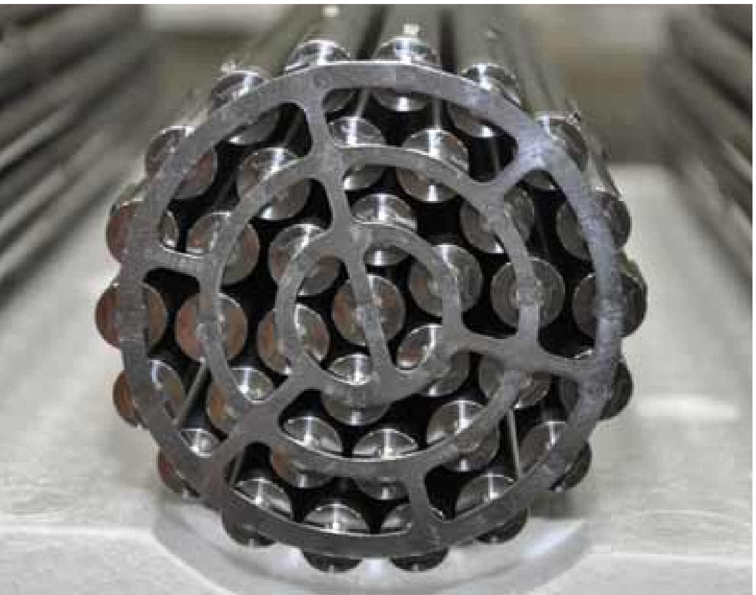
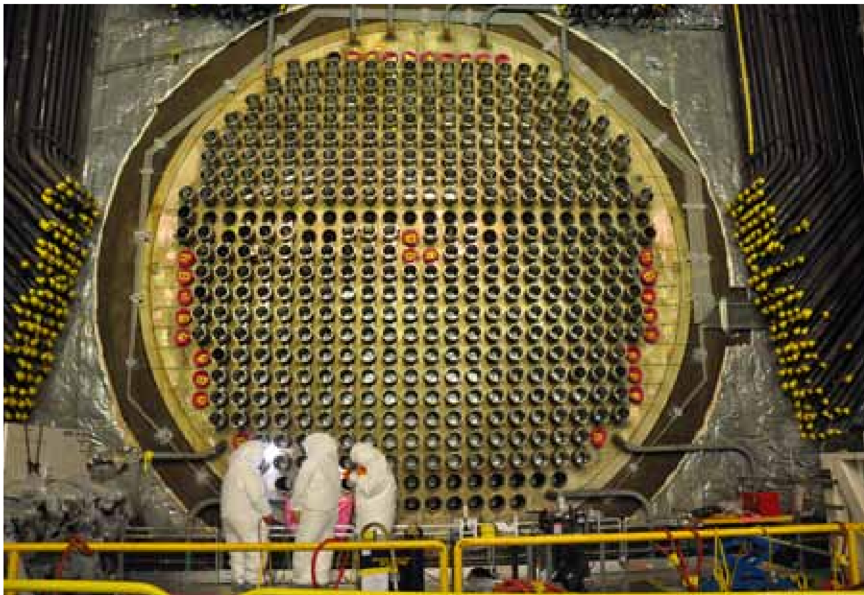
Innovation at work

A Guide to Bruce Power






Low Cost, Safe,
Clean, Reliable.

Ontario is counting on Bruce Power to generate over 25 per cent of the province's electricity to the end of the decade and for generations to come.

During our first 10 years of operation, Bruce Power has revitalized the Bruce site and is on track in 2012 to transform it into the largest nuclear facility in the world with the return to service of Units 1 and 2. Once all eight units are operational, the Bruce Power site will produce 6,300 megawatts (MW), or well over a quarter, of Ontario's electricity.

Through $7 billion of private investment, Bruce Power will have doubled the number of operational units on the Bruce Power site, transformed the workforce through new hiring and training, extended the life of operating units through innovation, and positioned the site for long-term stability.

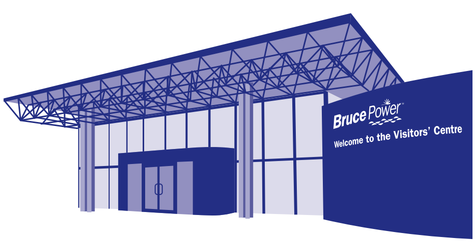
Ontario's Long Term Energy Plan has earmarked the Bruce Power site to generate 6,300 MW in the coming decades as the province relies on our site to power one out of four homes, schools, businesses, farms, schools and hospitals with low-cost, highly reliable, clean electricity. To achieve this, Bruce Power's investors will need to invest billions to continue to extend the life of the remaining units on the site.

By building on the experience we have gained over the last 10 years with renewing our infrastructure, we are in a strong position to progress with a comprehensive asset life management program to continue to invest in our units, while ensuring we continue to provide the province with reliable, low-cost electricity to continue to stabilize both supply and electricity rates.

Bruce Power Visitors' Centre

The Bruce Power Visitors' Centre is open to the public Monday to Friday from 8:30 a.m. to 4 p.m. and houses interactive displays about Bruce Power and nuclear energy.

3394 Bruce County Rd. 20 (4th Concession)
west of Hwy. 21, Tiverton, ON
519.361.7777



Bruce Power's Corporate Office

P.O. Box 1540 Tiverton, Ontario, Canada N0G 2T0
1.866.748.4787
www.brucepower.com

Duty Media Officer

1.519.361.6161

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About Bruce Power

Bruce Power is a Canadian-owned partnership of TransCanada Corporation, Cameco Corporation, Ontario Municipal Employees Retirement System (OMERS), the Power Workers' Union and The Society of Energy Professionals.

Formed in 2001, Bruce Power is Canada's only private sector nuclear generator and operates one of the largest nuclear facilities in the world capable of producing 6,300 MW or over a quarter of Ontario's electricity. Bruce Power's shareholders are also the owners of Ontario's first commercial wind farm, Huron Wind, which produces enough electricity for 3,000 local homes annually.

Ontario's Long Term Energy Plan is counting on Bruce Power to provide a reliable source of clean, affordable electricity for the province's ratepayers for decades to come.

The company employs approximately 4,000 people and in the last 10 years has been the single largest private investor in Ontario's electricity infrastructure with a total injection of $7 Billion into the Bruce Power site. The site is leased from the Province of Ontario under a long-term arrangement where all of the assets remain publicly owned, while the company makes annual rent payments and funds the cost of waste management and eventual decommissioning of the facilities.

Bruce Power

TransCanada

OMERS

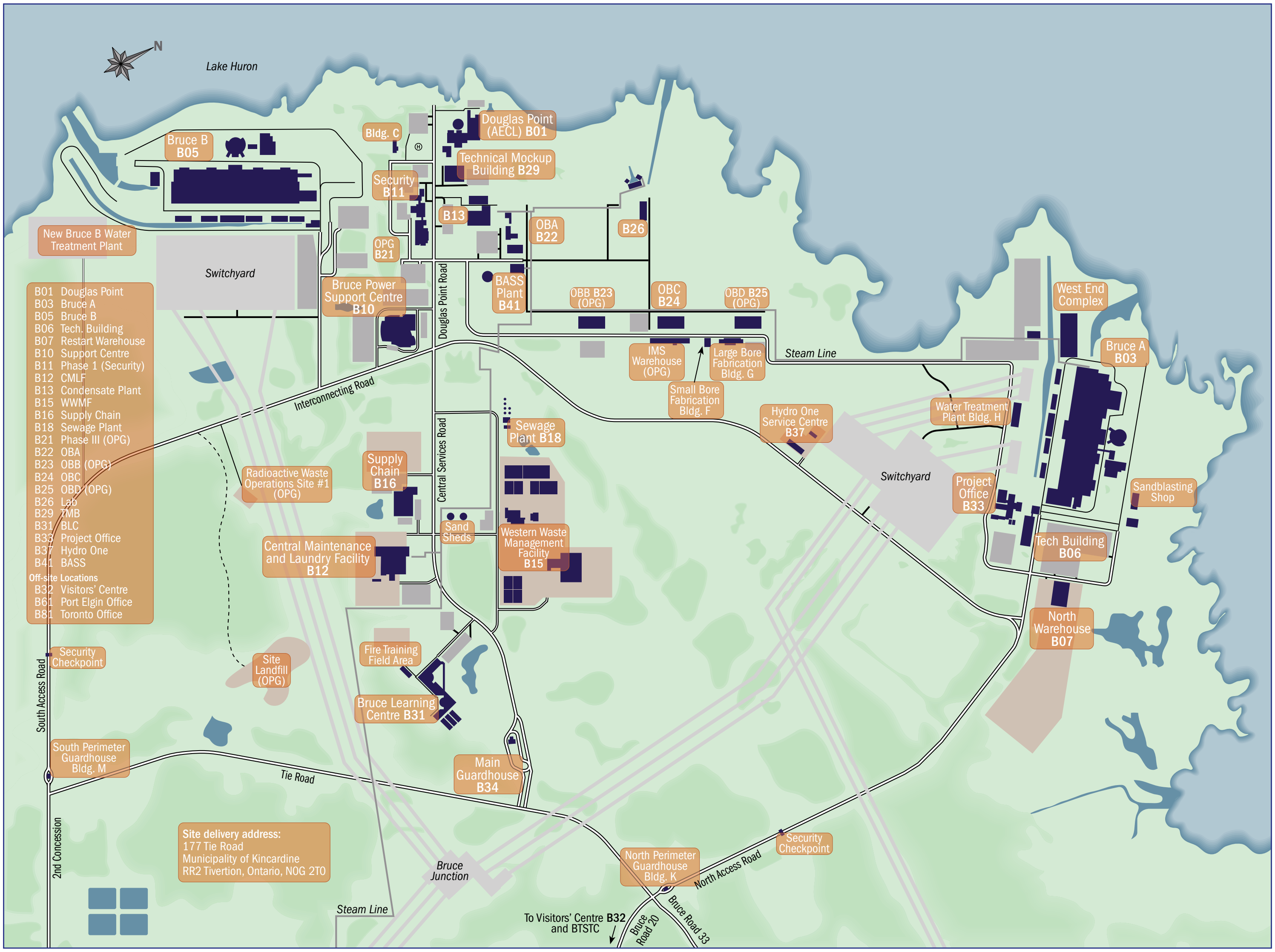
Cameco

THE SOCIETY OF ENERGY PROFESSIONALS IFPTE LOCAL 160

POWER WORKERS' UNION


Congratulations!
20,000,000
TIME INJURY
Treated Injuries
Safety
First


Bruce Power



Site facts

Number of employees

Over 4,000 employees.

Site size

2,300 acres, which is large enough to hold the Metro Toronto Zoo, Canada's Wonderland, Exhibition Place, Ontario Place and the African Lion Safari.

Location

Situated on Lake Huron, between the towns of Kincardine and Saugeen Shores, 250 km northwest of Toronto.

Bruce Power amenities

The site has more than 56 km of roads and is like a small city, including our own fire department and emergency response team, laundry facility, learning centre, high tech training centre, medical staff, security team and works department.

Flora and fauna

Bruce Power is located in the midst of woodlands and wetlands and is home to more than 235 species of plants and more than 200 species of wildlife. These include 150 bird species, 15 kinds of reptiles and amphibians, 20 types of mammals and 90 varieties of fish.

Safety record

Bruce Power has one of the strongest industrial safety records in Ontario's electricity sector. In May, 2010, Bruce Power achieved a major safety milestone reaching 22 million hours worked without an acute lost time injury. In December, 2011, the Bruce A Restart project celebrated 15 million hours without an acute lost-time injury.

Historical Timeline

1960
Douglas Point construction begins.

1967
Douglas Point is powered up for the first time.

1968
Plans are announced for Bruce A and the Bruce Heavy Water Plant.

1969
Bruce A construction begins. BHWP A construction begins. Bulk Steam proposal accepted.

1972
Bulk Steam in service. Application and approval for Radioactive Waste Management 20-acre site. Construction begins on waste management site.

1973
BHWP A in service. Ontario Hydro purchases from AECL.

1974
BHWP B construction begins. Waste Management Site completed, licensed, in service. BHWP D construction begins; half-finished when mothballed in 1979.

1975
Government approves Bruce B proposal. Construction begins for incinerator for waste management.

1977
Bruce B begins construction. | Bruce Units 1 and 2 in service. | Waste Management Incinerator in service.

1978
Bruce Unit 3 in service

1979
Bruce Unit 4 in service. BHWP B construction completed. | Construction stopped on BHWP D.

1980
BHWP B commissioned for service.

2001
May 12 | Bruce Power assumes operational control of site, confirms plans to restart Units 3 and 4. **December** | Bruce Power wins Financial Times' Global Energy Award as Successful Investment Decision of the Year.

2002
February 15 | Units 6 and 7 are world's top-performing CANDU reactors. **May 1** | Ontario's electricity market opens to competition. **December 23** | TransCanada Corp. and OMERS agree to join Cameco, PWU and The Society in revised partnership as British Energy withdraws.

2004
January 8 | Unit 3 returns to service. Bruce A Restart deemed 'Project of the Year' by Power Engineering Magazine.

2003
July 7 | Bruce Technical Skills Training Centre opens. **August 14 |** Massive blackout leaves large parts of Ontario and northeastern U.S. without electricity. Units 5, 7 and 8 remain online to help Ontario through crisis. **October 7** | Unit 4 returns to service.

2005
October 17 | Multi-billion agreement reached to refurbish Bruce A units. **October 24** | CEO Duncan Hawthorne named Canadian Energy Person of the Year.

2006
Achieves highest output in 5 years with over a 50% increase. | Company workforce transformed with 1,200 new hires. | First ever replacement of steam generators takes place at Bruce A.

1981
Units E3, E4 BHWP in service. | Unit 1 rated Number 1 reactor in world for year, running at 97% capacity.

1983
Construction of Bruce Learning Centre (formerly Western Nuclear Training Centre).

1984
May 5 | Last day of operation for Douglas Point. BHWP A mothballed. Bruce Unit 6 in service.

1985
Bruce Unit 5 in service.

1986
Bruce Unit 7 in service.

1987
Bruce Unit 8 in service.

1988
Bruce Units 3, 4, 6 and 7 place Top 10 worldwide performance for the previous year.

1991
Rehabilitation project approved for Bruce A.

1993
Faced with largest surplus capacity of electricity in its history, Ontario Hydro defers decision made in previous year to retube Unit 2.

1994
Work begins to dismantle BHWP-A.

1995
October 8 | Bruce Unit 2 laid up.

1997
October 16 | Bruce Unit 1 laid up.

1998
March 16 | Bruce Unit 4 laid up.
April 9 | Bruce Unit 3 laid up.

1999
April 1 | Launch of Ontario Hydro's five successor companies, one of which is Ontario Power Generation (OPG).

2007
Fuel channel replacement in Units 1 and 2 gets underway. | Unit 5 hits a new record with a 475-day run.

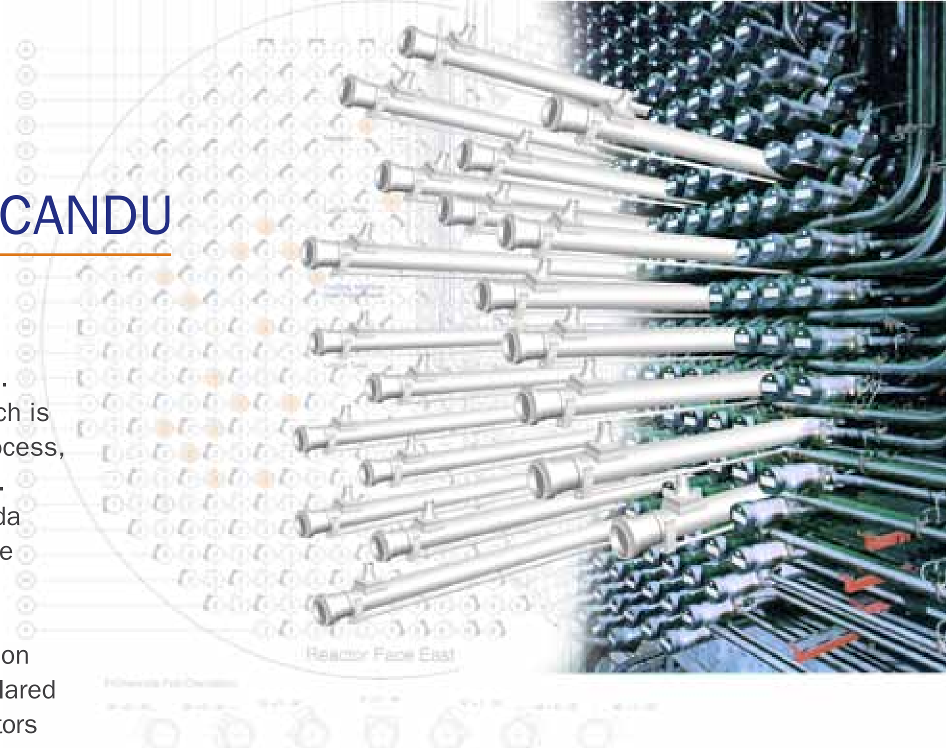
2008
10 million hours worked without a lost-time injury. | Units 3 and 4 extended to 2010 and 2015 respectively. | 12,000 local residents sign petition to support new build option at Bruce. | Province announces a commitment to 6,300 MW from the Bruce site.

2009
Hired over 300 new employees, over half from Ontario's automotive and manufacturing sector. | Units 5 and 6 reach 25 years of operation. | Unit 1 reactor disassembly complete. | First new fuel channel installed in Unit 2.

2010
Unit 5 named the top CANDU unit in the world. | Last of the Bruce B Units raised to 93% power. | Bruce Power receives Minister's Apprenticeship Employer Award. | Long Term Energy Plan released earmarking critical role of Bruce Power.

2011
Bruce Power celebrates 10th anniversary. | Major construction complete on the Bruce A Restart Project. | Fuel loaded in Units 1 and 2. | Unit 3 outage begins to extend life of reactor to the end of the decade.

Making electricity with CANDU



What is a CANDU reactor?

CANDU stands for **CAN**ada **D**euterium **U**ranium. Deuterium is another name for heavy water, which is what is used as the moderator in the fission process, and uranium is what makes up the fuel bundles. Developed in Canada by Atomic Energy of Canada Ltd. (AECL), the first CANDU reactor came on line near Deep River, ON in 1962. The prototype 20,000 kilowatt plant was followed by the 200,000 kilowatt Douglas Point generating station on the Bruce Power site. Douglas Point was declared in service in 1968. There are now 23 CANDU reactors in Canada and nine abroad (India, Korea, Romania, Argentina, China).

The key components of these reactors are natural uranium *fuel*, heavy water *moderator* and heavy water *coolant*.

What fuels the CANDU reactor?

The uranium fuel for reactors at Bruce Power is produced in Canada. From exploration to mining, milling, conversion and manufacture, Canada is a world leader in low-cost uranium production.

Uranium ore is processed into a powdery substance called yellow cake. The yellow cake is then chemically refined into uranium dioxide which is baked into small ceramic pellets. The pellets are sealed inside small metal tubes, which are assembled into fuel bundles. Each bundle, approximately the size of a small fire log, weighs 23.65 kg (52.1 lb).

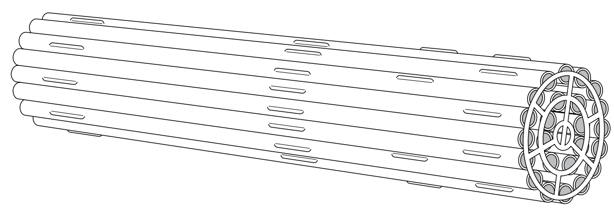
How is the CANDU reactor structured?

The calandria

The calandria is essentially a large metal drum with flat ends, filled with several hundred tonnes of heavy water moderator. It is about 6 metres long and 7 m across and has 480 channels through it that contain the heavy water moderator. Stainless steel end-fittings support the 480 pressure tubes and contain removable plugs to allow for fuel changing. A large shield tank filled with light water surrounds the calandria and provides thermal and radiation shielding from the irradiated fuel during operation. Cooling pipes, which are embedded in the walls, protect the concrete from overheating.

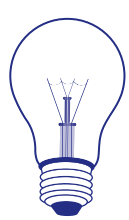
Fuel Facts

- Each seven gram pellet — roughly the weight of two nickels — contains as much potential energy as three barrels of oil.
- A single fuel bundle can supply 100 homes with electricity for a year, which is comparable to 400 tonnes of coal or 270,000 litres of oil or 300 million litres of natural gas.



Pressure tubes

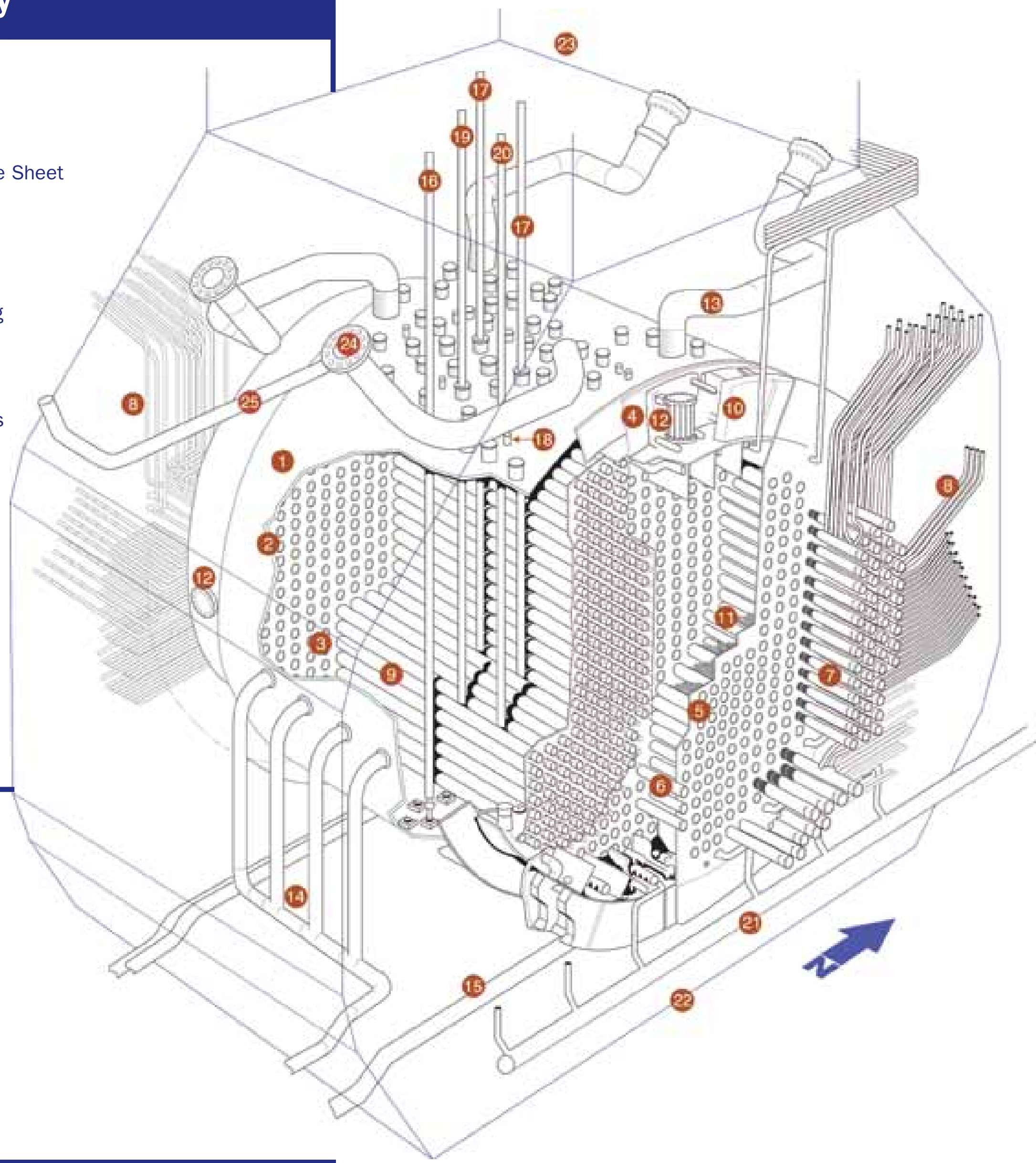
Each 6.3 m (20.6 ft) pressure tube is inserted inside its own horizontal calandria tube, which is secured on both ends to the calandria tube sheets. The two tubes are held apart by rings called garter springs. The space between the two tubes, called the annulus, is filled with carbon dioxide gas. The gas is circulated as an insulator and monitored for the presence of moisture, which would indicate a leak in either the pressure tube or the calandria tube.



One megawatt is equivalent to a million watts. An average household light bulb is 60 watts.

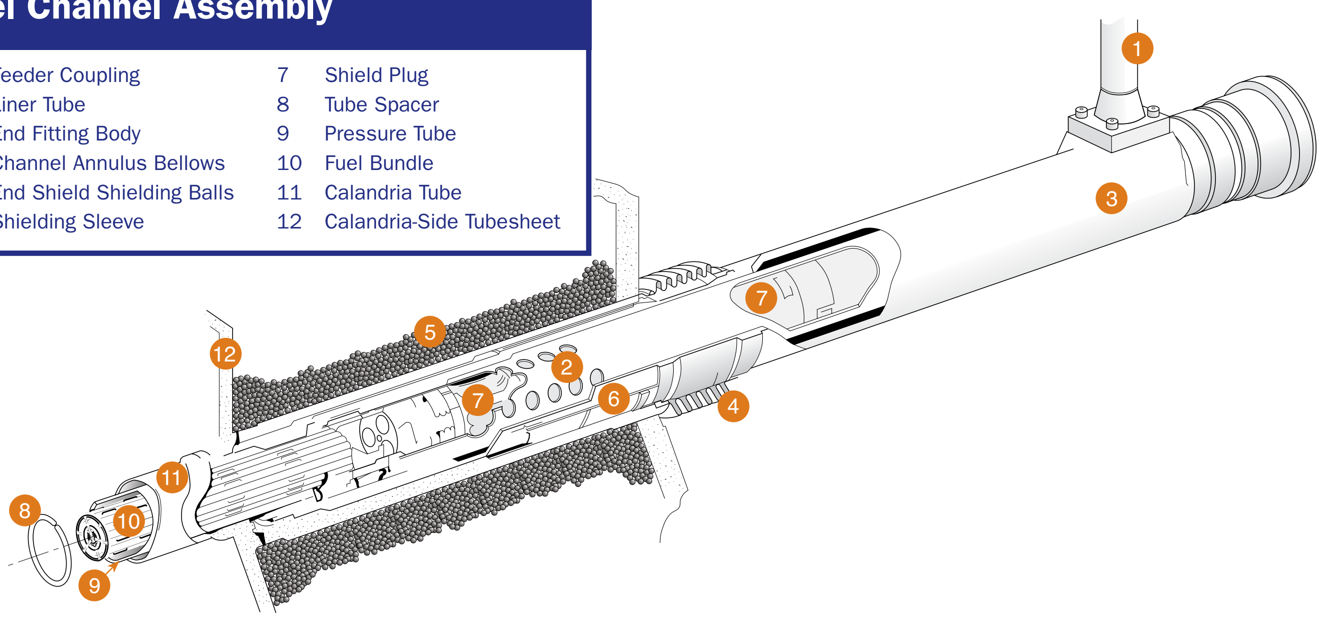
Reactor Assembly

1 Calandria
2 Calandria Shell
3 Calandria Side Tube Sheet
4 Baffle Plate
5 Fuelling Machine Side Tube Sheet
6 Lattice Tube
7 Fuel Channel End Fitting
8 Feeders
9 Calandria Tubes
10 Shield Tank Solid Shielding
11 Steel Ball Shielding (End Shield)
12 Manhole
13 Moderator Discharge Pipes
14 Moderator Inlets
15 Moderator Outlets
16 Shut-off Unit
17 Adjuster Unit
18 Vertical Flux Detector
19 Control Absorber
20 Liquid Zone Control Unit
21 End Shield Cooling Piping
22 Shield Tank
23 Shield Tank Extension
24 Rupture Disc Assembly
25 Moderator Overflow



Fuel Channel Assembly

1	Feeder Coupling	7	Shield Plug
2	Liner Tube	8	Tube Spacer
3	End Fitting Body	9	Pressure Tube
4	Channel Annulus Bellows	10	Fuel Bundle
5	End Shield Shielding Balls	11	Calandria Tube
6	Shielding Sleeve	12	Calandria-Side Tubesheet



How do we make electricity?

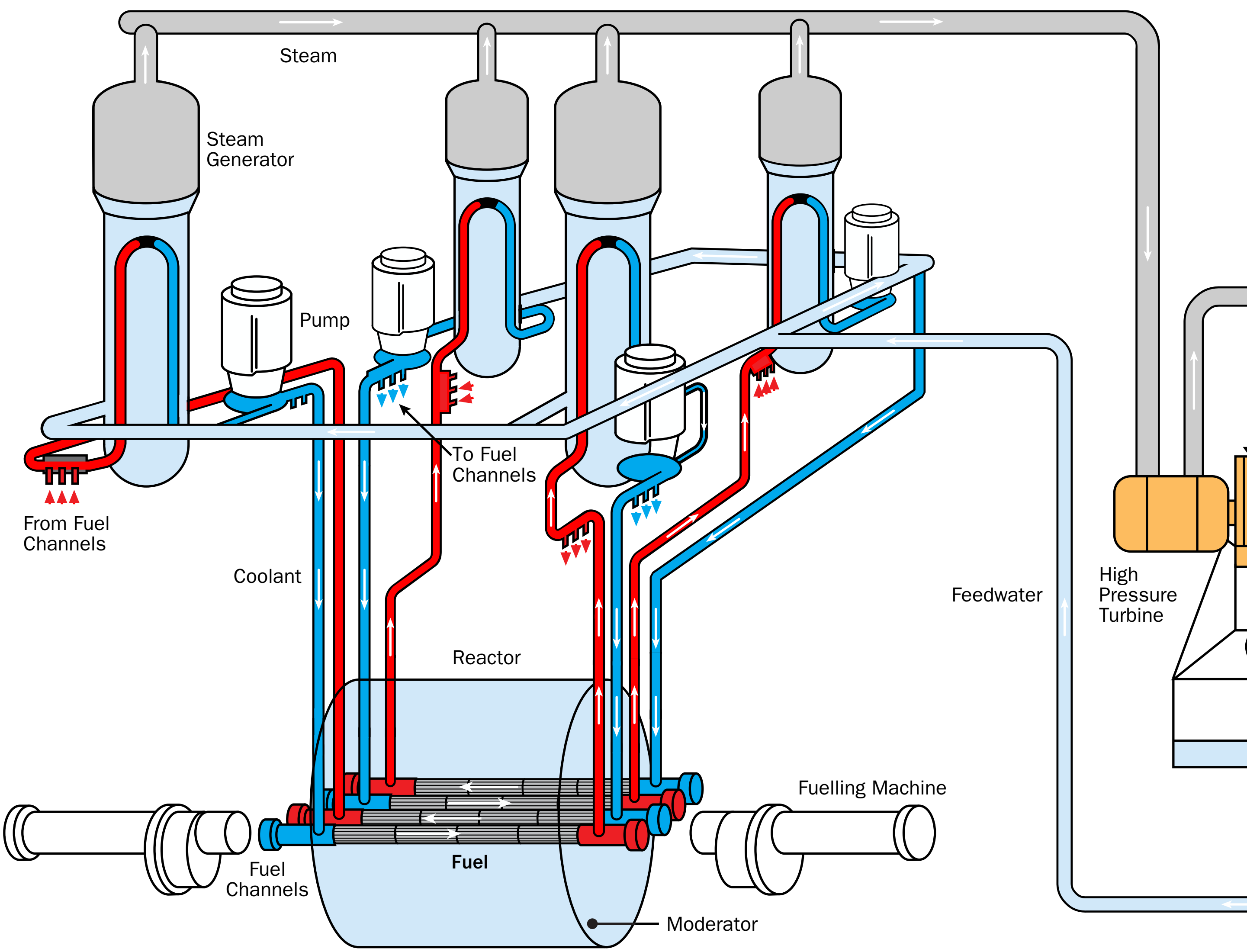
In a nuclear plant, a reactor performs the same function as a furnace in a fossil-fuelled generating station. It produces heat to turn water to steam to drive a turbine generator.

The heat is created in a reactor by the "fissioning" or splitting of uranium atoms. When the centre or nucleus of a uranium atom fissions, it splits into fragments which separate rapidly and generate heat. Two or three neutrons are released and they go on to collide with other atoms.

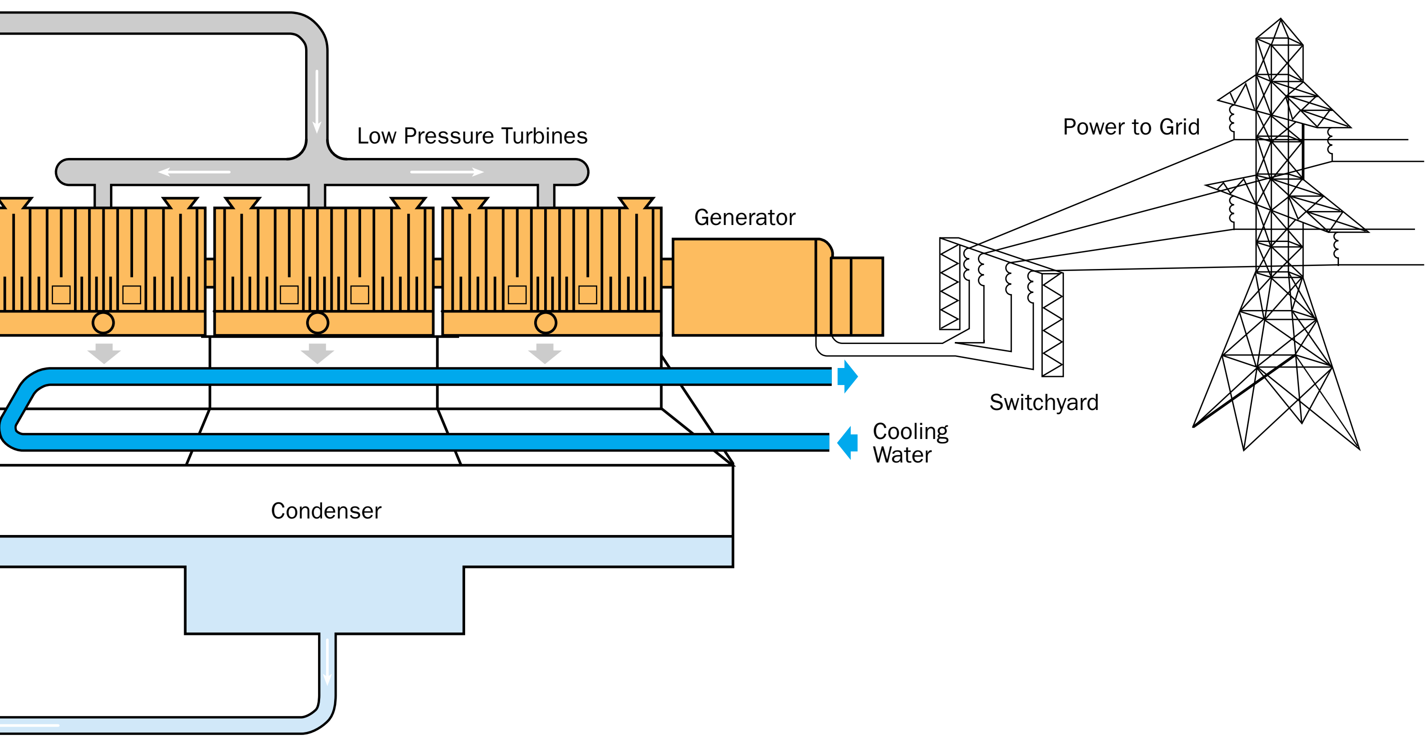
Heavy water 'moderator' is used to slow the neutrons down and sustain the fission process in a controlled chain reaction. Heavy water is also used as a 'coolant' to remove heat from the fuel and carry it to steam generators.

The heat in the steam generators turns light water to steam which is piped to a series of turbine rotors. The rotors are connected to a shaft which in turn spins the generator. Mechanical energy is converted into electrical energy which is fed to the province's electricity grid.

CANDU Pressurized Heavy Water Reactor



1. A fuelling machine feeds fuel into one of the Bruce A reactors. **2.** A steam generator is loaded on a transport carrier at Bruce A. Weighing approximately 100 tonnes, the vessels are 12 metres high when in their upright position. **3.** New rotors in Bruce B. **4.** Bruce B turbine hall at Unit 6.



What happens to the fuel when it is finished producing heat in the reactor?

The CANDU system employs a unique on-power refuelling system for optimum performance. Two identical fuelling machines rise from a fuelling duct under the reactor and latch onto opposite ends of a designated fuel channel. Each machine is operated remotely from the control room. With both machines latched on and brought up to system pressure, the ends of the fuel channel are opened and new fuel is exchanged for used fuel — one machine discharging and the other accepting. Each bundle stays in the reactor for 12 to 20 months, depending on where it is located in the calandria. Once removed, it is moved to the fuel bay as wet storage.

Used Fuel Facts*

- Used fuel bundles are very radioactive after being removed from the reactor. A few metres of water in a used fuel storage bay provides adequate shielding to protect workers and the public from the radiation.
- One year after removal from the reactor, a used nuclear fuel bundle gives off less than 0.1% of the heat it emitted while in the reactor.
- After about 10 years in a water-filled storage bay, used fuel bundles are cool enough to be placed in dry storage containers.
- If all of the used fuel used in Canada over the last 50 years was put in one place and stacked like firewood, it would fill a soccer field to the height of an average adult.

**Source: CNA Factbook*

A worker inspects a fuelling machine at Bruce B.

Used fuel bay

Once fuel is removed from a reactor, it is transferred by remote control to a water-filled storage bay like the one shown to the right. The bay is about six metres deep and roughly the same size as an Olympic-sized swimming pool, except it is constructed of double-walled reinforced concrete. Used fuel is safely stored and each bundle is accounted for and monitored. Fuel bundles are stored in the cooling bays at the stations for at least 10 years. After that, they are taken out of the bays and transported to a dry used fuel storage facility owned and operated by Ontario Power Generation (OPG) on the Bruce site. OPG accepts and stores used fuel from the Bruce A and B stations as part of the lease agreement with Bruce Power.

Cobalt

Bruce Power provides much of the world's cobalt-60. Small metal bundles containing natural cobalt-59 pellets are inserted vertically into the reactors at Bruce B. During reactor operation, the cobalt-59 absorbs a neutron to become cobalt-60, a radioactive substance. Removed from the reactor during regular maintenance outages, the cobalt-60 is marketed worldwide as a source for gamma sterilization. It is used to sterilize disposable medical supplies including sutures, syringes, surgical gowns and masks. Cobalt-60 is also used to sterilize pharmaceutical wares, cosmetics, spices, and other consumer products that include fruit, seafood, poultry and red meat.

Secondary used fuel bay at Bruce B.

Nuclear safety

To achieve optimum safety, Bruce Power, along with other nuclear plants, operate using a 'defense-in-depth' approach. This ensures accidents don't happen by using high quality design, equipment and operators.

Safety systems

Each CANDU unit has four special safety systems. They include Shutdown System No. 1 (SDS1), Shutdown System No. 2 (SDS2), the Emergency Coolant Injection System (ECIS), and the Containment System. These systems are tested frequently but not used in day-to-day operations. Completely independent of one another, they activate automatically if reactor systems exceed established parameters.

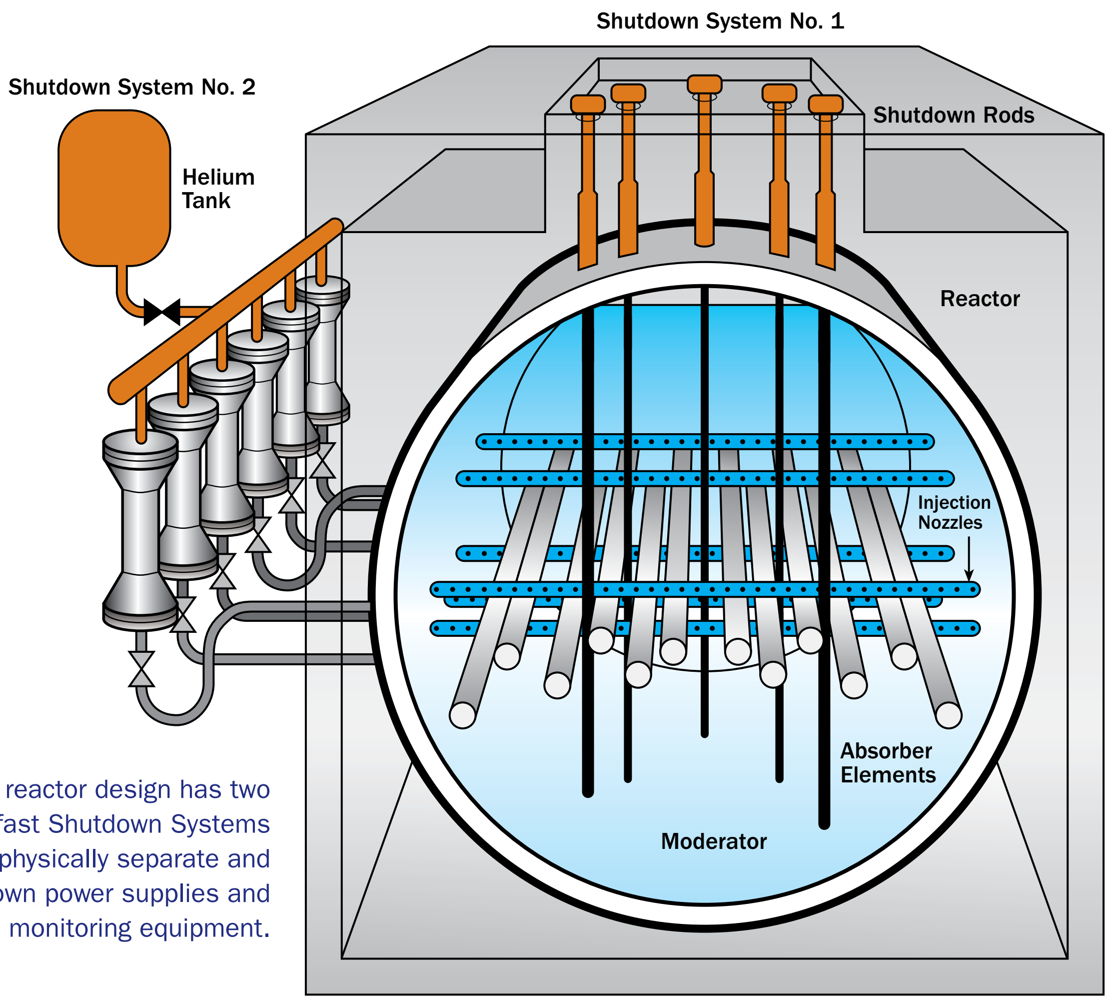
Both Shutdown Systems reduce the heat being generated from 100 per cent to 10 per cent in just two seconds. Each system is completely independent and designed to be fail-safe, which means if a component of one of the shutdown systems fails, the rest of the system is capable of performing its function, or is automatically activated to shut down the reactor.

Shutdown System No. 1 (SDS1)

This is the primary means of quickly shutting down the reactor. In SDS1, mechanical cadmium rods drop in from the top of the reactor core and stop the chain reaction by absorbing neutrons. The rods drop into the core within two seconds when a reactor trip signal cuts off the electricity to the clutch.

Shutdown System No. 2 (SDS2)

SDS2 contains six tanks of gadolinium nitrate in heavy water which are connected to perforated tubes that run horizontally through the reactor. SDS2 is activated when the isolation valves at the top of the tank open. High-pressure helium injects the gadolinium into the moderator and shuts down the reactor in seconds.



The CANDU reactor design has two independent fast Shutdown Systems that are physically separate and have their own power supplies and monitoring equipment.

Emergency Coolant Injection System (ECI)

This system is designed to provide cooling water to the heat transport system if a leak occurs. When called upon, the system injects light water over the fuel to stop it from overheating.

The ECI works in three stages: high pressure injection, medium pressure injection and low pressure recirculation. High pressure injection uses pressurized tanks to inject water into the heat transport system. The medium pressure stage supplies water by pumping it from a storage tank. The long-term recirculation stage recovers water that has been collected in the basement of the reactor building and pumps it back into the heat transport system through heat exchangers.*

*Source: www.aecl.com, www.cna.ca

Containment System

Each reactor is located in its own airtight vault with concrete walls that are more than a metre thick. Maintained at a negative pressure, the reactor vault is connected to the station's central fuelling duct. The central fuelling duct in turn connects to two pressure relief ducts that link to a large cylindrical structure called the vacuum building.

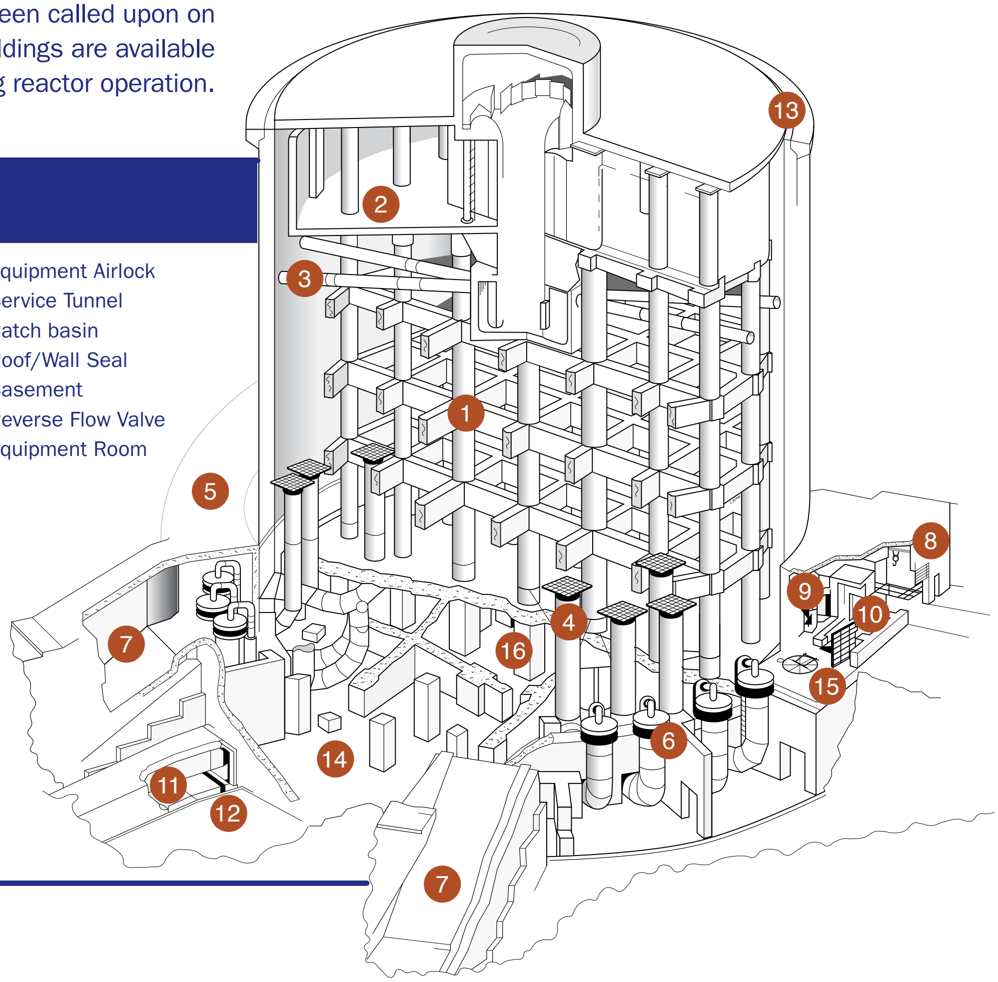
Maintained at one-tenth atmospheric pressure, the vacuum building is poised to suck up radioactive steam and contaminants in the unlikely event of a reactor accident. Once triggered, it douses the steam and contaminants with water from an overhead storage tank.

Unique to multi-unit CANDU stations like Bruce A and Bruce B, the vacuum building provides an additional protective barrier to the release of radioactivity.

Although they've never been called upon on the Bruce site, vacuum buildings are available 100 per cent of the time during reactor operation.

Vacuum Building

1 Internal Structure
2 Emergency Water Storage Tank
3 Distribution and Spray Headers
4 Vacuum Duct
5 Valve Manifold
6 Pressure Relief Valve
7 Pressure Relief Duct
8 Monorail and Hoist
9 Personal Airlock
10 Equipment Airlock
11 Service Tunnel
12 Catch basin
13 Roof/Wall Seal
14 Basement
15 Reverse Flow Valve
16 Equipment Room



Emergency response

How does Bruce Power prepare for potential emergencies?

As part of our operating license, Bruce Power maintains a robust and multi-faceted emergency response program.

This includes our Emergency and Protective Services department, which features an award-winning security services, a fully equipped fire department, an ambulance and an emergency response organization, which offer around-the-clock response. The company also has fire pump trucks that can provide an external source of water to station fire water systems, which, in turn, are used as an emergency cooling water source for critical systems. In the unlikely event of an emergency, we also have an air/light truck that can remotely provide self-contained breathing apparatus for site staff.

Regulated by the Canadian Nuclear Safety Commission

The effectiveness of Bruce Power's emergency response program is continuously assessed through a series of drills and exercises. Every year, the company runs numerous drills and major exercises, which are evaluated by the nuclear industry's regulator, the Canadian Nuclear Safety Commission. The regulator consistently rates Bruce Power's capabilities as 'fully satisfactory.'

Every five years, the company also participates in a provincial nuclear emergency drill, which is led by Emergency Measures Ontario. This drill tests not only the site's emergency plans, but also those of the Municipal Emergency Plan.

The Community Emergency Management Coordinator for Kincardine maintains a call-down list for all households (approximately 35-40) within a three kilometre radius of the site perimeter in case action, such as sheltering or evacuation, is necessary. The area is also served by warning sirens and people in this zone are provided handouts on the required response and reminded of those actions each year.

Bruce Power is a recognized world leader in on-site security

Site security has always been a priority at Bruce Power. However, after the events of Sept. 11, 2001, a renewed focus was placed on security with a substantial hardening of all levels of defense.

Today, security is completely self-contained with its own elite Nuclear Response Special Weapons and Tactics (SWAT) team that does not rely on outside assistance. Security has adopted many of the procedures employed by provincial police, including the use of force continuum.

While many of the specific tactics remain classified, they do include sophisticated surveillance systems, detection alarms, assessment cameras, X-ray screening, metal detectors, vehicle searches, delay barriers and armed response.

Award-winning Nuclear Response Team

In 2005, Bruce Power entered its first SWAT competition as a way of measuring against the best in the world and keeping the team sharp.

From 2008-2011, Bruce Power finished first overall at the U.S. National SWAT Championships, an international competition consisting of eight, live-fire tactical events that test fitness, weapons skills and team organization. Scoring is based on time and target hits with events conducted in full tactical gear in head-to-head stages.

In 2006, the team entered the U.S. Department of Energy's Security Protection Officer Team Competition (SPOTC) for the first time and finished first in its category and has continued to take first prize for five straight years.

Nuclear safety facts

- Canada's nuclear power program has an exemplary safety track record with more than 50 years of occupational and public health and safety, and is a leader in the industry worldwide.
- Nuclear power generation is the only energy technology for which there is an international oversight agency at the UN level — the International Atomic Energy Agency.
- Because of stringent monitoring and regulation at the international and national level, nuclear power generation is one of the safest energy technologies.
- Nuclear power generation has the lowest rate of fatalities and injuries per unit of generated electricity than fossil fuels, hydroelectric power, and even wind and solar.

**Source: CNA Factbook*


Bruce Power
MOBILE OPERATIONS CENTRE
MOBILE OPERATIONS CENTRE


EMERGENCY SERVICES
Bruce Power

Radiation overview

Radiation is energy that travels through space. Humans have been exposed to radiation from natural sources since the dawn of time. Sources of radiation include the ground we walk on, the air we breathe, the food we eat and the solar system overall.

Types of radiation

There are three basic types of nuclear radiation:

Alpha particles are produced from the radioactive decay of heavy elements such as uranium. They are composed of two neutrons and two protons identical to the nucleus of a helium atom. Because of their relative size and electrical charge from the two protons, alpha particles can travel only a very short distance in any material. For example a sheet of paper can stop alpha particles.

Beta particles are electrons that come from the transformation of a neutron in the nucleus of an atom to a proton. They can travel up to about five metres in air and one centimetre in tissue.

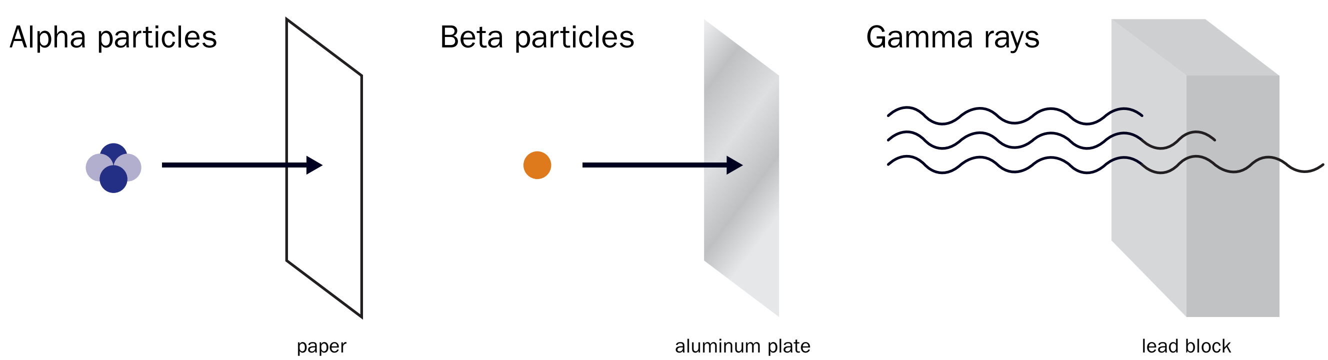
Gamma rays are electromagnetic radiation similar to X-rays. Unlike alpha and beta, which are produced by machines, gamma rays are emitted from the nucleus of a radioactive atom that is in an excited state. Gamma rays travel at the speed of light and can penetrate long distances in air and tissue. Several centimetres of lead or metres of water are needed to stop typical gamma rays such as those from cobalt-60, which is used for cancer therapy.

How is radiation measured?

The amount of radiation received by a person is referred to as ‘dose’, and is measured in units known as microsieverts.

Background radiation comes from natural sources (soil, rocks, water, air and vegetation) and artificial sources (medical X-rays, industrial sources like smoke detectors, and even watches). According to Health Canada, the amount of natural radiation each of us receives is between 2,000 and 4,000 microsieverts per year. The Canadian Nuclear Safety Commission has established an upper limit of 1,000 microsieverts per year for members of the public from human-made sources of radiation (see chart on Page 23).

Alpha radiation is readily stopped by a sheet of paper, beta radiation is halted by an aluminum plate and typical gamma rays are stopped by several centimetres of lead.



Time. Distance. Shielding.
To reduce radiation exposure, nuclear energy workers keep their distance from radioactive sources, limit their exposure time and use shielding. They are also equipped with a wide range of personal protective equipment to limit exposure.

Estimated dose (microsieverts)	Activity
5	sleeping next to your spouse for one year
10	a year of watching TV at an average rate
10	a year of wearing a luminous dial watch
10	a year of living in the U.S. from nuclear fuel and power plants
10	a day from background radiation (average, varies depending on location)
20	having a chest X-ray
65	flying from Melbourne to London via Singapore
300	yearly dose due to body's potassium-40
460	maximum possible off-site dose from Three Mile Island accident
400-1000	average annual dose from medical sources
7,000	having a PET scan
8,000	having a chest CT (CAT) scan
50,000	off-site dose from accident at Chernobyl Nuclear Power Plant (estimates vary widely)
700,000-13,000,000	staff and firefighters at the Chernobyl Nuclear Power Plant during and immediately after the accident
2,000,000	typical single dose to cancer region from radiation therapy
65,000,000	typical total dose to cancer region from radiation therapy

Ontario's energy supply mix

Ontario's goal is to become a jurisdiction that can be powered using clean energy sources that do not pollute or release climate-changing, greenhouse gases. To realize this goal, the province is phasing out coal-fired generation by 2014 and revitalizing its electricity system with renewed nuclear capacity and additional renewable generation.

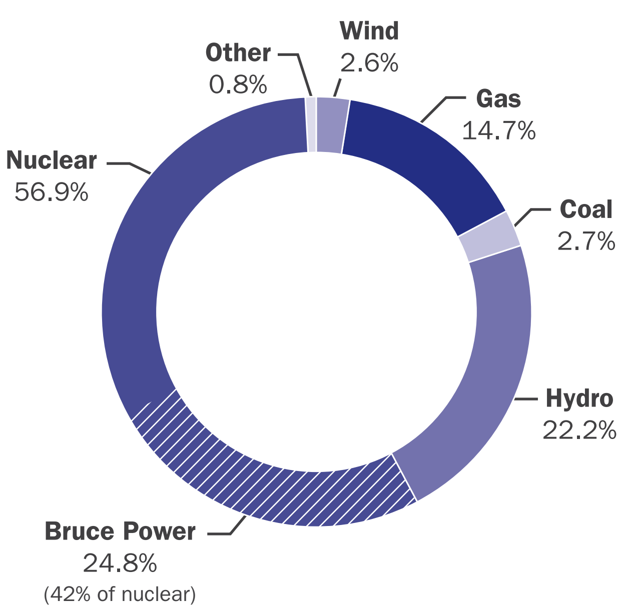
Renewing our electricity system and investing in cleaner technologies has led to higher electricity rates for consumers in the Province of Ontario. However, the key to keeping these rates as low as possible, while the province continues to renew its infrastructure, is to ensure low-cost nuclear generation continues to provide most of the electricity the province needs each and every day, around the clock.

"Output from the Bruce Power site is key to not only maintaining a reliable source of electricity, but to stabilize market prices in Ontario with low-cost baseload generation. That's critical to the competitiveness of our manufacturing sector and economy as a whole."

IAN HOWCROFT, CANADIAN MANUFACTURERS AND EXPORTERS

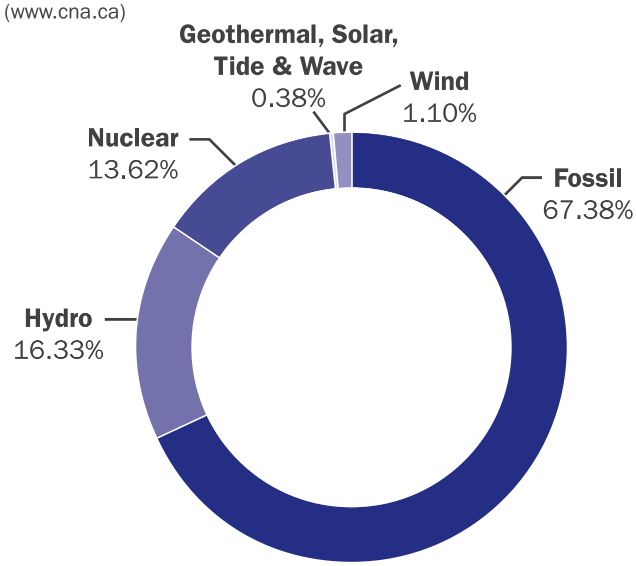
Ontario Electricity Generation in 2011

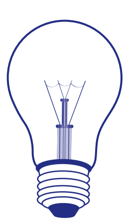
(www.ieso.ca)



Global Electricity Generation in 2011

(www.cna.ca)





Bruce Power supplied about a quarter of Ontario's energy in 2011. That's one out of every four light bulbs, computers, and medical devices in the province.

Securing low-cost, reliable nuclear for Ontario ratepayers

With nuclear power producing well over half of Ontario's electricity, the long-term security from this critical supply source is essential to ensure low-cost, reliable power for the province's ratepayers. Ontario's nuclear generation comes from three facilities in the province — Bruce, Darlington and Pickering.

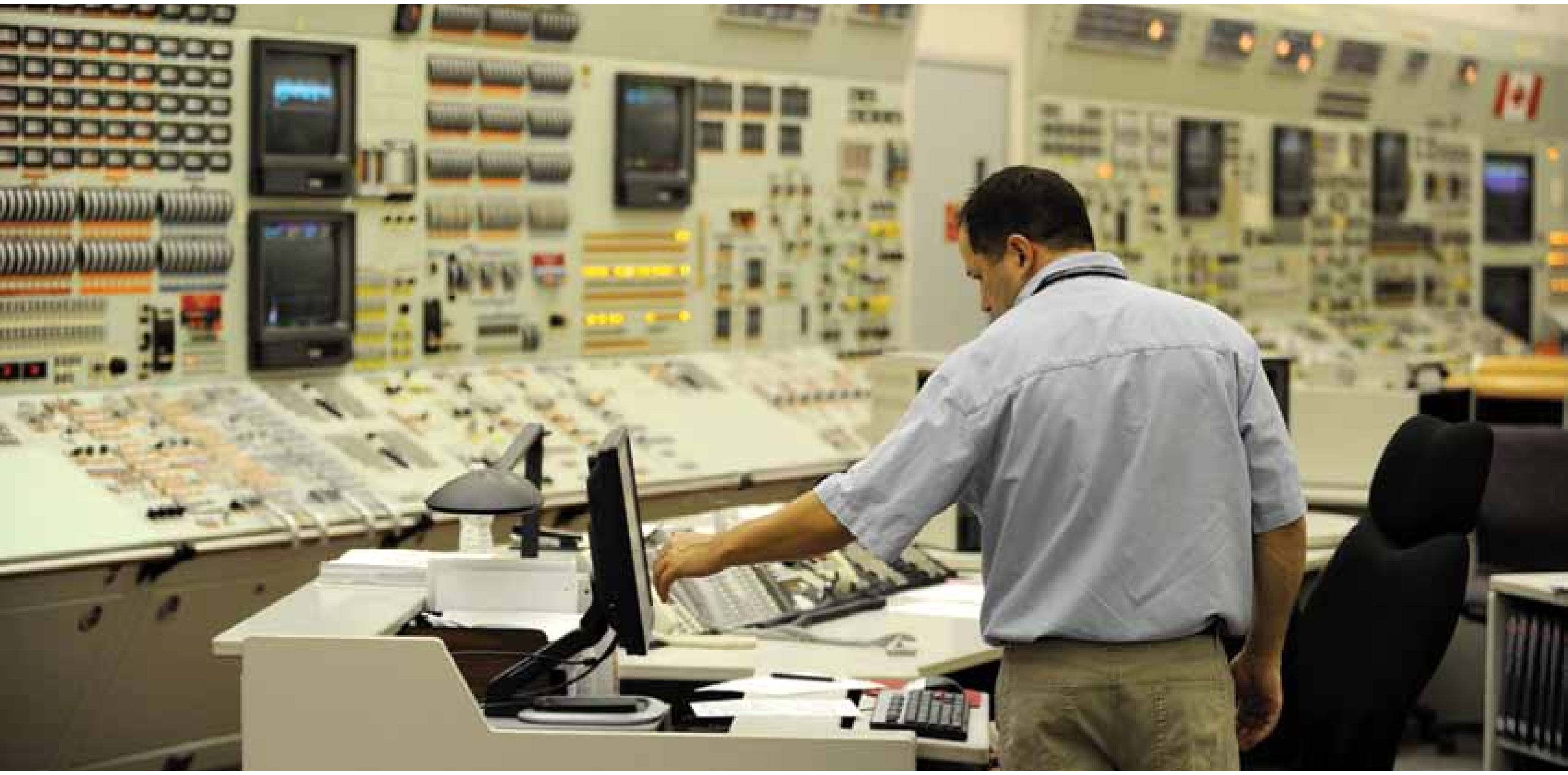
The Long Term Energy Plan and operators of Ontario's nuclear facilities are progressing with the following, with respect to existing nuclear facilities over the next 10 years:

- 6,300 MW will be secured from an eight-unit Bruce Power site
- Four units at the Darlington site will be refurbished between 2016 and 2022
- Units at Pickering will continue to operate until 2020

Over the next decade, while investments and refurbishment activities are being undertaken at Bruce and Darlington, it will be essential to ensure nuclear generation can continue to be counted on to meet both supply needs for the province and to ensure prices remain stable, while a significant amount of low-cost nuclear generation is taken out of the market for refurbishment.

"Nuclear generation is ideally suited for providing baseload generation because of its unique economic and operating characteristics. Nuclear plant operational design and economics depend on the plants being able to operate steadily throughout the year. A generation mix of 50 per cent nuclear combined with baseload hydroelectric generation is sufficient to meet most of Ontario's baseload requirements."

ONTARIO'S LONG-TERM ENERGY PLAN



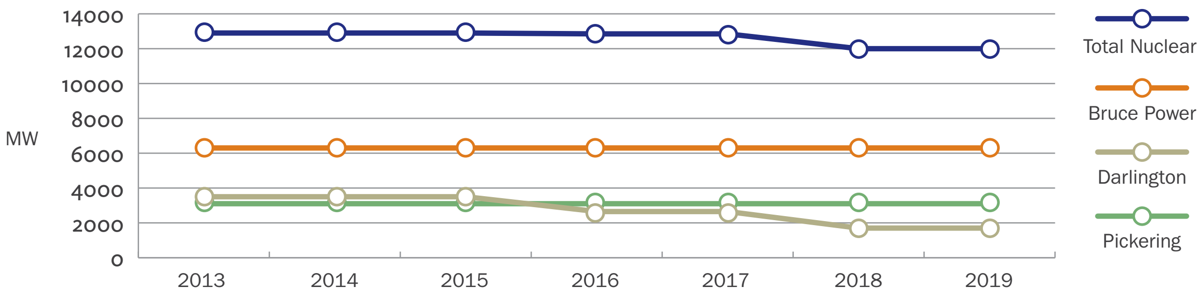
Meeting the demand when Ontario needs it most

The next decade will be critical for Ontario's nuclear fleet as important investments will be made to extend the operational life of both the Bruce and Darlington units, which, combined, are expected to provide over 10,000 megawatts of nuclear for decades to come.

To the end of the decade, Ontario's nuclear fleet will need to be counted on to continue providing large volumes of low-cost electricity, while the assets are renewed for the long-term.

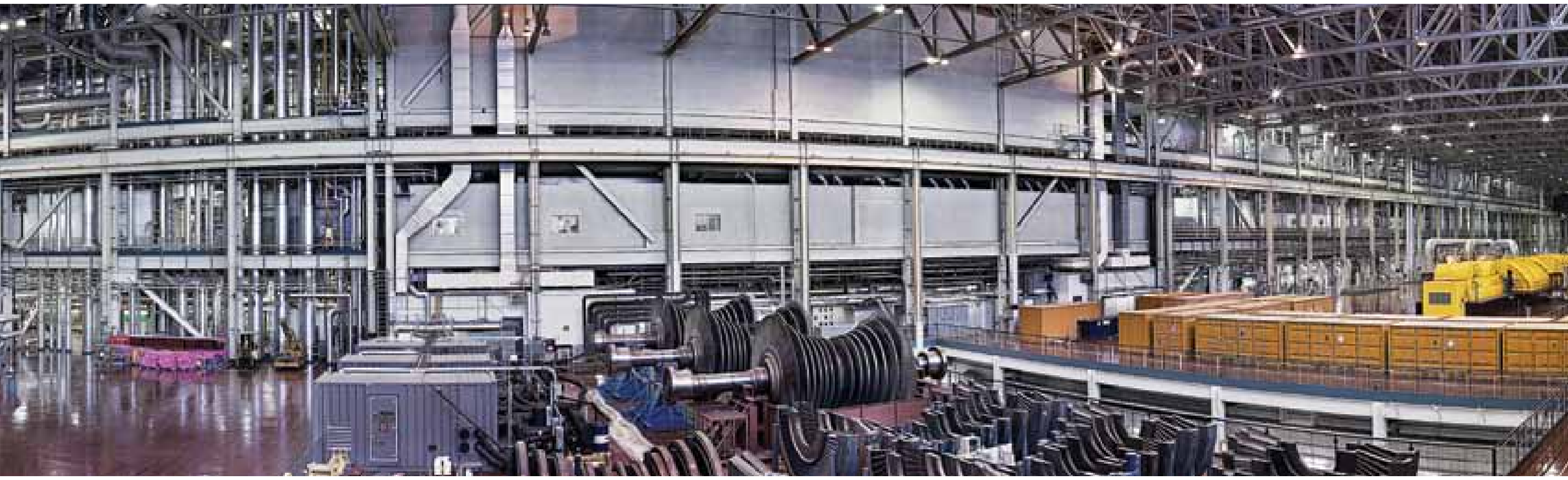
Ontario Power Generation (OPG) has stated it will undertake refurbishments of all four Darlington units between 2016 and 2022, using the approach of removing a unit from service for about a three-year period, while key components are replaced. OPG's Pickering facility will continue to operate during this period until it is expected to be removed from service around 2020.

Ontario nuclear supply with Bruce B output secure (2013-2019)



"The renewal and continued operation of Ontario's nuclear fleet will mean almost 25,000 jobs and annual economic activity of over $5 billion for nearly a decade. This will be one of the most significant single drivers of infrastructure job creation in the province."

PATRICK DILLION, ONTARIO BUILDING AND CONSTRUCTION TRADES



Jobs, investment and more low-cost electricity

Changing demographics, investing in people and skills

Bruce Power has hired 2,700 staff to gear-up for an eight-unit operation and to replace 1,200 staff who have retired:

2001: PERCENTAGE OF EMPLOYEES UNDER 35
8%

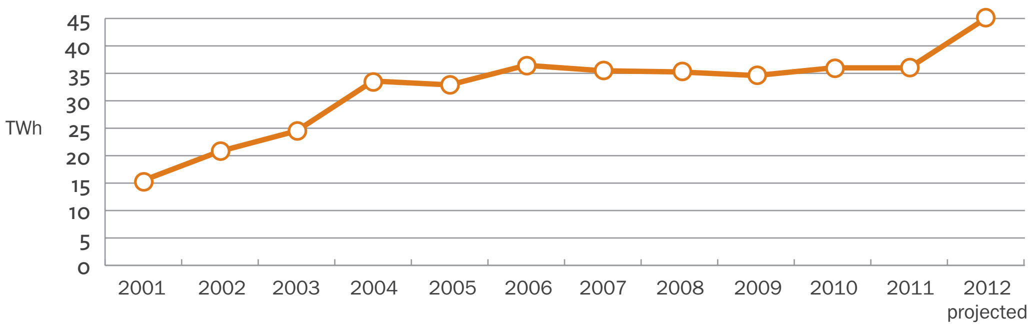
▶ 10 YEARS LATER

2011: PERCENTAGE OF EMPLOYEES UNDER 35
25%

Investment and supporting Ontario's economy

A report issued in July, 2010, by the Canadian Manufacturers and Exporters, concluded Bruce Power's eight-unit operation will generate over $1.6 billion in total economic activity for Ontario on an annual basis. This includes between 8,000 and 9,000 direct and indirect jobs for the province, primarily based in southwestern Ontario.

Bruce Power's electricity output (2001-2012)



TOTAL AMOUNT OF INVESTMENT IN THE BRUCE POWER SITE
$7 billion

Securing 6,300 MW from the Bruce Power site through ongoing asset management

In Bruce Power's first 10 years of operation and through $7 billion of investment, the company has successfully:

- Enhanced the operational performance of running units through strategic investments and ongoing investment in the plant
- Made enhancements to Bruce A Units 3 and 4 to return the units to service and extend their operational life
- Fully refurbished Units 1 and 2, replacing all major components such as the reactor core, steam generators, feeder tubes and electrical systems

As Bruce Power looks forward to securing 6,300 megawatts from the site, the company plans to build on this experience, recognizing all activities that need to be undertaken are all known to the company. We can now benefit from a decade of experiences, meaning the cost and schedule to carry out these activities can be managed with less risk moving forward.

Innovation at work

In Bruce Power's first 10 years of operation, innovation has been a central component to the company's success not only on a first-of-a-kind refurbishment with Units 1 and 2, but with the life extension and improved operations from Units 3 through 8. This innovation has allowed Bruce Power to safely enhance and extend the output from the Bruce site meaning more low-cost, reliable electricity for Ontario ratepayers.

- **Restart of Units 3 and 4:** Following one of the most comprehensive assessments ever done on a CANDU station, Bruce Power proceeded and completed the return to service of Units 3 and 4. At the height of activities, more then 1,100 people worked on the project, consuming five million hours of work, and installing nearly 60 kilometres of new cable, while seeing more than 200,000 electrical connections being made. In addition, security was significantly enhanced following the events of Sept. 11, 2001.
- **Steam generator replacements:** Transported from Alberta's oilsands, one of the world's largest cranes was used to replace the 16 steam generators in Units 1 and 2. To prepare for the job, work crews had to sever the steam generators from their connections and clear a path to temporary ports in the reactor building roofs. Multiple obstructions, including 154-tonne steam drums, mechanical components, electrical systems and civil encasements had to be removed and then reinstalled after the new vessels were in place. This was the first time steam generators have ever been changed out in a CANDU nuclear plant.
- **Robotic tooling for the retube program:** A retube control centre was established as a base to operate remote-controlled tooling to remove radioactive fuel channels on Units 1 and 2. The channels were cut into small pieces of waste to be safely managed.
- **Increasing the output from Bruce B:** Through a process known as 'core re-ordering,' which involves changing the direction in which fuel is inserted into the reactor core, all Bruce B units have been increased from 90 to 93 per cent reactor power. Combining all four Bruce B units, this is a 100 megawatt increase in generation, enough electricity to power 100,000 Ontario homes.
- **West Shift program:** West Shift, which began in late-2011 as part of a six-month Unit 3 maintenance outage, allows crews to move fuel channels back into their original position after they elongate after years of high temperatures, radiation and pressure. Each channel is cut free from the reactor and welded into place to extend the life of the reactor. Once completed, this will extend the life of Unit 3 significantly.

"In Bruce Power's first 10 years of operations we have proven to be an organization that fosters innovation in everything we do. This has enabled us to extend the life of our operating units, while tackling the industry's first full refurbishment of a CANDU unit. As we look ahead to investing in and managing the life of our Bruce B assets in particular, we are starting from a position of strength having worked on virtually every component of these reactors over the last decade."

GARY NEWMAN, CHIEF ENGINEER, BRUCE POWER.

Innovation and improvement

Through the construction activities on Units 1 and 2, we not only completed a number of innovative, first-of-a-kind work programs, but we also improved as we progressed, building on experience gained as we moved forward. All activities were carried out on Unit 2 first, followed by Unit 1.

In every major area of project work we demonstrated significant improvements:

STEAM GENERATOR REPLACEMENT

57% faster

REMOVAL OF PRESSURE TUBES

8% faster

CLEANING/PREPARATION OF REACTOR

53% faster

INSTALLATION OF PRESSURE TUBES

42% faster

REMOVAL OF CALANDRIA TUBES

77% faster

ELECTRIC SYSTEM REFURBISHMENT

50% faster

The first fuel bundle is loaded into Unit 2.

Bruce A station profile

In Service	Lay-up	Restart
Unit 2 – 1977/09/01	1995/10/08	2012
Unit 1 – 1977/01/14	1997/10/16	2012
Unit 3 – 1978/02/01	1998/04/01	2004
Unit 4 – 1979/01/18	1998/03/16	2003

Number of Reactors
Four

Net Rated output
Unit 1 – 750 MW*
Unit 2 – 750 MW*
Unit 3 – 750 MW
Unit 4 – 740 MW
** When restarted in 2012*

Fuel
Natural uranium dioxide (UO_2)

Moderator
Deuterium oxide – heavy water

Coolant
Pressurized heavy water

Building and structures

Reactor building

Material	Reinforced concrete
Width	92 ft (28.04 m)
Length	104 ft (31.7 m)
Height	162.5 ft (49.53 m)

Reactor vault

Length	104 ft (31.7 m)
Height	46.5 ft (14.18 m)
Width	92 ft (28.04 m)
Wall thickness	6 ft (1.83 m)

Reactor auxiliary bay

Length of bay	1,426 ft (434.7 m)
Width	150 ft (45.7 m)
Height	48 ft (14.6 m)

Turbine Hall

Length	1,460 ft (445 m)
Width	180 ft (54.86 m)
Height	134 ft (40.8 m)

Vacuum building

Inside diameter	160 ft 6 in (49 m)
Inside height	149 ft (45.4 m)
Wall thickness	3 ft 9 in (1.14 m)
Water storage	2.2 million gallons ($10,000\ m^3$)

Reactor vessels

Calandria

Material	Austenic stainless steel
Main shell inside diameter	27 ft 9 in (8.46 m)
Main shell thickness	1.25 in (3.17 cm)
Total length	19 ft 6 in (5.95 m)

Calandria tubes

Quantity	480
Material	Zircaloy – 2 seam welded
Inside diameter	5.077 in (12.9 cm)
Wall thickness	0.054 in (0.137 cm)

Reactor physics

Number of fuel channels	480
Number of fuel bundles	5,760

Fuel facts

Type	37 element bundles
Length	19.5 in (49.5 cm)
Number per channel	12
Total weight of bundle	52.1 lb (23.65 kg)

Turbine generator

Turbine

Turbine set per reactor	1
Number of high-pressure cylinders	1
Number of low-pressure cylinders	3
Speed	1,800 rpm

Generator

One per turbine	18,500 volts

Bruce B station profile

Number of Reactors
Four

Net Rated output
Unit 5 – 795 MW
Unit 6 – 822 MW
Unit 7 – 822 MW
Unit 8 – 795 MW

Fuel
Natural uranium dioxide (UO_2)

Moderator
Deuterium oxide – heavy water

Coolant
Pressurized heavy water

Construction schedule
Start of construction: late-1977
In service dates:
Unit 6 – 1984/06/26
Unit 5 – 1985/03/01
Unit 7 – 1986/02/22
Unit 8 – 1987/05/22

Building and structures

Reactor building

Material	Reinforced concrete
Width	92 ft (28.04 m)
Length	104 ft (31.7 m)
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Turbine generator

Turbine

Turbine set per reactor	1
Number of high-pressure cylinders	1
Number of low-pressure cylinders	3
Speed	1,800 rpm

Generator

One per turbine	24,000 volts

Glossary of nuclear terms

The following is a list of terms which are commonly used in the uranium industry and the nuclear fuel cycle.

Alpha particle: A positively charged particle from the nucleus of an atom, emitted during radioactive decay. Alpha particles are helium nuclei, with two protons and two neutrons.

Atom: A particle of matter which cannot be broken up by chemical means. Atoms have a nucleus consisting of positively charged protons and uncharged neutrons of the same mass. The positive charges on the protons are balanced by a number of negatively-charged electrons in motion around the nucleus.

Background radiation: The naturally occurring ionizing radiation arising from the earth's crust (including radon) and from cosmic radiation.

Baseload: The part of electricity demand which is continuous, and does not vary over a 24-hour period. Approximately equivalent to the minimum daily load.

Becquerel: The unit of intrinsic radioactivity in a material. One Bq measures one disintegration per second and is thus the activity of a quantity of radioactive material which averages one decay per second.

Beta particle: A particle emitted from an atom during radioactive decay. Beta particles may be either electrons (with negative charge) or positrons.

Biological shield: A mass of absorbing material (e.g., thick concrete walls) placed around a reactor or radioactive material to reduce the radiation (especially neutrons and gamma rays) to a level safe for humans.

Calandria: In a CANDU reactor, it's a cylindrical reactor vessel which contains the heavy water moderator. It is penetrated from end-to-end by hundreds of calandria tubes, which accommodate the pressure tubes containing the fuel and coolant.

CANDU: CANada Deuterium Uranium reactor, moderated and cooled primarily with heavy water.

Chain reaction: A reaction that stimulates its own repetition, in particular where the neutrons originating from nuclear fission cause an ongoing series of fission reactions.

Cladding: The metal tubes containing oxide fuel pellets in a reactor core.

Control rods: Devices to absorb neutrons so the chain reaction in a reactor core may be slowed or stopped by inserting them further, or accelerated by withdrawing them.

Coolant: The liquid or gas used to transfer heat from the reactor core to the steam generators.

Core: The central part of a nuclear reactor containing the fuel elements and any moderator.

Critical mass: The smallest mass of fissile material that will support a self-sustaining chain reaction under specified conditions.

Criticality: Condition of being able to sustain a nuclear chain reaction.

Decay: Disintegration of atomic nuclei resulting in the emission of alpha or beta particles (usually with gamma radiation). Also the exponential decrease in radioactivity of a material as nuclear disintegrations take place and more stable nuclei are formed.

Decommissioning: Removal of a reactor from service, also the subsequent actions of safe storage, dismantling and making the site available for unrestricted use.

Deuterium: An isotope of hydrogen, also known as heavy water. Occurs naturally in all bodies of water (one part in 7,000 in the Great Lakes). Its nucleus contains an extra neutron, not found in hydrogen.

Dose: The energy absorbed by living tissue from ionizing radiation.

Dosimeter: A device that measures cumulative dose of radiation during exposure.

Fission: The splitting of a heavy nucleus into two, accompanied by the release of a relatively large amount of energy and usually one or more neutrons. It may be spontaneous but usually is due to a nucleus absorbing a neutron and thus becoming unstable.

Fission products: Daughter nuclei resulting either from the fission of heavy elements such as uranium, or the radioactive decay of those primary daughters. Usually highly radioactive.

Fuel bundle: Structured collection of fuel rods or elements, the unit of fuel in a reactor.

Gamma rays: High-energy electromagnetic radiation from the atomic nucleus, virtually identical to X-rays.

Greenhouse gases: Gases in the earth's atmosphere which absorb long-wave heat radiation from the earth's surface and reradiate it, thereby warming the earth. Carbon dioxide and water vapour are the main ones.

Grid: The layout of an electrical transmission and distribution system.

Half-life: The period required for half of the atoms of a particular radioactive isotope to decay and become an isotope of another element.

Heavy water: Water containing an elevated concentration of molecules with deuterium atoms.

Ion: An atom that is electrically charged because of loss or gain of electrons.

Ionizing radiation: Radiation (including alpha particles) capable of breaking chemical bonds, thus causing ionization of the matter through which it passes and damage to living tissue.

Isotope: An atomic form of an element having a particular number of neutrons. Different isotopes of an element have the same number of protons but different numbers of neutrons and hence different atomic mass.

Kilowatt (kW): A standard unit used to measure electric power, equal to 1,000 watts. A kilowatt can be visualized as the total amount of power required to light ten 100-watt light bulbs.

Kilowatt-Hour (kWh): A standard unit for measuring electrical energy.

Light water: Ordinary water (H_2O) as distinct from heavy water.

Megawatt (MW): A unit of power, representing the rate at which energy is used or produced. One megawatt-hour represents one hour of electricity consumption at a constant rate of one MW.

Moderator: A material such as light or heavy water or graphite used in a reactor to slow down fast neutrons to promote collision with lighter nuclei to expedite further fission.

Natural uranium: Uranium with an isotopic composition as found in nature, containing 99.3% U-238, 0.7% U-235 and a trace of U-234. Can be used as fuel in heavy water-moderated reactors.

Neutron: An uncharged elementary particle found in the nucleus of every atom except hydrogen. Mobile neutrons travelling at various speeds originate from fission reactions.

Nuclear reactor: A device in which a nuclear fission chain reaction occurs under controlled conditions so that the heat yield can be harnessed or the neutron beams utilized. All commercial reactors are thermal reactors, using a moderator to slow down the neutrons.

Poison: A neutron absorber which can slow or stop the nuclear reaction. Gadolinium is commonly used.

Radiation: The emission and propagation of energy by means of electromagnetic waves or particles.

Radioactive Waste: Materials left over from making nuclear energy. Radioactive waste can harm living organisms if it is not stored safely.

Radioactivity: The spontaneous decay of an unstable atomic nucleus, giving rise to the emission of radiation.

Radionuclide: A radioactive isotope of an element.

Radiotoxicity: The adverse health effect of a radionuclide due to its radioactivity.

Radon (Rn): A heavy radioactive gas given off by rocks containing radium (or thorium). Rn-222 is the main isotope.

Reactor pressure vessel: The main steel vessel containing the reactor fuel, moderator and coolant under pressure.

Sievert (Sv): Unit indicating the biological damage caused by radiation. One joule of beta or gamma radiation absorbed per kilogram of tissue has 1 Sv of biological effect.

Slightly enriched uranium: Uranium in which the proportion of U-235 (to U-238) has been increased above the natural 0.7 per cent.

Stable: Incapable of spontaneous radioactive decay.

Used fuel: Nuclear fuel removed from a reactor following irradiation. No longer usable in its current form because of depletion of fissile material, poison build-up or radiation damage.

Helpful Links

CNSC
(Canadian Nuclear Safety Commission)
www.nuclearsafety.gc.ca

CANDU Owners Group
www.candu.org

International Atomic Energy Agency
www.iaea.org

WANO
(World Association of Nuclear Operators)
www.wano.info

Canadian Nuclear Association
www.cna.ca

Nuclear Energy Institute: Understanding Radiation (PDF)
www.nei.org/filefolder/Understanding_Radiation_1.pdf

Natural Resources Canada
Energy Sector
www.nrcan.gc.ca/eneene

Our Vision, Mission and Values

Our Vision

To be Canada's world class nuclear operator.

Our Mission

Bruce Power is committed to providing safe, reliable, affordable and environmentally sound electricity. We will achieve this through living our values, which will condition every decision and action we take. We will leverage the skills and creativity of Canada's most dynamic and innovative team to achieve sustainable performance excellence.

Our Values

Safety First

We embrace and practice strong nuclear safety principles recognizing that reactor safety, industrial safety, radiation safety, and environmental safety are essential to the successful achievement of our long-term goals and key to our reputation.

Professionalism and Personal Integrity

We believe in honouring ourselves, our business, and our personal commitments.

Respect and Recognition

We recognize that our people are essential to our success and respect their exceptional efforts.

Passion for Excellence

We demonstrate commitment to continuous improvement to create sustainable performance excellence which benefits all of our stakeholders.

Social Responsibility

We recognize business excellence and our financial strength as an opportunity for contributing to the greater good.

BRUCE POWER | P.O. Box 1540 Tiverton, Ontario, Canada N0G 2T0 | 1.866.748.4787

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