HOW IT WORKS

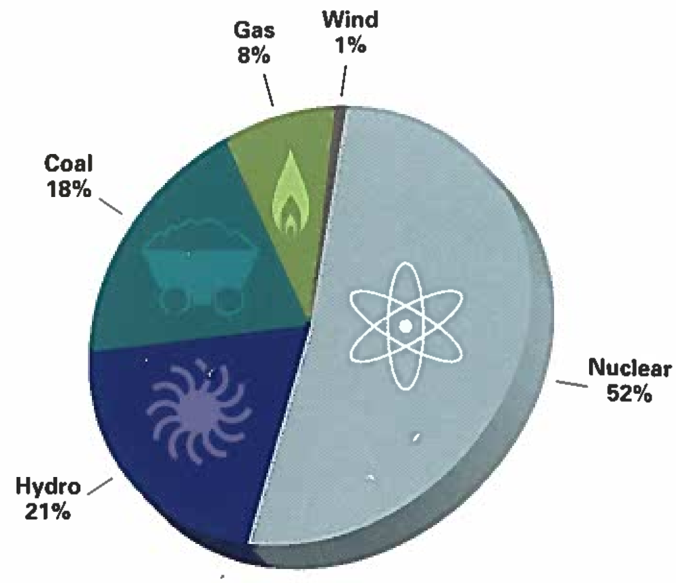
ELECTRICITY GENERATION

ONTARIO POWER GENERATION

HOW IT WORKS
ELECTRICITY GENERATION

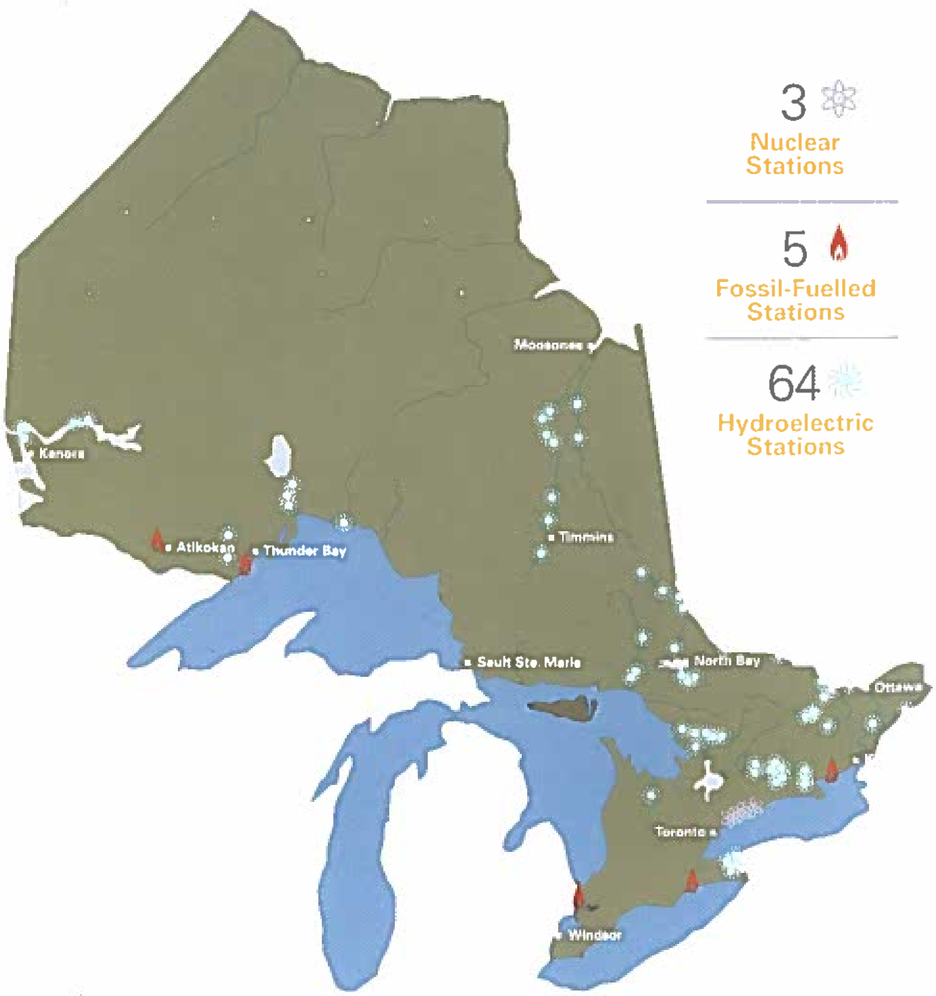
ELECTRICITY IN ONTARIO

Ontario gets its electricity from a mix of energy sources. Half of our electricity comes from nuclear power. The remainder comes from a mix of hydroelectric, coal, natural gas and wind.



2007 ONTARIO ELECTRICITY GENERATION MIX[1]

Most of Ontario's electricity generating stations are located in the southern half of the province close to where the demand for power is greatest. The majority of these power stations are owned and operated by Ontario Power Generation (OPG), a government owned company that generates 70% of Ontario's electricity. To the right is a map of the 72 generating stations operated by OPG across Ontario.



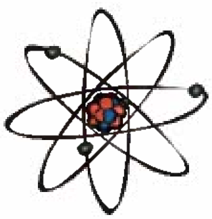
[1]Source: Independent Electricity System Operator – www.ieso.ca

HOW IT WORKS
ELECTRICITY GENERATION

GENERATING POWER

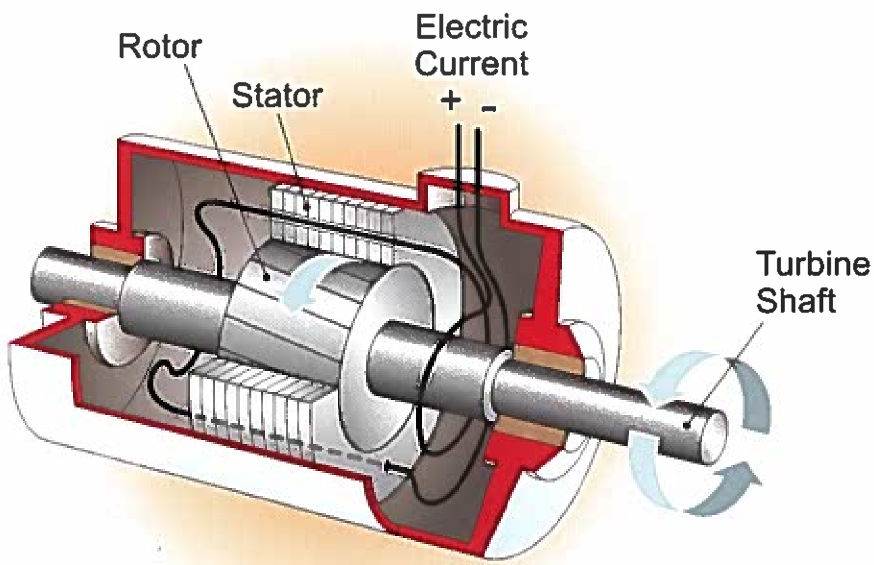
Most power plants, whether they are nuclear, hydroelectric, fossil-fuelled or wind, do essentially the same job, transforming kinetic energy, the energy of motion, into a flow of electrons, or what we call electricity.

At a power plant, a huge **GENERATOR** is used to make the electricity. Inside a generator, a giant magnet called a **ROTOR** spins inside coils of copper wire called a **STATOR**. This pulls the electrons away from their atoms, and a flow of electrons is created in the copper wires. Those electrons can then be sent along power lines to wherever electricity is needed.



In a generator, magnets pull electrons away from atoms in copper wire creating a flow of electrons in the copper wire. This flow of electrons is what we know as electricity.

Giant wheels called **TURBINES** are used to spin the magnets inside the generator. It takes a lot of energy to spin the turbine and different kinds of power plants get that energy from different sources. In a hydroelectric station, falling water is used to spin the turbine. In nuclear and fossil-fuelled generating stations, steam is used. A wind turbine uses the force of moving air.



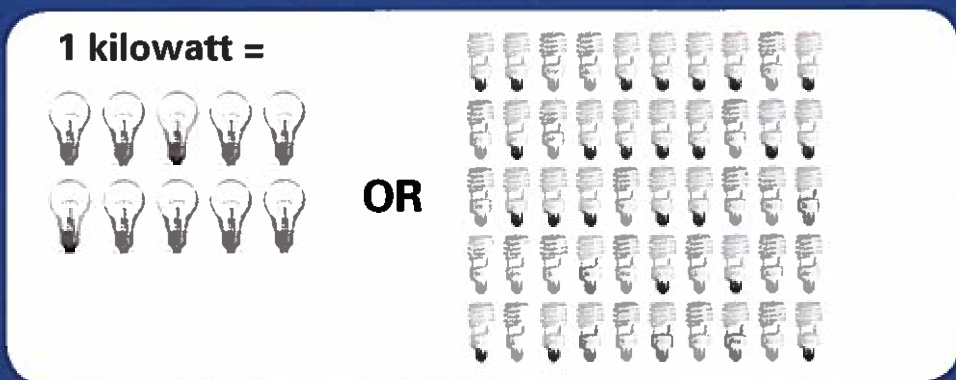
SIMPLIFIED ELECTRIC GENERATOR

HOW IT WORKS
ELECTRICITY GENERATION

UNDERSTANDING POWER DEMAND

Unlike other commodities, electricity needs to be consumed as it is generated. There is currently no economical way to store large quantities of electricity for later use. The supply and demand for electricity must be kept in constant balance. As demand increases the supply must increase proportionately.

Electricity is usually measured in kilowatts and megawatts. One megawatt is equal to 1,000 kilowatts. 1 kilowatt could power ten 100-watt light bulbs or fifty 20-watt compact fluorescent lights.



To power the light bulbs for an hour you would need 1 kilowatt hour of electricity. A kilowatt hour is the amount of electricity consumed or generated over a 1 hour period. An average house consumes 1,000 kilowatt hours of electricity a month.

Our society has a constant demand for electricity. Even when you are asleep, think of all the things in your home that continue using electricity like air conditioning, outdoor lighting, digital clocks, and all the gadgets that need to be recharged for the next day.

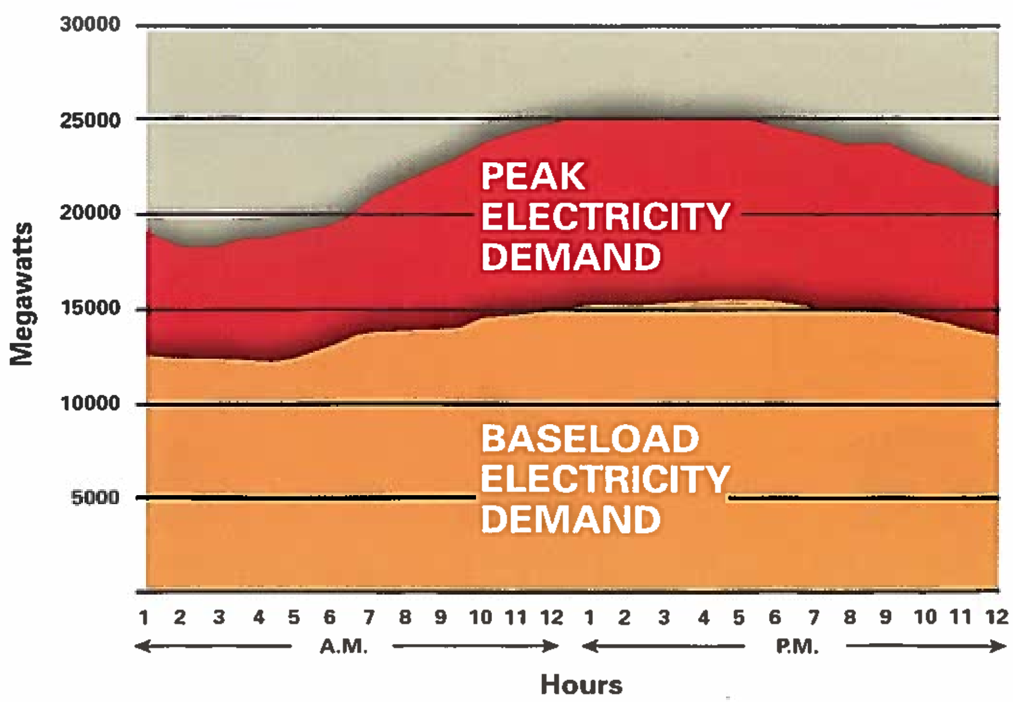
HOW IT WORKS
ELECTRICITY GENERATION

BASELOAD VS PEAK DEMAND

The constant steady demand for electricity is called **BASELOAD DEMAND**. In Ontario our baseload demand for electricity is around 12,000 – 15,000 megawatts depending on the time of year. Ontario uses nuclear and large hydroelectric stations to meet baseload demand. This is because these types of generating stations can produce electricity at a constant and reliable rate.

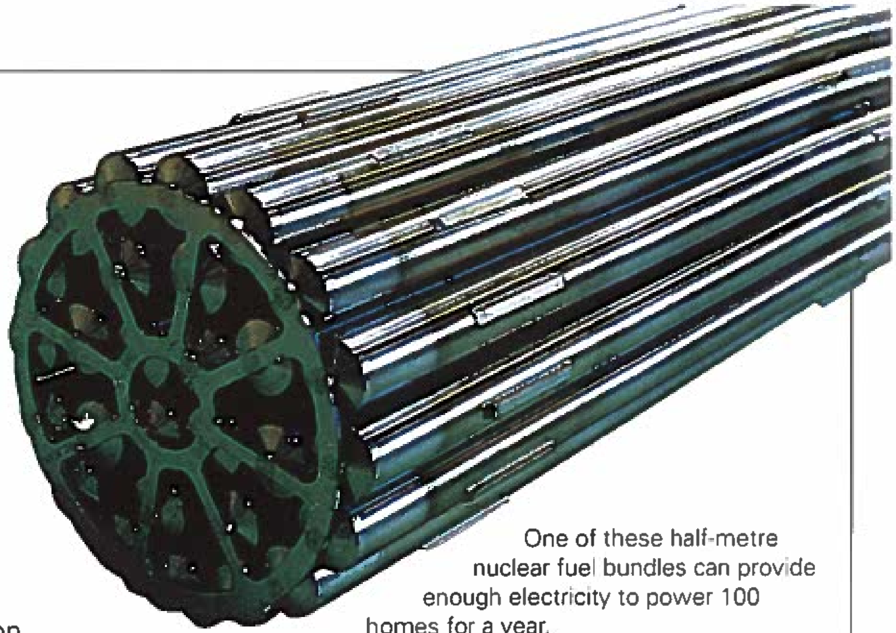
However, the demand for electricity varies throughout the day. Between 4pm – 7pm as people arrive home from work and school and turn on their lights, ovens, televisions and dryers the demand for electricity is usually at its highest. This increase is what we call **PEAK DEMAND**. Typically, peak demand in Ontario can be as much as 10,000 megawatts more than baseload demand. On the hottest days of the summer, this number can soar even higher as people turn up their air conditioners to keep cool.

To meet the sharp increases in electricity demand throughout the day Ontario uses fossil-fuelled generating stations like coal, oil and natural gas plants as well as smaller hydroelectric stations. These types of generating stations can quickly increase or decrease their power output whereas a nuclear station is less able to vary its electricity output. As well, because electricity from fossil-fuelled sources tends to be more expensive, and has a larger impact on the environment it's best to only use them when demand exceeds the output of other generating sources.



This graph shows electricity demand on a hot summer day. As temperatures increase throughout the day, so does the demand for electricity.

HOW IT WORKS
ELECTRICITY GENERATION



One of these half-metre nuclear fuel bundles can provide enough electricity to power 100 homes for a year.

NUCLEAR POWER

Nuclear power plants use **URANIUM** to generate heat and boil water into steam. Uranium has the largest atoms of the 92 naturally occurring elements on earth making uranium atoms more likely than other atoms to split.

When subatomic particles called **NEUTRONS** come in contact with uranium atoms, the atoms split releasing heat energy. This occurs all the time in nature, but at a very slow rate. Nuclear reactors are able to greatly speed up this process by slowing down the neutrons and increasing the likelihood that they will hit and split the uranium atoms. When uranium atoms split they also release more neutrons which can then go on and split additional atoms ensuring a chain reaction of atom splitting. This is called **NUCLEAR FISSION**.

At the heart of every nuclear reactor are **FUEL PELLETS** no bigger than the tip of your finger. Despite their small size, these fuel pellets hold the potential to produce tremendous amounts of energy.

A single nuclear fuel pellet like the one shown above can power an average home for 6 weeks.

Ontario's nuclear reactors use fuel pellets that are made from naturally occurring uranium that is mined in Canada. The pellets are inserted into tubes about half-a-metre in length made from a zirconium alloy, a special type of metal that has a high resistance to corrosion. The tubes are welded shut and several are assembled together into what is called a **FUEL BUNDLE**. One of these half-metre fuel bundles can provide enough electricity to power 100 homes for a year.

1 fuel pellet

=

807 kilograms of coal

or

677 litres of oil

or

476 cubic metres of natural gas

HOW IT WORKS
ELECTRICITY GENERATION

Ontario's Darlington Nuclear Station is one of the most efficient nuclear stations in the world and is capable of powering 15% of the entire province.

Hundreds of fuel bundles are inserted into the core of a nuclear reactor where the uranium atoms split giving off vast amounts of heat. The heat is used to boil water to create steam, which then spins a turbine and generator producing electricity.

Nuclear power stations are able to produce tremendous amounts of electricity from a very small amount of fuel. A single one inch nuclear fuel pellet can produce the same amount of energy as 807 kilograms of coal, 677 litres of oil, or 476 cubic metres of natural gas.

As well, because nuclear power plants do not burn any fuels, they produce virtually no smog or greenhouse gas emissions. They do however produce nuclear waste which needs to be handled and stored very carefully.

NUCLEAR GENERATING STATION

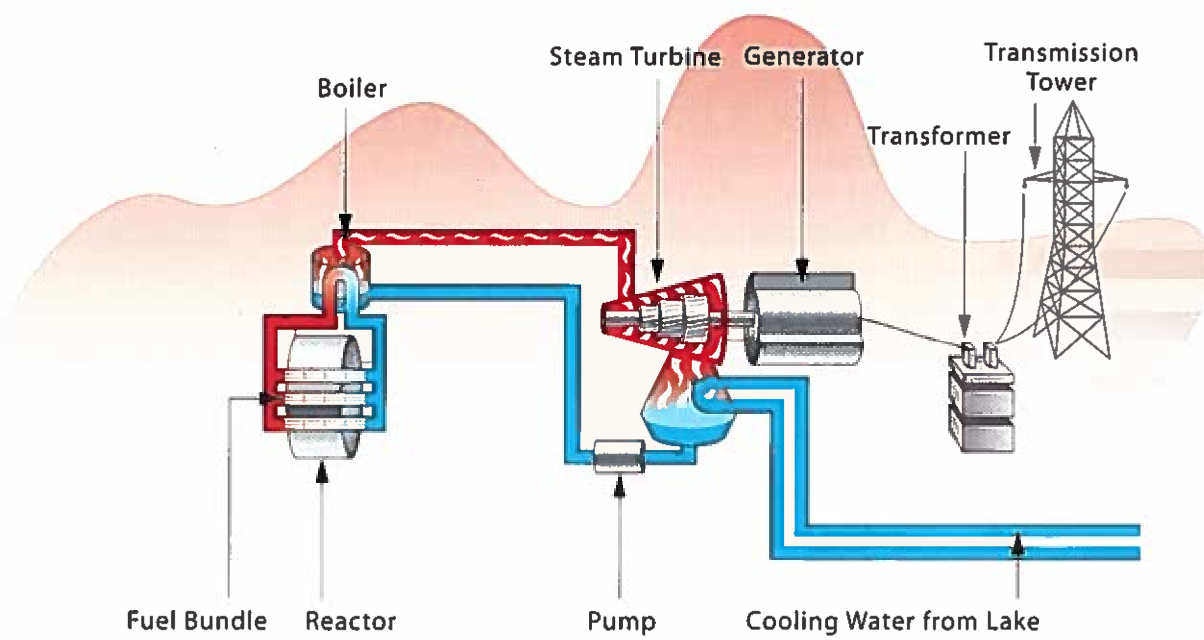


Diagram of a nuclear generating station.

HOW IT WORKS
ELECTRICITY GENERATION

MANAGING NUCLEAR WASTE

When uranium atoms split they form two smaller atoms, called **FISSION PRODUCTS.** These fission products are highly radioactive. As a result, the fuel bundles that hold the uranium need to be isolated from the environment for an extended period of time once they are removed from a reactor.

Fission products are so unstable they fall apart or disintegrate. When this happens, tiny fragments of the fission products are emitted in all directions. Atoms that spontaneously disintegrate in this manner are said to be radioactive.

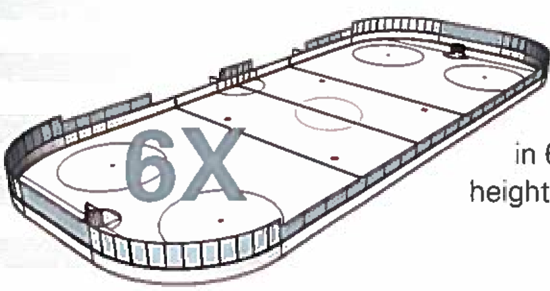
A worker at the Pickering Nuclear Station looks over the used fuel bundles in the water-filled bay. The fuel bundles will remain in the water for about 10 years.

When they can no longer generate heat efficiently, used fuel bundles are removed from the reactor and placed in **WATER-FILLED BAYS** to cool down. These water-filled bays are located on the same site as the reactors and are built using reinforced concrete, lined to prevent leaks and designed to withstand earthquakes. The water in the bays helps cool the fuel bundles as well as provide shielding from radiation. The fuel bundles will remain in the bays for approximately 10 years after which time they will have cooled and the radiation they emit will have decreased significantly.

The fuel bundles are then removed from the bay and placed in what are called **DRY STORAGE CONTAINERS**. These containers are made of concrete and steel and provide shielding from radiation. The containers are welded shut and stored in highly secure warehouses located on the same site as the nuclear generating station.

After being removed from the water-filled bays, the used fuel is placed in storage containers like the ones shown here. The containers are stored on the site of the nuclear station in highly secure warehouses where they are constantly monitored.

Canada's long-term plan for managing used nuclear fuel is to have a central, contained isolation facility in a deep rock formation. In the interim, scientists around the world are looking for new and innovative solutions to manage nuclear waste over time.



The total amount of used fuel produced from Canada's nuclear power plants over the past 50 years could be stored in 6 hockey rinks up to the height of the boards.

HOW IT WORKS
ELECTRICITY GENERATION

The Sir Adam Beck Generating Stations near Niagara Falls can provide enough electricity to meet the needs of 10% of the entire province.

HYDROELECTRIC POWER

Ontario has been using water to make electricity for over a century. In fact, some of Ontario's hydroelectric stations are over 100 years old and are still generating electricity for us today.

Hydroelectric power stations convert the kinetic energy of falling water into electrical energy. To convert the kinetic energy of falling water to electricity, most hydroelectric stations use either the natural drop of a river, such as a waterfall, or a dam is built across a river to raise the water level and provide the drop needed to create a driving force.

Water is collected at the top of the dam in what is called the **FOREBAY**. From there, the water flows into a pipe called a **PENSTOCK** which carries it down to a turbine **WATER WHEEL**. The water pressure increases as it flows down the penstock. The pressure and flow of the falling water drives a turbine which in turn spins a generator. This creates electricity that can be sent across transmission lines to wherever the power is needed.

Hydroelectricity is one of the most economical and environmentally friendly ways of generating electricity. It produces virtually no smog or greenhouse gas emissions and is a renewable energy source – the water can be used again and again.

Ontario currently has over 70 hydroelectric generating stations but there are only a few rivers left in the province where new stations can be built. After that, other sources of energy will be required to meet our need for electricity.

HYDROELECTRIC GENERATING STATION

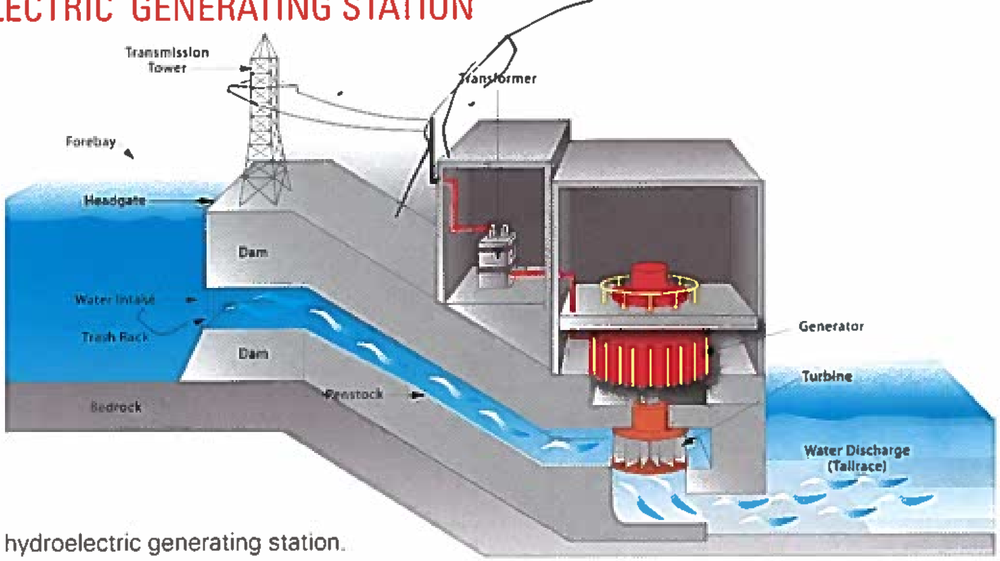


Diagram of a hydroelectric generating station.

HOW IT WORKS
ELECTRICITY GENERATION

The Nanticoke Generating Station on the shores of Lake Erie is the largest coal-fired power plant in North America. When running at capacity the station can meet up to 20% of Ontario's electricity demands.

FOSSIL-FUELLED POWER

Fossil-fuelled generating stations burn **COAL, OIL** or **NATURAL GAS** to generate electricity.

In the case of a coal-fired generating station, the coal is stored in large coal piles just outside the station. From there, the coal is brought into the station on a conveyor belt where it is fed into large pulverizers that crush the coal into a fine powder. Large fans blow the coal powder into a giant furnace where it is burned giving off vast amounts of heat. The temperature in the furnace can reach over 3,000°C.

The furnace is surrounded by tubes filled with water. The immense heat from the burning coal turns the water in the tubes into steam. The steam is then transferred under pressure at high speed through large pipes to a turbine where it pushes the turbine blades causing them to spin. From there, the process is the same as in a nuclear or a hydroelectric generating station; the turbine spins the generator producing electricity.

The steam is condensed back to water using cooling water, usually from a nearby lake or river. It is then pumped back into the water tubes surrounding the furnace to continue the process.

COAL-FIRED GENERATING STATION

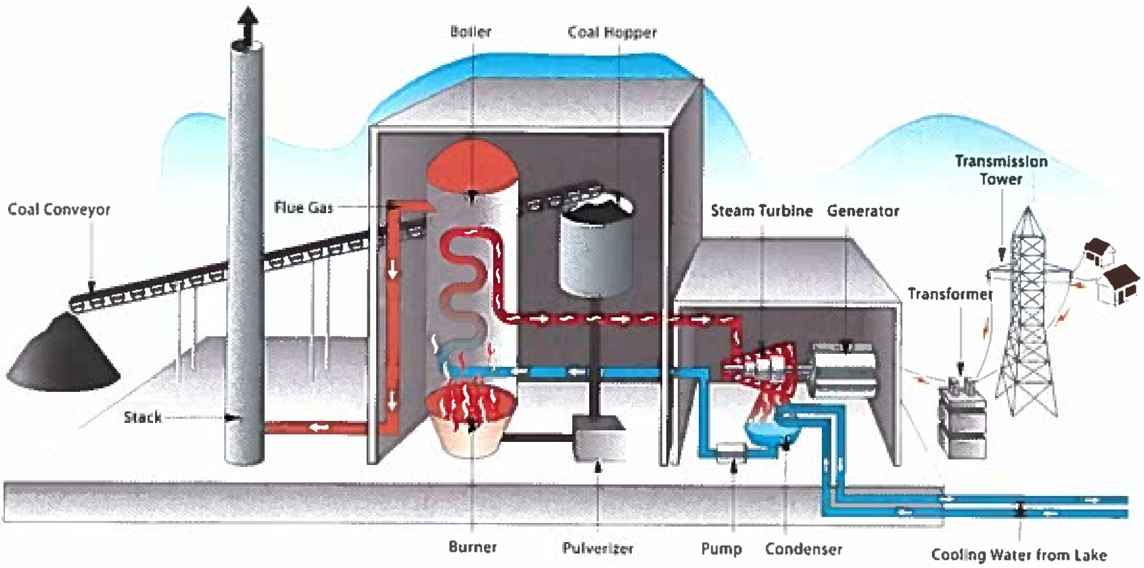


Diagram of a coal-fired generating station.

HOW IT WORKS
ELECTRICITY GENERATION

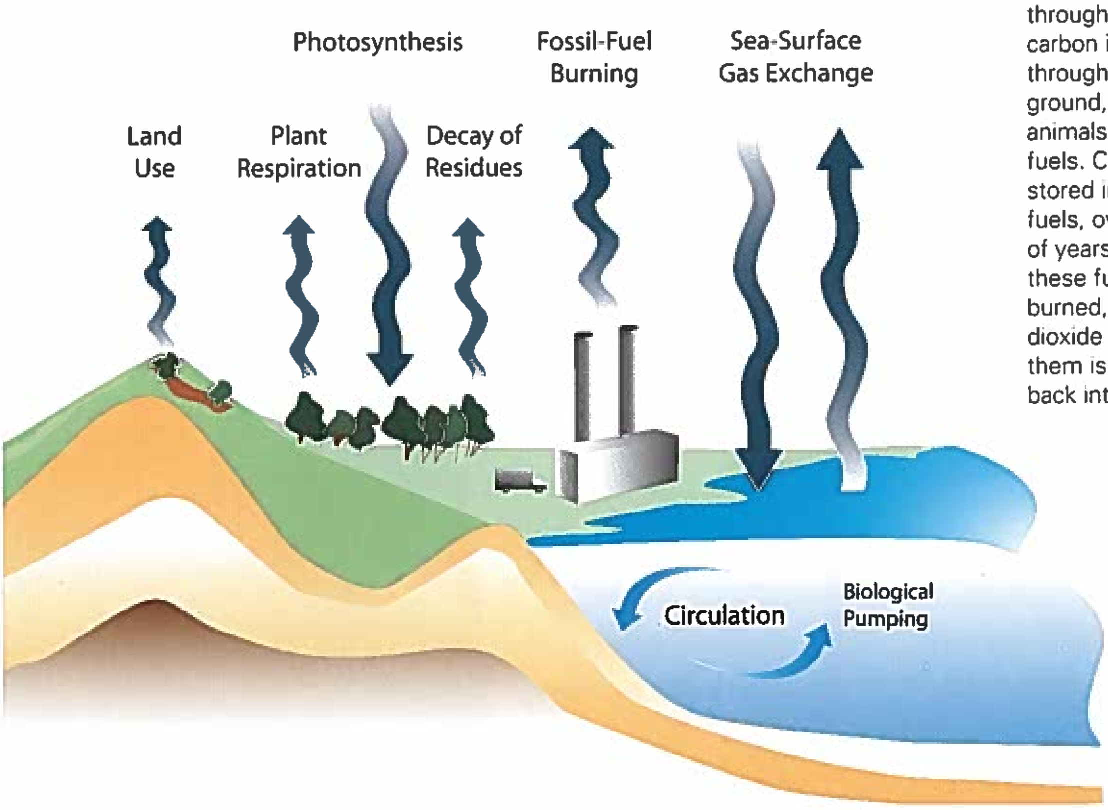
Natural gas power plants such as the Portlands Energy Centre located in Toronto are used primarily to meet Ontario's peak demand for electricity.

Fossil-fuelled power plants play an important role because, unlike a nuclear station, they are able to quickly adjust to changes in electricity demand. Their output can be easily increased to help meet periods of peak demand.

Burning fossil fuels to generate electricity creates a number of byproducts that impact the environment. This includes gases like **SULPHUR DIOXIDE (SO_2)** and **NITROGEN OXIDE (NO_2)** which contribute to smog and acid rain. Some of Ontario's coal-fired generating stations use special technologies that can reduce or almost eliminate these pollutants.

Another gas that is released when burning coal is **CARBON DIOXIDE (CO_2)**, which is a **GREENHOUSE GAS**. Greenhouse gases trap heat in the earth's atmosphere and can cause temperatures on the earth's surface to rise. This effect is known as global warming.

THE GLOBAL CARBON CYCLE



The carbon cycle is the process through which carbon is cycled through the air, ground, plants, animals, and fossil fuels. Carbon is stored in fossil fuels, over millions of years. When these fuels are burned, the carbon dioxide stored in them is released back into the air.

HOW IT WORKS
ELECTRICITY GENERATION

Pelletized grain screenings as shown in the picture above can be used to generate carbon free electricity.

BIOMASS ENERGY

Biomass energy is energy generated from the burning of plant material and consists mostly of agricultural and milling byproducts such as grain and wood pellets. No food products are included in biomass in Ontario.

Biomass is considered a **CARBON NEUTRAL** energy source. That means that the amount of carbon dioxide released when burning it is equal to the amount of carbon dioxide the plants absorb when being grown.

In Ontario, testing of biomass fuels is being conducted at several coal-fired generating stations. Biomass is mixed in with the coal before it is fed into the furnace. This reduces the amount of coal that needs to be burned at the stations and has several environmental benefits including:

- Reduction of CO_2 emissions
- Reduction of sulphur emissions
- Reduction of mercury emissions

Biomass could theoretically replace some or all of the coal being burned at some coal-fired generating stations in Ontario.

The silos shown here store biomass for use at the Nanticoke Generating Station and will help reduce the station's net CO_2 emissions.

HOW IT WORKS
ELECTRICITY GENERATION

The Pickering wind turbine shown here produces enough power for 330 homes a year.

WIND POWER

Wind turbines that generate electricity operate in much the same way as a hydroelectric generating station. Instead of falling water, wind turbines use the kinetic energy of blowing air to spin the blades of the turbine which are connected to a generator.

Wind power currently provides about 1% of Ontario's electricity but it is the fastest growing energy source in the world and it will be playing an increasing role in supplying our electricity.

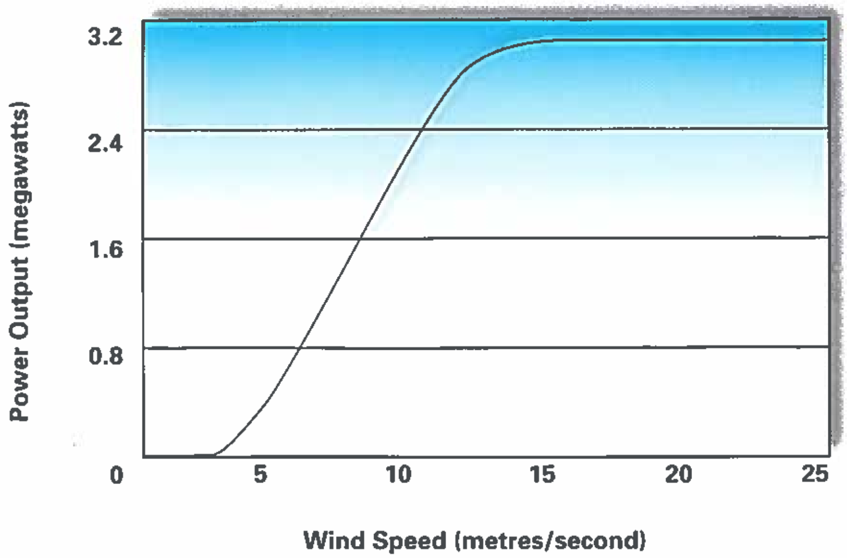
The amount of electricity a wind turbine can produce depends on the strength and consistency of the wind at any given time. Generally, the wind needs to be blowing at 10 km/hr for a wind turbine to effectively convert kinetic energy into electricity.

Most types of power plants can run 24 hours a day, however, wind turbines can only generate electricity when the wind is blowing. Because of this, wind turbines cannot be relied on to help meet peak electricity demand.

In Ontario, the wind blows fast enough to generate electricity an average of 20% of the time.

The graph below shows how power output from a 3 megawatt wind turbine varies depending on wind speed.

GENERIC MEGAWATT TURBINE[1]



[1]Source: Ontario Power Authority - www.powerauthority.on.ca

HOW IT WORKS
ELECTRICITY GENERATION

UNDERSTANDING CO_2 EMISSIONS

Fossil-fuelled generating stations that use coal, oil or natural gas to generate electricity burn their fuels to give off heat. This results in the release of greenhouse gases into the atmosphere.

Other generating facilities like wind turbines, solar panels and nuclear stations do not give off any greenhouse gas emissions when converting their energy sources into electrical energy.

For example, a nuclear station does not emit any greenhouse gases when converting the heat energy of split uranium atoms into electricity. However, the construction of the station itself and the mining of uranium does produce greenhouse gas emissions.

The same is true for solar and wind generating facilities. While solar panels do not produce any emissions when converting the sun's energy to electricity, the process for manufacturing and installing solar panels does emit greenhouse gases.

In order to get the whole picture on how much CO_2 different forms of electricity produce, all these factors need to be taken into consideration. This is commonly referred to as **LIFE CYCLE EMISSIONS** because it takes into consideration all emissions resulting from a facility's operations, from construction to demolition.

The chart below shows life cycle emissions for different forms of electricity generation. The CO_2 emissions are measured in grams per kilowatt hour of electricity generated. An average home uses 1,000 kilowatt hours a month.

LIFE CYCLE CO_2 EMISSIONS[1]

Nuclear	Natural Gas	Coal-Fired	Hydroelectric	Wind	Solar
30.5	450.0	986.0	25.0	65.5	372.0
Grams of CO_2 produced per kilowatt hour of electricity generated.					

[1]Source: "Hydropower-Internalized Costs and Externalized Benefits" Koch, Frans F. International Energy Agency, Ottawa (2000).

OPG would like to thank the science teachers across Ontario who contributed their time and expertise to the development of this booklet.

For more information please visit:
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