wood pellets are made of sawdust and other industrial waste.

What is biomass?

Biomass is organic material that comes from recently dead plants and animal waste. It contains energy that once came from the Sun. Plants convert energy from the Sun into chemical energy. This process is called photosynthesis. Animals eat plants to use and store this energy in their bodies.

> Misconception Alert
> Fossil fuels are not considered biomass.

Wood, waste from crops, landfill gas, and municipal solid waste are some of the common types of biomass. In Canada, industrial wood waste is the most common type of biomass.



Examples of biomass include landfill gas, municipal waste, wood and crop waste (Let's Talk Science using images by armckw via iStockphoto).

How do we use biomass to generate electricity?

There are three ways of using biomass to generate electricity. Biomass is either:

- burned;
- broken down by bacteria;
- or converted to a gas or liquid fuel.

Burning biomass is the most used method. This is also called **combustion**. The term for burning matter to generate electricity is **thermal generation**.

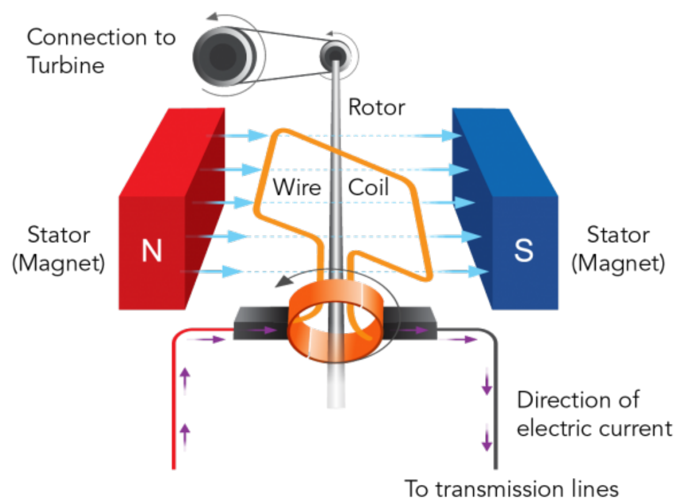
Electricity isn't produced directly from this combustion. Burning solid biomass materials heats giant boilers filled with water. This transforms liquid water into steam. The steam creates pressure in the boiler. The force of the steam rotates a **turbine**. The turbine then moves a wire coil in a **generator**.

Some biomass plants generate electricity by burning **methane**. Methane is a gas that can be collected from **landfills**. These plants use a slightly different process than plants that burn solid biomass.

The products of burning methane, instead of steam, cause the turbine to spin. As with solid biomass, the rotation of the turbine drives a generator.

Generators convert mechanical energy into electrical energy. First a force from the water vapour or gas makes the **rotor** turn. The rotor has a coil of wire that spins inside a fixed magnet around it, called the stator. The rotation causes changes in the magnetic field which forces electrons to move along the wire. This generates electric current. We call this **electromagnetic induction**. The metal wire constantly moves inside the magnet. This creates a continuous flow of electrons, generating electricity.

> Did you know?
> The type of current generated in this way we call alternating current.

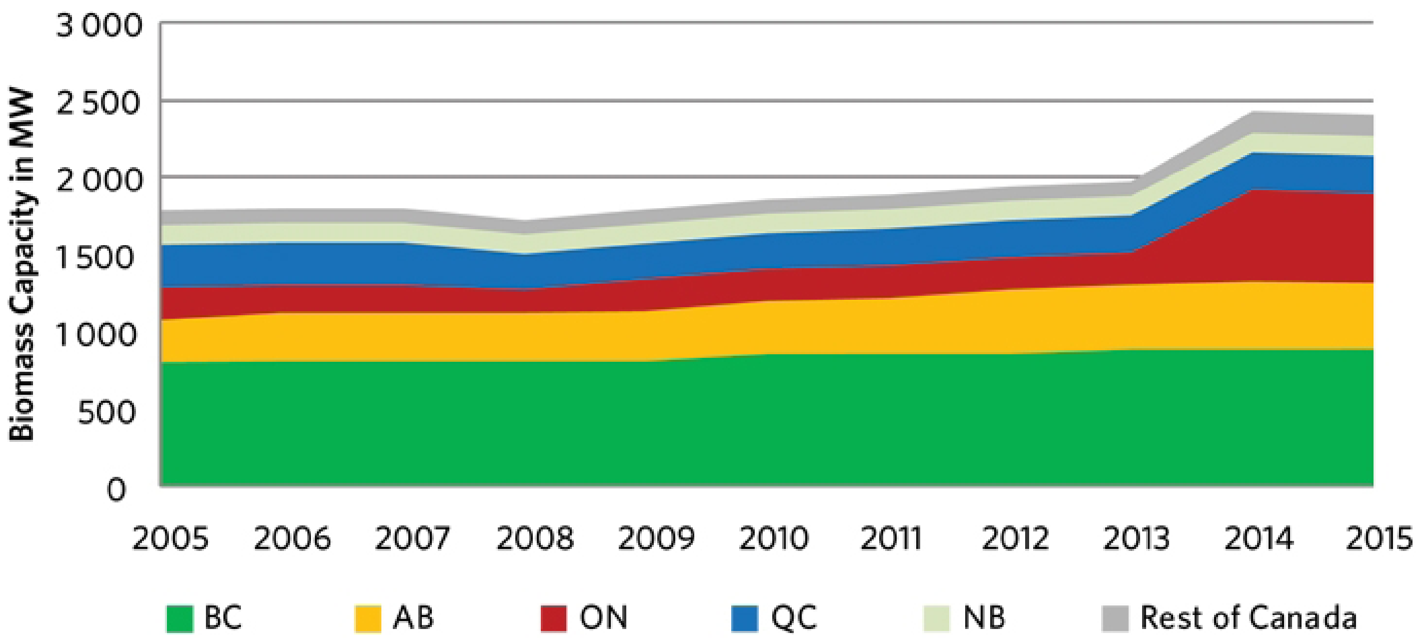


Parts of a generator (Let's Talk Science using an image by Graphic_BKK1979 via iStockphoto).

> Did you know?
> Fuels made from biomass can run engines or heat homes.

How much power can biomass generate?

Biomass facilities can generate anywhere from 2 to 1000 megawatts of electricity. At the end of 2014, Canada had 70 biomass power plants. Together, these plants can produce 2 043 megawatts of electricity.



Graph showing biomass capacity in Canada (Source: Canada Energy Regulator).

Atikokan Generating Station is North America's largest 100% biomass power station. It is located in Northwestern Ontario. This station used to generate power by burning coal. After modifications in 2014, it now burns wood pellets. It can generate 205 megawatts of electricity by burning wood pellets. This is enough electricity to power about 70 000 homes.

Advantages of Biomass Electricity Generation

Unlike other types of **renewable energy** resources, biomass plants can generate power all the time. They don't rely on intermittent things such as wind or sun. This makes electricity from biomass reliable.

But biomass is different from other types of renewable energy sources. Unlike the wind and the sun, biomass is consumed when electricity is generated. To make biomass renewable, the consumed plant material needs to be replaced as quickly as it is used. This may be through growing new crops or planting trees. If this were to happen, then burning biomass would not increase greenhouse gas levels. But if it does not happen, then burning biomass will increase **greenhouse gas** levels. Another advantage of using biomass is that it can prevent some types of waste from going to landfills.

Disadvantages of Biomass Electricity Generation

Burning biomass produces similar greenhouse gases to burning fossil fuels. These greenhouse gases contribute to rising global temperatures. Burning biomass also releases other pollutants into the air. These pollutants include particulate matter, nitrogen oxides, and sulphur dioxide.

Air pollution can cause respiratory issues, heart disease, cancer, and other health issues.

Biomass-generated electricity can also impact the environment in other ways. For example, cutting down trees can lead to **deforestation**. Growing plants to use as biomass can impact soil quality and water usage. Growing these plants instead of other plants can reduce **biodiversity**.

We could solve some of these problems with technology. For example, more careful land use, air filters or cleaner sources of biomass could help. Other sources of biomass, like methane gas from food waste, may be more common in the future. These technologies may make producing electricity from biomass better for the environment.

Generating Electricity: Wind Power

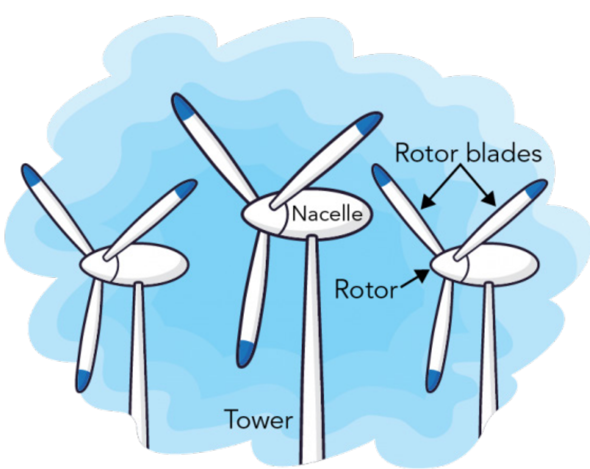
We can use moving air, or wind, to generate electricity. This is called wind power. In 2021, Canada had the ability to generate 14 300 MW of wind power.

> Did you know?
> About 5% of the world's electricity comes from wind power.

Wind Turbines

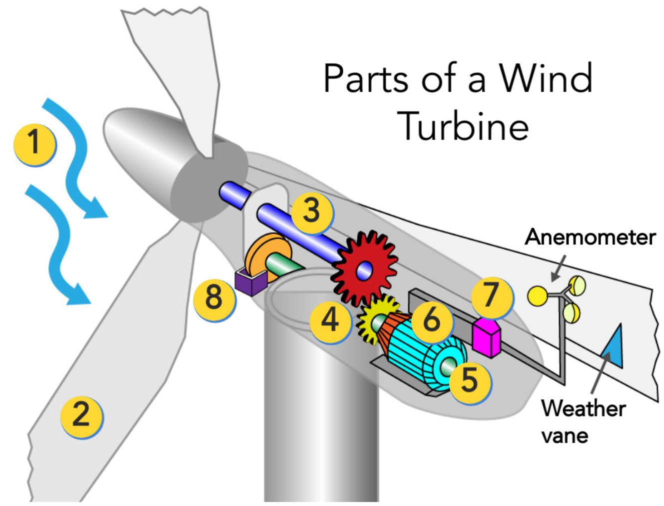
Wind power is usually generated using a wind turbine. Wind turbines are mechanical systems that convert **kinetic energy** into **electrical energy**. Kinetic energy is energy that comes from movement. Wind is the movement of air. There are wind turbines on land and in water.

Modern wind turbines are complex machines with three main **subsystems**. These are the **rotor** and its **blades**, the **nacelle** and the **tower**.



Wind turbine (public domain image on Wikimedia Commons).

How does a wind turbine work?



Wind turbine showing the interior parts of the nacelle (© 2020 Let's Talk Science. Derivative work of public domain image by the US Office of Energy Efficiency and Renewable Energy via Wikimedia Commons).

1. Wind blows towards the front of the **nacelle**.
2. The wind causes the **rotor blades** to turn.
3. The blades turn the **low-speed shaft**. This shaft is attached to a **large gear**.
4. A **small gear** meshes with the large gear. The smaller gear turns faster than the large gear. This is because of the **gear ratio**.
5. The small gear is connected to the high-speed shaft. The shaft runs through the **generator**.
6. The generator converts mechanical energy into electrical energy by spinning a **magnet** within a coil of wire.
7. A **control box** receives information from an **anemometer** and a **weather vane**. Controllers on the ground use this information to turn the nacelle or switch the turbine on and off.
8. A **brake** can also be applied to stop the rotors from spinning.

How much power can a wind turbine generate?

That depends on its size. The larger the rotors, the more power the turbine can generate. So it's probably not a surprise that wind turbines are getting bigger.

The largest wind turbines on land in North America are about 111 m tall. Their rotor blades can stretch to a diameter of 135 m. That's taller than the Peace

Tower at the Parliament Buildings. And the rotor blades reach wider than a football field. Wind turbines found offshore in the ocean can be even larger.

> Did you know?
> The world's biggest offshore wind turbine is the Haliade-X. Its rotor blades reach a diameter of 220m and it is 260m tall.

What is a wind farm?

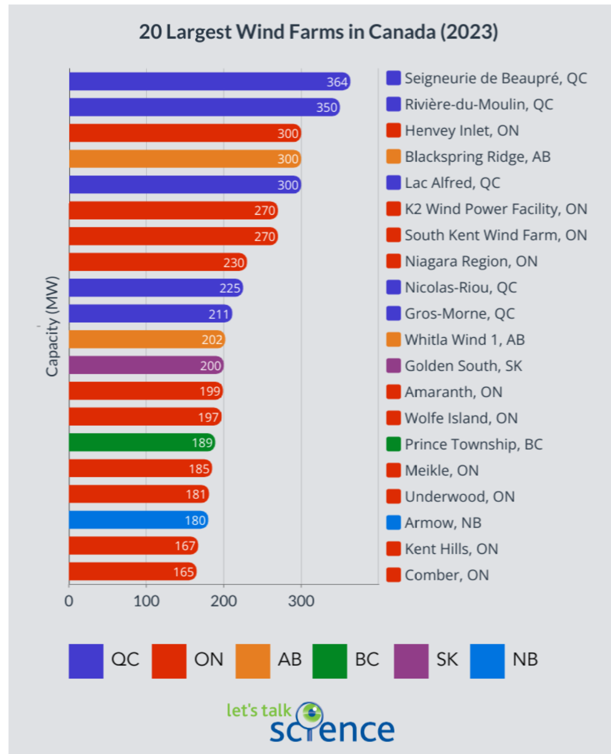
You might see many wind turbines close together. This is called a wind farm. Wind farms can have a few turbines up to several hundred. Canada has a lot of wind farms. Some of these are very large!

Advantages of Wind Power

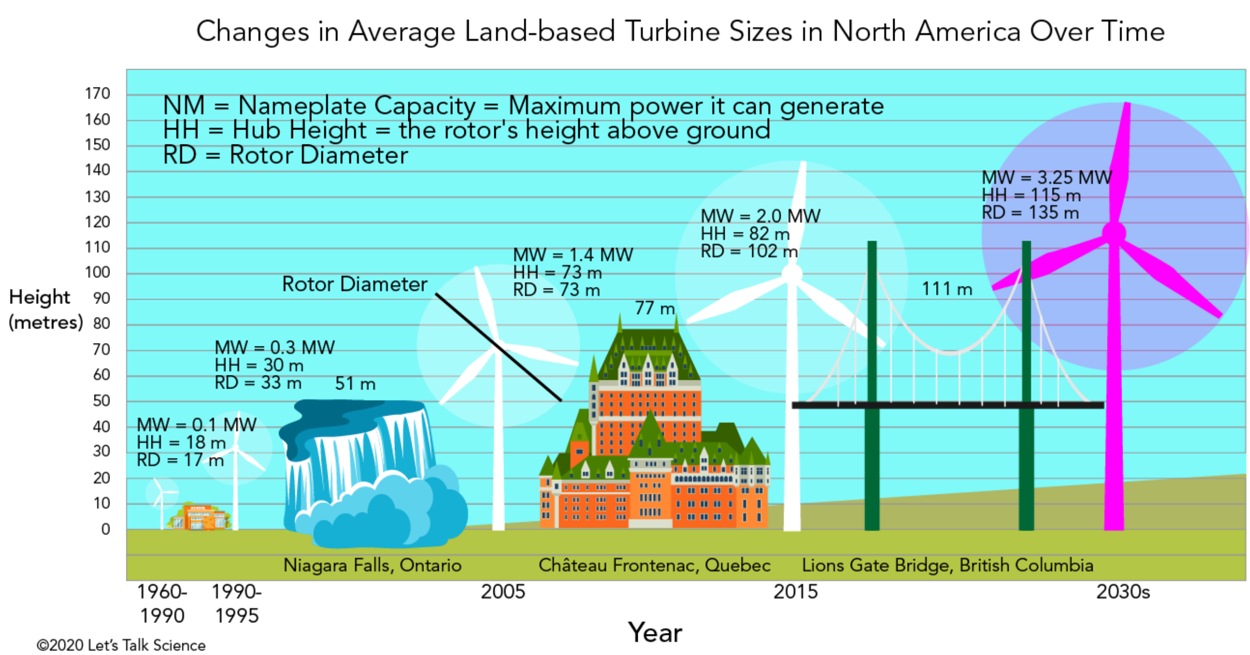
Wind power is called a renewable source of energy. This is because the energy from wind will not run out. Fossil fuels will run out. Wind power is also a clean form of electricity generation. It doesn't produce greenhouse gases. But greenhouse gases are produced when we manufacture turbines and set them up.

Disadvantages of Wind Power

Wind turbines can only run when the wind is blowing. And they can't run when the wind is too fast or too slow. To have reliable power when it's needed, this means other electricity sources or forms of electricity storage may be needed alongside wind power. Some people are concerned that wind turbines may affect human health. They can definitely harm birds and bats, though turbine builders study animal habitats and migratory routes so they cause as little impact on wildlife as possible.



20 largest wind farms in Canada (2023) (©2023 Let's Talk Science).



Turbine sizes compared to some Canadian landmarks (©2020 Let's Talk Science. Berkeley LAb).

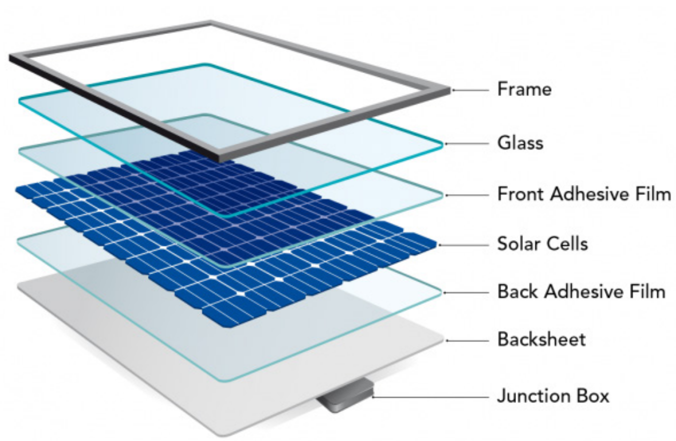
Generating Electricity: Solar Cells

The Sun is a source of energy we use to generate electricity. This is called solar power. In Canada, we had the ability to generate 4000 megawatts of solar power in 2022. This is 25.8% more than we could generate in 2021! Although it makes up less than 1% of our total electricity generation, solar power is increasing in Canada.

Solar Power for Electricity

Solar power converts energy from the Sun into **electrical energy**. One way to do this is with **photovoltaic** materials. These can be used to create an **electric current** when they're exposed to light. This is called the **photovoltaic effect**. **Photovoltaic cells** or **solar cells** can do this. Manufacturers often put lots of solar cells together to make **solar panels**.

A solar panel is made of solar cells sandwiched between layers of clear **adhesive film**. In front of this is a layer of glass held by a frame. Behind is a layer of aluminum called the **backsheet** which can conduct electricity. The electricity generated by the solar cells leaves the solar panel at the **junction box**.



Parts of a solar panel (Let's Talk Science using an image by alejomiranda via iStockphoto).

How do solar cells work?

Solar cells are usually made mainly from silicon. **Silicon** is a naturally-occurring chemical element. It is also a **semiconductor**. Semiconductors act as both a **conductor** and an **insulator**.

> Did you know?
> Silicon is the second-most abundant element on the planet, after oxygen.

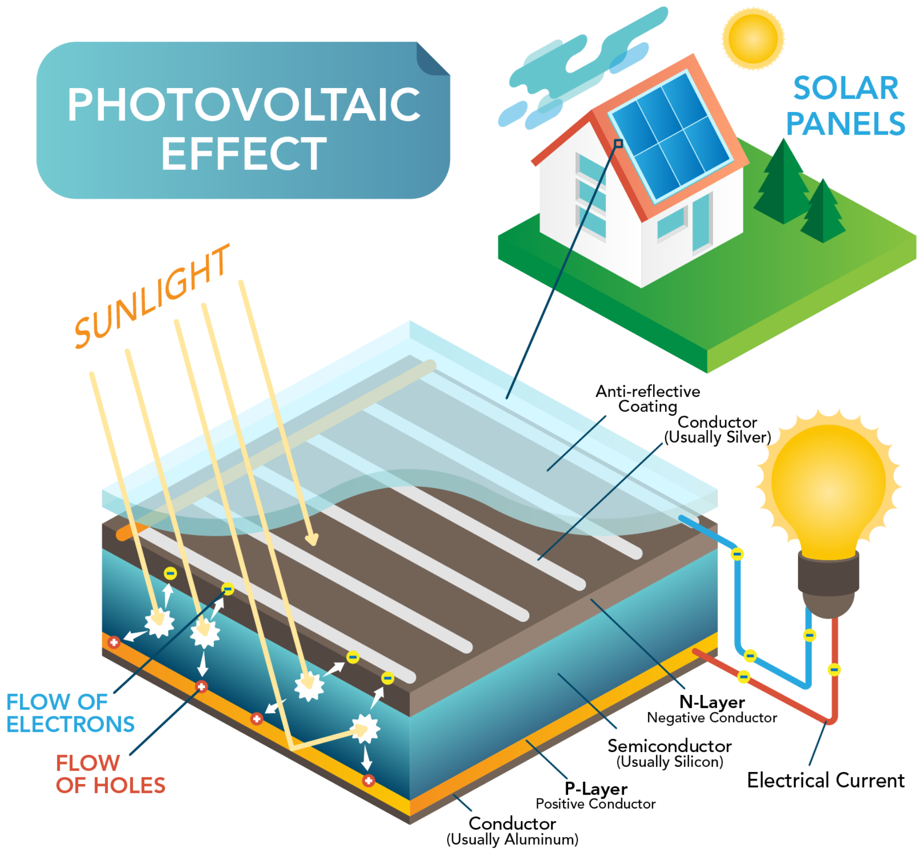
A solar cell has three main layers.

1. The top, or **N-Type layer**, can give away **electrons** easily. This layer faces towards the light. N-type stands for "negative type". This layer is made of silicon and an element, such as phosphorus, which has more electrons than silicon.
2. The middle layer is made of silicon. **Photons** of light with wavelengths in the range of 350 to 1 140 nm are absorbed in this layer. This is light in the visible part of the **electromagnetic spectrum**. The photons knock electrons off the silicon atoms. These loose electrons move to the N-type layer. The silicon atoms now have a positive charge. We call these "holes." The holes move to the P-type layer.
3. The bottom, or **P-Type layer**, can receive extra electrons. This layer faces away from the light. " P-type stands for "positive type". This layer is made of silicon and an element such as boron, which has fewer electrons than silicon.

The loose electrons are collected by thin conductive strips of silver just above the N-type layer. The loose holes are collected by a thin, conductive sheet of aluminum just below the P-type layer. Connecting a wire between these two conductive materials allows the electrons to flow. A flow of electrons is an electric current.

How much power can a solar panel generate?

One standard solar cell is 15.6 cm x 15.6 cm square. It can generate about half a **volt** of electricity. That is about one third of the **voltage** of a fresh AA alkaline battery. That's not very much.



Photovoltaic Effect (Let's Talk Science using an image by VectorMine via Getty Images).

Luckily you can connect solar cells together. Twelve photovoltaic cells is enough to charge a cellphone. Many solar panels are needed to power a house.

What is a solar farm?

You can often see many solar panels together. This is called a **photovoltaic power station** or a **solar farm**. In 2018, 98% of Canada's solar energy was generated in Ontario. But many other regions have a lot of photovoltaic potential. These are some of the sunniest places in Canada!

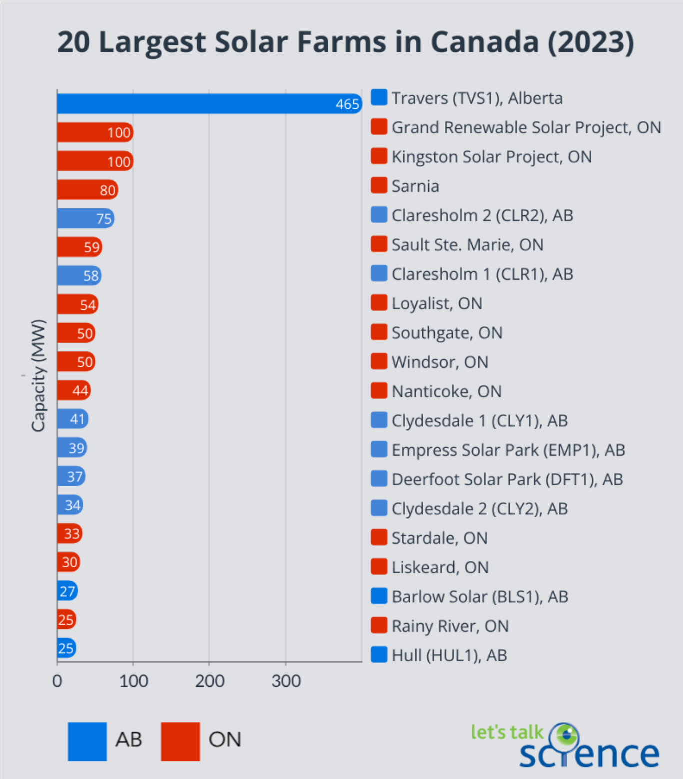
Solar panels in a field (Source: querbeet via iStockphoto).

> Did you know?
> The biggest solar farm in Canada is the Travers Solar Project in southern Alberta. It has a nameplate capacity of 465 MW. It first began generating electricity in 2022.

Solar power can be especially helpful in remote communities, which often rely on diesel generators for electricity generation. Getting the fuel to them is difficult and burning it to generate electricity releases **greenhouse gases**. In Fort Chipewyan, in a remote part of northeastern Alberta, a solar farm opened at the end of 2020 owned by three first nations groups. With the new solar panels, the community will burn 800 000 litres less diesel fuel each year. This means 2170 tonnes of greenhouse gases will no longer be produced.

Advantages of Solar Energy

Solar power is a **renewable** source of energy. This is because the energy from the Sun will not run out. **Fossil fuels** like oil, gas and coal are not renewable. Solar power is a clean way of generating electricity. This is because it does not produce **greenhouse**



20 largest solar farms in Canada (2023) (©2023 Let's Talk Science).

gases which make climate change worse. It also doesn't produce air, water or noise pollution when the panels are operating. But like almost anything we make, pollution and greenhouse gases are produced when solar panels are manufactured, set up and disposed of.

Disadvantages of Solar Energy

Solar panels generate the most electricity when the Sun is shining. They don't work as well on cloudy days. They work better when they are placed closer to the Equator because the Sun shines more directly on them. They also work better in the summer, when days are longer.

Solar farms need a lot of land. This is land that could be used for other things, like wildlife habitat or farms. Solar panels are not very good at converting sunlight to electricity. Most solar panels are about 20% efficient. That means only 20% of the solar energy it collects is converted into electrical energy.

But even this is a big improvement on how it was only ten years ago and there is more good news on the horizon. A new solar panel has reached 47 percent efficiency in the lab and nearly 40 percent in the field. This means the future of solar electricity generation could be very bright!

Generating Electricity: Hydroelectric Power

In Canada, we often use moving water to generate electricity. This is called **hydroelectric power**—often shortened to **hydropower**. Almost two thirds of electricity in Canada is produced using hydropower. Hydropower is a renewable source of energy. This is because we can use water over and over again to generate electricity.

> Did you know?
> Hydroelectricity generates about 16% of the world's electricity.

Types of Hydroelectric Generation

There are four main ways to generate electricity using moving water. These are:

- Storage and Pumped Storage
- Run-of-river
- Tidal Hydropower
- Wave Hydropower

The first two ways happen in rivers. The second two ways happen near or in oceans.

Storage Hydropower

Storage is one of the most common ways of producing hydropower. This usually starts with building a structure called a **dam** across a river. The dam blocks the flow of the river, storing water above it. This storage area is called a **reservoir**.

Aerial view of the Revelstoke Dam in Revelstoke, British Columbia. The blue at the top of the image is the reservoir (Source: Kelownian Pilot [CC BY-SA 3.0] recoloured via Wikimedia Commons).

The water in the reservoir is at a higher elevation than the water in the river on the other side of the dam. This means the water in the reservoir has **gravitational potential energy**. When the water flows down through the dam, this is converted into **kinetic energy**.

Inside the dam structure is a **turbine**. A turbine is a device that converts kinetic energy into **mechanical energy**. The turbine is attached to a **rotor** in the **generator**. The generator converts mechanical energy into electrical energy. It does this by spinning a wire within a powerful magnet. When more electricity is needed, workers can let more water flow through the dam.

Parts of a hydroelectric dam (Let's Talk Science using an image by bubblea via Getty Images).

Parts of a Hydroelectric Generating Station

1. **Reservoir** - The source of water for the generating station.
2. **Intake** - The water moves into the dam through the intake. A mesh screen filters out debris.
3. **Penstock** - These are tubes that the water travels through.
4. **Turbine** - The moving water spins a turbine.
5. **Generator** - The turbine turns a rotor in the generator.
6. **Power Station** - The generator is located in the power station.
7. **Power Lines** - Power lines carry the electricity away from the power station.
8. **Outflow** - Water exits the dam and continues to flow down the river.

Storage hydroelectricity has some advantages. People can use the water in reservoirs for drinking water. They can also use the water for irrigation. They can even use it for recreation, like sailing.


Dam of the Ghost Reservoir, Alberta (Source: Ingo Schwarze [CC BY 4.0] via Wikimedia Commons).

This method also has some downsides. Storage hydroelectric systems affect natural water systems. They change where and how water flows and often affect the plants and animals that live in the water. This means people in local communities can lose the fish and wildlife they depend on for food.

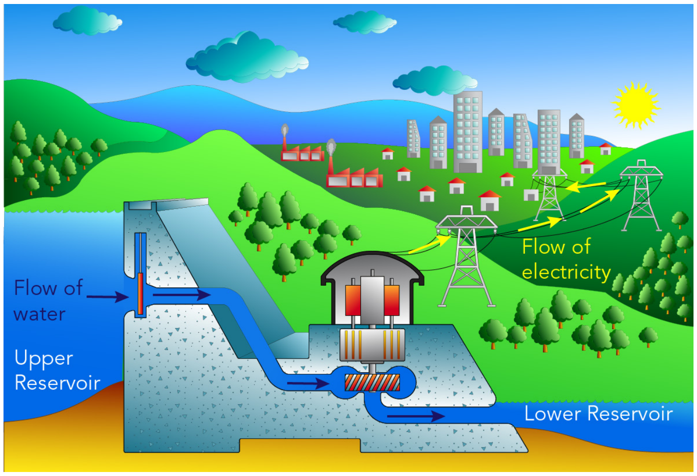
Building reservoirs also often involves flooding land. If land is flooded, people cannot use it for farming, hunting or homes. Flooding can also damage the ecosystems along riverbanks by covering them with water. Sometimes dams fail. This can cause a lot of damage to nearby human and natural environments.

The lands of Indigenous communities in Canada have often been flooded without their consent. Communities have lost the land they depend on for hunting, fishing, foraging, and cultural needs. Scientists have also found that rotting plants and soil under the water can release toxins. These accumulate in the fish and birds people eat, causing health consequences. Many Indigenous people and their supporters protest the construction of hydroelectric projects near their communities.

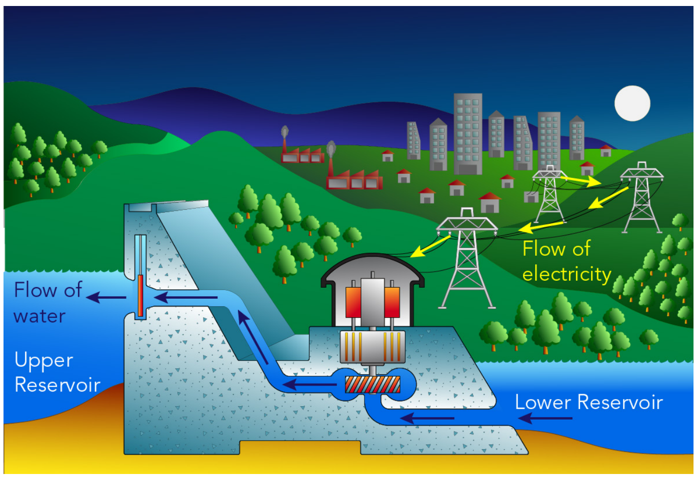
Pumped Storage Hydropower

Pumped storage is a variation of the traditional storage method. Here, there are two reservoirs of water. One is at a higher elevation and one is at a lower elevation.

When more electricity is needed, water is allowed to flow from the upper reservoir down to the lower reservoir. Electricity generation happens in the same way as standard storage hydropower. When less electricity is needed, such as at night, a pump moves water from the lower reservoir up to the higher one. These pumps are powered by other forms of renewable energy.



Pump storage in the daytime (Let's Talk Science using an image by bubblea via Getty Images).



Pump storage at night (Let's Talk Science using an image by bubblea via Getty Images).

The advantage of pumped storage systems is that they do not need to be on a river. All they need are two bodies of water at different elevations.

These systems do have a disadvantage. They use more electricity than they generate. So why do we use them? The electricity they generate when people need it most, can be sold at a high price. And the electricity they buy to pump water uphill has a lower price. This is because the pump runs at night, when fewer people need electricity. So, pumped storage systems can make a profit.

Run-of-river Hydropower

Run-of-river hydropower gets its kinetic energy from the natural flow of a river. These systems usually don't use reservoirs. This means run-of-river systems can't store much energy.

Sometimes the river flows through a turbine system. You can see this in the picture below. To the left is the hydropower station. To the right is the natural flow of the river.


The Lower Bonnington hydropower station on the Kootenay River, British Columbia (Source: AmyBFortisBC [CC BY-SA 4.0] via Wikimedia Commons).

Other times, some water is diverted away from a river through the turbine system. Then, this water is returned to the river, downstream.

The advantage of run-of-river systems is that they are less disruptive to rivers. They have smaller effects on water flow. And land does not need to be flooded for reservoirs.

There are disadvantages to run-of-river systems. They usually can't generate as much electricity as storage hydropower systems. And they can't operate without flowing water. If the flow of the river decreases, so does electricity generation. This is a problem because climate change is causing less rainfall in some areas. Finally, run-of-river systems need specific river conditions. The water in the river must be flowing fast enough, and at a high enough volume for electricity to be generated.

Tidal Hydropower

Tidal hydropower uses the natural rise and fall of oceans, called **tides**. Tidal hydropower can be found along coastlines of the world. For these systems to work, the water level must change by at least 5 metres. That's quite a lot!

Tidal power uses similar structures to hydropower systems on land. For example, a **tidal barrage** is like a run-of-river system. And **tidal turbines** are like wind turbines.

An advantage of tidal hydropower is that tides are very predictable. This makes them a reliable energy source.

There are disadvantages to tidal hydropower. First, most places do not get high enough tides for it to work. Tidal hydropower can also affect sea life. Finally, salty ocean water can be hard on mechanical parts. All these factors mean tidal hydropower has not yet been used a lot.

Wave Hydropower

Waves in the ocean also have lots of energy. People are working to harness this energy in different ways. Engineers have tried using different types of objects that move with the waves. This movement is used to do different things. Some systems use the movement to push air or other fluids through a turbine connected to a generator. Other systems use the up and down motion of waves to move a magnet inside a generator, which can generate electricity.

> Did you know?
> The first commercial wave hydropower system was built on the Isle of Islay, Scotland in 2000. It was closed in 2011. But engineers learned enough from it to build another, larger plant in Spain.

Although wave hydropower has a lot of potential, it also has a lot of challenges. As with tidal power, ocean water is hard on mechanical devices. And unlike tides, the size and speed of waves are unpredictable. This means they are challenging to design for. Finally, objects on, or in the ocean can affect sea life. They can also be a danger to ships.

Despite the challenges, people are eager to design innovative ways to harness the power of waves.

Redefining Energy with Small Modular Reactors

Introduction

What do you picture when you think of a **nuclear reactor**? Is it a HUGE piece of technology that uses the power of atoms to generate electricity? There are many nuclear reactors in Canada. They operate at facilities like the Bruce Nuclear Generating Stations and Ontario Power Generation Stations (Pickering and Darlington) in Ontario and the Point Lepreau Nuclear Generating Station in New Brunswick. Nuclear reactors are an important part of generating a lot of electricity with low carbon emissions.

A nuclear facility usually includes reactor buildings, turbines, cooling towers, and other structures. The size of a nuclear power plant depends on the number and sizes of its reactors. A traditional nuclear power plant can cover several square kilometres of land. It can also be several stories tall.

Darlington nuclear facility(Source: Public domain image by Ontario Power Generation via Wikimedia Commons).

But what if we could make nuclear reactors smaller? This is just what engineers around the world are working on.

What is a Small Modular Reactor?

Small modular reactors (SMRs) are a new kind of nuclear reactor. SMRs are like mini nuclear power plants with new features and designs. They are designed to be safer and take up less space than a traditional reactor.

SMRs work in a similar way to a traditional nuclear reactor. They use **fission** to take the energy from splitting atoms to make heat.

That heat is then used to generate electricity.

Types of SMRs

SMRs come in various sizes, designs and power levels. This means they can be used to power different things. These include buildings, neighbourhoods or even entire communities.

SMRs using several different technologies are being developed in Canada. These include:

Molten Salt Reactor

Molten salt is salt that is solid at room temperature and liquid at higher temperatures. This can be used both to fuel and to cool the reactor. Traditional nuclear reactors use solid uranium for fuel and water for cooling.

Sodium-cooled Fast Reactor

This type of reactor uses liquid metal instead of water for cooling. In sodium-cooled reactors, the metal is sodium.

High-temperature Gas-cooled Reactor

These reactors use solid uranium for fuel. But instead of water, they use helium for cooling.

How small is small?

Small modular reactors come in many different sizes. They can be as small as a shipping container or as big as a whole city block!

How much power do SMRs produce?

The power an SMR can generate depends on the size and design. Today, an SMR can generate up to 300 megawatts of electricity. These can be part of the energy mix for larger communities.

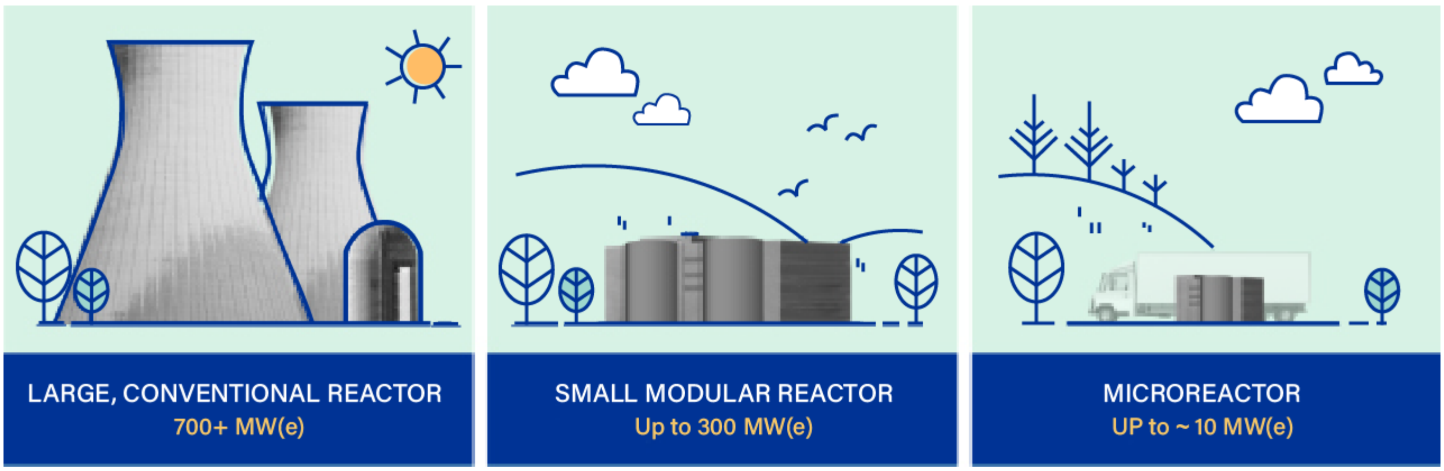
There are also very small SMRs that generate between 2 to 30 megawatts of power. SMRs that generate less than 10 megawatts of power are called microreactors. These are ideal in situations with very limited space. Or where a smaller amount of power is needed.

What are the benefits of SMRs?

SMRs can bring clean energy to a variety of locations and situations. They do not need a lot of space and they can be easy to transport. This makes SMRs an ideal choice for rural and remote communities. These communities may not be connected to the electricity grid.

Like all nuclear reactors, SMRs do not produce **greenhouse gases** when they are running. SMRs can be a cleaner replacement for **diesel generators**. These are machines that use diesel fuel to generate electricity. Diesel generators currently supply electricity in many remote communities.

> Did you know?
> You can use the Remote Communities Energy Database to see what kind of energy powers some communities across Canada.



Small Modular Reactors (Source: A. Vargas, International Atomic Energy Agency).

Traditional nuclear reactors generate a lot of electricity. This is why they are usually found in regions with large cities. Other parts of Canada need less electricity. SMRs can help in these areas because they can be built to meet a region's specific energy needs.

Large facilities like pulp and paper mills and oil refineries often need their own sources of energy. SMRs can supply the on-site power and heat they need.

SMRs in Canada

Canadian provinces are beginning to explore SMRs as a way of generating electricity. The government of Canada has created the SMR Roadmap and the SMR Action Plan to guide this development in the coming years.

Four SMR projects are currently in development. These are:

- Global First Power
- NB Power's ARC-100 Project
- OPG's Darlington New Nuclear Project
- SaskPower's proposed SMR project

Concept image of the BWRX-300 SMR plant at the Darlington nuclear facility (Source: GE Hitachi Nuclear Energy. Used with permission).

Regulating and Licencing SMRs

The SMR Action Plan includes the rules and regulations around new nuclear technologies. The Canadian Nuclear Safety Commission (CNSC) regulates and licences all nuclear facilities and activities in Canada.

The CNSC also oversees the management of radioactive waste. Managing waste safely is a crucial part of making sure SMR projects are safe.

When deciding whether to licence an SMR project, the CNSC listens to different people involved. These include the public, the companies, and Indigenous Nations and communities. Everyone is encouraged to share their thoughts. And there is funding available to help people take part in these discussions. It's important for as many people as possible to be part of the decision-making process.

Careers in Nuclear Energy

Working in nuclear energy is all about helping provide clean and efficient power. There are many different careers in this field.

- **Nuclear engineers** design and run nuclear reactors to make sure they work safely and well
- **Nuclear physicists** do research to make nuclear technology even better
- **Radiation protection specialists** keep an eye on radiation levels to keep everyone safe

There are also careers in areas related to nuclear energy. These include creating laws and policies to protect the environment, regulating nuclear energy, and managing power plants. Jobs in nuclear energy are important for the future of clean power. It's a great field for people who like science and engineering, and care about the environment.

Let's Talk Science appreciates the contributions of the Canadian Nuclear Safety Commission in the development of this part of the handbook.

How could you design a wind-powered elevator?

Consider using the Design & Build Process with this challenge.

This activity will help build skills related to the Identify the Problem, Research, Generate Ideas, and Plan phases of this process. The optional part can help with the Create and Test & Evaluate phases as well.

Materials:

- Pencil
- Paper

Optional materials:

- Tape
- Scissors
- Recycled paper and/or sticky notes
- String
- Drinking straws
- Craft sticks
- Scrap cardboard
- Fine yarn or thread
- Pipe cleaners
- Load for testing

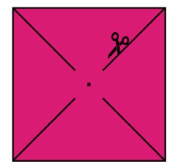
What to do!

Imagine you are an engineer who wants to use wind power to lift small loads. Your task is to design a device that uses energy from moving air to lift an object vertically, kind of like an elevator.

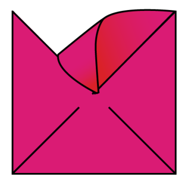
1. **Identify the Problem** - Think about how you can use the air and what will move the load.
2. **Research** - You might want to review what you know about wind power to get some ideas about how to convert moving air into mechanical energy.
3. **Generate Ideas** – What kinds of parts will you need? What will move? How will it move? Where will the load go? *Hint: Make a paper pinwheel and think about how you could use it as part of your design.*

How to Make a Pinwheel:

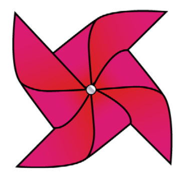
Step 1: Cut out a square of paper.



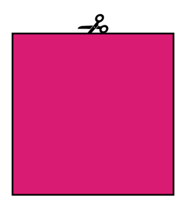
Step 2: Cut towards the middle from each corner.



Step 3: Curl one point towards the middle.



Step 4: Curl alternating remaining point towards the centre. Fasten them to the centre with a pin or paperclip.



4. **Plan** – Which ideas are your best? How will you show people what your device looks like and how it works?

Optional challenge:

Build your wind-powered elevator! The elevator should only use energy from moving air to lift the load.

What's happening?

Moving air is an important source of energy. It is in action all over the place! It makes kites fly and sailboats sail. Even your breath can spin a pinwheel.

Sarah Elliott-Le Dreff

Senior Manager, Project Controls
Ontario Power Generation -
Darlington New Nuclear Project

Why does it matter?

Historically, windmills have been used to pump water and grind grain. Modern wind turbines are basically sleek, high-tech windmills.

Windmills convert kinetic energy from the wind into mechanical energy. This is used to move parts like paddles or grinding stones. Wind turbines also convert kinetic energy from the wind into mechanical energy. In this case, it is used to move parts of a generator to create electricity.

Concept image of the BWRX-300 SMR plant at the Darlington nuclear facility (Source: GE Hitachi Nuclear Energy. Used with permission).

Investigate further!

- How could you change your design to lift heavier objects? What about lifting multiple objects at the same time?
- If you scaled up your design for a real-life construction company, what materials would you use? What other factors should you think about?
- What other wind-powered things can you design and build?

I was born in Oshawa, Ontario, Canada. I grew up in Whitby, Ontario. I now live in Markham, Ontario.
I completed my training/education at: Queen's University, Bachelor of Science in Mathematics with a minor in Physics. Humber College Continued Education, Project Management Certification.

What I do at work

I lead a team that provides cost, schedule, risk, and reporting services to the Darlington New Nuclear Project. This project will build Canada's first grid scale Small Modular Reactor. My day is usually divided into four types of work.

1. **Spending time with the Project Teams:** I use this time to learn about any issues they are facing. This includes such things as risks or challenges that might affect the project. It also gives me time to learn about, and celebrate, their successes.
2. **Addressing Project Team issues:** Here, I work with my section managers to see how best we can use our team to support the Project Team. I also work with my section managers to make sure they have what they need to lead their sections.

3. **Supporting my team:** I help them with any problems they may be having in project controls strategy. This could be related to such things as cost management, phase gate planning, developing or implementing reports. Other problems could be related to managing the change control process, and ensuring our project schedules are in good quality.
4. **Writing, developing and communicating reports.** These reports are for various stakeholders and for various project executives. This includes such things as Performance Reports, Board of Directors Reports, and presentations to external stakeholders.

Having a math and physics background supports my day-to-day decision making. It also helps me address many of the technical issues my team faces. This could include performance metrics, financial accounting, and logic.

My career path

In high school, I always wanted to work for Ontario Power Generation. I wanted to help develop clean energy solutions for the province. In University, I took math and physics courses where I learned the fundamentals of problem solving and nuclear energy. I completed a Co-op term at Ontario Power Generation. This gave me experience at OPG and expanded my network. It enabled me to demonstrate my ability to learn quickly and help others. I believe this experience helped me gain my full-time employment with the company.

I am motivated by

What makes me excited about work is knowing that every day is different. There are always new challenges to solve, and new people to learn from. This also means I'm always working on a project that will not only be beneficial for my company but also for Ontario and Canada. I enjoy collaborating with experts across the nuclear and Project Controls industry. Using a logical approach to solving problems makes work interesting and right for me. I enjoy creating a positive and supportive environment for my team.

How I affect peoples' Lives

My work supports Canada's Climate Change Goals. Being a part of a project with first-of-a-kind technology motivates me. It also provides rewarding and fulfilling feelings. By helping and guiding my team I am also affecting their lives and their careers.

Outside of work I

Outside of work, my favourite place to be is with my family (Husband Perrik, and sons Nate, Ethan and Joshua). We enjoy hiking, biking, camping or skiing. I also love doing Hot Yoga and going for jogs to unwind and disconnect.

My advice to others

My advice to a young person would be to not underestimate the various career paths of math and physics. Through OPG and Project Controls, I'm able to use my math and physics background in ways I never dreamed possible when I was in school. I'd advise everyone to say YES to opportunities to help others. This helps strengthen your team, but these actions will be noticed by leadership and recognized.

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