# "OKAY LET'S GO": 80 YEARS AGO CANADA BECAME THE SECOND NATION TO HARNESS THE ATOM

**SUMMARY**: For Canada, nuclear fission was a scientific coming-of-age story half a century in the making. Take a journey from Rutherford to CANDU, which peaked in 1945 when Canada astounded all by leaping into the big leagues of nuclear science and engineering.

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At the end of WWII Canada didn't know what it couldn't do.

For six harrowing years the young nation had punched above its weight on numerous fronts – military, industry, aerospace, agriculture, science – to help bring the world's greatest conflict to a close.

And on September 5, 1945 – a month after the world learned of nuclear fission when two atomic bombs destroyed Hiroshima and Nagasaki – Canada again stunned the world by firing up its ZEEP reactor ("Zero Energy Experimental Pile", Fig. 1) in remote Chalk River, Ontario, becoming the second country to harness the atom.

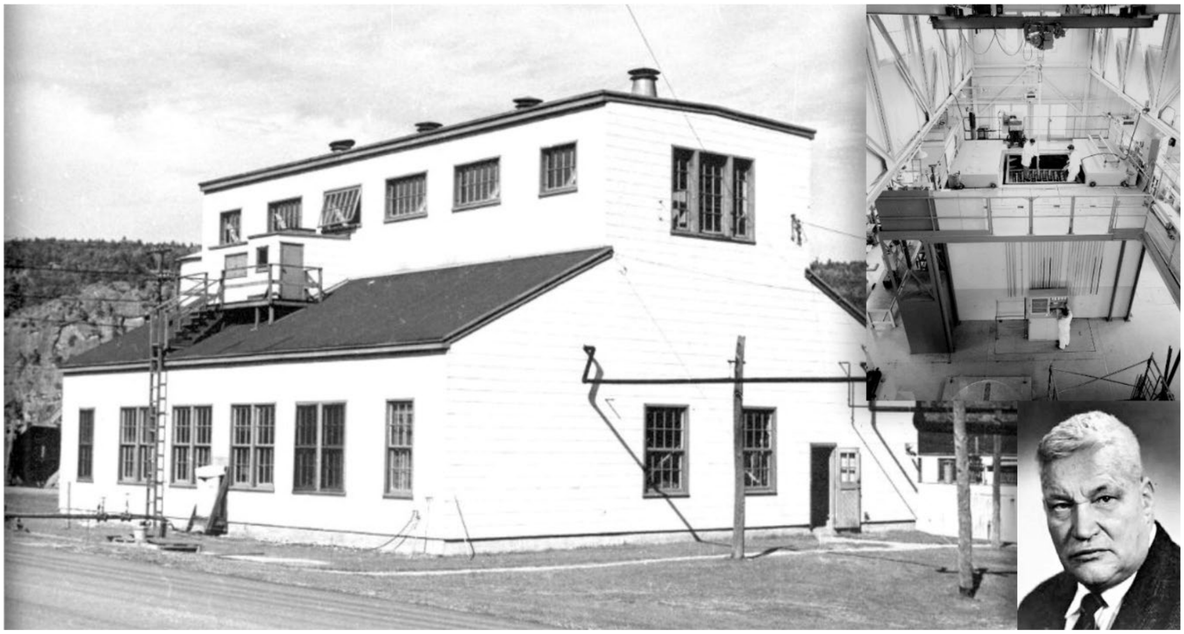

Figure 1. The ZEEP reactor at Chalk River Laboratories: first criticality Sept 5, 1945. Inset top: interior of ZEEP. Inset bottom: Dr. Lew Kowarski, one of the first to experiment with heavy water and fission in Paris, and later head of ZEEP design in Canada. *(Photo source: AECL)*

At the time neither the lab at Chalk River, nor the nearby townsite of Deep River housing its scientists and their families, was on the map – both created in secrecy during the darkest days of the war: effectively a satellite operation of the Great U.S. Secret the world came to know as the Manhattan Project.

The Allies' goal was ostensibly a nuclear weapon to end the war, but the new wonder of nuclear science was unmistakably the long-term prize – and Canada had been all-in since 1942 with a pronouncement as understated as it was bold:

"Okay, let's go!"

Those words were famously uttered on August 17, 1942 by the honourable Clarence Decatur (C.D.) Howe as he created the Canadian nuclear program with the stroke of a pen.

Howe, known as the "Minister of Everything" in Prime Minister Mackenzie King's wartime cabinet, had been considering a request from Britain to transfer a significant piece of its wartime nuclear project (under the code name "Tube Alloys") to Canada – the mission: to investigate the possibility of a heavy water reactor.

Figure 2. The Montreal Group of the National Research Council *(Photo source: AECL)*. Inset: The Hon. C.D. Howe. *(Photo source: Legion Magazine)*

It was a hefty commitment, and nobody could say for sure what would come of it, but the allure was undeniable: first-floor access to a new science (discovered scarcely three years earlier) that promised to revolutionize industry, medicine and energy production.

With its hearty "*Okay, let's go*", Canada invited a team of top French and British scientists to join a Canadian contingent setting up shop at the University of Montreal. It would be known as "The Montreal Lab" (Fig. 2) under the auspices of the National Research Council (NRC).

Remarkably, this was not Montreal's first brush with cutting edge nuclear science: that happened half a century earlier when the redoubtable Ernest Rutherford earned his 1908 Nobel Prize conjuring up concepts like half-life, alpha, beta and gamma radiation at McGill University (Fig. 3).

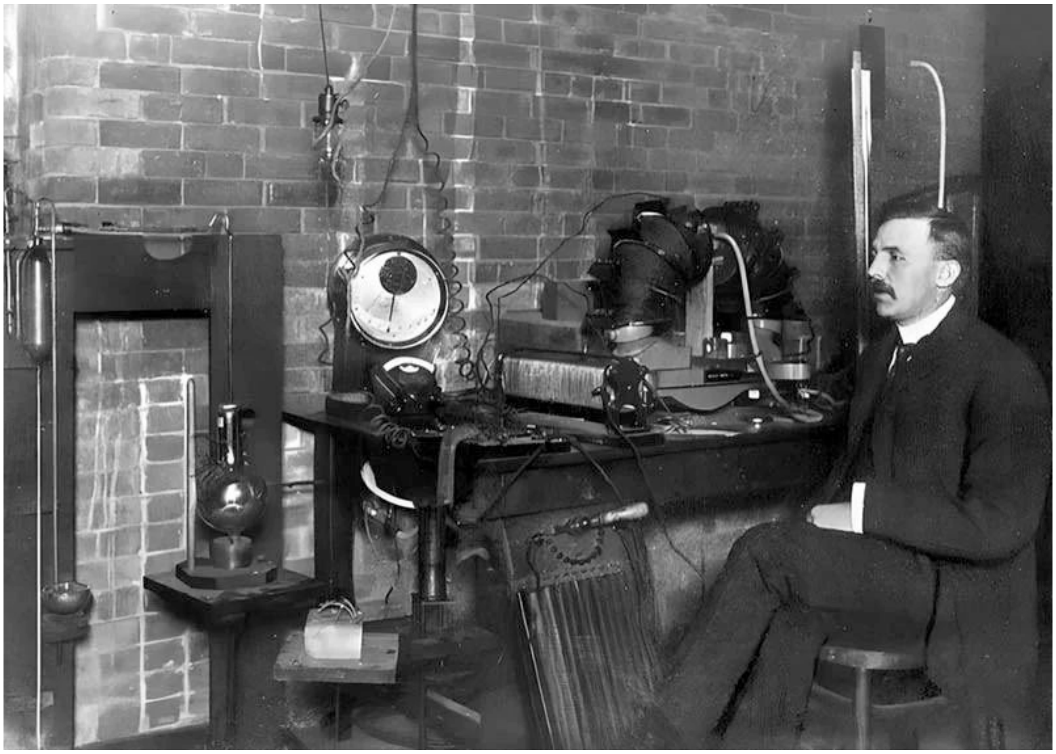

Figure 3. Ernest Rutherford in his lab at McGill University, Montreal, 1905. *(Photo source: Wikimedia)*

Around that time, a thousand kilometres to the east in Charlottetown, PEI, a lad named George Laurence was born. Two decades later young Laurence would find himself studying under Rutherford in Britain, and by the outbreak of WWII was a respected researcher at the NRC laboratories back in Ottawa.

That's when an earthquake broke science.

Nuclear fission – the splitting of the uranium atom, considered impossible by contemporary knowledge – was announced to the world in January 1939. Germans Otto Hahn and Fritz Strassman did the experiments, Austrians Lise Meitner and her nephew Otto Frisch pieced the unconventional physics together, and an entire half-century of nuclear theory converged overnight.

Canada's George Laurence, working in secrecy in downtown Ottawa with the help of B.W. Sargent of Queen's University (a fellow Rutherford protégé), was the first to assemble a large graphite reactor to test the theory (Fig. 4). Later, in 1942, Enrico Fermi would attain physics superstardom with the first fully functional version under the football stands at the University of Chicago, but Laurence put Canada on the map by being one of the first to test the process.

Figure 4. The National Research Council (NRC) laboratories on Sussex Drive in Ottawa. *(Photo source: NRC)* Inset top: Dr. George Laurence. Inset bottom: depiction of Laurence's graphite pile. *(Photo source: Nuclearfaq.ca)*

This earned Canada an unlikely seat at the Manhattan Project table, confirmed in August 1943 by Mackenzie King, Churchill, and Roosevelt at their Quebec Conference to discuss how the war would end (Fig. 5).

Canada was tasked with building a large prototype reactor based on heavy water.

Figure 5. Canadian Prime Minister Mackenzie King, US President Franklin D. Roosevelt, and British Prime Minister Winston Churchill at the Quebec Conference in August 1943, where Canada's role in the then-top-secret Manhattan Project was agreed. *(Photo source: Imperial War Museums)*

A natural variant of water but 10% denser, heavy water was first discovered only a decade earlier – and until the discovery of fission had almost no practical use. Then overnight its status soared as one of the rarest and most sought-after materials of the Second World War.

The reason: it was immediately recognized as a key ingredient for a nuclear reactor running on unenriched uranium (the kind found in nature).

Unfortunately, although it is found wherever you find water (approximately one water molecule in 3200 contains deuterium, a heavy isotope of hydrogen), separating heavy water from regular water is not trivial. In time Canada would master the process but in that period it was in short supply.

In fact, early in the war the French had ended up with almost all the world's inventory of heavy water (185 kg), spirited out of Norway on the eve of Nazi occupation (Fig. 6), and again spirited out of France on the eve of its Nazi occupation – eventually ending up, along with its French scientist caretakers, at the Montreal Laboratory.

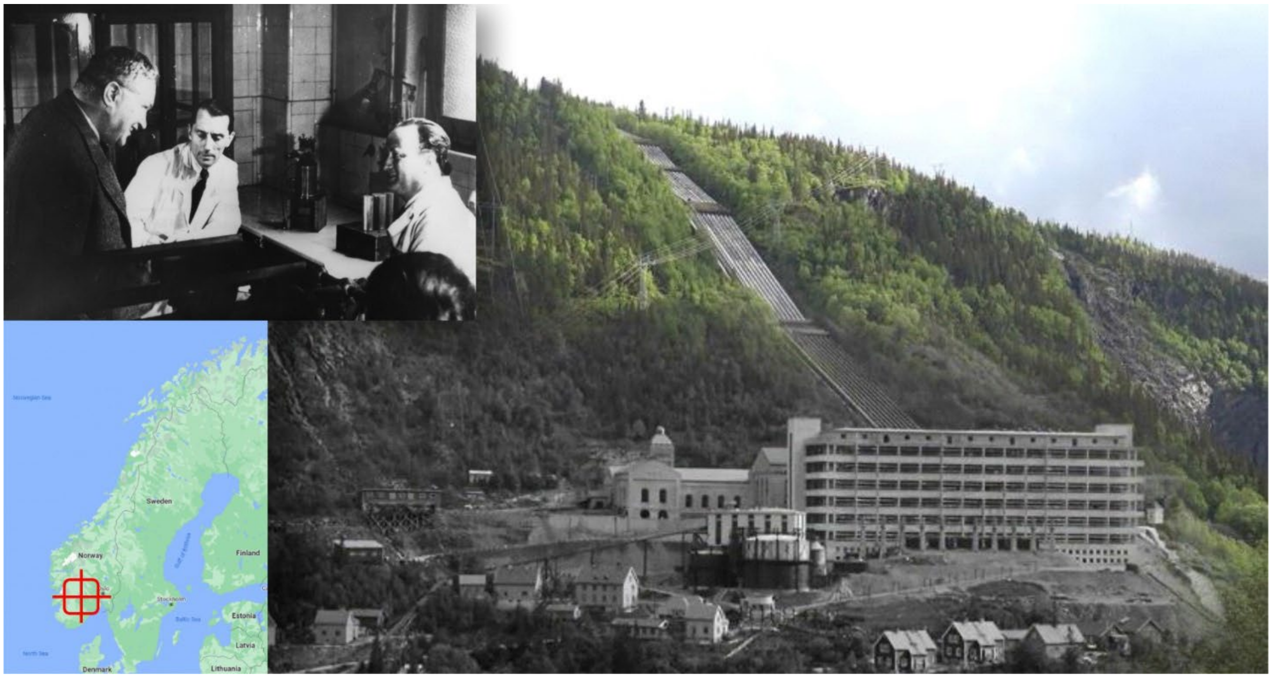


Figure 6. The Vemork hydroelectric plant (Norway) produced most of the world's heavy water pre-WWII. *(Photo source: National Library of Norway)* Inset top: Scientists Lew Kowarski, Frederic Joliot-Curie, and Hans von Halban experimented with heavy water in Paris. *(Photo source: public domain)* Inset bottom: location of Vemork plant.

Additional heavy water in the massive quantities demanded by a reactor (many tonnes) eventually arrived via the Manhattan Project – interestingly, its first production site technically on Canadian soil at Trail, BC.

Uranium, of course, was the other essential ingredient, and here Canada was blessed.

Since 1930 uranium had been mined in the Northwest Territories for its lucrative radium content – a wonder element since the days of Madame Curie, especially useful during the war making aircraft instruments glow in the dark.

In fact radium's singular commercial value is evident in the fact that it made economic sense at the time to mine it in Great Bear Lake, NWT, then ship it 5000 km southeast to Port Hope, Ontario for extraction – at that point basically casting its host uranium rock aside as waste.

Then in 1939 the discovery of nuclear fission flipped Port Hope's objective: uranium itself became the main attraction.

Meanwhile, the decision to build a large research reactor unleashed Canadian science and industry into uncharted territory (a metaphor extending to the living conditions of scientists and their families as they moved to the new company townsite of Deep River, Ontario, on the banks of the Ottawa River about 200 km upstream from Ottawa).

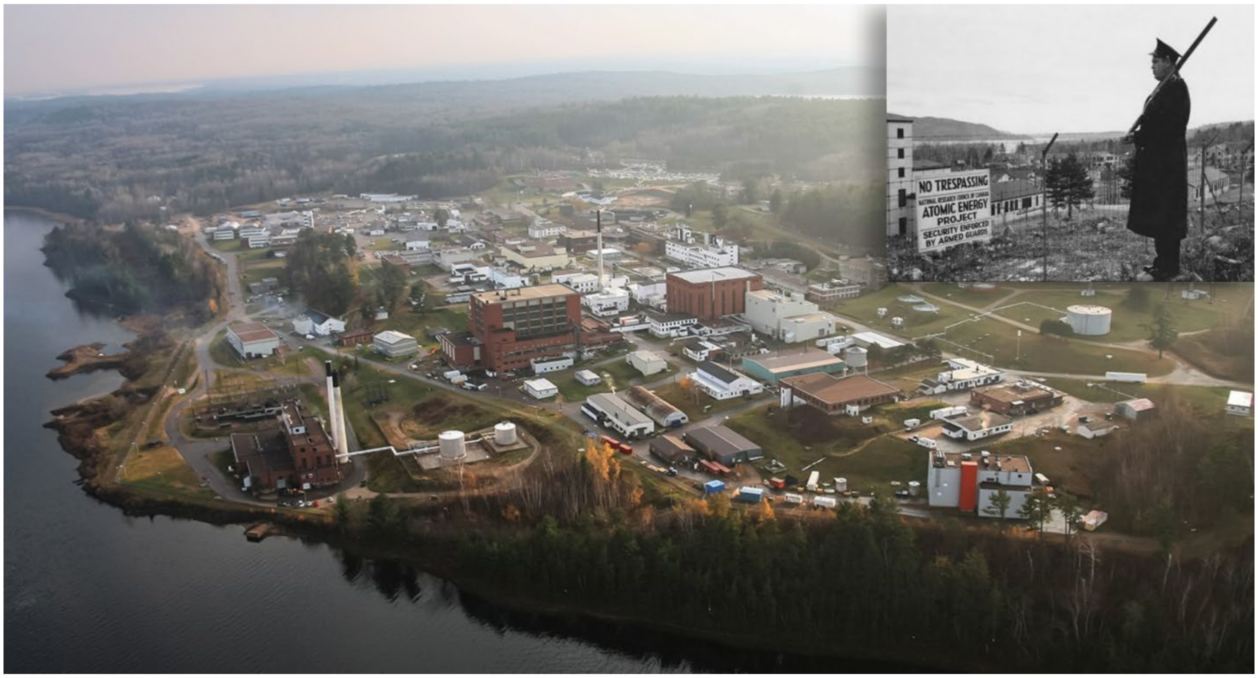


Figure 7. Chalk River Laboratories today, operated by Canadian Nuclear Laboratories (CNL). *(Photo source: CNL)* Inset: armed guard in the early days. *(Photo source: AECL)*

Nearby the massive nuclear campus at Chalk River was under construction, with all the infrastructure of self-contained, cutting-edge science: at its heart, an innovative nuclear reactor that would change the course of medicine, industry, and electricity generation (Fig. 7).

That reactor would be known as the National Research eXperimental, or NRX – the most powerful research reactor on the planet in its day, and a scientific watershed for Canada.

But that day was still three years away: for now, with the war still raging and Canadians preparing to storm the shores of Normandy, Canadians back home prepared to storm the shores of nuclear science.

First on their list was a small test reactor, also based on heavy water – something to get their feet wet (so to speak) before tackling the full might of NRX.

This would become known as ZEEP: Zero Energy Experimental Pile – built over the following year in the looming shadow of NRX next door (Fig. 8). True to its name, ZEEP generated almost no measurable energy, but provided the physics platform for fine tuning the NRX design. It continued to host important experiments at Chalk River until 1970.


Figure 8. The ZEEP reactor in 1945, with the NRX reactor under construction next door. *(Photo source: AECL)*

More than this however, ZEEP was the first reactor to start up outside the U.S., heralding the entry of Canada into the nuclear big leagues.

The date was Sept 5, 1945. The war had just ended and a new world was emerging from its ashes – a world where nuclear energy held an early promise of prosperity and peace.

Canada would help define this new world. With its flagship research reactor NRX starting up in 1947, joined by the even more powerful NRU (National Research Universal) a decade later, Canada would soon gift to humanity the medical revolution of cobalt-60 cancer therapy (saving lives already by 1951), and a host of other medical and industrial radioisotopes (Fig. 9).

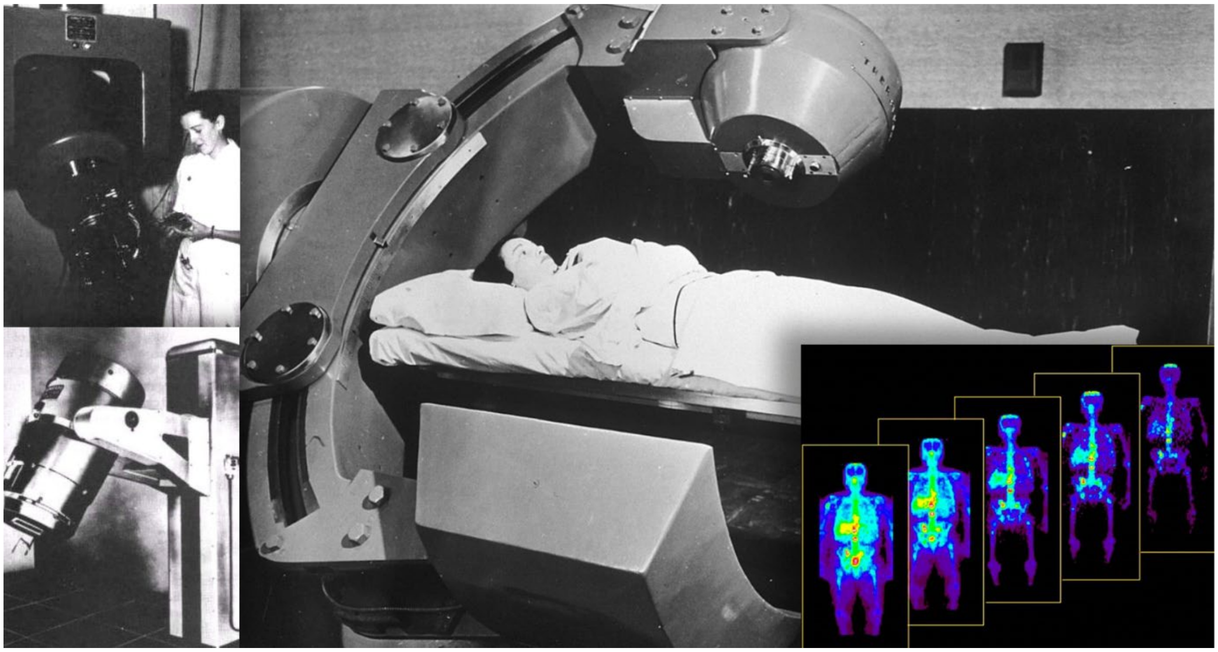

Figure 9. The earliest use of nuclear energy for peaceful purposes was the production of radioisotopes to diagnose and fight disease. Left insets: the first cobalt-60 cancer therapy units in Saskatchewan and Ontario (1951) *(Photo source: AECL)*; right inset: nuclear imaging. *(Photo source: Riga Technical University)*

This new world demanded oversight since nuclear reactors would soon be operating in dozens of countries, and in 1957 Canada helped establish the International Atomic Energy Agency (IAEA) to ensure that this evolved safely and securely. (At home this mission had been upheld since 1946 by one of the first national nuclear regulators, later rebranded the Canadian Nuclear Safety Commission, CNSC).

Chalk River Laboratories itself became a mecca for nuclear science – the best and the brightest attracted by the unmatched capabilities of its two research reactors (Fig. 10), soon accompanied by other new tools for probing the universe. One significant legacy of this era is the technique of neutron scattering – using neutron beams from a research reactor to probe the structure and behaviour of materials. In 1994 Chalk River's Bertram Brockhouse (later of McMaster University) shared the Nobel Prize in Physics with Clifford Schull of the USA (Oak Ridge Laboratories, and later MIT) for this game-changing contribution to science.

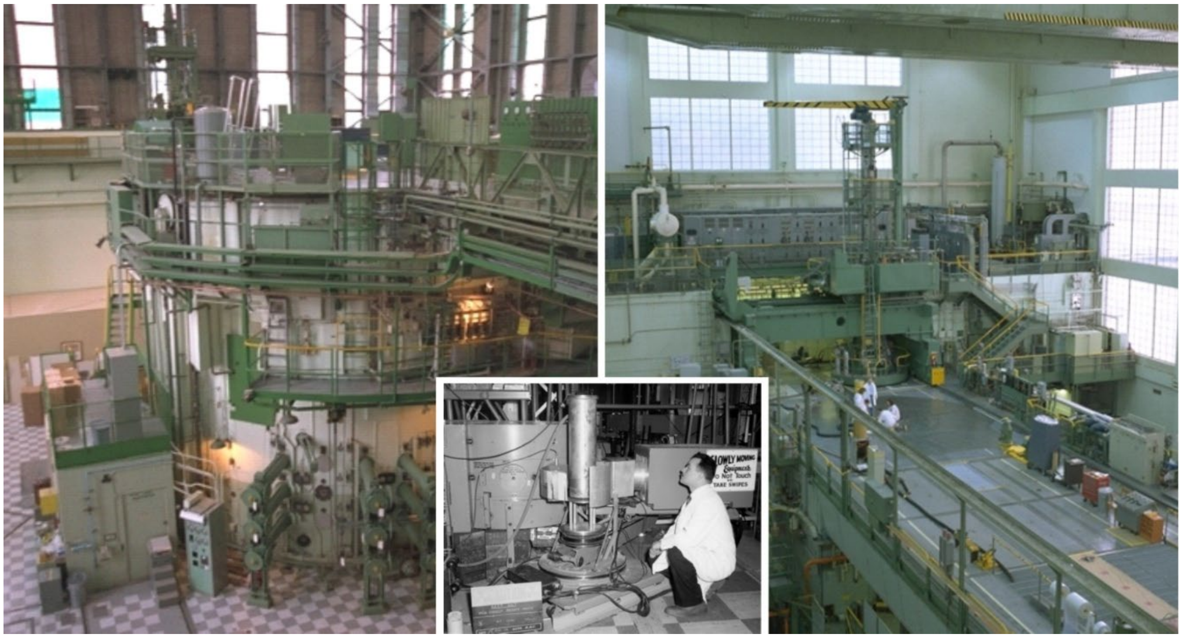

Figure 10. Giants of early nuclear science: the NRX reactor (left, 40 MW, 1947-1993) and NRU reactor (right, 120 MW, 1957-2018). Inset bottom: Dr. Bertram Brockhouse in the NRX - 1994 Nobel laureate in Physics for neutron scattering. *(Photo source: AECL)*

By the 1960s Canada, through its new crown corporation Atomic Energy of Canada Ltd. (AECL), had developed one of only two power reactor concepts to reach full commercialization: the CANDU reactor.

CANDU was almost a contradiction: arguably the most efficient power reactor on the planet, running on natural (unenriched) uranium that – under most circumstances – can't be made to support its own fission chain reaction.

The Canadians not only made it work; they made it one of the safest reactors in operation. Today these machines power half of Ontario, and enable that most industrialized of Canadian provinces to have an almost 100% clean electricity grid (Fig. 11).

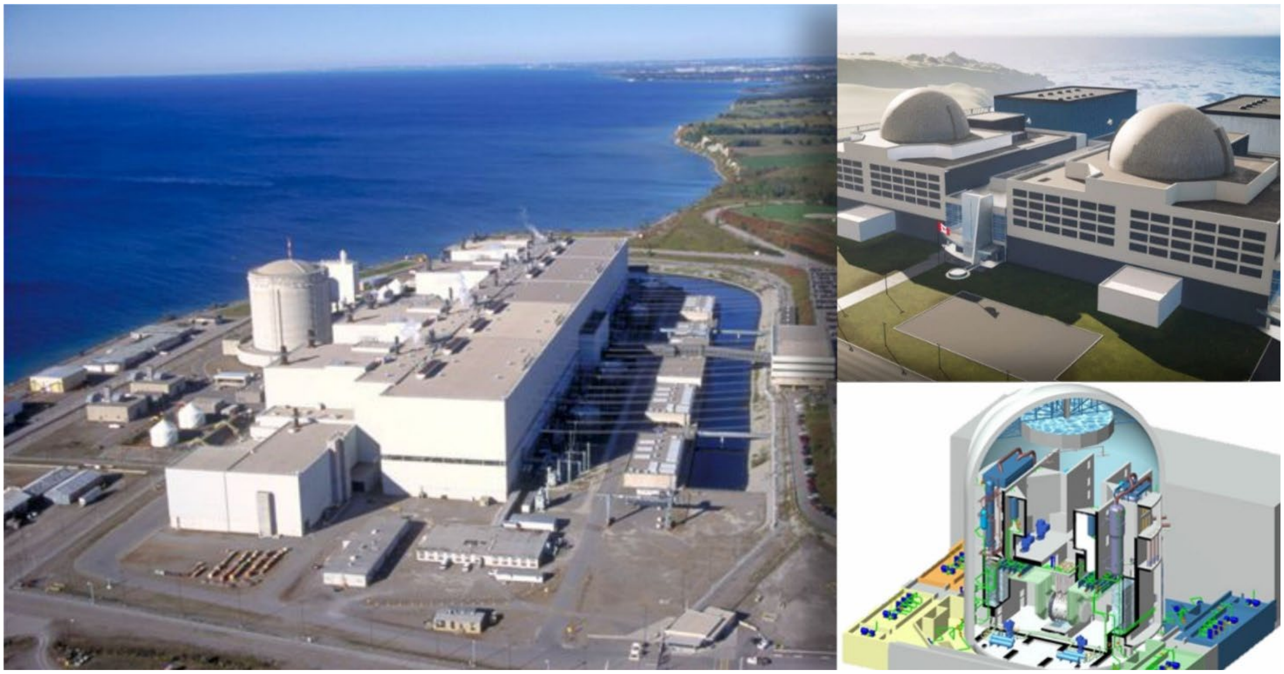

Figure 11. Darlington NPP near Toronto (3600 MW from four CANDU units). *(Photo source: OPG)* Inset right: CANDU MONARK (1000 MW, developed by AtkinsRéalis - Candu Energy) takes the CANDU product forward, building on over 60 years of fleet experience. *(Photo source: AtkinsRéalis - Candu Energy)*

And increasingly, while doing so, they are producing medical isotopes on the side – fighting cancer and heart disease (both diagnosis and treatment), and generally carrying forth the torch of nuclear energy's first philanthropic role in Canada.

Today CANDU reactors quietly tout Canadian ingenuity on four continents, their very name a respectful nod to the spirit of their genesis: 80 years ago when 20th century physics reached an apex in two countries, and equally today as the world searches for sustainable solutions to energy supply and climate deterioration.

Okay, let's go.


Figure 12. ZEEP's legacy: sustainable energy supply, environmental protection, and isotopes for water, agriculture and medicine.

## FURTHER READING


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